

**Assessing Technology Adoption in the European Air
Traffic Management:
The Cases of Virtual Centre and Flight-Centric
Operations**

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Abstract

This research focuses on emerging technologies in the European air traffic management (ATM), specifically investigating technology adoption by the main stakeholders. The European ATM consists of a highly fragmented aviation infrastructure, built and managed by actors with diverse interests. Rapid developments in information and communication technologies affect the European ATM, as also the case with other network industries. Air Navigation Service Providers (ANSPs) and the industry, more generally, started experimenting with digital technologies, such as Virtual Centre (VC), and Flight-Centric Operations (FCO), also known as Sector-less ATM, technologies. These technologies have the possibility to disrupt or at least change the current air navigation services (ANS) provision. However, there is lack of research related to the possible adoption of these technologies in the context of the European ATM in general and the Single European Sky (SES) in particular. This PhD thesis investigates the possible adoption of two emerging technologies using two case studies: flight-centric operations and virtual centre on the European ATM. The following two questions will be answered in this thesis. The first research question is: How and to what extent will emerging technologies - in particular flight-centric operations and virtual centre be taken up and ultimately adopted by the relevant actors of the European ATM? The second research question is: What will the consequences of such adoption be on the process of implementing the Single European Sky? In order to analyze, understand and evaluate the technology adoption, this thesis takes a socio-technical approach using stakeholder theory (ST), combined with actor-network theory (ANT) methodology. Different from the traditional technology adoption research approaches, such as innovation diffusion, an interpretive stance is taken to examine how new technologies come into existence and evolve. The processes of ANT, packed into problematisation, interessement, enrolment and mobilisation are used to explain the adoption of flight-centric operations and virtual centre technologies. Coupled with investigating the factors and barriers affecting the technology adoption, the thesis presents a conceptual framework to examine technology adoption in the European ATM. The data is collected qualitatively through participant observation, interviews and document analysis. The interactions between the key actors are analyzed for further recommendation on the adoption of these new technologies.

Résumé

Cette recherche se concentre sur les technologies émergentes dans la gestion du trafic aérien en Europe, et enquêter spécifiquement sur l'adoption des technologies par les principales parties prenantes. La gestion du trafic aérien européen consiste en une infrastructure aéronautique très fragmentée, construite et gérée par des acteurs aux intérêts divers. L'évolution rapide des technologies de l'information et de la communication affecte la gestion du trafic aérien européen, comme c'est également le cas avec d'autres industries de réseau. Les fournisseurs de services de navigation aérienne et l'industrie ont commencé à expérimenter des technologies numériques, telles que le centre virtuel et les opérations axées sur le vol, également appelées technologies trafic aérien sans secteur. Ces technologies ont la possibilité de perturber ou au moins de modifier la fourniture actuelle des services de navigation aérienne. Cependant, il y a un manque de recherche concernant l'adoption éventuelle de ces technologies dans le contexte de la gestion du trafic aérien européen en général et du Single European Sky en particulier. Cette thèse de doctorat étudie l'adoption possible de deux technologies émergentes à l'aide de deux études de cas : les opérations centrées sur le vol et le centre virtuel sur la gestion du trafic aérien européen. Les deux questions suivantes seront répondues dans cette thèse. La première question de recherche est : comment et dans quelle mesure les technologies émergentes - en particulier les opérations centrées sur le vol et le centre virtuel seront-elles reprises et finalement adoptées par les acteurs concernés de la gestion du trafic aérien européen ? La deuxième question de recherche est la suivante : quelles seront les conséquences d'une telle adoption sur le processus de mise en œuvre du Single European Sky ? Afin d'analyser, de comprendre et d'évaluer l'adoption de la technologie, cette thèse adopte une approche socio-technique utilisant la théorie des parties prenantes, combinée à la méthodologie de la théorie des acteurs-réseaux. Différente des approches traditionnelles de recherche sur l'adoption de technologies, comme la diffusion de l'innovation, une position interprétative est adoptée pour examiner comment les nouvelles technologies voient le jour et évoluent. Les processus de la théorie acteur-réseau, emballés dans la problématisation, l'intérêt, l'enrôlement et la mobilisation, sont utilisés pour expliquer l'adoption d'opérations centrées sur le vol et de technologies de centre virtuel. Couplée à l'étude des facteurs et des obstacles affectant l'adoption de la technologie, la thèse présente un cadre conceptuel pour examiner l'adoption de la technologie dans la gestion du trafic aérien européen. Les données sont collectées de manière qualitative grâce à l'observation des participants, aux entretiens et à l'analyse de documents. Les interactions entre les principaux acteurs sont analysées pour des recommandations supplémentaires sur l'adoption de ces nouvelles technologies.

Zusammenfassung

Diese Forschung konzentriert sich auf neue Technologien im europäischen Flugverkehrsmanagement und untersucht insbesondere die Übernahme von Technologien durch die Hauptakteure. Das europäische Flugverkehrsmanagement besteht aus einer stark fragmentierten Luftfahrtinfrastruktur, die von Akteuren mit unterschiedlichen Interessen aufgebaut und verwaltet wird. Die rasante Entwicklung der Informations- und Kommunikationstechnologien wirkt sich auf das europäische Flugverkehrsmanagement aus, wie dies auch bei anderen Netzindustrien der Fall ist. Flugsicherungsdienstleister und die Industrie im Allgemeinen experimentiert mit Virtual Center und Flight-Centric Operations. Diese Technologien haben die Möglichkeit, die derzeitige Bereitstellung von Flugsicherungsdiensten zu stören oder zumindest zu ändern. Es fehlen jedoch Forschungsergebnisse im Zusammenhang mit der möglichen Einführung dieser Technologien im Kontext des europäischen Flugverkehrsmanagements im Allgemeinen und des Single European Sky (SES) im Besonderen. Diese Doktorarbeit untersucht die mögliche Übernahme von zwei neuen Technologien anhand von zwei Fallstudien: flugzentrierter Betrieb und virtuelles Zentrum am europäischen Flugverkehrsmanagement. Die folgenden zwei Fragen werden in dieser Arbeit beantwortet. Die erste Forschungsfrage lautet: Wie und in welchem Umfang werden aufkommende Technologien - insbesondere flugzentrierte Operationen und virtuelle Zentren - von den relevanten Akteuren des europäischen Flugverkehrsmanagements aufgegriffen und letztendlich übernommen? Die zweite Forschungsfrage lautet: Welche Konsequenzen wird eine solche Übernahme für den Prozess der Umsetzung des einheitlichen europäischen Himmels haben? Um die Übernahme von Technologien zu analysieren, zu verstehen und zu bewerten, verfolgt diese Arbeit einen sozio-technischen Ansatz unter Verwendung der Stakeholder-Theorie in Kombination mit der Methodik der Akteur-Netzwerk-Theorie. Anders als bei den traditionellen Forschungsansätzen zur Einführung von Technologien wie der Verbreitung von Innovationen wird eine interpretative Haltung eingenommen, um zu untersuchen, wie neue Technologien entstehen und sich entwickeln. Die Prozesse der Akteur-Netzwerk-Theorie, die in Problematisierung, Interesse, Registrierung und Mobilisierung gepackt sind, werden verwendet, um die Einführung flugzentrierter Operationen und Technologien für virtuelle Zentren zu erklären. Zusammen mit der Untersuchung der Faktoren und Hindernisse, die die Einführung von Technologien beeinflussen, bietet die Arbeit einen konzeptionellen Rahmen zur Untersuchung der Einführung von Technologien. Die Daten werden qualitativ durch Teilnehmerbeobachtung, Interviews und Dokumentenanalyse gesammelt. Die Interaktionen zwischen den Hauptakteuren werden analysiert, um weitere Empfehlungen zur Einführung dieser neuen Technologien zu erhalten.

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Acronyms

4D 4-Dimension Trajectory

A6 ANSP partnership between DFS (Germany), DSNA (France), ENAIRE (Spain), ENAV (Italy), NATS (UK) and NORACON

AAS Airspace Architecture Study

ACC Area Control Centre

ACCHANGE Accelerating Change by Regional Forerunners

ADB Asian Development Bank

ADSP ATM Data Service Provider

AMAN Arrival Management

ANS Air Navigation Services

ANS-CR ANSP of the Croatia

ANS-CZC ANSP of the Czech Republic

ANT Actor-Network Theory

AO Aircraft Operator

ATC Air Traffic Control

ATCO Air Traffic Controller

ATFCM Air Traffic Flow and Capacity Management

ATM Air Traffic Management

ATS Air Traffic Services

ATSU Air Traffic Service Unit

CAQDAS Computer Assisted Qualitative Data Analysis Software

CBS Cloud-Based System

CCS Co-Flight Cloud Services

CERT Computer Emergency Response Teams

CFDPS Cloud Flight Data Processing System

COCTA Coordinated capacity ordering and trajectory pricing for better-performing ATM

COMPAIR Competition for Air Traffic Management

COSER Common Services

COOPANS ANSP partnership between Austria (Austro Control), Croatia (Croatia Control), Denmark (Naviair), Ireland (Irish Aviation Authority), Portugal (NAV Portugal) and Sweden (LFV)

CWP Controller Working Position

DFS Deutsche Flugsicherung: ANSP of Germany

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DIT Diffusion of Innovation Theory
DLR German Aerospace Center
DSNA Direction des Services de la navigation aérienne: ANSP of France
EAMAN Extended Arrival Management
EASA European Aviation Safety Agency
EATM European Air Traffic Management
EC The European Commission
EHR Electronic Health Record
ERP Enterprise Resource Planning
ESB Enterprise Service Bus
EU European Union
ENAV Società Nazionale per l'Assistenza al Volo: ANSP of Italy
ENAIRE ANSP of Spain
EUROCONTROL The European Organisation for the Safety of Air Navigation
FAA Federal Aviation Administration
FAB Functional Airspace Block
FAB Functional Airspace Block
FCO Flight-Centric Operations
FDP Flight Data Processing
FDPS Flight Data Processing System
GTC Grameen Telecoms
HMI Human Machine Interfaces
HUNGAROCONTROL ANSP of Hungary
ICT Information and Communication Technologies
IS Information Systems
MoF Sri Lankan Ministry of Finance
MUAC Maastricht Upper Area Control Centre
NATS National Air Traffic Services: ANSP of the United Kingdom
NewPENS New Pan-European Network System
NM The Network Manager
NPT Normalization Process Theory
NSA National Supervisory Authority
PCP Pilot Common Project
PCU The Model of Personal Computer Utilization
PRC Performance Review Commission
RPAS Remotely Piloted Aircraft System
RPAS Remotely-Piloted Aircraft System
SCT The Social Cognitive Theory
SES Single European Sky
SESAR Single European Sky ATM Research
SESAR-DM SESAR Deployment Manager
SESAR-JU SESAR Joint Undertaking

SID SESAR Innovation Days
SOC Security Operations Centre
ST Stakeholder Theory
STATFOR Statistics and Forecast Service
STATFOR Statistics and Forecasts Unit of Eurocontrol
STS Science and Technology Studies
SWIM System Wide Information Management
TAM Technology Adoption Model
TAM2 Extended Technology Adoption Model
TMM The Motivation Model
TPB Theory of Planned Behaviour
TRA Theory of Reasoned Action
UTAUT Unified Theory of Acceptance and Use of Technology
VATC Virtual Air Traffic Control
VC Virtual Centre
VHF Very High Frequency
VoIP Voice over Internet Protocol
WAN Wide Area Network

1 Introduction

European air traffic management (ATM) is experiencing a fast-changing socio-technical environment, primarily driven by technological changes and improvements. These changes originate mainly from the rapid development of information and communication technologies. New technologies affect the current provision of services, opening up a frontier for new business models, and even ultimately disrupting the ATM market. Thus, it is strategically important to analyze the adoption of new technologies in the context of European ATM, examining how the institutions and actors adapt to this drastically changing landscape. For this reason, this thesis focuses on analyzing the adoption of two new technologies in European ATM, virtual centre and flight-centric operations, also called sector-less ATM.

The adoption of new technologies by the relevant actors in European ATM is a socio-technical phenomenon. Besides technical, a number of factors, such as social, political, economical, and legal affect the development and adoption of new technologies. Hence, this creates the need to understand these factors, and the alignment of actors' objectives regarding these technologies. Technology adoption research consists of various perspectives, ranging from technological determinism to social determinism [Tatnall and Gilding(1999)]. Specifically, this thesis adopts a combination of stakeholder theory (ST) and actor-network theory (ANT), the middle approach, to study the adoption of flight-centric operations and virtual centre technologies by relevant stakeholders in European ATM. ANT and stakeholder theory guide this research to identify the main actors, their roles and relationships in the technology adoption process.

The success and failure in the adoption process of these technologies are dependent on the actors' objectives, and the alignment of their interests in a stable network. This introduction chapter provides an overview of the current technical and institutional situation in European ATM revolving around emerging technologies. Furthermore, it summarizes the main motivation and relevance of the research question to the context. First, a brief history of Single European Sky (SES) initiative has been provided. Second, the definition and context of the specific technologies, flight-centric operations and virtual centre technologies are summarized briefly. Third, the audience and research question are introduced, while also providing insight

on the practical relevance of the research topic for the European ATM. Finally, the chapter concludes with presenting a brief overview of the thesis structure.

1.1 Background

The European air traffic management (EATM) consists of the services, infrastructure, and institutions to support, manage and deliver the necessary means for assisting aircrafts from departure to landing. ATM consists of air traffic control (ATC), air navigation systems (ANS), air traffic flow and capacity management (ATFCM). Throughout Europe, the provision of ANS is carried out by Air Navigation Service Providers (ANSPs) as national service providers, where they have sole responsibility for their corresponding airspace. The network is managed by EUROCONTROL, which is appointed by the European Commission (EC) as the Network Manager (NM). The objectives of EUROCONTROL includes research, development, operations and performance monitoring within close cooperation with all the aviation stakeholders. Specifically, for the new technologies EUROCONTROL also provides the roadmap for the development of a seamless Pan-European ATM. The development of new technologies is managed within the European ATM programme of EUROCONTROL. This programme later expanded into Single European Sky (SES) and the Single European Sky ATM Research programme (SESAR) with the inclusion of aviation stakeholders.

The Single European Sky (SES), initiated by the European Commission (EC), is the grand project for the Pan-European planning, development and execution of air traffic solutions in European ATM [Baumgartner and Finger(2014)]. The objectives of the SES target specific areas of performance, technology, safety and capacity. The high level target objectives of the SES includes 3-fold increase in capacity, improvement of safety by a factor of 10, reduction of the cost of the provision of ATM services to airspace users by 50 percent, and 10 percent reduction in environment effects. Following SESI, there are also improvements and additional pillars called as SESII and SESII+ [Commission(2018)]. Consequently, a research branch called Single European Sky ATM Research (SESAR) formed the European ATM Master Plan as a roadmap for Pan-European planning. Within these developments, new organizations called European Aviation Safety Agency (EASA) and Performance Review Commission (PRC) has been formed. EASA became responsible for assisting the EC for aviation safety, certification, standardization and training in a European scale. Respectively, PRC and its corresponding unit PRU aim to provide independent information and advice derived from EUROCONTROL's research, data and consultation background.

The SES II introduced a new perspective by adopting a gate-to-gate approach for air navigation services (ANS). The importance of Functional Air Space Blocks (FABs) has been emphasized, while also focusing on central network management. Concretely, the technological pillar SESAR has been enhanced by creating the SESAR Joint Undertaking (SESAR-JU). SESAR-JU has been tasked by the EC for the research, development, and validation of SESAR, combining both private industry partners and public institutions. The defragmentation and harmonization of

European ATM are targeted in SESII+, where the concept of centralized functions and services are introduced. The bottlenecks in the SES and FABs are mentioned in order to justify a single aviation authority and industry-led infrastructure.

Despite efforts from the actors in the European ATM, there still exists a bottleneck in achieving cost and performance improvements. The main reason is the misalignment of interests of the main actors in the European ATM. The interplay of strategical decision making among the actors creates a complex dynamic behavior. This behavior can be observed throughout the design, planning, execution and deployment phases of projects related to European ATM. Moreover, there is a misalignment between technology and governance in the European ATM [Baumgartner and Finger(2014)]. Yet, the recent developments in the digital technologies enable service-based architectures replacing legacy system solutions. Hence, there is a need to evaluate the adoption of these technologies in the context of European ATM. Specifically, flight-centric operations (sectorless ATM) and virtual centre technologies have the potential to disrupt the current provision of services by enabling new forms of service provision.

Considering the rapid rise of new technologies, SESAR-JU published a report on the modernization and digitalization of the European airspace, called 'A Proposal for the future architecture of the European airspace' [SESAR-JU(2019)]. Specifically, the EC requested this study due to the limited progress of the SES programme. The study points out that an evolutionary approach is needed, driven by modern technologies, while also separating service provision from infrastructure. Currently, conventional ATC architecture has three distinct layers, from top to bottom, the airspace layer, air traffic service (ATS) layer, and physical layer as illustrated in Figure 1.1 [SESAR-JU(2019)]. The airspace layer includes a sectorized approach, which is used in conventional ATC. Each ANSP has the total control of their own airspace, controlling the traffic segregated by sectors. Yet, this approach has its limitations. The main limitation is the capacity crunch that has been pushing the traffic to its limits for the last years in European airspace. This is due to the fact that the routes are fixed within constrained national airspace structures.

The next layer, called air traffic service layer, encompasses all the services and applications necessary to provide air traffic services. Currently, these services are provided by national ANSPs in the form of vertically integrated applications and information services, such as surveillance, and meteorological information. Since each ANSP and the corresponding Member State has their own solution for the components in the air traffic service layer, there is limited automation, and low level of information sharing. The final layer, which is the physical (ground) layer, composes of the ground infrastructure, such as radars and sensors to provide ATS. This layer is highly fragmented, because each ANSP invests in their own infrastructure, hardware and software separately.

The Airspace Architecture Study (AAS) identifies the factors limiting the overall capacity in conventional operations. Mainly, the study states that the organization of airspace is not optimal [SESAR-JU(2019)]. The pulling factors for the capacity are the limited use of data

Current architecture

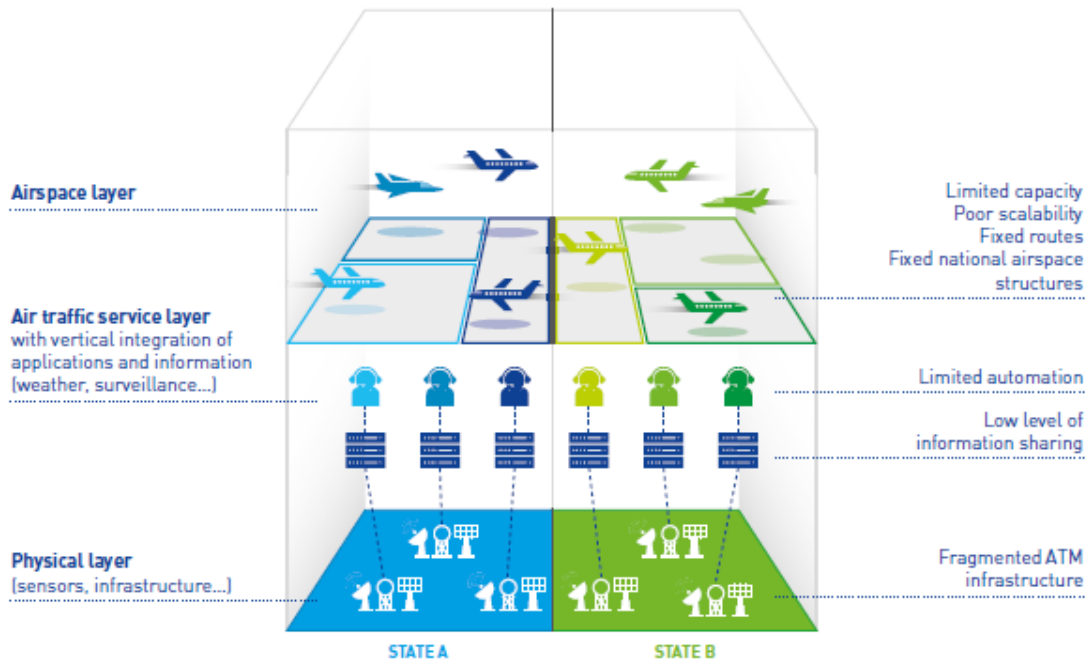


Figure 1.1 – Current Air Traffic Architecture as proposed by Airspace Architecture Study [SESAR-JU(2019)]

communications, limited opportunity to create new sectors, and limited automation support for controllers. Moreover, there exists constraints that limit the scalability and resilience of capacity. These constraints are limited predictability, information sharing, and flexibility of the use of resources as being the main barriers [SESAR-JU(2019)]. On top of that, there stands geographical constraints on air traffic service provision following national borders.

AAS proposes a solution to these limitations by designing the Single European Airspace System, separating the data (application) services layer from the air traffic services layer [SESAR-JU(2019)]. This, in turn, brings multitude of changes in ATS provision and the business models of the actors involved. The main change is the separation of the framework dimension from the operational, and technical dimensions. The newly designed framework dimension now includes the regulatory aspects and definition of air navigation services. Respectively, operational and technical dimensions include the airspace, operations, technology, infrastructure, and data services. The main aim of this new architecture is to optimize the organization of airspace, hence increasing capacity. Furthermore, the new architecture enables building scalable and resilient solutions with dynamic capacity management. This is followed by progressive increase in the levels of automation with the support of standardized ATM data services. The difference between the current conventional architecture and the proposed Single European Airspace System is illustrated using Figures 1.1 and 1.2.

1.1. Background

The new architecture, called the Single European Airspace System, has four major layers. From top to bottom, these layers are network airspace operations, air traffic services, data and application services and infrastructure. Here, a clear separation exists between data (application) services and conventional air traffic services layers. This is due to the fact that it is easier to defragment data and application services when they are separated from the core ATC services provided by ANSPs. For the provision of these services, a new entity, called ATM data service providers (ADSP) is proposed. Consequently, a shift in the model of service provision in the areas of flight data processing functions (correlation, trajectory prediction, conflict detection and resolution), and arrival management planning is expected. In the future, these services are expected to be provided by harmonized, and defragmented ADSPs overall Europe. Additionally, ADSPs, when operational, will also cover ATM data services that aid in the virtual defragmentation of the European air traffic system.

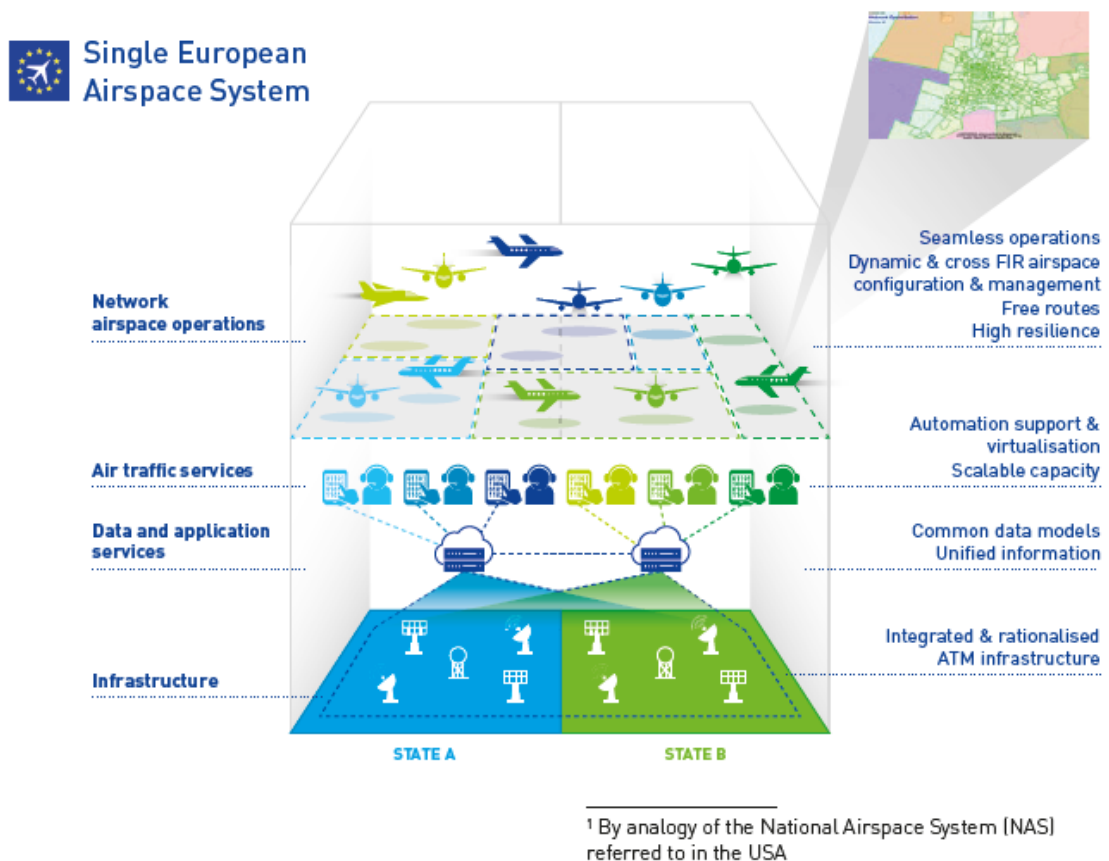


Figure 1.2 – Future Single European Airspace System as proposed by Airspace Architecture Study [SESAR-JU(2019)]

1.2 Research Motivation & Rationale

There are two main challenges that the European ATM is currently facing regarding new technologies. The first challenge is the identification of the ways for switching from legacy-based technologies or solutions to service-based architectures. The second challenge is the defragmentation of ATS and ATC infrastructure and services. Both of these challenges are intertwined, where new technologies could provide the solution for both of the challenges. The technical solutions in the SES range from minor improvements on legacy systems to major technical infrastructure changes using service-based architectures. New air traffic technologies are emerging rapidly, as currently the case in almost all information and communication technologies. In parallel, ATM is shifting its paradigm from legacy system-based solutions to service-oriented architectures. This, in turn, prepares the grounds for the current institutional governance in European ATM to adapt to these radical changes. Upcoming technologies in European ATM, such as virtual centre, flight-centric operations, remote towers, and remotely piloted aircraft systems (RPAS) currently disrupt the legacy system-based architectures. Additionally, the European ATM is facing congestion and technical challenges due to increasing air traffic and fragmentation of infrastructure. Previously, before the effects of COVID-19, the Statistics and Forecast Service (STATFOR) of EUROCONTROL estimated that the yearly growth rates for air traffic will be between 2.2% and 3.8% in medium and high traffic scenarios. Additionally, the Challenges of Growth from EUROCONTROL expected that by 2040, flights per year will reach to 16.2 million with 53% increase compared to current year. Therefore, the capacity should increase by 16% percent in order to accommodate the flights. Yet, currently COVID-19 have a detrimental effect on the civilian air traffic, additionally carrying an uncertainty which is expected to span for a number of years.

There are several solutions to the defragmentation of systems and infrastructure offered by the main actors in European ATM. SESAR is the leading advanced research programme of harmonization and standardization among European service providers. The Airspace Architecture Study and the new Master Plan, providing the roadmap for the European ATM, emphasizes the importance of new digital technologies, such as virtual centre, flight-centric operations, and integration of RPAS [Eurocontrol(2019)]. Considering this technology-driven environment, this thesis aims to examine the technology adoption process revolving around new technologies. By following the actors, the research carries out an extensive analysis of the adoption processes from a socio-technical perspective. This research focuses on two key developing technologies in European ATM: flight-centric operations (sectorless ATM) and virtual centre. In order to select the technologies for the study, a qualitative assessment, supported by participant observation and documentary analysis, has been carried out to point Europe as a laboratory of technical experiments for European ATM [Finger and Button(2017)]. The assessment clearly states that the new technologies are driving European ATM towards service-based architectures, while also supporting that there is a need to analyze the potential of these technologies.

This research aims first to examine and describe the main actors forming the network of

interests regarding the adoption of two emerging technologies: flight-centric operations and virtual centres. Secondly, the alignment of actors regarding these technologies is analyzed from a perspective combining both stakeholder theory and ANT. Further, the thesis presents a conceptual framework to examine technology adoption in the context of European ATM. This involves the identification of the actors, their roles and relationships between them while they adopt new technologies. The dynamic process of adoption is described using ANT tools, namely problematisation, intersement, enrolment and mobilization [Callon(1984)]. ANT is used as a methodological tool to model the technology adoption process, while theoretical standpoint is based on stakeholder theory in defining and identifying the actors involved. This section continues with describing the need for research in adoption and the current practical research gap in European ATM research and the literature.

Currently, majority of information and communication technologies (ICT) adoption research is based on Rogers' Diffusion Model [Eze et al.(2018)Eze, Chinedu-Eze, and Bello]. This model aims to understand the adoption process by predicting the level of adoption by the users. Additionally, similar models focus on variance or factor approach. These include innovation models, intention-based models, resource-based view and Porter's model [Eze et al.(2018)Eze, Chinedu-Eze, and Bello]. However, it does not take into account the behavior of actors and their objectives in the adoption process. Contrary to this perspective, this thesis uses a socio-technical standpoint, where the best of both worlds from stakeholder theory (ST) and actor-network theory (ANT) are combined to understand the network as a collection of translations of actors' objectives[Latour(2005)]. A socio-technical perspective provides rich description of actors, and their objectives. The actors are motivated by various factors, ranging from technical, political, economic, legal, and social. The actors translate their objectives in combination with other actors and their own interpretations [Tatnall and Gilding(1999)]. Even though, there are examples of socio-technical analysis of economic and technical scenarios for European ATM, as for our knowledge, a socio-technical approach for investigating technology adoption has not been used extensively in ATM research.

The adoption of newly emerging technologies in European ATM is becoming an increasingly important issue. The rapid developments in ICT are affecting European ATM as similar to other network industries. In order to understand the technical developments in European ATM, it is important to investigate the possible adoption of new technologies. In that sense, this thesis targets a practical gap to define the actors, their objectives and the network formation around specific technologies. ANT and ST help us to explain how the relations in networks develop and stabilize to adopt ICT over time. The main idea is to enhance the technology adoption theories from only understanding the users' perspectives on the adoption of new technologies towards investigating the socio-technical interactions and theories to explain the adoption phenomenon.

The successful implementation and deployment of new technologies for European ATM are dependent on the actors' interests and objectives. The actors form various networks to invest, adopt and deploy new technologies. In the specific case of European ATM, there are

Chapter 1. Introduction

diverse actors, such as air navigation service providers (ANSP), the manufacturing industry, the Member States of EUROCONTROL, Network Manager as EUROCONTROL, SESAR Joint-Undertaking (SJU), the European Commission (EC), European Aviation Safety Organization (EASA). SESAR, as the research pillar of the SES, is responsible for the analysis of validation and feasibility for new technologies. SJU manages the solutions within the SES in direct support with the network manager, EUROCONTROL. The network managing function requires EUROCONTROL to cooperate and coordinate the stakeholders, guiding the way of adopting new technologies in parallel with SES regulations. In that sense, this thesis tackles a practical gap to understand how and to what extent the adoption of flight-centric operations and virtual centre technologies will be.

The traditional methods of investigating technology adoption focus largely on the technical side, leaving the social as the context in which its development and adoption take place [Tatnall and Gilding(1999)]. This limits the adoption process to technological determinism, in which technically superior solutions are treated as the most favorable. In contrast, social determinism uses social categories to understand technology adoption. In this view, the artifact gains a social identity and interpretation that follows technical context. Specifically for European ATM, even though the technical developments and factors are pushing the actors for innovation and adoption of new technologies, there are various factors such as social, political, economical, and legal affecting the adoption of new technologies. For this reason, this research treats the adoption problem from a socio-technical viewpoint, where both technical and social are treated correspondingly.

SES offers the actors in European ATM a portfolio of technical solutions to advance the current legacy system infrastructure towards service-based architectures. Then, these solutions are discussed with the relevant actors during feasibility, design, validation and implementation phases. Mainly, the concept of operations report provides the technical feasibility for each solution. Following the technical aspects, the economic impacts are analyzed by providing the business model and cost-benefit analysis. While these technologies (solutions) are on the verge of development, there emerges a need for the analysis of the extent, challenges and factors affecting the adoption. This follows from the fact that a number of solutions offered by the SES project are adopted, some are partly adopted, and some face challenges during the adoption process. It becomes strategically important to analyze the extent, factors and challenges of technology adoption for each related actor inside a solution. By this, during various stages of technological solutions, key actors would be able to point out the factors affecting the adoption and build the networks accordingly.

This thesis specifically focuses on flight-centric operations (FCO) and virtual centre (VC) technologies as the main cases to investigate the technology adoption process in European ATM. These two technologies have the potential to shift European ATM from legacy system-based architectures to service-based architectures. For flight-centric operations, SESAR PJ10.01-b solution works on the provision of ground-based automated support for managing separation across several air traffic control sectors. In particular, FCO shifts sector-based ATC towards

managing certain number of aircraft throughout their flight segment within a larger airspace or along flows of traffic. Cloud-based technologies can be regarded as the collection of technologies that enable virtualized infrastructure, such as Virtual Centre, Cloud Flight-Data Processing System. Specifically, SESAR PJ16.03 - Work Station, Service Interface Definition & Virtual Centre Concept aims to provide an operating environment in which different ATS units, even across different ANSPs, will appear as a single unit and subject to operational and technical interoperability. In this thesis, the aim is to aid in the development of these solutions by analyzing and defining the stakeholders first. Second, the research investigates the extent of the adoption by analyzing the factors affecting the actors and their objectives. Third, the thesis identifies the consequences of the adoption of these technologies on the process of implementing the Single European Sky.

1.3 Personal Interest on the Research Topic

This thesis is a by-product of the unique opportunity allowing me to observe the air traffic domain as an engineer. Because, being an engineer, we are trained to have a worldview of solving or optimizing engineering problems. Yet, the world we live in is just not an engineers' world. There are dynamics occurring from all other dimensions, such as social, political, economical, and legal. The human perception and interaction with technology always fascinate me through my life journey. We are both discovering new magical items as technical artefacts, and directly ingest them into our daily lives in an irreversible way. Technology plays an important part of our lives, as most of us spend a major part of our lives in front of a computer screen. Though, technology is evolving also, it is changing shape, and form according to our needs in a fast-paced digital world. Majority of network industries, are either already disrupted, currently being disrupted, or will be disrupted by the new technologies.

What is technology? It is a tough question to answer in simple terms. I, personally, perceive technology as a human function amplifier. By this, I mean look around us, look at every single piece of technology we use, it is created to amplify a function that we as humans have. So following this definition, the first basic technology that the first humans created helped them to survive. This special craft enabled us to better function, transport, communicate, entertain, produce, and deliver effectively. Overall, technology amplifies all the basic needs of a human being as a whole. The rate of its development in the last 50 years is astonishing. There are no area left untouched by technological change. Being a human function amplifier, it is a huge oversimplification to treat technology just as a technical artefact. Furthermore, it is impossible to separate the human from technology counterpart, because they coexist. Every technology serves for a human function, if not making it better for humans to function. Even, with the latest advancement of technology, even technology starts to replace human functions, namely jobs.

Within this complex changes, it is hard to approach technology from a purely technical perspective. There exists social, political, economical, legal, and additional dimensions to

it. The adoption of technology includes changes in all these fields. It is similar to changing a human function. Yet, there are challenges associated to it. Not always the change is optimal for all the stakeholders. It is precious for me as a researcher to observe this phenomena. Air traffic domain can be regarded as an introvert network industry with its slow-paced technological change and closed, tightly protected working environment and market. However, similar to all network industries air traffic could not refuse the vast changes in the technological landscape. Yet, its tightly knit doors make it hard for the new technologies penetrate its market. From a technical point of view, the defragmentation and the technical upgrade of the current systems is achivable. Yet, from the political and social factors revolving around new technologies make it a challenge to move on with the current actors in the European ATM.

As a researcher, this unique opportunity of observing the main actors, while working in EUROCONTROL, made me decide on the topic of examining the adoption of certain technologies. The main reason is to investigate how these actors align their interests when introduced to a new, disruptive technology. The problem is not just a technical engineering problem, and I am motivated to understand the factors affecting the adoption of these technologies. Even though technically and economically feasible, some technologies could not penetrate the ATM market. Thus, from the start of my working time in EUROCONTROL, I observed the unique need to evaluate the actors' interests towards adopting new technologies. The SES creates the backbone for the interaction of the stakeholders towards defining the same goals for the future of air traffic management.

1.4 New Challenges for the European ATM

Before presenting the detailed objectives of this research, it is crucial to examine the emerging challenges brought forth by the emergence of new technologies in European ATM. Emerging information and communication technologies (ICT) are becoming the major drives deciding on the fate of organizations and industries [Eze et al.(2018)Eze, Chinedu-Eze, and Bello]. The rate of technological progress is high, but institutions and regulations are facing a hard time to keep up with it. In order to reach the objectives of SES, stakeholders in European ATM should keep up with the new technologies and adopt them effectively to reduce the costs for airspace users in a safe and efficient manner.

Currently, the development phase of SES is managed by SESAR Joint Undertaking, which is a public-private partnership with the Network Manager EUROCONTROL, air navigation service providers (ANSPs) and the industry as the technology providers. The solutions in SES are driven by the current and future needs of air traffic management and control. However, in a fast-changing environment of emerging ICT, some solutions will prevail while others eventually disappear. A number of key technologies are identified by participant observation and summarized briefly to the reader in the following section.

This section starts with explaining the paradigm shift towards open service-oriented architectures. Then, the section continues with summarizing the digital ATM technologies and

virtualization. Finally, the section concludes with emphasizing the importance of the dynamic allocation of resources for the European ATM.

1.4.1 Paradigm Shift Towards Open Service-Oriented Architectures

The European ATM stays fragmented despite the efforts of the actors towards defragmenting it. Mainly, this is due to the misalignment between the technology and the institutions in the European ATM. On one side technical developments push the system towards adopting new technologies. On the other side, the institutional structure could not create the necessary momentum towards ingesting new technologies inside the European ATM system. However, there is an important need to shift towards open service-oriented architectures from legacy systems in order to increase performance and efficiency of the overall system.

The legacy systems consist of each ANSP having their own infrastructure, hardware and software, locally as a service provider for their national airspace. Concretely, this creates the main fragmentation issue in the Europe. Currently, each European Member State have the sovereign responsibility of the provision of ANS and ATC services in their national airspace. Specifically, local solutions with low-level of sharing of data and information between the nodes in the system. In this configuration, coordination and data sharing between the nodes in the network stay limited. Additionally, the resources could not be dynamically allocated leading to decreased performance and cost-efficiency.

Open service-oriented architectures, originated from ICT, utilize a common basis, including infrastructure, hardware and software, to provide services, usually built on a cloud infrastructure. In the European ATM, there are couple of new technologies and solutions to support this new type of architecture. Among these the virtual centre supports the remote provision of ATC and ANS services without being locked to the location of the service provider. Additionally, System Wide Information Management (SWIM), offered by EUROCONTROL, targets to standardize the services and systems between the service providers supporting an open service-oriented architecture. Yet, the alignment of actors towards adopting these new and radical technologies include challenges and addressed in these thesis.

1.4.2 Digital ATM Technologies & Virtualization

Digitalization is a contemporary topic, similar to many other network industries, the European ATM aims to utilize the new technologies that could support the fully digitalized infrastructure, hardware and software. Yet, the word, digitalization, in itself, is not quite fit for the actual meaning in the context of the European ATM. Already, there are operational digital technologies that are supporting the systems in the European ATM. More, digitalization means utilizing new methods of service provision with the support of new technologies, such as digital voice communication, satellite solutions, and cloud-based systems. Eventually, this is expected to lead towards better coordination between the service providers, higher levels of data and

information sharing, and enabling of automated solutions for the European ATM.

The legacy communication systems in the European ATM still rely on the basic principles of radar and very high frequency (VHF) radio communication. New digital communication systems, such as voice over internet protocol (VoIP) and satellite-based communication systems could solve the current frequency congestion problem. The modernization of the current communication system is crucial to increase the performance and efficiency of the overall system. The frequency congestion problem limits the capacity of the service provision. The service provision is adversely affected by the low bandwidth of information sharing. There exists low level of information sharing between the ground and the aircraft. With new technologies, real-time data communication could enable sharing of various data between the ground and the air, and also between the aircraft. By increasing the coverage, speed and bandwidth of communication with satellite technologies, majority of the congestion problems would be solved.

Digitalization also brings the utilization of cloud-based ATM technologies into the European ATM. Currently, the air navigation and air traffic control services are provided locally by the ANSPs from local implementation of infrastructure, hardware and software. The shift towards open-service oriented architectures could be supported by the cloud-based service provision in the European ATM. Most prominently, the virtual centre directly address this problem by introducing a common share infrastructure, hardware and software to support several service providers. With virtual centre, location independent provision of air traffic control and navigation services could be possible. This is revolutionary in the case of the European ATM, where the service provision is currently locked to a single local provider.

1.4.3 Dynamic Allocation of Resources

Another important challenge is how to enable dynamic allocation of resources and staff in the European ATM for the provision of ATC and ANS services. Currently, the provision of the services remain static, where a fixed amount of resources, hardware, software and staff is allocated for the estimated workload for the sectorized control of air traffic. This creates issues for the reduced cost-effectiveness in the provision of the services and inefficiencies of under-utilization of staff effort. Concretely, the system responds to the changes in the capacity and allocation in a static way without a dynamic allocation of resources or staff. Only the network management functions optimize the trajectory of the flights. Yet, it still remains as a pre-allocated optimization with static methods to manage the overall network.

Dynamic allocation of resources and staff is crucial for the future of the European ATM. First, it enables to adjust the capacity of the airspace according to the needs of the Second, ATCO effort could be optimized with better utilization of workload with dynamic allocation of services. From this perspective, flight-centric operations offer a new approach for the air traffic control by shifting towards trajectory-based control rather than conventional sector-based control. Mainly, air traffic control is provided within small airspace portions, called sectors, and each

1.5. Description of Technologies Under Investigation

ATCO is responsible for a specific sector and the aircraft passing through this sector. Flight-centric operations aim to merge the sectors as much as possible utilizing the optimal dynamic allocation of ATCO workload depending on the capacity needed.

1.5 Description of Technologies Under Investigation

1.5.1 Flight-Centric Operations (Sector-less ATM)

Initially named as the sectorless ATM, flight-centric operations faced a number of changes in its definition, context and concept. The key element of the technology is to be able to move from conventional sector based operations towards a sectorless airspace control, ultimately merging all the sectors by focusing on the flight itself. The concept is first officially introduced by Duong et al. (2001) to handle increasing traffic in a complex airspace, while also keeping the safety at check [Duong et al.(2001)Duong, Gawinowski, Nicolaon, and Smith]. In order to solve this problem, a number of initiatives, Free-Flight in European Air Traffic Management Program (EATMP), User-Preferred Routes, Autonomous Aircraft Operations, and Flexible Use of Airspace are created by various actors in the European ATM. Yet, previously there does not exist a predefined formula for the overall management of change in the airspace sectorization. Addressing this problem, Duong et al. (2001) offered the decentralisation of the airspace sector control towards a trajectory-based flight control. Henceforth, this brings substantial changes in the work practices of ATC and ATCOs, regarded as a revolution rather than an evolution. Back in 2001, two possible options are considered for the sectorless ATM. First is the location independency of the ATCO as an ATCO being attached to an airline. Second is the evolving role of ATCOs towards a real-time dynamic flow manager.

Following the initial definition of the concept, Riviere (2004) further continued to validate the route network for sectorless ATM and built optimized techniques [Riviere(2004)]. Moreover, these validations insisted on the need to introduce new practices into ATC, while moving away from the traditional sector based approaches. Riviere (2004) suggested that sectorless ATM shifts the paradigm of ATC in discrete steps. In order to reach trajectory-based operations, the airspace should be redesigned with optimal routes, both optimizing the network, traffic and flows at the same time. These changes could be implemented by a complete overhaul of the current airspace structure, where a new method of network optimization, Trunk Route Generation, is offered as one of the possible solutions. Yet, Riviere (2004) suggested that more evaluations have to be carried on to validate the route network structure. Correspondingly, two issues have been identified for sectorless ATM. In terms of extension and level of allocation, the user, ATCO, should be taken into account for further evaluation. Additionally, fast-time simulation using real data could aid the validation process for sectorless ATM.

The sectorless concept gained traction by the joined contribution of DLR and DFS [Korn et al.(2009)Korn, Edinger, Tittel, Kugler, Putz, Hassa, and Mohrhard]. Korn et al. (2009) examined the feasibility of the concept, pointing on en-route ATC efficiency increase by 100 percent.

A bigger portion of the airspace, including the whole German airspace, extending into the European airspace, is considered for the real-time simulations. The physical requirements for ATCOs in sectorless operations are defined as a new controller working position (CWP) providing the necessary support tools for the sectorless control. Consequently, this should be supported by reliable coordination tools for the ATCOs working under sectorless rules, assisting the situational awareness level of the ATCOs. Furthermore, Korn et al. (2009) summarized the foreseen benefits of sectorless ATM as follows [Korn et al.(2009)Korn, Edinger, Tittel, Kugler, Putz, Hassa, and Mohrhard]:

- The traffic load can be easily distributed in a very balanced way over the controllers on duty.
- Airspace capacity is no longer restricted by sector capacity. Instead, it is expected to increase ATCO efficiency of up to 100 percent.
- It offers an easy way to implement contingency actions since controllers can take over aircraft regardless of which center they are currently working for.
- Coordination actions between adjacent sectors are no longer necessary. The amount of voice communication between the aircraft and ATC are reduced. There are no handover and identification communications necessary.
- SESAR (or NextGEN) concept elements, like business trajectories, can be easily incorporated in this concept since the ATCO will have in mind the entire flight of his aircraft. ATCO is only supposed to interfere in case of conflicts. The better the individual business trajectories are coordinated with each other, the less difficult will be the job of the ATCO.
- As the airspace structure (sectors, airways, etc.) are no longer necessary, a direct-to based traffic organization can be envisaged.
- ATCOs will immediately see what their control actions will mean to the aircraft. A closer relationship between controllers and aircrews will be established. The ATCO could be regarded as an additional (temporary) aircrew member taking care for conflict free routing.

1.5.2 Virtual Centre

The virtual centre technology aims to defragment the provision of ATC by combining and standardizing the infrastructure, hardware and software between the European Area Control Centres (ACCs). Currently, there are 64 ACCs spread around the European airspace that provide ATC services for the aircraft locally. This creates a patchwork of solutions to develop, support, maintain these systems with low-level of information sharing between the systems. Based on the principles of open service-oriented architectures and backed by cloud-based infrastructure, virtual centre aims to virtually defragment the services by enabling location

1.5. Description of Technologies Under Investigation

and infrastructure independent provision of the services. Establishing this needs pre-requisite technologies, such as a new digital communication infrastructure supported within a Wide Area Network (WAN). Concretely, the ANSPs would be able to subscribe to services in a plug-and-play fashion using common data centres defragmented in a Pan-European scale. Additionally, the virtual centre requires modifications in the working positions of the ATCOs in order to support the modernized service interfaces. The components of the virtual centre is illustrated in Figure 1.3.

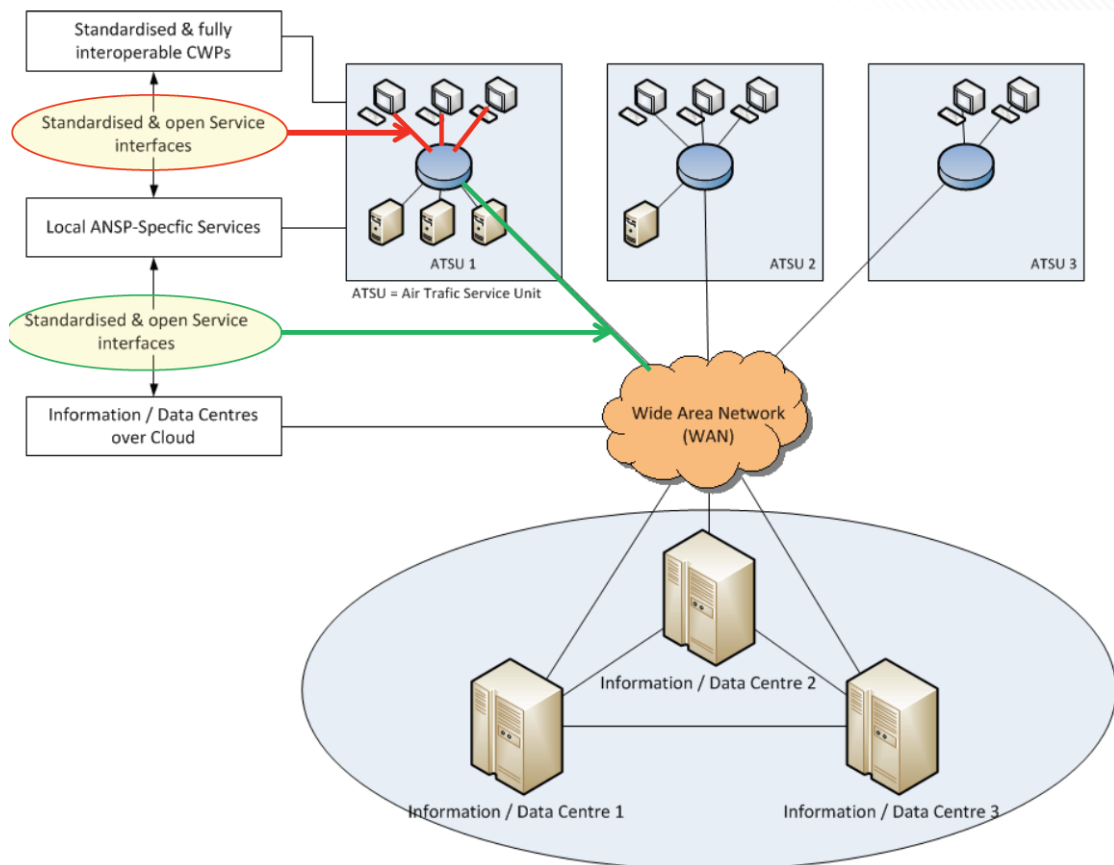


Figure 1.3 – Virtual Centre Model [Skyguide(2020)]

The initial aim of the virtual centre is to reduce costs by combining two or more ACCs together. Skyguide, the Swiss ANSP, introduced the concept in 2014 with the ambition of combining the Zurich and Geneva ACCs into a single centre. By this, the procedures, hardware, and software between the ACCs would be standardized within a new open service-oriented architecture. Of course, this would require heavy initial investment for the ANSP in order to be an early adopter of the technology. The micro-problem of the Swiss ANSP, combining the two ACCs, is a general problem for the whole Europe, where fragmented ACCs deliver separate services within their predefined sectors. Hence, virtual centre is regarded as a role model for the defragmentation solution for the whole Europe. By this, the fragmented ACCs could be merged towards optimizing the use of the resources. Virtual centre relies on a 3 layer approach,

which directly separates into data, application and services layers. Mainly, a cloud-based system would support the sharing of information between the ACCs, and ultimately ANSPs throughout Europe.

Currently, the implementation of the virtual centre remain local, initially defragmentation happens inside a single ANSP by combining its internal ACCs. Additionally, a number of contingency scenarios between ANSPs, where the delegation of airspace between ANSPs are considered. This requires further standardisation of all the procedures to support virtual centre technology between ANSPs. Additionally, rationalization of infrastructure is required to further introduce cost-effectiveness benefits. The virtual centre introduces radical changes inside the European ATM. First, the technology creates a paradigm shift from legacy systems towards service-oriented architectures in the European ATM. Second, it introduces radical changes in the business models of the actors, where location independent provision of services would be possible. Third, virtual centre could create the necessary momentum to virtually defragment the current fragmented provision of services in the European ATM.

1.6 Research Objectives

The aim of this research is to improve our understanding on the adoption of new technologies in European ATM. Specifically, for flight-centric operations and virtual centre, we would like to understand the actors, their objectives and relationships between them, while they adopt these new technologies. The research objectives are guided by the researcher's interest to examine what constitutes this dynamic technology adoption process. This section directs the research questions, while a separate chapter on research design focuses on how the question evolved and the approach to the research. The research questions of this study are listed as below:

1. How and to what extent will emerging technologies, in particular flight-centric operations and virtual centre be taken up and ultimately adopted by the relevant actors of European ATM?
2. What will the consequences of such uptake or adoption be on the process of implementing the Single European Sky?

Following the main research questions, using stakeholder theory, combined with actor-network theory approach, we want to investigate the following sub-questions:

- 1.1. Who are the actors that are involved in the technology adoption process in European ATM, specifically for the technologies, flight-centric operations and virtual centre?
- 1.2. What are the key roles or objectives of the actors in the technology adoption process?
- 1.3. What factors (enablers, inhibitors) influence the adoption process of new technologies? (technical, economic, social, legal, and political factors)

2.1. What are the implications of these technologies to the implementation of the Single European Sky, and its high-level target objectives? (capacity, cost-effectiveness, safety, environment, defragmentation)

1.7 Research Process and Method

This research aims to provide the stakeholders in European ATM an examination of the evolutionary process of technology adoption using a socio-technical approach. The research process and method are designed to investigate the roles and objectives of the actors related to specific technology adoption. Specifically, this research uses case studies to investigate the research problem. First, a conceptual framework is developed to interpret the technology adoption process in European ATM. Next, a preliminary study is executed to get familiar with the interview method and the use of conceptual framework. Then, the research process follows the design of the case studies. Mainly, multiple sources of evidence in the form of interviews, participant observation, and documentary analysis are used for data collection during this research. The summary of the research process is illustrated in Figure 1.5.

1.7.1 Methodology

Following the definition of the research problem, the main research methodology is selected as holistic multiple case studies. Specifically, the case studies investigate separately the adoption of two new technologies in European ATM: virtual centre and flight-centric operations. The selection of the case study as the main methodology originates from asking a 'how' question in the research objectives. The main goal of the research is to investigate the process of technology adoption, analyzing the actors, their roles, and relationships during the adoption process. For this reason, the unit of analysis is the technology adoption process, while the context of the case study changes with specific technology. The two case studies follow exactly the same case study protocol, as described in the research design chapter in detail.

The combination of stakeholder theory (ST) and actor-network theory (ANT) is the building block for the theoretical background. Inspired from both theories, a conceptual framework is designed to investigate the technology adoption process in European ATM. This framework adopts the definition of stakeholders from the stakeholder theory, while borrows the translation stages, and factors affecting the technology adoption from the ANT tools. Consequently, the conceptual framework guides the case studies through their design, data collection, analysis and reporting phases. The specific details for the utilization of the conceptual framework for the case studies are described in the case study design section of the thesis.

Initial Conceptual Framework

The need for a socio-technical conceptual framework to investigate technology adoption is evident for this research, since from the previous literature review in European ATM, there is a gap in analyzing the technology adoption. Consequently, the current approach for assessing the potential of new technologies is either in the form of technological validation or cost-benefit analysis. There is an apparent need for the analysis of the actors, their roles, relationships and factors affecting the adoption of new technologies. In that regard, the conceptual framework adopts theoretical standpoint from both the stakeholder theory and actor-network theory, as illustrated in Figure 1.4.

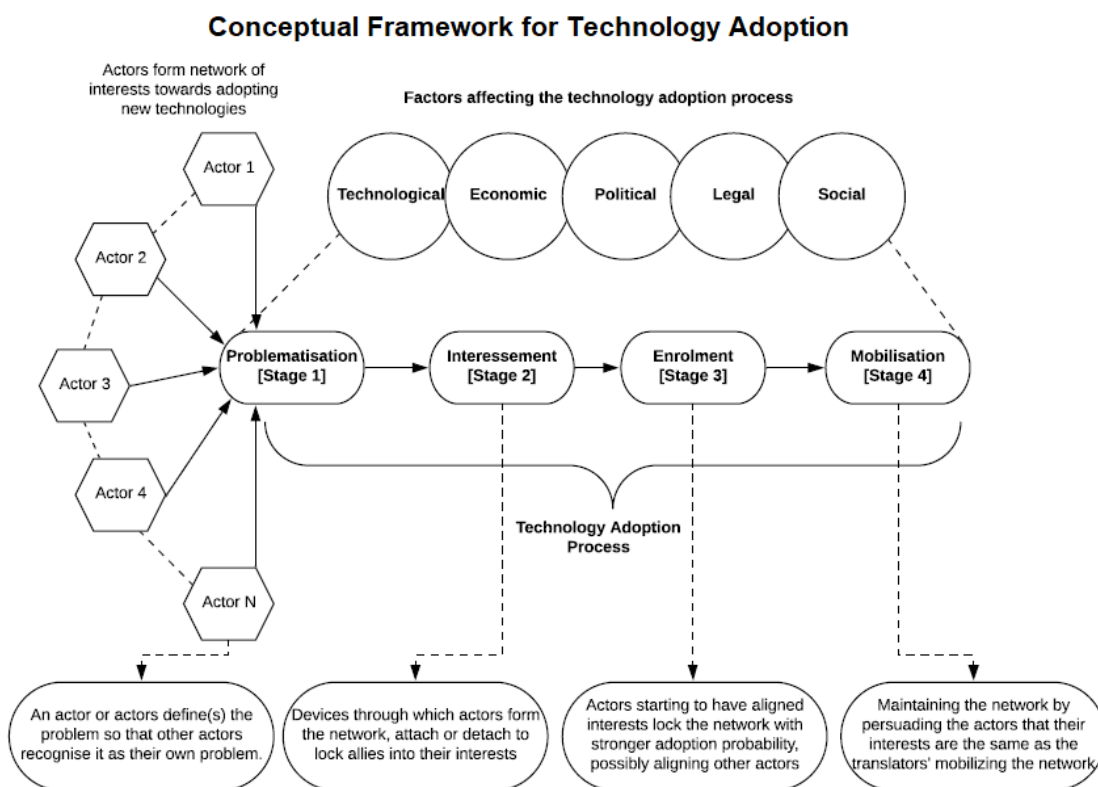


Figure 1.4 – Initial Conceptual Framework for Technology Adoption

The technology adoption process is represented using four stages of translation, as adopted from ANT. These stages are called problematisation (Stage 1), interessement (Stage 2), enrollment (Stage 3), and mobilisation (Stage 4). A number of actors form a network of interests towards adopting new technologies. These actors encompass the stakeholders in European ATM, involved either directly or indirectly in the technology adoption process. These actors have their own objectives, and as also defined in ANT, pass through stages of translation, while they define their objectives through the adoption process. During these stages, a number of factors affect the technology adoption process. These are categorized into technological, economic, political, legal, and social factors. The separation between the categories is

1.7. Research Process and Method

not mutually exclusive, in that we can have a combination of factor categorization, such as socio-political, and eco-political, etc.

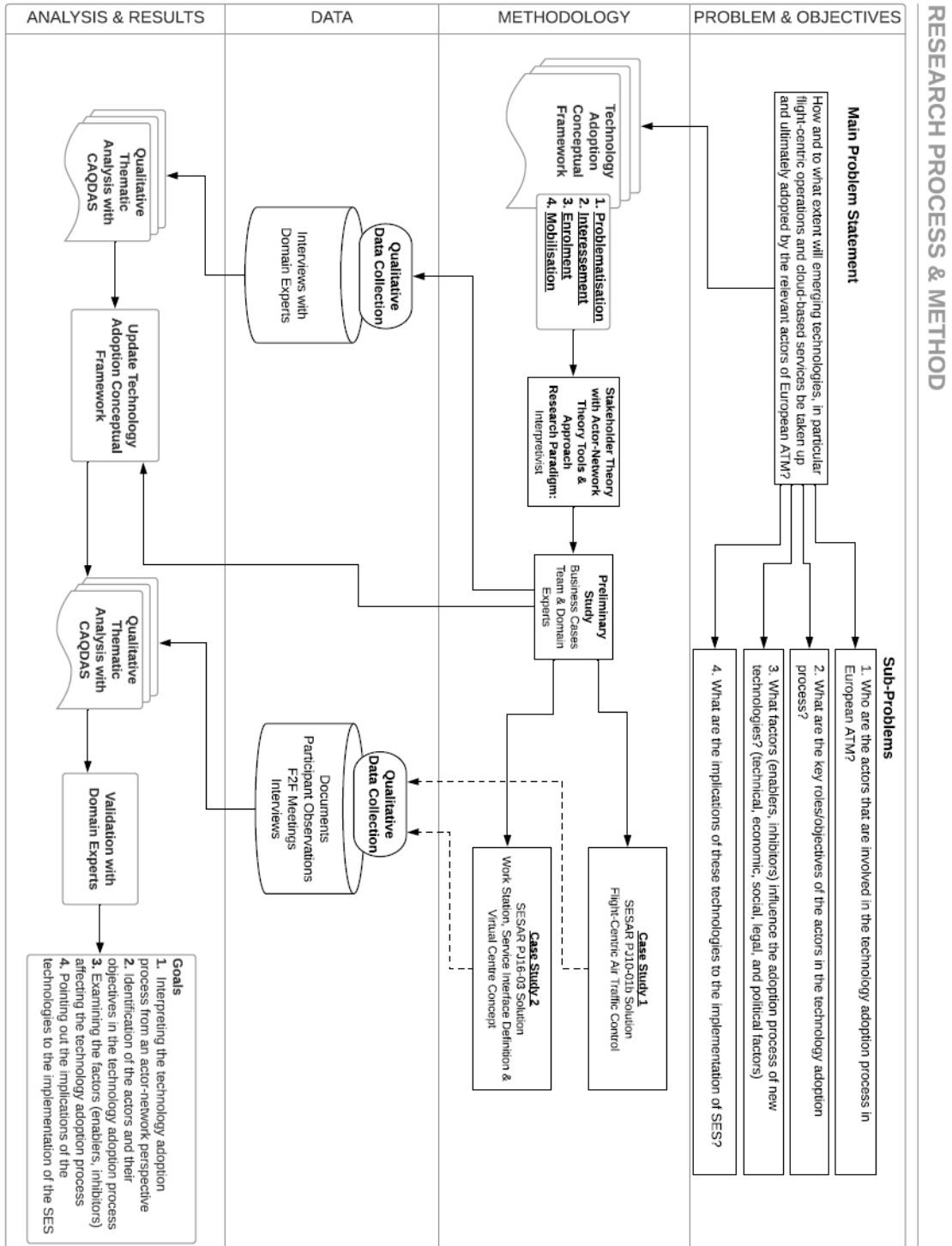


Figure 1.5 – Research Process & Method

Chapter 1. Introduction

The phases of the technology adoption process are systematically adopted from Callon's work on the sociology of translation [Callon(1984)]. In that, Callon describes the four moments of translation, which then becomes the basis for the ANT approach. Yet, only the human actors are considered as stakeholders in the technology adoption process, while factors affecting the adoption process are used to replace the non-human actors in ANT representation. The problematisation stage consists of the definition of the identities and interests of other actors, which align with its own interests, creating obligatory passage points. By definition, an obligatory passage point is a situation that has to occur in order for all the actors to satisfy the interests. The second stage, intersement is where the focal actor/s convince other actors to agree on and accept the definition of the focal actor/s. The third stage, enrolment, happens when an actor accepts the interests defined by the focal actor/s and set out to achieve them through actant allies, which align with the actor-network. If all these stages are executed successfully, then actors ensure that they also represent other actors' interests, which is the mobilisation stage. Within these stages, the conceptual framework aims to understand the motivations and actions of groups of actors who form elements, linked by associations, of heterogeneous networks of aligned interests. In this context, the stages of technology adoption in European ATM are described using the four moments of translation of ANT. The specific details of the design and theoretical basis of the conceptual framework is also described in the research design chapter.

1.7.2 Preliminary Study

The preliminary study is the first trial of the conceptual framework for the technology adoption by interviewing the domain experts in the working environment. An initial set of interview questions are designed to understand the key technologies, key actors, their roles, and relationships in the technology adoption process, as provided in the research design section. This initial study provided the updates on the initial set of questions, and the conceptual framework. The obligatory passage points are added to the design of the conceptual framework. The improved interview protocol and the questions are also described in the research design chapter.

Interviews Initial Part

A powerful method, interviews are the main data source for the preliminary study to have the domain experts' feedback on the interview questions and the conceptual framework. The partners for the interviews are selected using a purposeful and snowball sampling method. The researcher contacted the interview partners previously, and booked for a face-to-face semi-structured interview of 60 minutes. Additionally, the initial part of the interviews involves questions to understand the key new technologies in European ATM. Additionally, it is a way to examine who are the actors involved, and to get an initial idea on the conceptualization of the technology adoption process.

In order to execute the interviews, the first version of an interview protocol is prepared using an initial interview protocol, as described in research design section. The questions are mainly guided from the main research questions, specifically looking into understanding new technologies and how they come into existence in European ATM environment. The preliminary study helped to understand the technologies, that have a drastic influence on the current architecture of European ATM. The selection of technologies under investigation is an iterative process, where the researcher conjoined his participant observation, interview results, and personal preferences. The selected technologies are flight-centric operations and virtual centre, as also described briefly in the introduction section.

Participant Observation

The participant observation, as being a part of the Business Cases team in EUROCONTROL, is primarily used to select the technologies under investigation. After careful examination of the latest solutions offered by the stakeholders in the SESAR portfolio, the researcher settled down to analyze the adoption of flight-centric operations and virtual centre technologies. These key technologies have been observed to create paradigm shift from legacy systems to service-based architectures in European ATM. Second, participant observation is used extensively in the case studies by joining the face-to-face project meetings, events and conferences where key stakeholders are present. Qualitative data collected from the participant observation is thematically analyzed to examine actors objectives, factors and challenges affecting the technology adoption. Then the data is analyzed using computer assisted qualitative data analysis software (CAQDAS), such as NVivo. The participant observation as a detailed method is explained both in the research design section, and inside the case studies.

1.7.3 Case Study Design

The main part of this thesis is the case studies to investigate the adoption of two new technologies in European ATM: virtual centre and flight-centric operations. The main purpose of the case studies is the examination of the technology adoption process, the actors involved, roles of the actors, the relationships between them, and factors affecting the technology adoption process. Specifically, the two technologies are selected as a result of participant observation and documentary analysis. Moreover, their disruptive nature on the current conventional ATC and business models of the main actors in European ATM made them ideal candidates for the case studies. The case studies are supported by multiple types of data collection, interviews, participant observation, and documentary analysis. Concretely, the aim is to triangulate multiple sources to come to terms with results that have significance. This methodological path provides protection also for the validity by maintaining chain of evidence. The interpretive nature of case studies is also an important factor for the researcher to select case studies as the main methodology. Compared to other methods, Yin (2016) suggests that the use of case studies depends on three factors: form of research question, control of behavioral events, and focus on contemporary events. Yin (2016) compared the five main research methods

(experiment, survey, archival analysis, history, and case study) within these factors to show the optimal use of case studies. The case study method is mostly suitable when the research question is in the form of how and why, does not require control of behavioral events, and focuses on contemporary events. Moreover, Yin (2016) states that the essence of a case study is to try to illuminate a process or set of decisions, answering why and how they were implemented and with what result [Hollweck(2016)]. Here, the decisions can be taken from individuals, organizations, processes, or programs.

The two case studies follow exactly the same case study protocol, only the technology under investigation changes depending on the case, as described in detail in research design chapter. First, each case study starts with investigating the background and literature review for specific technology under investigation. Following that, the case studies include the design of the case study by providing the theoretical basis that guides the research methodology. This includes the presentation of the conceptual framework to investigate the technology adoption process inspired from ANT and stakeholder theory. Then, the case studies continue with data collection from multiple qualitative sources of interviews, participant observation, and documentary analysis. This is followed by the thematic analysis of the qualitative data in order to reach higher order themes. Finally, these themes are used to form the analysis for the technology adoption process in the form of graphical representation.

Yin (2016) suggests that a case study should assure its quality by focusing on four areas: construct validity, internal validity, external validity, and reliability [Hollweck(2016)]. Most multiple-case studies are generally more reliable than a single-case study. The access to the relevant data and its sources is important in the decision of the cases. The researcher is able to participate in the definition and adoption phases of these technologies. Additionally, there is documentary archive and supplementary interviews that the researcher is able to rely on both for the two cases. Moreover, the researcher attends to specific events with main stakeholders to follow discussions, and the main factors affecting the adoption process of these technologies. The research design on the case studies include a logical path, which is guided by the research question, follows three distinct methods of data collection, and thematic data analysis to reach conclusions. In order to systematically develop the research design for the case studies, this research initially decided on the four step process offered by Yin (2016) [Hollweck(2016)]:

1. Definition of the research question:

- How and to what extent will emerging technologies, in particular flight-centric operations and virtual centre be taken up and ultimately adopted by the relevant actors of the European ATM?
 - Who are the actors that are involved in the technology adoption process in the European ATM, specifically for the technologies, flight-centric operations and virtual centre?
 - What are the key roles or objectives of the actors in the technology adoption process?

- What factors (enablers, inhibitors) influence the adoption process of new technologies? (technical, economic, social, legal, and political factors)
- What will the consequences of such uptake or adoption be on the process of implementing the Single European Sky?

Following the main research questions, using stakeholder theory, combined with actor-network theory approach, we want to investigate the following sub-questions:

- What are the implications of these technologies to the implementation of the Single European Sky, and its high-level target objectives? (capacity, cost-effectiveness, safety, environment, defragmentation)

2. The unit of analysis of the case studies:

- The unit of analysis is the technology adoption process, specifically virtual centre for the first case study, and flight-centric operations for the second case study.

3. The logic linking the data to the propositions:

- This research uses three methods of data collection for the case studies: qualitative interviews, participant observation, and documentary analysis. The qualitative data collected from the data sources are analyzed using thematic analysis to identify the actors, technology adoption process, and factors affecting the technology adoption process.

4. The criteria for interpreting the findings:

- The conceptual framework to understand technology adoption is specifically designed to interpret the qualitative data collected. Using a combination of stakeholder theory and ANT, the framework evaluates the actors, their relationships, and factors affecting the technology adoption specifically for the two cases. The main criteria is thematic evaluation of the qualitative data, by coding and interpreting the data. Identification of rival explanations and alternative methods are also presented in the analysis section of this thesis.

1.8 Structure of the Thesis

This section provides the structure of thesis to the reader, by highlighting the main chapters and their content. The first chapter, introduction, provides the background, research motivation and objectives, and description of technologies with relevant actors in the technology adoption process. Moreover, the introduction chapter provides a brief summary of the technologies under investigation, virtual centre and flight-centric operations. The second chapter, literature review starts with the discussion of the previous literature review on technology adoption. First, the chapter summarizes the previous technology adoption models in the literature, and then moves onto the technology adoption research using ANT and ST. The literature

Chapter 1. Introduction

review consists of a wide array of applications of ANT on the technology adoption research field. Then, the chapter provides the overview and use of stakeholder theory combined with actor-network theory methodology to investigate the research problem.

The third chapter, research design, explains the research paradigm, methodology, and strategy that guide the research. Since the research uses qualitative case studies as the primary research method, the chapter provides the case study design and protocol. The two case studies focus on the technology adoption of the virtual centre and flight-centric operations separately. Each case study uses three methods for data collection: semi-structured interviews, participant observation, and documentary analysis. This section also provides the approach on the design of the conceptual framework for technology adoption, interview question design, triangulation and the approach on the thematic data analysis. The fourth chapter, called guide to case studies, provides an overview of the identification and relevance of the actors in the technology adoption process. Additionally, the guide prepares the reader for the upcoming extensive case study descriptions in the following chapters.

The fifth chapter and sixth chapter presents the overall technology adoption process for the virtual centre and flight-centric operations respectively. This chapter focus on the extensive case studies, the roles, relationships of the actors creating the environment for the adoption of the technologies. Additionally, the barriers and challenges combined with the factors affecting the adoption process are presented. Following the case studies, chapter 7, analysis aims to explain the benefits of the two technologies by providing the suggestions for the actors to improve the technology adoption process in the European ATM. The final chapter, conclusion and discussion, aims to finalize the thesis by summarizing the results for the research problem. Additionally, this chapter includes recommendations to the relevant actors in European ATM within the scope of the technology adoption of these two new technologies. The thesis finalize with the further discussion and recommendations for future research.

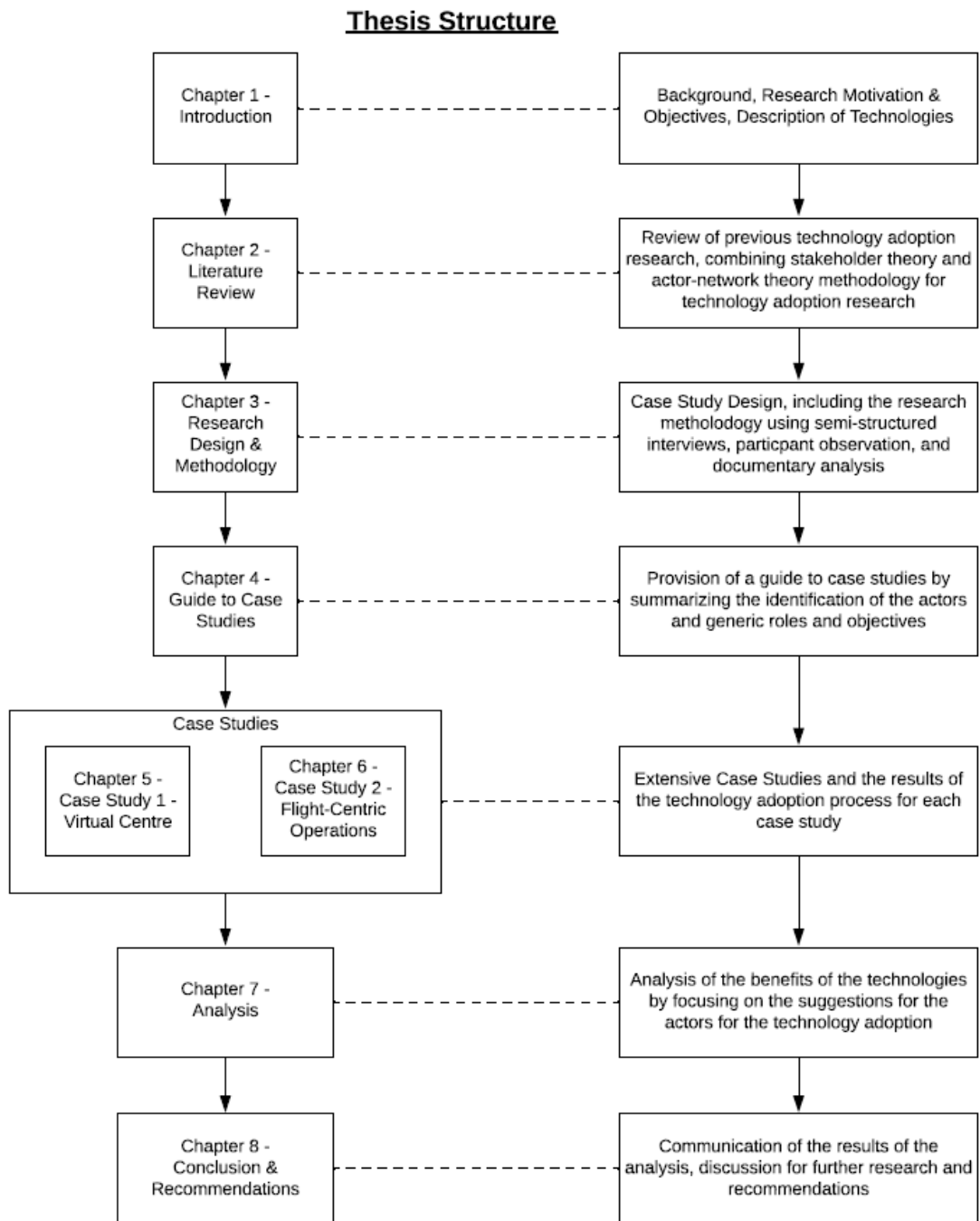


Figure 1.6 – Thesis Structure

1.9 Definition of Actors in European ATM

Before moving into the literature review, it is crucial to understand briefly, who are the actors involved in European ATM, what are their roles, and key tasks. Previously, Baumgartner et al. (2014) defined the actors and their interests in the context of the Single European Sky [Baumgartner and Finger(2014)]. Initially, the definition of the actors is based on the previous literature by defining the actors, basing our initial definition on the previous work in literature. Then in the analysis chapter, we will look on the specific cases of technology adoption, and how these actors behave while they adopt new technologies, specifically for the virtual centre, and flight-centric operations.

1.9.1 Actors and Their Interests

Air Navigation Service Providers (ANSPs)

ANSP is an organisation which locally provides the air navigation services for a specific airspace of a country. Mainly, ANSPs are state entities with a few exceptions of privatized shareholders. Based on the ATM Cost-Effectiveness (ACE) 2017 bench-marking report, there are currently 38 ANSPs in Europe, providing air navigation services for its Member States. Civil Air Navigation Services Organization (CANSO) represents the trade association of ANSPs. CANSO also needed to adapt to the changing regulatory environment brought by the SES [Baumgartner and Finger(2014)]. With the emergence of new technologies, ANSPs also need to adapt to the evolving needs of European environment. Mainly, ANSPs remain in between the users (airlines), owners (Member States), and employees (ATCOs).

The air navigation services can be generalized into three categories: ground infrastructure, communication, navigation, and surveillance (CNS) provision, and ATM. Since the main function of the ANSP is service provision, any new technology that affects the provision is considered by the ANSP. ANSPs are also responsible for all the necessary hardware, software, and maintenance to function any technology in order to provide these services. Responding to the performance scheme and pilot common project (PCP) requirements, ANSPs also adhere to the practices and recommendations of the EC. Baumgartner et al. (2014) argues that the efficiency of ANSPs are affected by two factors: current route-charging scheme, and sovereignty of airspace. The optimization of the route of flights is not the best given that the routes are charged according to the kilometer of the flight. The sovereignty of the airspace makes it harder for ANSPs to share information, data, and collaborate in new technologies.

Airspace Users

The airspace users include the European airlines and the associated associations, consisting of scheduled airlines, cargo freights and business aviation. The formation of the SES and its target objectives mostly formed by the requests of the airspace users. In that regard, cost-

1.9. Definition of Actors in European ATM

effectiveness of the provision of ANS and ATC carry utmost importance for the airspace users, as well as maintaining the aviation safety. Thus, airspace users aim to get benefits from the modernization of the European ATM with new technologies that could potentially bring cost-effectiveness, while also increasing other key performance areas.

The SES consultation process initiated several associations regarding the low-fare, charter, regional and business aviation. These associations aim to maintain the interests of the user community, as well as following the progress of the SES to ensure that the guidelines of the performance scheme are followed.

The Manufacturing Industry

The manufacturing industry is the main provider of the hardware, software and maintenance to the systems that provide air traffic services in the European ATM. Since the market functions in a monopolistic way, there is slow pace in the development and innovation of new technologies. Currently, legacy systems are in use providing conventional ATC services. Each ANSP has an industry partner, which provides them the necessary hardware and software to provide services. The fragmentation over the European airspace is apparent of the ground systems and deployment. The interoperability between the flight data processing systems is limited due to the fact that the industry partners provide tailor-made solutions to each ANSP [Baumgartner and Finger(2014)].

The business interests of the manufacturing industry inhibit harmonization of the ground infrastructure. This is due to the fact that defragmentation would reduce the number of products in the market. Additionally, harmonization brings competition which is clashing with the monopoly structures of the manufacturing industry today. One of the main objectives of SESAR is to defragment the current fragmented infrastructure and service provision in Europe.

Controller Unions

A number of European and global professional staff organizations exist in order to support and protect the rights and social conditions of the ATCOs, ANSP staff and pilots. Among these, globally International Federation of Air Traffic Controllers' Association (IFATCA) and International Federation of Air Traffic Safety Electronics Association are the main ones. For the European case, European Trade Union Organization and the European Cockpit Association creates a platform for the coordination between the staff between the ATCOs and flight crews [Baumgartner and Finger(2014)]. These organizations mainly protect the social interests of the air traffic controllers (ATCOs) by establishing coordination with various European institutions.

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Airports

Airports are the main hubs of the air traffic network. In Europe, they are considered under the SES scheme by giving them the observatory role in the SES I package. Following that in SES II, the gate-to-gate approach included airports directly in the performance scheme. In the first reference period (RP1) (2012 - 2040), airports initially reported their terminal ANS costs and charges for performance review. In RP2, the airports are reviewed under their airport air traffic flow management (ATFM) delay, pointing their capacity performance high-level objective. This delay is the airport induced ground delay due to constraints.

Even though the performance optimization is right for SES targets, not all airports are interested in a gate-to-gate approach. Rather, it is economically much beneficial for airports to optimize its slots. In the case of new technologies, airports carry an important value being the main hubs connecting the network. Considering flight-centric operations, vertical integration would enable point to point traffic in Pan-European airspace. But, this is highly dependent on the how the airports allocate slots for these trajectories. Regarding virtual centre, airports can also benefit some of the virtualized services. With the service-based architectures, airports could also aid the sharing of data between the hubs, hence improving performance.

The Military

The military has the multiple properties embedded in a single actor. It is mainly an ANSP and airspace user with advanced authority and capabilities. Military provides service for its own airspace as an ANSP, while also uses the civilian airspace whenever it needs as an airspace user. Without the consensus of the military, it is challenging to progress with the SES. When it comes to accept and adopt new technologies, the military becomes a decisive actor. The first priority of the military is to protect national sovereignty and security. There are many reserved areas in the European airspace, which makes inefficient for the civilian air traffic. The project Advanced Flexible Use of Airspace targets this by optimizing the airspace reservations of the military.

The military is a decisive player, where it might intervene with the SES process when it sees an effect on the either national sovereignty or security. In the future, new technologies surely create new issues related to the cyber-security legislation due sharing of data throughout Europe, or by enabling location independent services. Thus, the Military act as a decisive actor through the Member States and its corresponding local ANSP.

Member States

The European states play a key role on the research, development, and deployment of the SES. First, the SES is funded by the EU within EC legislative. The design of the SES has been designated to SESAR-JU and EUROCONTROL. The Member States actually include a number of actors under its umbrella. Specifically, the ANSPs, and the Military functions under the

responsibility of the Member States.

The National State Authorities (NSA), on the other hand, are independent regulators of the air transport security and economics. Yet, the policy function of the NSAs still remain in correspondence to the Ministry of Transport. Although airports are locally owned, they are regulated in a national level. A similar case is airports, where they are generally privately-owned, but regulated by the national regulator.

The primary interest of the Member States is that they want to make sure that the safety, security of air traffic are intact. Following that they support ANSPs and protect their political, social, and economic interests. Development of the airports is one of the key roles of the Member States, as the airports benefit the country in the mean of economic development. The Member States also act as associates of the ICAO, and for the European states EUROCONTROL, where they represent their national interests and need to comply with the regulations and recommendations by these international organizations.

Supra-national and Multi-Stakeholder European Actors (EUROCONTROL, EASA, SESAR-Joint Undertaking, SESAR Deployment Manager)

In Europe, the supra-national actors are EUROCONTROL and EASA. EUROCONTROL, having 41 European Member States, and 2 comprehensive agreement states outside Europe, is founded on 1960, and called the European Organisation for the Safety of Air Navigation. A rather new initiative, founded on 2002, EASA is the European Aviation Safety Agency, having 32 Member states. On the top level, both organizations seem to have the same objectives, yet EASA is specified for the standardisation and training, while EUROCONTROL is tasked with the research and development for the SES and assigned by the EC as the Network Manager.

Having a coordination role of the Network Manager, EUROCONTROL controls, and optimizes the overall ATM network of the Europe, by designating the optimal flight plan and routes for flights. Additionally, EUROCONTROL is responsible for the executive branch of the SESAR programme within joint partnership with SESAR-JU. The EC funds the SESAR project under the Horizon 2020 work programme, in close collaboration with the European ANSPs, industry partners and supra-national actors. EUROCONTROL is governed in the framework of an international convention, which is called the Revised Convention. The structure of EUROCONTROL includes 3 main functions: EUROCONTROL commission as the governing branch, the agency as the executive branch, and the and the Provisional Council, which represents the interests of the Member States. Furthermore, the Central Route Charges Office (CRCO) acts as the financial branch where the route charges are collected from the airlines and distributed to the Member States and its local ANSPs for service provision. Additionally, the agency of EUROCONTROL is responsible for supporting of each stage of the SES with research and development, and the creation of the necessary synergies between the actors in support of the SES.

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In order to realize the European ATM Master Plan, the European Commission established two separate multi-stakeholder organizations. First, SESAR-JU is created for establishing a public, private, academic collaboration for research and development of the SESAR programme in 2007. The main aim of the SESAR-JU is research and development for the European ATM modernization within close cooperation with all the stakeholders. Following the creation of SESAR-JU, the EC established SESAR Deployment Manager (SESAR-DM) in 2014. SESAR-DM become responsible for the deployment of the Common Projects and also SESAR solutions and technologies with its partners including ANSPs, airlines, airports, military, the Network Manager, and meteorological service providers. Together, these organizations are responsible for the development and deployment of new technologies presented in the SESAR framework.

2 Literature Review

This literature review includes an overview of the previous research done in the context of the European air traffic management focusing on relevant technology adoption models, starting from generic methods, then narrowing down to actor-network and stakeholder theory and its use in technology adoption research. Specifically, this chapter investigates previous literature on innovation diffusion, technology acceptance model, unified theory of technology acceptance, and using a combination of ST and ANT for technology adoption research. Focusing on stakeholder theory and ANT, the section presents how the thesis combines them in order to approach to the research problem. This is where the contribution to the current literature is presented. First, the chapter starts with presenting the previous research done in the field of the European ATM related to the research topic. Second, the chapter continues with providing a background for various approaches in technology adoption research, including ANT and ST separately. Then, the chapter continues with presenting the approach to the technology adoption problem from a combination of ST and ANT. Finally, the chapter concludes with evaluating various graphical representations for technology adoption, a critique of the previous literature, and the contribution to the current technology adoption approaches. The literature review guide provided in Figure 2.1 illustrates the steps of the literature review.

2.1 Previous Literature in the European ATM

The previous literature in the European ATM mainly focus on either qualitative analysis of the stakeholders and their interests, or comparison of various scenarios that are simulated with quantitative analysis. There is a lack of socio-technical research which considers both social and technical dimensions together. Since the actors in the European ATM each have their own objectives, the alignment of their interests, and relationships between them affect the process of adopting new technology. Thus, it is crucial to introduce a socio-technical approach to the field of European ATM research. This section initially presents 3 projects that were carried out by the joint cooperation with academia, and aviation organizations, such as SESAR-JU and EUROCONTROL. These projects include various scenarios that consider the use of new technologies, or the adoption of new technologies, such as virtual centre, remote

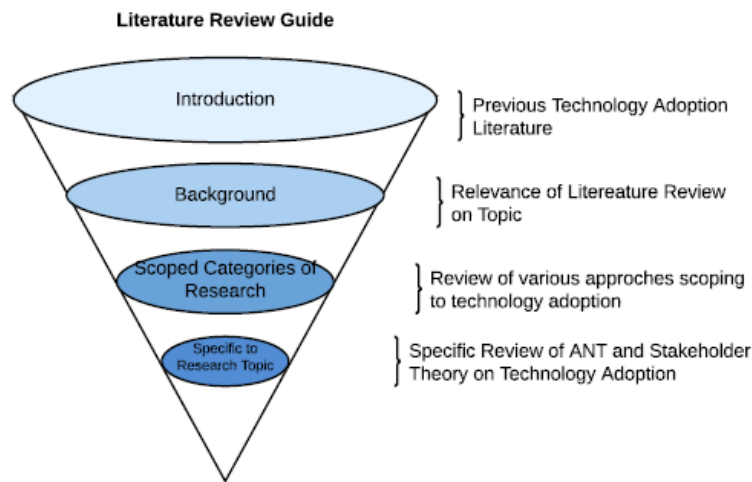


Figure 2.1 – Literature Review Guide

towers, and flight-centric operations by the stakeholders. The section concludes with the qualitative approaches on understanding the technological and institutional factors affecting the implementation of the SES.

SESAR Innovation Days (SID) has been organized by a joint cooperation between SESAR-JU, EUROCONTROL, and academia to share insights about the research and development activities related to the SESAR R&D, the European ATM research, programme. Starting from 2011, ATM experts and researchers contribute to the SESAR research by investigating new technologies for European ATM in SID. Specific workshops related to contemporary ATM topics are organized. The workshops cover a wide spectrum of research topics related to European ATM, including technical, economical, human factor aspects of solutions and technologies. In this review, this initial section covers the projects and publications in this workshop within the relevant scope of the research topic.

Seminal contributions have been made by the researchers participating in SID on various topics related to European ATM. Among those, there are 3 projects, respectively called Accelerating Change by Regional Forerunners (ACCHANGE), Coordinated capacity ordering and trajectory pricing for better-performing ATM (COCTA), and Competition for Air Traffic Management (COMPAIR), that are related to the topic of this thesis. This section presents previous studies from these 3 projects, building up on what was previously established to understand performance, business models, and new technologies in European ATM.

ACCHANGE is a project funded by SESAR-JU and worked in cooperation with Transport and Mobility Department of KU Leuven University to investigate new possible ways of air traffic control (ATC) provision utilizing new technologies [Blondiau et al.(2016)Blondiau, Delhaye, Proost, and Adler]. The project initially aims to understand the bottlenecks in air navigation provision, question a central implementation, and find a suitable financial regulation scheme for ANSPs to get right incentives. Through finding answers to these objectives, the project also

2.1. Previous Literature in the European ATM

tackles to find out if the ATM sector can drive this change with the support of new technologies. Looking also into the evolution of other network industries, Blondiau et al. (2016) explored the models of liberalisation of national monopolies in electricity, rail, and telecommunication industries. In order to show how certain policy changes affect the overall performance of ATC, the study presents quantitative economic models as a simulation.

The analysis of ACCHANGE mainly focused on institutional structure, cost-benefit analysis, new technology, and regulation. Furthermore, the study reported that there are a number of factors affecting the change in ATC. First factor is the home bias, which refers to national interests and sovereignty. Second, labour unions' resistance to change is referred as status quo bias. Third is the regulatory contradiction on how to align the cost cap regulation in the adoption of new technologies. And the final factor is the coordination complications, which exist between the main stakeholders in European ATM investing in synchronized development and deployment of new technologies. Consequently, a set of scenarios follows the analysis presenting 4 different models, a network congestion game, a labour union model, a public utility efficiency model, and an economic network model [Blondiau et al.(2014)Blondiau, Delhay, Proost, and Adler].

The models examine the factors affecting the scenarios and bottlenecks in the ATC provision. The first model is a network congestion game having two stages [Blondiau et al.(2016)Blondiau, Delhay, Proost, and Adler]. Initially, airport and en-route ATC providers decide on the set and off-peak charges. In the second stage, airlines prefer their flight paths according to schedule and charges from the first stage. Then, each scenario estimates the impact on the users, and on ATC providers considering the rerouting of airlines. Precisely, the network congestion game investigates the 4 possible scenarios as listed [Blondiau et al.(2016)Blondiau, Delhay, Proost, and Adler]:

1. The impact of privatization and deregulation
2. Defragmentation of the set of current providers
3. Introduction of technology via Pilot Common Project (PCP) and SESAR Step 1 project
4. The regional forerunner approach including the cooperation between en-route and airport ATC providers, and airlines

The results of the first model show that it is challenging to horizontally integrate the ATC providers without proper incentive mechanisms [Blondiau et al.(2016)Blondiau, Delhay, Proost, and Adler]. Either the regional forerunners, or the vertical integration between companies would imply change. Correspondingly, if there exists a mechanism for ATC companies charging for better quality and reduced congestion, then vertical integration will highly likely to be beneficial for the network. Furthermore, the model emphasizes the lack of competition for the flight paths in different regions without allowing the removal of economic regulation

Chapter 2. Literature Review

[Blondiau et al.(2016)Blondiau, Delhay, Proost, and Adler]. Especially, competition rises when service providers are able to compete on the provision of new services enabled by virtual centre, or time-limited auctioning mechanisms. As a key point, the model strikes the fact that SESAR Step 1 implementation has bottlenecks due to financial demotivation in the ATC sector. The first model concludes by stating that a separate hybrid peak or off-peak price cap might increase adoption of standardized technologies in the SESAR umbrella.

The second model of ACCHANGE is a union bargaining model which analyses the behaviour of an ANSP under a bargaining process between ATC union and national regulator [Blondiau et al.(2016)Blondiau, Delhay, Proost, and Adler]. The aim of the ATC union is to protect air traffic controllers (ATCOs) and request higher salaries. The results of the bargaining model shows that if the power concentrates on the ATC union, then salaries and employment increase, yet a price-cap regulation might fail. Consequently, new technologies, such as virtual centre changes the landscape for competition, but ANSPs are not interested in standardisation of new technologies. Furthermore, the third model, which is a public-utility model with asymmetric information, investigates the incentive mechanisms of ANSPs given a national ATC regulator following its objectives. Specifically, the model includes several scenarios for the management of ANSPs, looking into ownership type of ANSPs and management board structure. This model shows that using price-cap regulation is beneficial and efficient than cost-plus regulation. Concretely, ANSPs perform better as profit-maximizing firms rather than state-owned enterprises. The price-cap might alter the quality of service if it is not regulated correctly.

The final network model examines the ATC unions and the efficiency of ATM operations. Specifically, this model focuses on the vertical cooperation and its use in creating incentives for cost-efficiency and better technology adoption. Additionally, the parameters of wage, risk aversion, profitability of ATM operations, profitability of airport operations, and effectiveness of price-cap regulation determine the success of regional forerunner model. The main result, combining the 4 models, is that regulating price or changing the charging regime is only partially successful in creating change for the main actors in European ATM. Not only the cost-efficiency targets should be studied within these models, but also the monetary compensation. Because monetary compensation also affects other key performance areas (delays, technology adoption, environmental targets, and safety). A solution would be to switch to hybrid price-cap, and to support change in the European ATM by institutional and regulatory mechanisms. This will, in turn, bring better performing cost-efficient network system, where technology adoption of the actors happens much efficient.

ACCHANGE also points out that introducing competition in European ATM might drive actors to create bottom-up change [Blondiau et al.(2016)Blondiau, Delhay, Proost, and Adler]. Hence, this approach moves away from traditional collaborative approaches, which have been tested as inefficient in the past. For ACCHANGE, the way forward lies on the regional forerunner model, in which the model favors competition between the actors and create incentive mechanisms for cost-efficiency and better technology adoption. Furthermore, future

2.1. Previous Literature in the European ATM

research should investigate the mechanisms to increase competition in European ATM. First option would be the creation of new business models by altering the roles of the main actors. Following that, the second option would be changing the structure of the ATC provision in Europe. For the business models, the initial move should consist of aligning market forces to reduce fragmentation overall Europe. For example, changing the ownership model of the ANSPs to share-based or cross-ownership models would help increase competition inside and between ANSPs. Contracting and tendering services to other providers, ANSPs or manufacturing industry would additionally benefit from increasing competition. Ultimately, changing the overall ATC structure with a new technology, such as flight-centric operations would radically disrupt and bring competition to the European ATM structure.

The research project COCTA, carried out by the collaboration between SESAR-JU Horizon 2020 program and an academia consortium (University of Warwick, University of Belgrade, Worms University of Applied Sciences), investigates a possible redesign of the ATM value chain. The main goal of the project is to improve efficiency and quality of air navigation service provision in Europe. To reach this goal, COCTA identifies that better coordination is needed in the capacity-demand balance. COCTA tackles this by enhancing the role of the Network Manager (NM) to have business relationships with the ANSPs and Aircraft Operators (AOs). In this way, the NM executes orders of en-route airspace capacity from ANSPs at strategical level, and adjusts sector-opening schemes at pre-tactical level [Starita et al.(2017)Starita, Strauss, Jovanović, Ivanov, Pavlović, Babić, and Fichert]. What is then changing is the ability of the NM offering differentiated trajectory products and services to AOs. In turn, this will enable AOs to better optimize their business needs and network performance goals. For the network, this means increased performance and cost-effectiveness due to better alignment of capacity and demand.

COCTA builds up on a mathematical model, which aims to minimize cost of capacity provision, delays, and re-routings. This minimization depends on the airspace sector reconfiguration and better trajectory assignment. The model uses a small-scale demonstration of joint demand and capacity management scenarios. Overall, COCTA alters radically the roles of the main actors in European ATM and its ATC value chain. This starts initially with the NM's decision making in cooperation with the ANSPs and the AOs. The numeric work of the project compares a network centric approach of coordinated capacity provision, and centralised demand management with non-existing route charging mechanism. The results show that performance depends on the airspace capacity levels in the network. The quantitative approach of COCTA helps into find the incremental differences of capacity on different airspace sectors [Starita et al.(2017)Starita, Strauss, Jovanović, Ivanov, Pavlović, Babić, and Fichert].

COCTA significantly support the redefinition of the functions and objectives of the NM. Within these changes, a new institutional framework would also need to support the objectives of the main actors. To enable this, COCTA offer 3 separate scenarios for the evolution of the NM:

- **Scenario 1:** ANSPs as Capacity Providers

- This scenario considers that the function of the NM would be transferred to another entity, such as an ANSP, or a consortium of ANSPs. Yet, the loss of neutrality of the functions of the NM would be problematic. This can be overcome by regulating the consortium for optimizing for the overall network, and not just for individual ANSP.
- **Scenario 2:** Aircraft Operators (AOs) as Capacity Users
 - The airlines could vertically integrate to get the demand-capacity balancing function of the NM. Both the airlines, and the NM will work for optimizing the overall performance and cost-efficiency of the network. However, since the airlines would optimize for the economic benefits, there would be inverse effects on the environmental side. Furthermore, the regional aircraft operators might create difficulties in decision-making process due to differentiated interests of the regional actors.
- **Scenario 3:** Independent Network Manager
 - Privatization of the Network Manager by creating a totally new actor is the main goal of this scenario. Therefore, ANSPs and Aircraft Operators would be neutral towards the newly formed NM. A privatized NM would optimize for the performance and cost-efficiency targets much better than the first or the second scenario. However, if the NM becomes a non-profit organization, then the profit maximization would be lower, yet it will remain that the NM stays in a neutral position to follow its functions.

Another project funded by the SESAR-JU, and executed by the Transport and Mobility in KU Leuven University is called COMPAIR. Essentially, this project examines the institutional approaches for air traffic control in Europe. This study suggests that competition would bring better performance to the European ATM system. Concretely, COMPAIR uses mixed methods of literature review, and qualitative instruments, such as interviews, expert discussions and surveys. The project starts by discussing that the provision of air traffic services in Europe has long been a national monopoly with fragmented infrastructure [Delhay and Blondiau(2016)]. The factors of price regulation, network characteristics, and fragmentation lead to slow adoption of new technologies, desynchronization between the actors, and inefficient implementations of ATM systems in Europe.

In order to increase the performance, COMPAIR offers four options to increase competition by bringing the right incentive mechanisms into the European ATM system. These options are listed as the following [Delhay and Blondiau(2016)]:

- **Option 1:** Regulatory approach using yardstick competition
- **Option 2:** Unbundling of central infrastructure management tasks from service provision tasks

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- **Option 3:** Auctioning approach using tenders to license air navigation services within certain charging zone
- **Option 4:** Sector-less based operations where trajectories are managed as origin-dest

The first option targets to increase competition by regulatory changes considering the ownership model of the ANSPs. Even though the ownership model of the ANSPs differ by country, most of the ANSPs remain as state-owned nationalistic monopolies. This is by itself inhibits competition for ATC services, and creates an inefficiency for the overall ATC system in Europe. Thus, this scenario introduces yardstick competition, where the price of the ATC services are regulated as if it is a profit-maximizing competitive firm. Hence, this creates a motivation for ANSPs to reduce their prices and increase efficiency as if they are under real competition.

The second option aims to unbundle some of the ATM services and open them to competition to attract new service providers into the market. The unbundling should start from the separation of terminal air traffic services [Delhaye and Blondiau(2016)]. In fact, these services are the ones that can bring benefit in a short-term. Consequently, some of the core en-route ATC services, such as information, communication, navigation, surveillance, and meteorological services, are candidates for the unbundling. The fact that these services can be provided by alternative service providers, even in some cases remotely, makes this option a natural enabler for competition. Effectively, the benefits from this option are increase in cost-effectiveness, better ANSP performance, and synchronization of the actors.

The third option suggests the tendering of the ATC provision licences in a fixed geographical area for a limited time [Delhaye and Blondiau(2016)]. This is a local solution, where for some ACCs, it is possible to tender some of their services to private firms. Hence, this will reduce costs for them, while also increase the chances of cooperation between the ANSPs to tender together. Neighboring ANSPs could cooperate and tender their ATC provision to the same private company. Remote or virtual services could use this kind of an option in their initial stages. This can enable the ANSPs to examine how much they can save with new providers supported by new technologies.

The final option looks into the sector-less, also called flight-centric operations, and its possible implementation in the European airspace. Currently, the structure of the European airspace is conventional sectorized, in which ATCOs are responsible for their assigned parts of airspace. National ANSPs manage the airspace above their borders, and optimize the flights for the network. Whereas in flight-centric operations, boundaries between the sectors disappear, and the flights are optimized for its take-off to landing trajectory. In turn, this can enable competition for the provision of the services, possibly also for the trajectories of flights. Airlines and ANSPs could pair up to optimize their trajectories for the overall benefit of the European network. Correspondingly, the defragmented sectors would bring increased ATCO productivity and cost-effectiveness.

The results from COMPAIR shows that short-term benefits are possible in implementing the

first 3 options. Yet, for the flight-centric operations, there exists challenges in terms of technical maturation, safety and its social acceptance from ATCOs. The option of unbundling is expected to enable competition if the national sovereignty does not inhibit its implementation. Additionally, this option is also supported by the experts and stakeholders. In the case of tendering, the barriers of national interest protection and social acceptability affect its feasibility. There also exists the question of whether the ANSPs will collaborate on this model of tendering for the services [Delhay and Blondiau(2016)]. The project assesses multiple options using qualitative methodology, showcasing some of the latest alternative options for the European ATM.

The majority of the previous research in SID is related to changing the provision of the services or building economic models for various scenarios. A recent study by Proost et al. (2017) investigates the economic regulation and its efficiency for European ATM [Proost et al.(2017)Proost, Glazer, and Blondiau]. Actually, the study combines what was previously offered in ACCHANGE and COMPAIR by comparing the theoretical assumptions of the economic regulation models. The three economic models that are targeted by the study are listed as below [Proost et al.(2017)Proost, Glazer, and Blondiau]:

- **Model 1:** Can regulation work when ATC is governed by union-government bargaining? (ACCHANGE)
- **Model 2:** The potential unbundling tower control (COMPAIR)
- **Model 3:** Competition for en-route ATC in Europe (COMPAIR)

The first model is a bargaining model between the ATC unions and the government, which is adopted from the ACCHANGE project. If there exists a public monopoly behaviour in this bargaining model, then the regulation is only dependent on the outcome of the bargaining between government and the unions. The aim of the unions is to maximize their salaries, while also increase power by the treat of strikes. Consequently, national governments want to maximize their national surplus from suppliers, and also attract foreign users. Under this model, the outcome depends on the bargaining power and preferences of the ATC unions. Surprisingly, the outcome of this model suggests that many EU policies will fail. First, since the ATC union power will decrease under regulation, the standardization of equipment will not take place. Second, Functional Airspace Blocks (FABs) will not function as expected due to the threat on the national sovereignty and power. Third, price-cap regulation might not work as expected due to the government stepping in with subsidies. Within this model, technology adoption increases on the condition that the monopolies stay and induce cost reduction. The solution for the challenges of this model lies either in privatisation, forced unbundling of some of the services, or enabling competition for the market via virtual centers.

Unbundling is the second model, where specifically the tower control services are targeted. There are two benefits of the auctioning of the tower services. The main benefit is the cost

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reduction that is previously proven by the collaboration between Spain and Sweden with the support of new technologies and better organization. Accordingly, this will bring reduction in the salaries of ATCOs due to the competition for the provision of tower services. The tower auctions also bring benefits for the transparency for the provision cost of the services. Most of the regional airports are supported financially by the corresponding State [Proost et al.(2017)Proost, Glazer, and Blondiau]. One solution to this is enabling cross-subsidisation of tower services by various ANSP services. In order to reach this, a mechanism is to have transparency in the bidding process for the provision of the tower services. Correspondingly, a number of States started to unbundle their tower services. These include United Kingdom, Spain, Germany, Sweden, and Norway. The airport tower services in these States are now either privatized or provided by newcomers in a competitive market. Proost et al. (2017) further provided the conditions for the market development. Naturally, airports compare the prices of their services to the other airports. This creates a natural tendency for the creation of the market when the airports are privatized. Yet, there are also legal factors affecting the process and fairness of the bids. Likewise, economic benefits also differ from country to country, bringing economies of scale improvement. Vertical integration is also seen beneficial where en-route control and tower control integrate to open for the service provision.

In order to understand how liberalization of the ATC services in Western Europe works, Proost et al. (2017) executed a case study including UK, Netherlands, Germany, Spain, Belgium, and France. The study examined the cost structure for each ATC, founding out that there exists limited scale economies for two bordering countries. Additionally, these States are all candidates for new technology adoption, which can reduce their costs by half [Proost et al.(2017)Proost, Glazer, and Blondiau]. In the model, the airlines, composed of Star Alliance, Oneworld, SkyTeam, EasyJet, and Emirates optimize for the best route. The results of the case study show that non-profit model provides the highest capacities, while utilizing new technologies and high labour levels. Yet, the prices remain close to the targeted price caps. Reduction of the prices are enabled by the introduction of the profit-maximizing firms providing the services. However, this means that the profits of the private firms will stay as 25 percent with utilizing technology with lower labour levels. In the case of enabling tenders, the case study estimates 3 private service providers serving for the 6 airspaces. In turn, this will enable defragmentation of the European airspace for the services that are unbundled and open to competition. Within this option, prices for the service provision are halved. Since the service are executed mainly for profit-maximation, it is expected that there will be drops in performance and capacity. The study concludes with stating that the current regulation enables gathering well structured information on how actors see the economic regulation. Additionally, introducing competition has found to be more efficient than only applying price regulation. The recommendations for the EU is to allow each country to tender airport tower services, and open them to competition. For a second step, this can be followed by tendering the en-route ATC services and opening them to competition.

Recently, Zeki et al. (2019) presented a number of future scenarios for the flight-centric operations, including the comparison with the conventional ATC and inclusion of new market

structures. Initially, this study pointed out that flight-centric operations open up new business models for the actors [Zeki et al.(2019)Zeki, de Matos, Purves, and Gibellini]. This is mainly due to the push from new entrants that could penetrate the market within the service enabled by flight-centric operations. Additionally, Zeki et al. (2019) identified that bargaining power of suppliers arise from the local provision of services in the ATC market with limited number of service providers. Thus, bargaining power of buyers of ATC services is low due to local provision of services by ANSPs in a non-competitive market. Following the discussion on the market structure that flight-centric operations enable, Zeki et al. (2019) presents future business models in case flight-centric operations get adopted in the Pan-European scale [Zeki et al.(2019)Zeki, de Matos, Purves, and Gibellini]:

- **Business Model 1:** Current ANSPs adapt
 - In this scenario, ANSPs adopt the flight-centric operations, switch from local provision towards enabling cross-border service provision with rationalized infrastructure. For ANSPs, this is expected to bring cost-effectiveness, while also creating custom solutions according to the air traffic complexity and flight-levels. This business model also enable larger ANSPs to provide services to small to medium sized ANSPs under flight-centric configuration.
- **Business Model 2:** Vertical integration
 - In the second scenario, larger airlines vertically integrate in order to provide ATC services themselves. This could also enable airlines merging with ANSPs in the future, bringing cost-effectiveness and competition for the provision of services. In this configuration, larger airlines could provide ATC services for small to medium sized airlines. Yet, this would require airlines to comply with the service provision of ATC, by deploying infrastructure, hardware and software to deliver ATC services.
- **Business Model 3:** New ATC providers
 - In the third scenario, new ATC providers, such as ICT giants, could penetrate the ATC market in order to provide location independent services. Either this could be in the form of providing specific flight-centric operations services in partnership with ANSPs, or directly providing ATC services in the place of ANSPs. This scenario requires regulatory and legal changes associated with the drastic changes brought forth for all the actors in the European ATM. Furthermore, this models enables competition both for the local and Pan-European provision of ATC services supported by the cross-border functions of flight-centric operations.
- **Business Model 4:** Network Manager as the main service provider
 - Based on the model offered by COCTA, this scenario offers that the Network Manager acts as a service provider additional to its role of capacity and demand balancer. In this model, ANSPs could subscribe to services offered by the Network

Manager. By this, a standardized way of data sharing and communication could be established with the close cooperation with aviation stakeholders. Defragmenting the service provision, this model also aims to increase cost-effectiveness.

2.2 Previous Literature on Technology Adoption Research

In information systems (IS) research, technology adoption is becoming an evolving area by encompassing various theories and models from other research areas. Technology, by itself, is changing form and context, even gaining a form of artificial intelligence. Thus, the study of technology adoption requires an interdisciplinary approach, where various models and theories adapt to the ever-changing environment surrounding technical artifacts. Sharma et. al (2014) reviewed the latest models of technology adoption by surveying the literature for technology adoption [Sharma and Mishra(2014)].

The review used the definition from Carr (1999) for technology adoption as the 'stage of selecting a technology for use by an individual or an organization'. A simple, but powerful definition incorporates the keywords of stage, selecting, technology, individual or organization. Thus, a technology adoption process involves the relevant actors (individuals or organizations) interacting (selecting) with each other to decide in phases (stages) whether or not to use a technology. The importance of technology adoption research lies in the fact that a lot of investment has been made on selecting new technologies. Yet, without analyzing the technology adoption process by organizations or companies, it is challenging to understand the risks involved in the adoption process. In order to minimize risk and to understand the dynamics of the adoption process, technology adoption research matured in the last decade.

A number of failures added to the importance of technology adoption research. Initial problems started with the challenging diffusion of Electronic Health Record (EHR) in US and Enterprise Resource Planning (ERP) systems. Recently, cloud computing and e-government applications are becoming contemporary technologies in technology adoption research. There are a number of approaches to the technology adoption research, specifically the ones that focus on the user and their preferences are commonly used. In many network industries, digital transformation opens up a new frontier for new technologies. A number of these new technologies have the ability to disrupt the main stakeholders by altering their objectives, and business models. The advancements in new technologies are rapidly emerging, and it is getting crucial to understand how the actors align their objectives around these new technologies. In that respect, investigating technology adoption is both important for the stakeholders and the academia.

In this section, previous technology adoption theories and models are summarized, starting from innovation diffusion, and evolving towards the Unified Theory of Acceptance and Use of Technology. Then, the section puts a special emphasis on the use of actor-network theory, and stakeholder theory in technology adoption research.

2.2.1 Technology Adoption Theories and Models

This section briefly describes the evolution of technology adoption models based on previous research. Sharma et al. (2014) provided a compact overview for the technology adoption models through its evolution [Sharma and Mishra(2014)]. Starting from Diffusion of Innovation Theory (DIT), the section progressively upgrades the technology adoption models through formation of Unified Theory of Acceptance and Use of Technology (UTAUT) with enhanced inputs. The characteristic properties of these models are summarized and compared in the final part of this section.

Diffusion of Innovation Theory (DIT)

In 1960s, Everett Roger initiated the technology diffusion research by pointing out the four factors that affects the diffusion of a new innovative idea. These factors are the innovation, communication channels, time and social system. Moreover, he also analyzed the process of diffusion in five stages: knowledge, persuasion, decision, implementation, and confirmation. The study treated users in six categories: innovators, early adopters, early majority, late majority, laggards, and the leap-froppers.

The famous S-curve of Rogers (1960) for the diffusion of innovation models, is inspired by the epidemic spread of infections through masses. The rate of diffusion starts slow, gaining momentum at a steep rate in the middle, and finally reaches saturation with late adopters. The behavior of the S-curve is illustrated below using Figure 2.2.

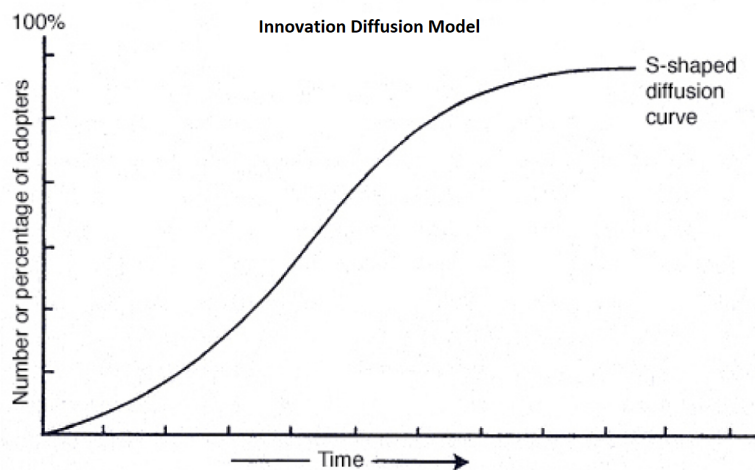


Figure 2.2 – S-Curve Innovation Diffusion Model by Time [Sharma and Mishra(2014)]

S-curve represents the user behavior and reasoning for the diffusion of new technologies. The penetration for a new technology starts slow with early adopters. Next, social factors determine the rate of spread. If the technology is socially acceptable, then the rate of diffusion increases until no more users left for accepting the technology. The changes in the slope of

2.2. Previous Literature on Technology Adoption Research

curve shows the rate and may be different for each technology. This behavior has mainly been used for analyzing the adoption of communication technologies in 1990s. The network effects were apparent as more users adopt the technology, the better acceleration of adoption becomes. The adoption of internet by global user population also follows a S-curve adoption pattern.

Theory of Reasoned Action (TRA)

Fishbein et. al (1975) embedded the social psychology aspect to the technology adoption literature by offering the Theory of Reasoned Action. The social aspects are collected into three social factors, namely behavioral intention (BI), attitude (A), and subjective norm (SN). The user-centric theory treats user as a decision-maker with social preferences. The addition of user attitude and subjective norm creates the behavioural intention. Then, the intention creates the decision for the user whether or not to adopt a certain technology. The theory is illustrated below in Figure 2.3.

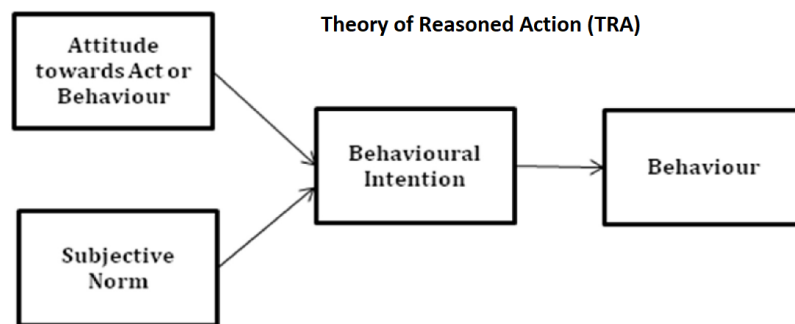


Figure 2.3 – Fishbein et. al (1975) Theory of Reasoned Action [Sharma and Mishra(2014)]

Theory of Planned Behavior (TPB)

Ajzen (1991) modified the Theory of Reasoned Action by adding the Perceived Behavioral Control (PBC) inside the model. This social parameter defines the users' perception of ease in adopting a certain technology. PBC has been introduced in order to respond to the criticisms of TRA being based on relatively static attitude construction without perception. Self-Efficacy Theory (SET), by Bandura (1977), influenced the basis of PBC through Social Cognitive Theory (SCT). Self-efficacy, in conjunction with PBC, defines how users exercise and perceive action in response to a situation. Coupled with the two other parameters in TRA, PBC determines the behavioural intention in TPB. The theory is illustrated in Figure 2.4.

The Social Cognitive Theory (SCT)

The term, self-efficacy, has been introduced by Bandura (1986) to represent the 'judgment of one's ability to use a technology to accomplish a particular job or task' [Sharma and

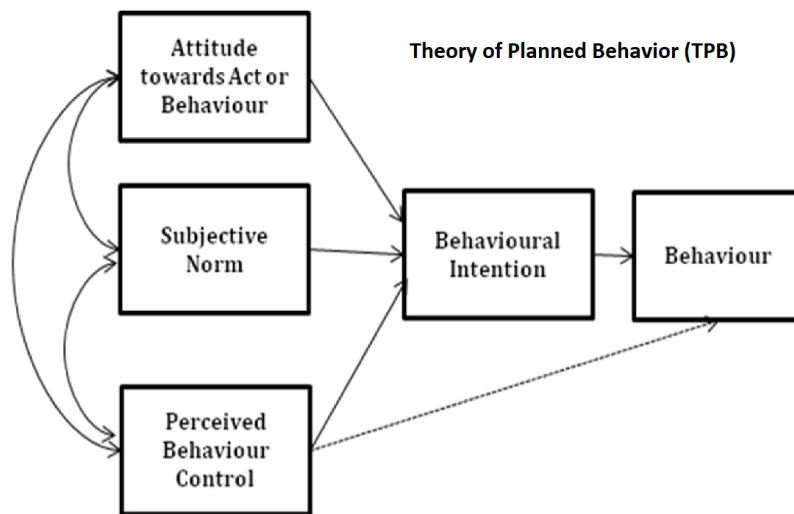


Figure 2.4 – Ajzen (1991) Theory of Planned Behaviour [Sharma and Mishra(2014)]

Mishra(2014)]. The relative perceived value that a user gives to a technology determines the users' behaviour on the adoption process of this technology. This is actually directly related to the concept of translation in ANT methodology.

SCT treats self-efficacy in two directions. The first is the direction in which the esteem and achievements of the person define outcome of their expectations. The second direction is where the user performance with a certain technology affects user expectations. The users' perception of a certain technology at work, affecting the performance, also determines the behavior of technology adoption.

Technology Adoption Model (TAM)

The simplification of previous technology adoption models created TAM as offered by Davis (1989). The perception of users has been parameterized in two terms: perceived usefulness and perceived ease of use. Basically, this model emphasizes the users' perception while regarding the technology adoption process. Similar to TPB, the idea of perception is based on the SET.

Perceived usefulness is defined as 'the degree to which a person believes that using a particular system would enhance his or her job performance'. Consequently, perceived ease of use is defined as 'the degree to which a person believes that using a particular system would be free of effort' [Sharma and Mishra(2014)]. The first trial of TAM started with the adoption of e-mail service and file editor at IBM Canada. The candidate factors for the adoption of technology have been surveyed. This study revealed that perceived usefulness is a dominant factor over perceived ease of use towards adoption. TAM has been used extensively, becoming a hands-on approach for technology adoption research. Yet, the model has been modified in Unified

2.2. Previous Literature on Technology Adoption Research

Theory of Acceptance and Use of Technology (UTAUT) by Vanketesh (2003). Currently, there is a shift from TAM to UTAUT, since the latter encompasses a wide area of adoption problems. The criticism of the model includes its limitations to respond to the changing landscape of technology and its adoption process. TAM is illustrated below in Figure 2.5.

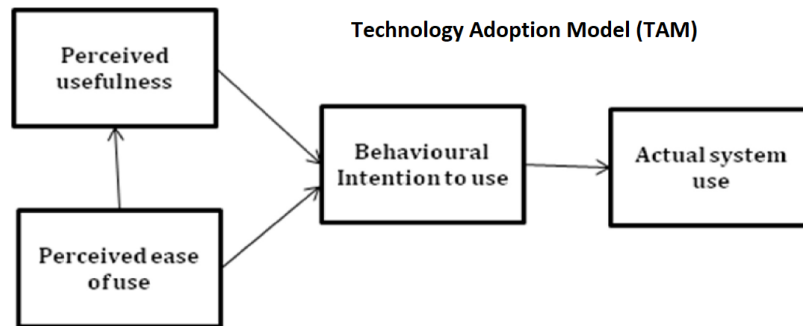


Figure 2.5 – Davis (1989) Technology Adoption Model (TAM) [Sharma and Mishra(2014)]

The Model of Personal Computer Utilization (PCU)

This model specifically investigates the factors affecting the utilization of PCs in a working environment. Different from generic technology adoption models, PCU is based on the Theory of Human Behaviour by Triandis (1977). Similar to TRA, behaviour is regarded as a collection of user attitudes and social norms in PCU. Additionally, habits and behavior complexity are investigated.

This theory proposes that various factors affect the use of computer by a worker in a working environment. These factors are long-term consequences, affect towards use, facilitating conditions, complexity, job-fit and social factors, as illustrated in Figure 2.6. Concretely, the theory focuses on the feelings, habits and social norms of the user related to the use of the computer. Yet, it is hard to generalize the theory to other technology adoption behaviour.

The Motivation Model (TMM)

Davis et al. (1992) offered TMM inspiring from the motivational theory to examine technology adoption models. The user is shaped by internal and external motivational factors. TMM categorizes previous models' factors inside extrinsic and intrinsic motivation. Perceived usefulness, perceived ease of use, and subjective norms are regarded as extrinsic motivation. This type of motivation occurs when a user perceives an outcome that is not directly related to the activity itself.

On the other side, intrinsic motivation happens when the user performs an activity and feels a pleasure directly for doing the activity. This can be observed when a user plays a computer game [Sharma and Mishra(2014)].

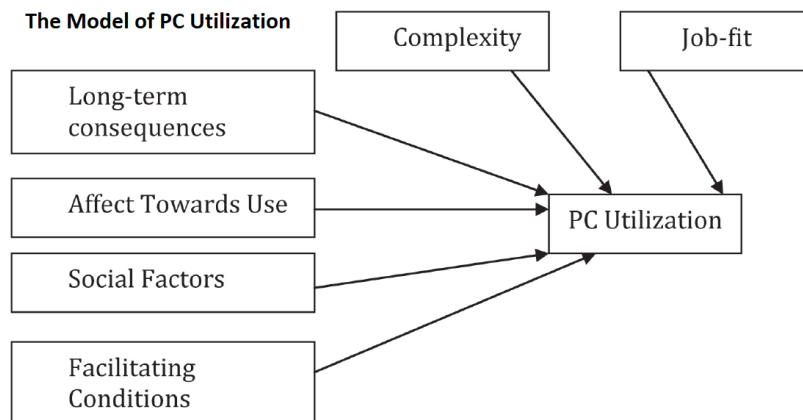


Figure 2.6 – Thompson et. al (1991) The Model of PC Utilization [Sharma and Mishra(2014)]

Extended TAM2 Model (TAM2)

Vankatesh and Davis (2000) collaborated to improve the TAM model by conceptualizing Intention of Use and perceived usefulness. Additionally, new social factors, such as image, norm and voluntariness have been added to TAM. Cognitive instrumental processes, such as job relevance, output quality and result demonstrability have been incorporated inside the model. The extended model has been illustrated in Figure 2.7.

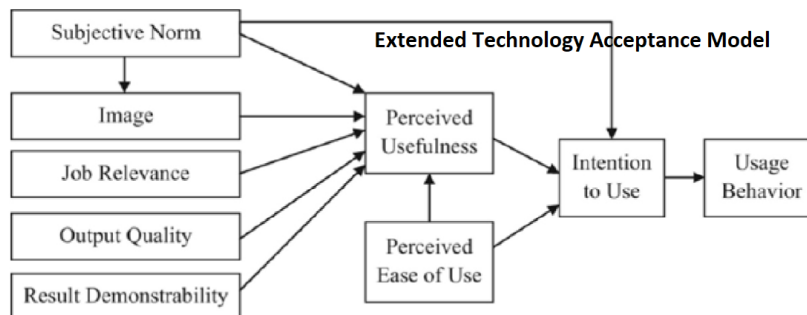


Figure 2.7 – Vankatesh & Davis (2000) Extended Technology Acceptance Model 2 [Sharma and Mishra(2014)]

Unified Theory of Acceptance and Use of Technology (UTAUT)

This model aims to unify all of the previous technology adoption models into a single unified model. The work has been carried out by Vankatesh in 2003 by reviewing systematically and combining the feasible factors from TRA, TMM, TAM, TAM2, DOI and SCT. UTAUT uses four determinants to model technology adoption process, namely performance expectancy, effort expectancy, social influence and facilitating conditions. This reduction of factors is the key for the UTAUT, where researchers consolidate on the idea that these four key constructs are the

2.2. Previous Literature on Technology Adoption Research

most influential.

The other parameters that influence the adoption process are treated as secondary. These are attitude towards using technology, self-efficacy, and anxiety. These factors are not used in the UTAUT model. It has been found that UTAUT model is able to model technology adoption behaviour with a variance of 70 percent, while previous models can only reach up to 40 percent. However, critics pointed out that UTAUT becomes overly complex with many parameters and is not used as is in technology adoption research. Many researchers tend to use UTAUT model as a draft model for theory building. The model and its parameters are illustrated in Figure 2.8.

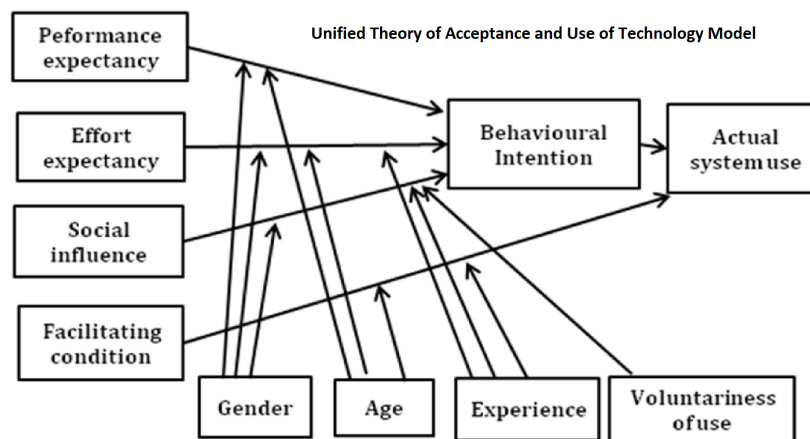


Figure 2.8 – Vankatesh (2003) Unified Theory of Acceptance and Use of Technology [Sharma and Mishra(2014)]

Normalization Process Theory (NPT)

Technology implementation and embedding is also modeled using Normalization Process Theory (NPT). This theory focuses on rationale, structure and function as its base. While the reciprocal interactions between people and artifacts are targeted by ANT, NPT provides explanation of technology implementation, embedding and integration. In order to conceptualize this process, NPT uses four generative mechanisms, namely coherence, cognitive participation, collective action and reflexive monitoring. NPT aims to explain how practices are embedded in their organizational and professional contexts. General proposition is that it is important to examine behavior of people to understand the embedding process. The production of practice involves agent interaction and evolution over time and space.

The constructs of NPT are based on four constructs that build upon generative mechanisms. Additionally, NPT favors that individual and collective contributions are interdependent. The first construct, coherence defines and organizes the components of a practice. Secondly, collective action examines the enacting of a practice. Third, cognitive participation focuses on the people implicated in a complex intervention. Lastly, reflexive monitoring organizes assessments of the outcomes of a practice. Here the important point is that NPT constructs

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Year	Theory/Model	Developed By	Constructs
1960	Diffusion of Innovation Theory	Everett Roger	The innovation, communication channels, time and social system
1975	Theory of Reasoned Action	Ajzen & Fishbein	Behavioral intention, Attitude (A), and Subjective Norm (SN)
1985	Theory of Planned Behaviour	Ajzen	Behavioral Intention (BI), Attitude (A), and Subjective Norm (SN)
1986	Social Cognitive Theory	Bandura	Affect, anxiety
1989	Technical Adoption	Fred D Davis	Perceived usefulness, Perceived ease of use
1991	The Model of PC Utilization	Thompson et al.	Job-fit, Complexity, Long-term consequences, Affect towards use, social factors, facilitating conditions
1992	The Motivation Model	Davis et al.	Extrinsic motivation and intrinsic motivation
2000	Extended TAM2 Model	Venkatesh & Davis	Social influence processes and cognitive instrumental processes
2003	Unified Theory of Acceptance and Use of Technology (UTAUT)	Venkatesh et al.	Performance expectancy, effort expectancy, social influence, and facilitating conditions
2009	Model of Acceptance with Peer Support	Sykes et al.	Behavioral intention, System use, facilitating conditions, network density, network centrality, valued network centrality, valued network density

Table 2.1 – Evolution of technology adoption theory and models [Sharma and Mishra(2014)]

happen simultaneously rather than sequentially.

Timeline of Technology Adoption Theories and Models

Technology adoption theories and models, from 1960 to 2009, have been reviewed by Sharma et al. (2014). All the models presented rely on the assumption there are some factors affecting the technology adoption behaviour. Yet, the models remain user-centric, and rely mainly on the user perception and behaviour as also summarized in Table 2.1.

2.3 Technology Research Using Actor-Network Theory (ANT)

This section aims to explain the ANT approach in technology and information systems research. Specifically, the section investigates ANT as a tool and how it is incorporated into technology research by examining the recent literature. As a socio-technical approach, ANT has been widely used to examine new technologies and their evolution into existence, offering a wider perspective of the social and technical together. This section summarizes the key properties of ANT by giving concrete research approaches and examples from previous literature.

Between 80s and 90s marked an era of interest by researchers on using socio-technical theories, specifically ANT, to understand information systems (IS) and new technologies. Walsham (1997) stated the potential value of the theory as a socio-technical approach, pointing out the power of using ANT in understanding how new technologies come into existence and perceived by the actors [Walsham(1997)]. ANT emerged as a social theory providing conceptual tools to approach emerging technologies from a different angle. For ANT, technology does not only constitute from an artifact, but also includes a social construction which is inseparable from each other. Elbanna (2009) pointed out how ANT has emerged as a theory and evolved in information systems research [Elbanna(2009)]. This work summarizes the origins of how ANT turned out to be a theory creating the network of human and non-human actors.

2.3. Technology Research Using Actor-Network Theory (ANT)

Latour and Woolgar (1979) initiated ANT by defining a term called 'laboratory'. They based the scientific study on an ethnographic study of scientific facts [Elbanna(2009)]. ANT has its roots in various fields of research, to name a few, anthropology, semiotics, and ethnomethodology. What makes ANT different from other views is that it sees scientific knowledge as a network of part social and part technical. Basically, it rejects the clear distinction between what is technical and what is social. Thus, ANT focuses on how technologies come into existence within its social network of actors, their roles, and their relationships. The theory covers a wide area ranging from economics, machines, social construction, and technologies as can be seen in information systems.

The creation of ANT, including the ground work up to its development, started in the Centre de Sociologie de l'Innovation - Ecole Nationale Supérieure de Mines de Paris around 1980s. The initial team of researchers consists of Bruno Latour, Michel Callon, and John Law. By time, ANT has changed both as a theory and a tool for its developers and users. This is due to the fact that the developers of the theory changed their field of research, place, and additionally were in a constant journey to explore its use [Elbanna(2009)]. For this reason, the guidelines to execute ANT research are not written in stone, yet ANT suggests the path of 'following the actors'. The ANT researcher is basically in a journey within its field of research by observing the actors, their relationships and how they align or misalign their network of interests. ANT allows the researcher to use any tool from its arsenal during the research process.

In the worldview of ANT, society is not only socially constructed [Latour(2005)]. The heterogeneous combination of human and non-human actors forms what we refer as the social. Yet, the social does not exist without its counterpart, the technical. The technical artefacts constitute from the interactions of the social, hence forming a socio-technical network. Thus, ANT treats the social and the technical in a symmetrical fashion, calling it a neutral approach. This is a material semiotic property of ANT where an actor can either be human or non-human, and treated equally in investigation. The relationship between the human and non-human actors are the focal point for the ANT researcher.

Understanding the definition of a network in ANT terms is also crucial, since it is fundamentally different from its mainstream use. Because, the definition of a network in ANT mainly focuses on how actors define each others' roles and relationships, rather than the way they are actually connected within the network. These roles and relationships effectively create interests between actors, and mobilise them to enlarge the formed network. There might be multitude of factors affecting the network of relations, such as technical, social, political, legal, and economic. These factors affect the formation of the network and how the network mobilizes within its actors. Accordingly, ANT emphasizes the socio-technical properties of a network consisting of relations between the actors. The first misunderstanding is the term 'network' itself. For ANT, a network is not directly a network of connections and relationship between actors as in the case of engineering. A network in ANT might lack all the characteristics of a technical network. Yet, a stabilized local network might take the form of an engineer's network as in the case of network industries. We can treat networks in ANT as a

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partial projection of an engineering definition of networks [Institut d'Etudes Politiques de Paris (Sciences Po) and Latour(2017)].

Secondly, ANT has very narrow connection to what social networks constitute. Social networks examine the social links between human actors. The networks are characterized by structural parameters, such as centrality, density, frequency, distribution, homogeneity and proximity [Institut d'Etudes Politiques de Paris (Sciences Po) and Latour(2017)]. Analyzing social relations is a reaction to extensive sociological terms, such as organizations, states, institutions. Concretely, ANT incorporates a portion of ideas of social networks, its treatment of non-human actors is somewhat different. ANT treats human and non-human actors similarly, where an actor can be product of nature or a social element.

Pioneered by the early works of Mumford (1981), there emerged a strand of research that adopts a socio-technical view towards investigating information systems. In particular, before ANT the social and technical are treated as separate entities. Walsham (1997) summarizes the relationship between the computer systems and the organization emphasizing the blend of the technical and the social in information systems from an ANT perspective:

It is no longer clear if a computer system is a limited form of organization or if an organization is an expanded form of computer system. Not because, as in the engineering dreams and the sociological nightmares, complete rationalization would have taken place, but because, on the opposite, the two monstrous hybrids are now coextensive [Walsham(1997)].

Even starting from 80s, there was an apparent need to understand the combination of human and non-human actors together. Within the rise of artificial intelligence and machine learning, we need new tools and methodological approaches to study socio-technical systems as one. As we are becoming inseparable from the technical artefacts, it is crucial to use the ANT tools as a qualitative researcher. Technical artefacts evolve into our daily extensions to allow us to execute human functions better. Hybrid forms of life appears in all of our lives, even so that machines started to replace some of the jobs. In this age of immense social and technical change, it becomes crucial to adopt tools of ANT in the socio-technical research.

The material semiotic nature of ANT treats the human and non-human actors in the same way. This is mainly based on the idea that it is the relationships, and relative roles between the actors that defines their properties. As a consequence of this a non-human actor may have a similar agency to a human actor in an ANT network. The network is tied with intermediaries, which represent these transactions and relations between the actors [Elbanna(2009)]. Even, an actor can be a network by itself, having two roles. The first one is the connection with other actors, and the second the connections within inside of the actor. Consequently, an actor may transform by how it is defined and how other actors define it. The network acts as a cumulative interaction of all of its actors, taking responsibility in all the stages of its transformation. Not only the formation, but also decomposition of the network is important. The ANT researcher

2.3. Technology Research Using Actor-Network Theory (ANT)

should take for granted some of the actors that are pre-defined in the network, black-boxed previously by the main actors of the system.

Since ANT offers a refusal to differentiate between human and non-human actors, it offers a change in ontology. This starts with a change in topology, where an actor is not a mere two or three dimensional being or structure. Rather it is a node with connections and translations attached to it. The creation of ANT starts with the idea that without incorporating technical artifacts it is impossible to understand what holds society together [Institut d'Etudes Politiques de Paris (Sciences Po) and Latour(2017)]. Thus, the only way to digest technical artifacts inside the system is by forming a network ontology.

An intriguing article poses the idea that we will not fully understand Foucault without understanding the central place of technology [Matthewman and Philosophy Documentation Center(2013)]. Hence, it is hard to understand ANT without understanding Foucault. Matthewman (2013) states that Foucault's ideas on the inclusion of the non-material realm is aligned with ANT. The first implication is that Foucault uses various terms and metaphors for technology. For him, the definition of technology divides into four types. First is the technology of production concerned with the creation, conversion and control of things. Second and third definition consist of the technologies of sign systems, symbolic communication and technologies of power which dominate, objectify and ultimately determine individual behaviour. Fourth and the own definition of Foucault is the technologies of the self where individuals transform themselves in order to attain a certain state of happiness, purity, wisdom, perfection and immortality.

The discussion by Matthewman (2013) includes Foucault's coverage of technology in four areas: as objects (in relation to stethoscopes and rifles), activities (such as disciplinary techniques and other exercises of power), knowledge (particularly medical and penological) and modes of organisation (hospitals and prisons). Mainly, Foucault's works focused on technologies of power, while also mentioning the technologies of the self [Matthewman and Philosophy Documentation Center(2013)]. Definition of technology is weak in Foucault's case emphasizing its subjective nature. Yet, his writings on technological innovation gives us a view on how his influence is on the upcoming STS and ANT literature. According to Matthewman (2013), technologies mediate between the physical world and culture, and between matter and meaning. This is highly correlated with the idea that technology acts as an agent. This is followed by the statement of Foucault, where he describes technology not only as a set of artefacts exercising power over nature, but also exercising power over ourselves as humans. Additionally, Latour (1999) adds to the discussion using ANT by describing three ideas that technologies permit mediation. As technology grows, it creates new possibilities and programmes of action. Second, a new network of relations and associations form within a new composition of technology. Finally, the delegation of work of humans directs towards technology. Within the rapid advancement of technology, such as artificial intelligence, there is even a risk of people losing their jobs, which also supports this argument.

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The term 'translation' plays a key role in ANT research. The basic definition includes all the dynamics of an actor while it interacts with other actors. These may consist of how the actors are shaped, relate to each other, define their roles, and mobilise. As the word itself suggests, translation is how each actor see each other in the network. By time, the actors get to know each other and position themselves in the network trying to align their interests. It is a very dynamic process which includes stages or what is called moments of translation in ANT terms. Elbanna (2009) explains these dynamics as strategies of translation based on Latour's previous work on the topic, which includes steps to clarify the translation process for the ANT researcher. Elbanna (2009) starts by defining the term 'interest' as what lies between actors and their goals. Following that, the first strategy is to tailor the network builder's project in a way to make the actors interested. The second strategy is to mobilise actors towards the network builder's goal. The third strategy is to abolish the path being followed to achieve a particular actor's interests, and move according to the builder's interests. The final strategy is to do away with explicit interests so as to increase the chances of the network builder to mobilise [Elbanna(2009)].

As Callon suggested, actor-network theory does not look into the technology adoption problem as a user-centric one-off decision event. Rather, ANT focuses on how certain technical devices, technologies come into existence and adopted by the actors as a continuing process [Callon(1984)]. Created by Callon and Latour, ANT initially has been used to investigate information technologies taken together the social and technical. Blending them both, ANT opens up new possibilities with regards to the research paradigm investigating technology adoption. Through literature, it has been observed that ANT research is mainly regarded as interpretivist or relativist. Latour (2017) insists that ANT uses a relativist approach, where there is a simple definition of a network without limits, distances or boundaries. Nodes are treated as actors that do some kind of work. The first property of an ANT network is that the tyranny of distance or proximity between the nodes are eliminated. Also, the network is not limited by space or geographical boundaries. The relationships are just mere associations between actors, maybe with a possibility of a physical connection. Following that property, the difference between small and large scale networks is somewhat problematic in ANT.

Iyamu et al. (2013) stressed the importance of understanding the socio-technical context of how information systems are developed and implemented. Since ANT is suitable for clarification of the social factors and links between actors, it is suitable to understand the development and implementation of information systems in organizations. Technology consists only a part of the implementation of an information system. The human factor, interactions, and the intertwined nature of technology with human constitute the system. The biggest criticisms to actor-network theory comes from its controversial introduction of agency to non-human actors. Even the definition of non-human actors becomes problematic in various contexts. Yet, it is important to understand this term to understand the ANT approach. Recent developments in social studies, especially the materialism trend in Science and Technology Studies (STS), show that there is a tendency to consider new objects as actors [Sayes(2014)]. A main criticism is that social scientists are not entitled to give agency to non-

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human, rather natural scientists and engineers have a tendency to use the ANT perspective. It has been widely argued also that giving purpose, life, will to objects is challenging from a social sciences point of view. Yet, supporters of ANT agree that even though non-humans do not have direct agency, they possess a type of causal agency.

In order to clarify the introduction of non-humans to the social world, Sayes (2014) provided the non-human contributions to the social world in four categories (I-IV). First, the study considers non-humans as a condition for the possibility of human society (Non-human I). Second, non-humans can also be acting as mediators in different contexts (Non-human II). Third, they have the ability to act as members of moral and political associations (Non-humans III). Finally, non-human actors gather in different temporal and spatial orders (Non-humans IV). By pointing out the different social roles possessed by nonhuman actors, Sayes (2014) argues that ANT provides a coherent methodology for incorporating non-humans into social scientific accounts. Regarding ANT as methodology, rather than a theory is key to understand non-human actors. By that, methodology shows up as assumptions, ideas and road-maps to the analysis, as also pointed by Sayes (2014). The term non-human, as used in different contexts, represents objects, animals, technological artifacts, tools, infrastructure, and many more excluding humans.

2.3.1 Actor-Network Theory in Technology Adoption Research

A considerable amount of technology adoption literature focuses on the user-centric technology adoption, rather than focusing on the how new technologies came into existence and be adopted by all the relevant actors [Faraj et al.(2004)Faraj, Kwon, and Watts]. Yet, numerous studies using ANT aim to explain the emergence and adoption of technologies as a socio-technical network. Studying complex technology evolution processes, Faraj examined the emergence and shaping of the web browser by using ANT principles [Faraj et al.(2004)Faraj, Kwon, and Watts]. This research identifies how the web browser came into being and evolved over time.

In order to understand the diffusion of technology, preliminary work on analyzing technological change using ANT was undertaken by Heeks (2015) in the case study of introducing new financial technology into the Sri Lankan public sector [Heeks and Stanforth(2015)]. The rapid rise in information and communication technologies in developing countries makes it important to understand the dynamics in the public sector. It is critically important that the ANT does not provide an implicit guidance on how to start and guide the research process. This paper also starts with investigating the focal actor and then follows the other engaged actors relevant to new technology adoption. The engagement with the actors provide which actors, human or non-human, should be investigated in the research.

The case study starts with the signing of a formal agreement between the Sri Lankan Ministry of Finance (MoF) and the Asian Development Bank (ADB) to fund a technical assistance project. The research is divided into the phases using the ANT translation methodology

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and terminology. Phase one is the building networks around best practice solutions, which includes the problematization, interessement, and attempted enrollment. The second phase is called re-building the project on new foundations, which is made up of de-enrollment and re-problematization, interessement, enrollment, and mobilization.

Shin et. al. (2003) analyzed the network neutrality in Korea by focusing on the relationship between the actors. The case study aimed to reveal the need of socio-ecological transition in broadband internet services. Specifically, the study investigates the relationship between technology and society towards adopting regulations and rules in information and communication technology. For this reason, the research relies on ANT's interpretive property of how a technological solution come into existence as a combination technical and social relations. The results of the study show that confusing policies and inconsistent regulation affect the process of network neutrality in Korea. The confusion stems also from frequent government reorganizations. Moreover, it is frequently observed that telecommunication regulators prefer to achieve market and industrial benefits, rather than focusing on the consumers. Therefore, this study pointed out the importance of network neutrality regulation, and the apparent need of favoring consumer interests and well-being of society.

In telecommunications domain, McBride (2003) investigated the adoption of mobile communication technologies within different countries [Mcbride(2003)]. The analysis done in this study forms the basis for our adoption of tools from ANT in the conceptual framework. McBride (2003) stated that government policy, geographical factors, physical infrastructure, economic models and culture affect the adoption of mobile technologies. This is aligned with the assumption that ANT has, where human and non-human factors affect the socio-technical events. Additionally, ANT is suitable for analyzing and interpreting the interaction of actors while they take-up new technologies. Then, McBride (2003) continues with explaining that adoption happens when the interests of the actors get aligned. He also touches the irreversibility property of technology, in which a system could not go back to a past state in the case of technological advancement.

The interpretive nature of ANT allowed the explanation of the adoption of mobile communications, focusing on the construction and implementation of this technology. There is a wide diversity between countries in the adoption of mobile technologies, and the reason is not just technical, but also social. There are a number of factors affecting the adoption, both in developed and developing countries. The different trends in the adoption of mobile communications throughout the world, such as Europe, Japan, Africa, and China created an opportunity to understand what affects the adoption. Legislation and governmental control have been found both promoting and inhibiting mobile technology adoption in national level. The penetration of the market depends on the market openness and fees for the telecommunication licenses differentiating between countries, such as Japan, and in Europe.

The perception of the technology and its ease of use also affects its adoption. The key features, such as latency, one-touch activation of Internet, flexible modes of use promotes the adoption

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of mobile technologies. Local culture and geographical factors, such as ethnicity, culture affect the spread of this technology. Additionally, economic or business models affecting the pricing models and tariffs of users influence the patterns of use and diffusion of mobile technologies. The services delivered by the mobile operators and their options also decide on the adoption from users. A concrete result provided by McBride (2003) is that the low tariffs and innovative service packages increased the spread of mobile phones in India [Mcbride(2003)]. McBride (2003) also states that cultural factors decide on the resistance to a new technology. The feeling of acquaintance and ownership to a technology create the attractivity to the users to adopt a new technology. All of these factors act in a dynamic way, where the links and relationships between actors are also affected by these factors. ANT provides various concepts and tools to the understand these dynamic links between actors, how they translate each others' objectives and which factors affect them while adopting new technologies.

The use of ANT comes into play when we try to understand how technology comes into existence, evolve, and spread within communities and organizations. ANT treats technology as a construction of both technical and social. It is important to note that technical superiority of a technology only be effective under the condition that it is also socially accepted. Besides technical, a lot of different factors affect the adoption of mobile technologies. McBride (2003) also emphasizes that ANT has both a interdisciplinary and cross-disciplinary approach. Various researchers used ANT to interpret cities as urban actor-networks, to understand geographical information systems and public water supplies. Specifically, the network industries, such as telecommunications, energy, urban transport, postal services, and air traffic services are a good candidate for ANT analysis. The approach and tools originating from ANT help the researcher to understand the construction of new technologies from both a technical and social standpoint. The interpretative nature of ANT tools allow the researcher to explore the story, while these technologies come into existence, evolve and be taken up.

The clarification of the concept of network in ANT is important for a researcher. Here, we are not just speaking about the physical network of nodes, transmission as present in a telecommunications network. The ANT network is the one that is created by mainly the actors, or stakeholders, their objectives and relationships between them. These actors include social, physical, and technical actors interacting with each other, having aligned or misaligned interests while adopting new technologies. The main property of a network in ANT is its heterogeneous associations. Another property of a network is its scale, where there is no division of large or small. What is more, there is no hierarchy, where a network is an arrangement without a centre or a placeholder. Mainly, it is the translations of objectives between actors that defines the network and its structure. The properties of the network, such as stability, dynamism, thus relies on how actors are defined within their aligned or misaligned objectives.

The actor, for an ANT network, is defined as any entity which have a physical, technical or social objective in the examined technology adoption event. Thus, their objectives and relationship between them define the ANT network, its spread and geography of the technology [Mcbride(2003)]. Actors can be both human and non-human actors, such as groups, technical

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artefacts, or even anything that the network regards as having a translation of its objectives. This is one of the key elements of ANT, where the treatment of actors do not differ because of their human or non-human nature. In network industries, physical infrastructure, environment, safety, can be good candidates for non-human actors affecting the overall network and objectives of human actors. In order for a successful adoption of a new technology, both the human and non-human actors need to align their own interests.

The two key elements that form the network are translations and inscriptions. Actors, by interacting with each other and the technology, define their own objectives in a technology adoption environment. The stability of a network highly depends on the alignment of the translations of actors' objectives. A stable network is formed when the translation of the actors' interests create a common picture, which fulfills the objectives of the actors. The properties of the network, inscriptions coexist with the translations of the actors' objectives. These can support the objectives of the actors, while also deciding on the fate of the network, its dynamic structure and its rigidity.

In technology adoption, one of the biggest challenges is to attract other actors' attention and interest into the network. A successful alignment of focal actors' interests is followed by the enrolment of interested actors into the network. Focal actors also try to attract interested actors to support their case and increase the chances of the technology that they are promoting. Here, non-human actors mainly act passively and human actors interact to find if they have aligned objectives and create relationships accordingly. As more actors join the network, the translations become stable and each actor justify the common goals of the network. If all of these stages in technology adoption execute successfully, then the network reaches the stability within a critical mass of adopters. Later in this phase, the technology becomes common place, and the property of irreversibility comes into play. This posits that when a technology becomes as essential and irreplaceable in the society, then it is nearly impossible to go back to the stage where this technology does not exist. Once the network is formed and functioning properly, it will function unless a new technological development comes into its way, and changes or disrupts its stability, and form a new network.

The term, black-box, is a generic term from system design, where a system is defined by its inputs and outputs. It means that a system can be represented by a function of its inputs and outputs. In ANT, black-box is used similarly to represent a stable, rigid, and irreversible network of actors' objectives and relationships. When a technology becomes common place within the ANT network consisting of human and non-human actors, it forms a black-box, which is a picture of the state of technology in its final form. The technology then becomes part of life, functioning naturally within the social environment. Much of the physical infrastructure for mobile communications is accepted naturally, also the modern communication methods are taken by granted by the users [Mcbride(2003)]. It is also important to understand the past black-box configurations, while examining the technology adoption of new technologies.

McBride (2003) used tools from ANT to understand the technology adoption process. First, it

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is the alignment of actors' interests that is under investigation. On the other hand, for the cases where the actors' interests do not align, the adoption process got into trouble, and the stability of the network is lost. In the case study investigating Grameen Telecoms (GTC), McBride (2003) shows the applicability of ANT and its concepts in analyzing the technology adoption. Clearly, McBride (2003) states that the village, its mobile infrastructure, social and human networks are not separable from each other. Focusing on satisfying the customers, GTC got aligned with the actors that are present in the village phone actor network [Mcbride(2003)]. When the alignment of the actors are guaranteed, the mobile technology became a black-box. Moreover, the concept called centre of calculation is important in analyzing the network of actors [Latour(2005)]. This is the location, where observations of the network take place and forms the basis for the examination of the actors and their objectives. Finally, the ANT concept of obligatory passage point is the critical milestone to be satisfied in which the actors come into an agreement with the focal actors to solve the barriers attested in the technology adoption process. This is critical, since if there are barriers to pass the obligatory passage point, then there should be a rework of the alignment of the actors in the network.

The use of ANT in technology adoption research can be both descriptive and interpretive. McBride (2003) focuses on the descriptive nature of ANT, while describing the technology adoption process in mobile communications. Following the actors and understanding them through the adoption process is the first step in the analysis. ANT allows the researcher to point out questions that address both the technical and social infrastructure [Mcbride(2003)]. These questions include understanding the characteristics of the stakeholders actors or groups, their interests, translation of their interests, and the formation of the network. This, in effect, guides the researcher to collect stories of the actors, and map the relationships between them, while they try to adopt new technologies. It is also crucial to study the before and after adoption cases to point out the barriers and provide recommendations for the future.

The steps to apply an ANT inspired methodology are provided by previous literature. Yet, it is not always clear on how to carry out these steps for data collection. McBride (2003) offers a three step approach, where the first step naturally is following the actors and circulations. This step includes a clear identification of actors/stakeholders, and the methods to reach them. The best possible is to be related with one or more of the focal actors in the process, which in our case is the Network Manager, EUROCONTROL. For each actor group, in order to understand their objectives and translations, qualitative data collection, in the form of interviews, participant observation, or documentary analysis is suggested. Also, for the technology under investigation, a historical review of the concept is necessary. McBride (2003) suggests that it is important to understand the relationship between actors in terms of current communication, power distribution, levels of trust, resource control, and influence [Mcbride(2003)]. The complexity of the actor network might also degrade its stability, simplification of the actor network will make the alignment of actors better.

The second step is designing the inscriptions between actors. Inscriptions will aid the alignment of actors' interests, while also turning the objectives of actors into a social, cultural, and

historical elements. These include services, marketing, politics in relation to the technology under investigation. The third step is the design of the enrolment strategies. The mechanisms for a successful enrolment of aligned actors create a stable network, where existing black-boxes open enabling the creation of new black-boxes around new technologies. The enrolments should consist of politics, power, and attitude. When the black-box is forming, it needs to collect support from both social and technical factors. The interactions between the actors decide on how the enrolment will be in the first place.

McBride (2003) concludes his case study of mobile communications by stating that the adoption depends on social networks and geographic landscape [Mcbride(2003)]. The tools from ANT provides the researcher to point out the detailed description of the technology take-up and spread. The recommendations, originating from understanding the objectives of the actors, provide insights on how the actor-network shapes in the context of technology adoption. Tailored inscriptions and enrolment strategies stick the network together, by considering the diverse geographic and social environments [Mcbride(2003)]. Culture is also seen as one of the decisive factors in technology adoption. The actor network should not just be based on a western style business models or motivations, since for another culture the network might not be the representative of the reality. Further, examining the focal actors, the power distribution among them are crucial elements in understanding the technology adoption. With power, the actors decide on to promote or inhibit the technology adoption processes. The network, and its stability are affected by the power relations between actors dynamically. That is why aligned interests are important, when actors with power have common interests, the probability of adoption increases. If in case two or more powerful focal actors get into misalignment, the network loses its stability, and black-boxing never happens, leading to unsuccessful technology adoption.

Faraj et al. (2004) criticized that much of the IT technology adoption research focuses on the adoption from the users' perspective and lacks in understanding how the technologies are created and be taken up [Faraj et al.(2004)Faraj, Kwon, and Watts]. Addressing this gap in literature, Faraj et al. (2004) studied the development and adoption of Web browser technologies in the 1990s. Using ANT and its three stages of translation (inscription, translation, and framing), the study executed content analysis based on archival data to identify the actors, their objectives, and actions. In the beginning of the 1990s, the web browser technologies was the hot topic, which became one of the standard technologies in 2000s. Back then, it was very crucial to understand how it come into existence and the factors shaping its evolution.

Although traditional technology adoption research provides the perception of users, it is far away from telling the story of adoption and the reasons why. Faraj et al. (2004) pointed that neither technological or social determinism is enough to explain a socio-technical phenomena, such as technology adoption [Faraj et al.(2004)Faraj, Kwon, and Watts]. Technological determinism treats technology as just a physical artefact, where users decide to adopt according to their perceptions, and factors. Oppositely, social determinism treats technology as a collective interpretation of the human actors. Rejecting a deterministic viewpoint, ANT takes

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the middle approach, where the emphasis is on understanding technology as a collection of ideas of the actors and the physical artefact. This physical artefact help the human actors to accomplish and even amplify their objectives. Effectively, this closes the gap between treating human and non-human actors separately. Concretely, the focus of the study is on the network and how it actually forms, rather than segregating the type of actors. Actually, the network will point out which actors (human or non-human) have a voice in the adoption process, by pointing out the objectives and barriers inside.

Analyzing the web browser technology, Faraj et al. (2004) incorporated ANT approach by using inscription, translation, and framing, as also shown in Figure 2.9. Clearly, the work describes inscription for ANT as the embodiment of actors' belief, social, economic relations, and assumptions about the artifact [Faraj et al.(2004)Faraj, Kwon, and Watts]. Another use of inscriptions is the design and use of technology, and all the meanings besides the physical structure that an artefact brings. It is a powerful method for actors to create technologies filled with vision and interactions. This makes a technology more than just having a physical structure, but also social dimension by creation. During the phase of a new technology development, actors, or network of actors shape a technology's functionality dynamically. This might be according to users' perceptions and needs, and also affected by the technological strategy of the actors.

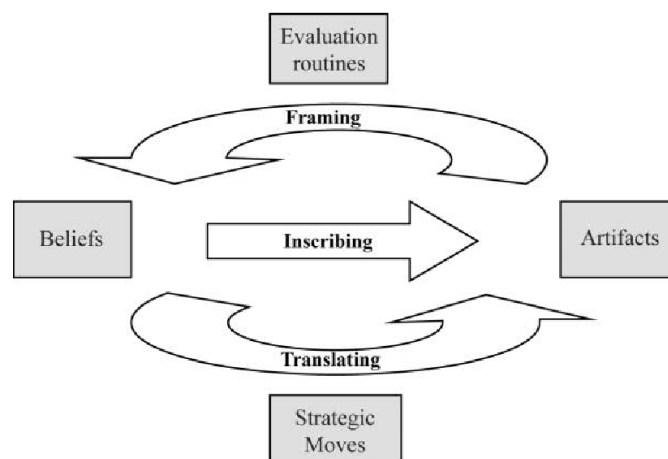


Figure 2.9 – Stages of Actor Network Theory [Faraj et al.(2004)Faraj, Kwon, and Watts]

Translation, as previously mentioned, is the means for actors to create interests, dynamically update them according to their own objectives, and come up with an agreement between each other. In this way, an actor network forms, and strengthens accordingly. Each actor initially defines their own objective, then aligns with the ones that fits to support their claim. The dynamic reactions of actors to each others' objectives decide on the fate of technology adoption. Faraj et al. (2004) provides the case of competition between mobile browser actors, Microsoft and Netscape to attract supporting actors and enrolment to get the best from the market share [Faraj et al.(2004)Faraj, Kwon, and Watts]. The framing context comes into play when users interact with the new technology and create their opinions about the adoption.

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Then, there is a dynamic play between the designers' perception of the user and the users' own perception. After the initial interaction with the user, the new technology molds into shape. By time, perceptions of the technology crystallizes. Faraj et al. (2004) provides an example of framing by stating that the Netscape browser incorporated new functionality by listening to users' needs. Once the technology reaches a satisfactory level and acceptance, irreversibility kicks in locking the technology inside the social structure.

Faraj et al. (2004) based his work on archival data of practitioners' journals, books, and annual data obtained from companies. Concretely, process theory approach is utilized to develop interpretations of longitudinal data [Faraj et al.(2004)Faraj, Kwon, and Watts]. Thematic interpretation includes beliefs, artifacts, and evaluation routines. This study introduced a fourth element, competitive move, to the already existing ANT approach. This is to understand the commercial interests on the development of the web browser. Microsoft and Netscape competed for the development process to assess their strategic moves. The first phase of the analysis included a design of the coding scheme with template coding. The second phase is refining the coding schemes, and the final scheme defragments into the four conceptual elements: artifacts, evaluation routines, beliefs, and strategic moves [Faraj et al.(2004)Faraj, Kwon, and Watts].

The findings from the study show that technology histories of specific actors create the beliefs that become embodied in the artifact. By time, these beliefs evolve and take shape within the technological artefact. The study identified that there are six type of beliefs in the technology adoption of the web browser: integration of protocols, add-on applications, platform-independent architecture, integration with platform resources, enterprise intranet, and provision of content [Faraj et al.(2004)Faraj, Kwon, and Watts]. The properties of the technological artefact, the web browser, extends beyond its physical properties, which support the ANT perspective. The resulting themes show the picture of the interactions between users, and evolution of technology. Faraj et al. (2004) confirmed that ANT is suitable for understanding technology adoption process by examining both the technical and social interactions between the actors. Sometimes the technology can depart from its original definition, and evolve by time. ANT is suitable to capture these dynamic changes and the factors adopting the adoption process.

In understanding information systems, Tatnall (1999) incorporated ANT to the previous qualitative research approaches [Tatnall(1999)]. The implementation and development of information systems are complex processes, where innovation translation from ANT is a powerful tool to examine them. Since the 1990s, researchers prefer qualitative methods to investigate information systems, their development, and evolution. Tatnall (1999) pointed out the limitations of the previous methods to understand information systems before introducing ANT. Similar to other ANT researchers, Tatnall (1999) argued that the attention is mostly into the technical side, rather than treating social and technical aspects equally. The social stays as an environment where the technology places itself, and examined separately from the physical artifact.

2.3. Technology Research Using Actor-Network Theory (ANT)

A number of researchers state that it is important to understand the disagreements, difficulties, and controversies surrounding technical innovations. This is due to the changing landscape that the actors interact with their own objectives, and interests. The property of ANT on treating the social and technological in the same way allowed Tatnall (1999) to examine the innovation and its diffusion process. Concretely, ANT has three principles: generalised symmetry, agnosticism, and free association [Callon(1984)]. The first one, generalised symmetry is explaining the conflicting viewpoints of actors with the use of neutral approach in the same way for human and non-human actors. Agnosticism means that the treatment and analysis are the same for both human and non-human actors regardless of their origin. The final principle, free association is leaving all the different treatments and determinism of social, technological, and natural. These principles guide Tatnall's (1999) work on understanding innovation diffusion by the use ANT.

According to Tatnall (1999), the adoption of an innovation depends on all the interactions in a chain of actors, who has any influence on it. Moreover, each actor shapes the innovation according to their beliefs and objectives. There is a continuous and dynamic transformation of adoption during its life-cycle until its mass acceptance. Innovations, technological breakthroughs are not created by itself with passive input. Rather, it is a collection of alliance between human and non-human actors. Translations between the actors help us to understand how actor-networks are created. Concretely, ANT is more focused on how the bonds between the actors are created rather than causes and effects in technology adoption. Tatnall (1999) proposes that it is the consortium of actors and their will and momentum which decide on the take up of a new technology. The interests between the actors evolve over time, shaping the path of technology adoption by forming chains of reasons. If successful, this turns into a black-box, stabilizing the objectives of the actors in a locked chain of interests.

Tatnall (1999) stressed that there is a main difference between the approach of diffusion models (innovation diffusion) and ANT (translation model). ANT sees the technology adoption as a socio-technical interaction between the actors, their objectives, and relationships between them. On the other hand, innovation diffusion focuses on the inertia, perception and behavior of the users during the adoption process. The superiority of ANT over innovation diffusion is its capability to explain how the actors align, form a network, and evolve during the process of adoption. Both the human and non-human actors are involved in this act of negotiation, defining and translating their common objectives. Detours form while actors define and translate their objectives. The heterogeneous engineer has been defined to control these detours and get the translations back into track. Tatnall (1999) gives an example related to the adoption of Java as a programming language. The innovation diffusion approach would rely on the characteristics, portability of Java, while also considering the channels of adoption and preference of programmers [Tatnall(1999)]. In contrast, innovation translation focuses on understanding the network, and how the alliances between programmers, potential users, and consulting company form through the adoption process. ANT does not only focus on the properties of Java, but also the potential applications and value it brings to the actors. As also foreseen, Java has translated into becoming a programming language for web applications.

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Lepa et al. (2006) investigated the adoption of the internet by older people using ANT [Lepa and Tatnall(2006)]. Moreover, this adoption process leads into a formation of virtual community networks, including e-mail, chat, community, and discussion groups. Lepa et al. (2006) approached this research from a socio-technical perspective to understand the adoption of internet and e-commerce by older people. Both the human (older people, various aged people), and non-human actors (computers, modems, browsers, internet service providers) are important in the analysis of the adoption using ANT. There are quite a number of social factors that affect the adoption of internet by older people. First, the older people perceive internet as a mean to reach relatives and friends in the form of a social communication channel. Second, they want to keep up with the upcoming trends in technology. These factors affect their social circles and relationships, the adoption decision of internet becomes more than a technical decision. The property of translation is visible in that the internet becomes a channel for communicating with friends and relatives. The research uses interviews as a method to collect data and points out the importance of following the actors during the process. Snowball sampling method is used, forming focus groups to reach participants. Various cases show the stages of translation (problematization, interessement, enrolment, and mobilisation) of internet. Lepa et al. (2006) examined how the older people in Australia perceive and use the internet. Additionally, the affects of the internet on the daily lives of older people are investigated.

Actor-network theory has become a contemporary method in analyzing developments in information technology. Despite its limitations, its conceptual framework is suitable for capturing the role of non-human elements, such as technology in socio-technical environments. Existing work in the field proves that the approach is practical as a theoretically informed approach to sampling and analysis by conceptualizing and interpretation [Cresswell et al.(2010)Cresswell, Worth, and Sheikh]. Recent developments in healthcare domain include the transition to the information technologies. Cresswell et. al (2010) investigated the introduction of electronic health record software. Additionally, the study highlighted the fact that it is important to theoretically analyze these new technologies to effectively implement them. Cresswell et. al (2010) also noted that studying IT systems in healthcare require socio-technical scenario analysis, where ANT comes in handy and practical.

The focus of the ANT approach in this work is the examination of the pragmatic approach in studying IT implementations in healthcare settings. The study points out that there are two ways of implementing ANT approach in this setting: conceptually and pragmatically. Concretely, Cresswell et. al (2010) pragmatically developed their research on existing cases of studies using ANT in technology introduction to healthcare domain. The practical value of an ANT-informed approach has been emphasized through the paper, focusing on the advantages of sampling by focusing on relevant informants that are related to technology development. Specifically, the study implemented multi-sited ethnography, where the research encompass multiple locations to gain insight on the wider social system. Previously, Bruni et. al (2010) carried out a study on electronic clinical record in an Italian hospital using a combination of ANT and multi-sited ethnography. The paper described that using ANT, they have negotiated

the existence of software in the organization. Specifically, it has been observed that successful integration of IT will only happen if other actors align to absorb the technology.

2.4 Technology Research Using Stakeholder Theory

Stakeholder theory has been used extensively to examine information systems and its stakeholders. The origins of the theory starts in management with Preston (1999) analyzing the main stakeholders in the great depression of United States between 1929 - 1941 [Mishra(2013)]. Preston (1999) defined the four main stakeholder groups as customers, shareholders, employees, and the general public. The trend of understanding stakeholders and their roles has also been carried out by Gibson, Friedman, Putler, and Miles. The power of the stakeholder theory lies in its simplicity both as a methodological approach and analytical framework. Additionally, in socio-technical research it is beneficial to look to technology or information systems from stakeholders' perspectives. As early as beginning of 1980s, Mumford (1979) emphasized the importance of considering the users in the development and implementation phases of information systems. For a successful implementation of information systems, it is crucial to understand the managers and the end-users. By time, the information system is getting more complex, and new stakeholders are emerging. This creates the need to understand the complex dynamics that shape the strategical decisions of the stakeholders [Pouloudi et al.(2004)Pouloudi, Gandecha, Atkinson, and Papazafeiropoulou].

Examining failures in information systems is also an intriguing topic of stakeholder theory. Lyytinen and Hirschheim (1988) studied the failures in information systems, and concluded that failure occurs if the expectation of the stakeholders are not met. At the same time, a failure for a stakeholder might be a success for other stakeholders. That is to say that each stakeholder may have their unique objectives surrounding a particular information system. This is also related to the translation concept that is described in ANT methodology. Moreover, the term stakeholder is changing through time in information systems, evolving from user centric to inter or intra-organizational definitions. Besides information systems and failures, stakeholder theory has been used extensively for a wide range of fields, such as strategic management, e-government, business planning, and project management. Within these fields, the successful analysis of the stakeholders provides an overall view of the projects and aid on the successful execution of their plans.

Across the corporate responsibility, and business ethics, stakeholder theory finds its place connecting them both and providing an analytical framework to approach the stakeholders [Mishra(2013)]. The term stakeholder finds its roots in early works in 1960s as to define the groups without whose support the organization would cease to exist. Freeman's generic definition combines all the areas under systems theory, corporate planning, corporate social responsibility, organization theory, and strategic management [Mishra(2013)]. Yet, there are differences between researchers on how to define a stakeholder, depending on the field of research and roles of the stakeholders. In particular if the firm is the focal point, then a

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stakeholder resembles groups of constituents who have a legitimate claim of the firm. On the other hand, if the field is corporate affairs, then participants in corporate affairs. Specifically, a basic definition of a stakeholder includes those that are impacted by the decisions and those that are impacted by those decisions in an organization.

This thesis adopts the definition of stakeholder of Freeman (1984), where a stakeholder in an organization is any group or individual, who can affect, or is affected by, the achievement of the organization's objectives. Particularly, Freeman (1984) divides the stakeholders into first to two main branches as internal and external. Then, internal stakeholders are composed of customers, employees, suppliers, and owners, whereas the external stakeholders are competitors, governments, and special interest groups. Under certain circumstances external stakeholders can be as important as the internal stakeholders. Consequently, both type of stakeholders are treated equally in the stakeholder analysis framework. Yet, another definition from Clarkson (1995) focuses on the division between primary and secondary stakeholders. Primary stakeholders are defined as without whose continuing participation the corporation can not survive as a going concern. On the contrary, the secondary stakeholders are the ones who have the capacity to mobilize the public opinion in favor of, or in opposition to, a corporation's performance. Considering many definitions of stakeholders, they are not treated as passive elements in stakeholder theory. Rather, they interact with each other in accordance to their objectives, and use power to direct their goals.

The stakeholder analysis framework consists of the definition of the stakeholders, their roles, and relationships between them in and around an organization. Thus, it is able to represent them as a map of relationships, and the nodes being the stakeholders. The initial representation of Freeman (1999) includes nodes of stakeholders connecting to the firm, since the firm is the focal point of Freeman's analysis. Figure 2.10 provides the initial representation of the stakeholder theory and its framework.

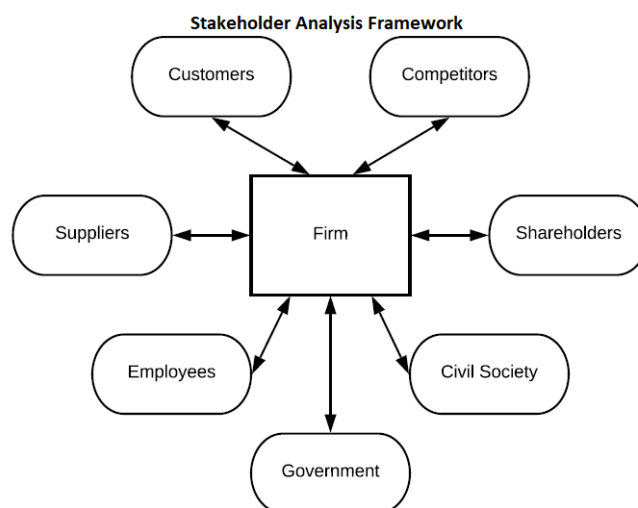


Figure 2.10 – Stakeholder analysis framework of Freeman (1984)

2.4. Technology Research Using Stakeholder Theory

The research paradigm surrounding the stakeholder theory has several dimensions, categorized as both descriptive, instrumental, and normative [Mishra(2013)]. Donaldson and Preston (1995) described stakeholder theory as having a nested structure of three dimensions. First, stakeholder theory is descriptive because it identifies the actors in the form of a constellation of actors' interests. This has a natural value on understanding the alignment or misalignment of the actors in a constellation. Second, it is instrumental since it provides a framework to examine the connections between stakeholders, specifically looking into their objectives while reaching their goals. And third, stakeholder theory is normative in that it includes persons or groups having particular interest in their natural socio-technical environment [Mishra(2013)]. Additionally, the theory is considered to be related to management where structures, practices, and attitudes are important when considering the objectives of the stakeholders.

Stakeholders in information systems mainly consist of either groups or individuals within the relevant organization. As previously mentioned, Mumford (1979) is one of the pioneers of including end-users in successful information systems development and deployment. Coupled with the evolving information systems, there emerged a need to consider a wide range of actors than the users and the developers. Both internal and external actors started to play important roles in the technology adoption and development. However, still there is an ambiguity in the definition of stakeholders in information system research. To give an example, Mishra (2013) points out that Buddy and Buchanan (1986) viewed organizations consisting of various stakeholders that can either enable or inhibit change or innovation. For them, the stakeholders can be identified by their interests and objectives, and how they get affected by information systems [Mishra(2013)]. Yet, another definition treats stakeholders as people who are affected in a radical manner, having will to understanding the nature and aim of the new information system.

Extending the previous definitions, Ahn and Skudlark (1997) presented a stakeholder as a group of people sharing a pool of values that define what the desirable features of an information system are and how they should be obtained. Furthermore, Lederer and Mendelow (1990) introduced the notion of the environment by including host organization's environment as everything within the organization that lies beyond the borders of the IS department. Consequently, soft systems methodology emphasized the importance of stakeholder identification and understanding each stakeholder's perspective. Checkland (1981) used CATWOE (customer, actor, transformation process, Weltanschauung, system owner, environmental constraints) to provide an overall picture for the information system, broadly describing the human activity system. Within the information systems, an important area is the development of information systems strategy and aligning it with the business strategy of the company [Mishra(2013)]. Stakeholder theory provides the different viewpoints of the stakeholders, which can be challenging for the implementation of information systems, if they are not aligned. It can happen that users are interested in reduction in prices, while management wants to maximize the revenue.

Stakeholder theory is instrumental in the way that following 7 steps identified by Benjamin

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and Levinson (1993) are suitable to put a neat analysis framework. The requirement and stakeholder interactions in information system created the 7 step framework. Moreover, it is expected to help to examine the changes brought by new information systems. The organizations can understand if the information system is feasible and bring benefits to the various stakeholders involved. The 7-step approach of Benjamin and Levinson (1993) is listed below:

1. Step 1 - Identify a vision or objective.
2. Step 2 - Describe a number of future states in terms of goals understandable by the stakeholder group.
3. Step 3 - Break the goals down into the process, technology, and organization and cultural steps necessary to balance organizational equilibrium.
4. Step 4 - Identify stakeholder groups whose commitment is necessary for achievement of each goal.
5. Step 5 - For each type of stakeholder, describe the needed changes, perceived benefits, and expected kind of resistance.
6. Step 6 - Analyze the effort required to gain the necessary commitment from the stakeholder group.
7. Step 7 - Develop actions plans for those stakeholder groups that are not committed enough.

Pouloudi (1999) pointed out the uses of the stakeholder concept in information systems research. Regarding its normative use, the theory have been used for understanding the ethical issues, and it is ethical to examine stakeholders. Rackley (1996) studied the obligations of professionals working in information systems in order to maximize productivity. Following that, Pouloudi (1997) informed on the socio-technical relationships between the stakeholders in the context of medical information privacy. Whereas, on the instrumental side, stakeholder theory aids in business planning and strategy formulation. Previous work done includes Earl (1989) identifying the importance of information systems stakeholders for organizations. Ruohonen (1991) examined the dynamics of stakeholder groups that are key for the success of information systems. Additionally, Lacity and Hirschheim (1999) investigated the misalignment of the interests of the stakeholders.

The definition of a stakeholder for information systems intrinsically changes into 'all those who have a practical concern for the effective application of new technologies, and who are in a position to take or to influence decisions about why and how they are used' as defined by Boddy and Buschanan (1986) [Mishra(2013)]. Considering this definition, there are vast area of usage for stakeholder theory in information systems. These include e-government,

2.5. Stakeholder Theory and Actor-Network Theory

health information technologies, business ethics, business intelligence systems, tele-center projects, strategies for stakeholders management. Additionally stakeholder theory also finds its use in investigating e-commerce, effect of information and communication technologies on organizations, corporate governance.

Most of the applications of stakeholder theory in information systems are related to identifying the relevant stakeholders, their objectives, and to examine their perspectives on particular new technology. For this, various researchers develop tools and frameworks to recognise and capture the stakeholders. Yet, stakeholder analysis could remain subjective depending on who is carrying out the research and how it is executed. This follows the discussion on how to decide what is critical and who are the primary or secondary stakeholders. Another factor affecting the ambiguity is that stakeholders are dynamically changing elements in the network. For strategic management, analyzing competing stakeholders is found to be crucial, and categorization of them helps to generate suitable strategies.

Stakeholder theory has been used extensively to examine the electronic services in information systems. Rowley (2010) identified the stakeholders' roles and their benefits in adopting new e-government technologies. In e-government systems, Flaks and Rose (2005) pointed out the alignment between stakeholder theory and objectives of the government on providing policy and services for citizens and organizations [Mishra(2013)]. On the contrary, Islam and Gronlund (2007) stated that stakeholder theory is not sufficient for examining the evolution of stakeholder preferences, changing due to the strategical moves of stakeholders. This changing behavior is also approved by Post et al. (2002) stating that the success of stakeholder management lies in learning the stakeholders' characteristics and objectives.

The success of the firm, that invests on a new technology, lies in finding a deal so that the main stakeholders, such as suppliers, customers, managers, and shareholders benefit from the investment. Satisfaction of the stakeholders is key to reach the targets of the projects, and to be competitive and successful [Mishra(2013)]. Additionally, the cooperation between stakeholders aids to define common goals and build trust in the stakeholder network. The stakeholder concept encompasses areas covering a wide spectrum, including the user-centric approaches to inter or intra-organization information system analysis. As the information systems are getting complex, the requirements to understand the stakeholders and their dynamic roles and relationships change. Hence, stakeholder theory also evolves to accommodate these changes by looking into the complex dynamics of stakeholders and the translation of their roles.

2.5 Stakeholder Theory and Actor-Network Theory

Stakeholder theory has been widely used to analyze how stakeholders influence the technology adoption process. Rather the tendency is to analyze the dyadic relationships and influences in the adoption [Rowley(1997)]. Rowley approached the stakeholder theory by using social network analysis, constructing multiple, interdependent stakeholder demands. This model

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predicts how organizations respond to the simultaneous influence of multiple stakeholders.

Identification of stakeholders and their relationships are keys to understand how firms or organizations operate. Yet, in order to understand the processes of change and adoption, there is a need to consider multiple and interdependent interactions between actors. This is crucial to understand that not only individual behavior of stakeholders, but also their network of actions determine the outcome of embracing change or not. As Rowley (1997) pointed, this can be approached from a social network analysis and also an actor-network theory approach, where we can also treat non-human as stakeholders.

The network approach focuses on the entire collection of stakeholders looking into the system as a whole. Rowley (1997) observed that the density of the stakeholder network surrounding an organization and the organization's centrality in the network influence its degree of resistance to stakeholder demands. Additionally, Rowley (1997) identified that there are four types of firm behavior: commander, compromiser, subordinate, and solitarian. He added that social network theory enhances stakeholder theory both as a theoretical approach and a methodological tool.

Both stakeholder theory and network theories are useful for the support role for other theories. Yet, it is crucial to state that these theories both stem from system theory [Rowley(1997)]. This makes them also suitable to explain the dynamic process of change, such as technology adoption. The moment when Freeman (1984) integrated stakeholder concepts into a structured model is key for the development of stakeholder theory. Following Freeman, Carroll (1989) investigated organizational aspects of business and society using stakeholder approach. Next, Brenner and Cochran (1991) suggested to use stakeholder models as opposed to using corporate social performance framework. Hence, this paved the way for stakeholder theory to move from supporting other theories to a master theory.

Stakeholder theory mainly focuses on the identification of the stakeholders and classification of stakeholders. The definition of stakeholder by Freeman consists of any group or individual who can affect or is affected by the achievement of the firm's objectives. By time, the definition of a stakeholder takes different directions, scoping of the definition to those who have power. Regardless of the definition, each organizations should satisfy its stakeholders' expectations. Concretely, a stakeholder environment forms within the shape of a network determining the response to change in the firm and the technology adoption. In fact, all stakeholders are linked to each other with existing and dynamic relationships between each other. These relationships become a determining factor the success of the projects and the technology adoption in general.

Network analysis is gaining popularity in the social sciences, hence the definition of it is still vague. Galaskiewicz and Wasserman (1994) stated that instead of analyzing individual behaviors, network analysis focuses its attention on how these interactions constitute a framework or structure that can be studied and analyzed it its own right. The main aim social network analysis is to understand the interdependence of actors and how their positions in

2.5. Stakeholder Theory and Actor-Network Theory

Principles	Assumptions	Methodological Issues
Behavior is interpreted in terms of structural constraints on activity	Actors and their actions are viewed as independent units	What are the boundaries of the network under study?
Analysis focus on the relations between units	Relational ties (linkages) between actors are channels for transfer of flow of resources	What type(s) of relations will be measured? Do the relations measured represent the range of relevant components of the construct?
A central consideration is how the pattern of relationships among multiple (actors) jointly affects network members' behavior	Network models focusing on individuals view the network structure environment as providing opportunities for and constraints on individual actions	Will binary or value data be collected? Does the operationalization of the relationship construct(s) require assessing the strength of the ties?
Analytic methods deal directly with the patterned relational nature of social structure	Network models conceptualize structure as enduring patterns of relations among actors	Are the ties directional or non-directional? Are the exchange ties between network partners reciprocal?

Table 2.2 – Relationship between Network and its Actors [Rowley(1997)]

networks influence their opportunities, constraints, and behaviors [Rowley(1997)]. Examining the network, researchers point out the factors and influences to the technology adoption tendency of an organization. Thus, not only intra-relationship between the social actors, but also inter-relationships determine an organization's successful adoption of a technology.

Rowley (1997) developed his theory using a focal firm viewpoint, where he incorporated the broader societal sector concept of the environment. This environment builds up on a group of firms, analyzing two network concepts: density of the network and centrality of the local firm in the network. Moreover, Rowley (1997) provided a mechanism for describing the simultaneous influence of multiple stakeholders and for predicting firms' responses [Rowley(1997)]. Additionally, stakeholder theory is advanced by using social network constructs, such as density and centrality. The advancements of this work also contribute to organizational theory by converging institutional and resource dependence theories. The stakeholder perspective in this work analyses the structural conditions affecting a firm's tendency to react to external resistance and demands. By that, this paper directs researchers to follow a wide spectrum of factors influencing organizational interactions. Combining social network analysis with stakeholder theory is fruitful, yet there is still more room for further integration into a comprehensive framework.

An extensive research has been carried out to combine stakeholder theory with actor-network theory methodology [Luoma-aho and Paloviita(2010)]. Luoma-aho targeted to widen stakeholder theory to include non-human influences to analyze complex corporate environment. The interactions between human and non-human actors are expected to translate into new stakeholder actions and decisions. For this reason, the paper presents three theoretical con-

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ceptual approaches to implement an ANT approach to stakeholder theory. These case studies show that corporate crises result partly from previously unacknowledged non-human spheres of influence and cause corporations serious losses. Furthermore, corporations which adapts to the non-human changes in their environment and monitor them closely are more likely to improve their reputation and success. Hence, the paper broadens stakeholder theory to understand the current corporate environment by highlighting the process of translation among stakeholders and non-human entities.

Prior to this study, stakeholder researchers have mainly focused on analyzing the social networks between corporations and their stakeholders. This is driven by the need to understand the human factor and the relations between stakeholder. Yet, it is partly correct to just understand the human and neglecting the non-human actors. ANT encourages to map both human and non-human stakeholders that affect the success of corporations [Luoma-aho and Paloviita(2010)]. Specifically, ANT treats human and non-human agnostically, where the interrelations between all actors are considered. This is important for the identification of the issues and stakes rather than the individual behavior of stakeholders. This paper aimed to further develop stakeholder theory by allowing variations and mapping the stakeholder network highlighting the process of translation, where actors convince others to join their cause.

Including non-human actors in the improvement for stakeholder theory has numerous implications. First, it targets the limitations of stakeholder theory, where new non-human actors can change the analysis drastically. Second, it would make it realistic to understand the four moments of processes of the actor-network theory. Third, the examples in the paper show that specific technologies, as a non-human actor, are a decisive factor in the success of critical projects. The first case presented is the IT-system merger of the Danish Danske Bank and the Finnish Sampo Bank in early Spring 2008. Second example is the late building process of a paper-mill in Uruguay in 2006 by the Finnish Corporation Botnia. Final example is the greening of the mobile phone market by Nokia as a globally influencing actor. Luoma-aho points out that these examples are key to understand different stakes and strike the importance of potential disbenefits for corporations in the projects [Luoma-aho and Paloviita(2010)].

The missing part of stakeholder theory is that it emphasizes the role of the organization and oversimplifies the complex corporate environment. This is due to the fact that the premise of stakeholder theory is focusing on the financial benefits by categorizing the stakeholders and analyzing them individually. Yet, many actors affecting the corporate environment have not included in the studies, especially the technology as a non-human actor. Previously, numerous studies have examined the social connections and organizations from a macro perspective. Furthermore, the aim is not the formation of network but how the quality of the network is, particularly looking into network properties. The broad definition of Freeman's stakeholder term push researchers to debate on how to integrate non-human actors in accordance to human actors. A definition by Vidgen and McMaster (1996) introduce the non-human term by describing a stakeholder as a "human or non-human organization unit that can affect as

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well as be affected by a human or non-human organization unit's policy or policies". Rather than equalizing non-human with human actors, it becomes important to incorporate the non-human influences in the analysis. In order to remedy this missing part, Luoma-aho suggested using an ANT approach and the process of translation.

ANT poses a standpoint away from the centrality and primacy of human subject [Luoma-aho and Paloviita(2010)]. The factors for the change and success of an organization are various: environment, regulation, people and technology, etc. From the ANT perspective, agency is not only limited to human but also encompasses non-human actors. Even an actor can be regarded as anything that has the ability to change anything in a network of actions. Previously, a few number of studies tried to combine ANT and stakeholder theory. Clark and Salaman (1996) has already introduced the process of translation in a consultancy context. Following that, Cooper (1992) analyzed modes of organizing. Cooper and Law (1995) have treated organizations as entities and processes. While, Sommerville (1999) studied practice of public relations by using ANT as a socio-technical approach. Cooren and Fairhurst (2008) emphasized that technology, machines have also a meaning of communication combining the micro and macro environment. Numerous case studies using ANT have been carried such as understanding actors' roles in telecommunication markets, corporate strategy formulation, infrastructure building and technology adoption.

ANT starts with describing the process of translation, which is the driving point of the methodology. The process can be best described as the definition of the relations and seeking meaning of these relations between inter and intra actors in the network. Law points out that translation is kind of a heterogeneous engineering, that seeks, molds and enrolls allies for an argument or position. Concretely, translation is a dynamic process of actors trying to find interpretations and links to other human and non-human actors. If the interactions between actors become fruitful, then a successful translation happens where every actors' aligned interests match. Hence this forms an actor-network, where it is also simultaneously an actor whose activity is networking heterogeneous elements and a network that is able to redefine and transform what it is made of [Callon(1984)]. Yet, in reality the translation process becomes challenging in that actors may have misaligned interests. In such a case, actors mobilize to reinitialize and reinterpret the interests of other actors' to collectively align the interests. Mobilization of actors, in the form of creating synergies, negotiations with partners and discussion happens and some actors, if possible, have support to be central in the network, forming obligatory passage points (OPP).

In ANT terms, translation initiates with a problematization phase. This phase starts with the formulation of the problem to be addressed (technology adoption, organizational change, strategic decisions, etc.), and then definition of the actors is introduced. OPPs are created by the most influential and powerful actors in the network. Consequently, translation is followed by the intersement phase, where actors negotiate with others to involve them into a network structure. It is crucial for the future of the network to analyze this intersement phase, especially for technology adoption processes. Following that, actors decide if they are

interested in the problem and join the network, which is called the enrollment phase. In this phase, communication between actors is important for the further stability and reluctance to changes of the network in the future. Even though, according to ANT, these phases are separated, this is not always the case. In some instances, we can see these phases occurring simultaneously or forming in various configurations and sequences. In a few cases, we can also see rupture of the network due to misaligned configuration of actors' interests.

Translation occurs in various categories for different stakeholders. The interpretation of the translation also depends on the type of stakeholder, whatever or not it is a human or non-human actor. Luoma-aho (2010) interpreted that these categories should be separated to sociocultural, political, legal, technological, spatio-temporal, and ecological [Luoma-aho and Paloviita(2010)]. Consequently, the study aims to provide case analysis using ANT approach in combination with stakeholder theory. The biggest improvement is to include non-human actors as stakeholders. This makes the translation process realistic in that some powerful non-human actors creates the obligatory points of passage for some projects.

The first case is called the bank merger and technological entities. In 2008, there happened a merging of banking sector, including the merge of The Danish Danske Bank and Finnish Sampo Bank. Sampo Bank has been decided to merge their functions and services, and modify their IT systems to match Danske Bank. As evaluated with a current stakeholder theory approach, the network seemed feasible to make the merge. Between the human actors, translation started well with positive negotiations. Yet, the non-human actors are not considered until the merge of the IT systems began. During the problematization phase, IT-problem become the main issue to solve. Even though the actor of IT services is non-human, its implications of cards not functioning, payments, salaries went missing, account and online services problems have translations related to human actors, users. Technological difficulties and unpredictable technological scale played an important role as a non-human actor in the network for the merger. For the interessement phase, employees of Sampo Bank attended a training in relation with the migration of IT platform and data. Additionally, the Finnish employees of Danske Bank were briefed about the drastic modifications in procedures due to the merger. Yet, the customers have not been informed about the possible system problems. Later, the CEO of Sampo Bank apologized for the problems that the customers faced and offered monetary compensation.

Following the interessement phase, the Danske Bank tried to enroll their employees' and customers' satisfaction by surveying and monitoring. This took the analysis to the enrollment phase, even though the results proved that Sampo Bank went to the bottom of the list of Finnish banking sector. Although the employees received protection by corporate communication and information, customers shattered the network due to misinformation of the merger. For this case, the network stopped in the enrollment phase and could not further continue to grow to succeed. The translation of the unsatisfied customers into an unstable network created problems in the technological sphere.

2.5. Stakeholder Theory and Actor-Network Theory

Another case is the building of a paper-mill in Fray Bentos, Uruguay by the Finnish Botnia corporation in 2006. This is a milestone for Uruguay, since it is the biggest industrial investment in the history of Uruguay. The problematization phase for the paper-mill started with real problems with the local people became concerned about the environmental, touristic, agricultural impacts. Here the network consists of human actors, who mainly oppose the process. Furthermore, the breakdowns in the infrastructure, and hostile political climate slowed down the construction. The spatial stakeholders consist of the Uruguayan and the Argentinian natural environment, infrastructure and weather conditions.

The interessement stage started with Botnia implementing everything legally right. Both an environmental impact assessment, socio-economic study has been done with five public forums. The blocking factors of local resistance and infrastructure shocked Botnia, coupled with non-human actors of the river and the national border. Botnia tried to increase interessement by providing monitoring data from the Fray Bentos mill's effluent and air emissions, while also collecting data from the measurement points in the river and air. Consequently, Botnia opened up an educational travelling exhibition on the pulp production process. These actions are all due to Botnia's ambitions to solve the conflict between Uruguay and Argentina.

In contrast to local and global opposition, Botnia successfully enrolled the Uruguayan Government on receiving the authorization to open up the mill. The pulp mill has become a success in operations for the first year. Yet, the local people from the Argentinian side of the river could not enroll as contended neighbors of a pulp mill. On the Botnia's side, the supporting actors are the international licensors, legislators, people on Uruguayan side of the river.

The final case presented in the paper is the greening of mobile phone market by Nokia. The company was the world leader in the mobile phone market, creating phones with consisting of 500-1000 components [Luoma-aho and Paloviita(2010)]. This creates an environmental impact in the product development and life cycles. Nokia, as the main actor, grabbed the weak signals of the market moving into a greening fashion, and the related upcoming regulations. Acting proactively, Nokia is engaged directly in creating new regulation and gaining power in political sphere. The problematization phase starts with the network collecting together other mobile operators, Motorola and Panasonic, component manufacturers, governmental organizations European Commission (EC) and research institutes. EC delegated Nokia as a driver for the project by running a pilot project to demonstrate the applicability of integrated product policy (IPP).

The interessement phase initiates with stakeholders negotiating options to improve environmental impact of mobile phones. The lead, Nokia, drafted a report on identifying environmental options during the life cycle of mobile phones. The competing actors are eliminated by Nokia's proactive moves, since also EC collaborated with Nokia on the future policy. Consequently, the EC also invited stakeholders in the network to give feedback on the social and economic effects of environmental options. Stakeholders enrolled to enhance the environmental impact of the mobile phones. The enrollment happened in various areas, such as

information and communication area, reduction of energy consumption, materials of concern, take-back of phones and environmental assessment methods. Actors formed specific task forces dealing with separate issues and monitored closely by the EC. Nokia gathered all the necessary information and progressed far greater than any other competitor.

This study combines stakeholder theory with actor-network methodology is remarkable in the sense that both are benefiting from each other. Luoma-aho (2010) introduced non-human actors into the stakeholder theory, where the research incorporated various stages of influence (socio-cultural, political, legal, technological, spatio-temporal, ecological) into the analysis. The non-human actors, such as technologies, infrastructure, political agendas are affecting the network critically. The three case studies highlight the importance of strategic importance in various aspects. The analysis shows that stakeholders who are proactive, getting into dialogue and had information on the context of the projects drive the networks.

2.6 Gaps in Literature

Both stakeholder theory and actor-network theory focus on understanding the actors, their roles, and relationships. As also suggested by Luoma-aho (2010), there is a need to further clarify the inclusion of the non-human factors in stakeholder theory [Luoma-aho and Paloviita(2010)]. The initial analysis of the study proves that non-human actors or factors directly affect the outcome of corporate communications. Concretely, this is also the case with the processes that involve multiple stakeholders. Hence, their objectives, decisions, and relationships are guided by internal and external factors. These factors can be political, social, economic, legal, or technical. Thus, there is a need to widen stakeholder theory to include non-human actors or factors. Specifically, the non-human actors or factors translates into objectives of each stakeholder in the technology adoption process. In this sense, this thesis targets to bring a socio-technical approach to the technology adoption by filling the gap of what was previously done in the field.

The process of technology adoption is evolving as the technologies are becoming more advanced and complex. Currently, it is not only the user that decides whether or not to adopt a new technology. New technologies, such as cloud-based technologies, virtual services, and artificial intelligence radically change the technological, and social landscape altogether. This also creates new approaches to examine the technology adoption process from multiple dimensions. In that sense, it is crucial to investigate the alignment of stakeholders towards adopting a new technology. Not all the time, the objectives or the interests of the actors are aligned. Yet, understanding why and how these misalignments are born and exist is important to understand the technology adoption process and make it more efficient for all the stakeholders.

Previous studies of technology adoption evaluated how the stakeholders come together and form a social network. Mainly, the relationships between the technology providers, service providers, and the users are investigated. Additionally, in corporate communications Luoma-

aho (2010) mentioned the lack of broader understanding of 'field-forces' of stakeholders [Luoma-aho and Paloviita(2010)]. Due to the absence of these understanding, some factors remain underanalysed and corporations tend to fail. For this reason, this thesis tends to combine stakeholder theory with the tools from ANT in order to first identify the stakeholders, and then investigate the factors affecting the technology adoption process. ANT helps to explain the objectives of the stakeholders, and show the translation of this objectives in the form of a network. Thus, it adds a crucial dimension to the stakeholder theory for examining technology adoption process. Specifically, the conceptual framework for the technology adoption has been designed to understand the stages of technology adoption and the factors affecting the adoption. Furthermore, ANT provides the foundation for understanding how each stakeholder, human or non-human, translates the interests of each other. This is also supported by examining the interrelations between the human and non-human factors. In this way, stakeholder theory can benefit from the concepts of ANT.

The technology adoption framework used in this thesis adopts the ANT concepts of translation and non-human factors. This provides a predictive tool for the stakeholder theory, in which not only the identification of the stakeholders and their objectives are important, but also the stages of translation on their interests, non-human factors affecting the technology adoption process are important. By introducing these, this thesis introduces a new approach for investigating the technology adoption process from a socio-technical perspective. The framework considers the identification of the stakeholders, their roles, relationships between them, while also investigating technical, political, economic, legal factors affecting the adoption process. It targets the gap in stakeholder theory, where stakeholders are broadly defined, and non-human influences are not considered properly. Freeman's definition of stakeholders as any individual or group who has a stake in a process still holds its value for identifying the stakeholders, but also the factors influencing them. Especially, on some occasions these factors turn out to be as critical as any stakeholder in the technology adoption process. Ignoring these factors might lead to failures in understanding and adopting new technologies.

Extended qualitative studies are also missing from the European ATM literature. There are cases of comparison of scenarios, specifically in the 3 research projects mentioned previously, but they still stay not in depth analysis of technologies under investigation. For this reason, this thesis targets to fill this gap by providing an extensive analysis of two technology adoption cases, virtual centre, and flight-centric operations. These cases are especially hand picked by the researcher as they are both new and disruptive technologies. There are a lot of changes in stakeholders' themselves, their roles and relationships brought by the two technologies due to their disruptive nature. Yet, this creates a unique chance to observe all these changes and how stakeholders realign themselves around these technologies. The aim of the framework is to capture how these changes occur, and stakeholder realign themselves while they try to adopt these technologies. One of the main problems in European ATM is that the adoption rate of technology is slow. Notably, it is a chance for this thesis to show what are factors affecting these slow rate of adoption, exemplifying with the cases of virtual centre, and flight-centric operations.

2.7 Graphical Syntax for Network of Actors

This section aims to describe the previous literature on the graphical description of ANT networks. Conceptually, ANT methodology does not provide strict steps to follow in order to describe the actors. Therefore, different representations of the network follow in various research. The main focus of this section would be information systems research, and the structural description of the actors involved in various processes related to information systems. The ultimate aim is to first understand the limitations of the previous literature, and then in the research design section present the constructed framework for the description of the network.

The idea of treating the human and non-human in a network translates into finding representative syntax for describing ANT. In order to assess whether or not a graphical syntax improves the use of ANT as a methodology, Silvis et. al (2014) designed an extensive toolbox [Silvis and M. Alexander(2014)]. The graphical syntax is found to assist researchers conceptualize the ANT research, highlight black-boxing, and follow the actor network method. This study is one of the best in covering the aspects of ANT tools inside a single representative framework. The simple representation allows the visualization of the key concepts of ANT, while also assisting researchers to follow guided research for ANT. Moreover, it tackles the problem of superficial understanding of the ANT concepts by emphasizing the actor-network boundaries [Silvis and M. Alexander(2014)]. Thus, the researcher is able to focus on the key constructs of the ANT methodology.

In IS research, ANT has been successfully used even though its controversial denial of differentiation of human and non-human actors. Thus, the mere definition of technology for ANT is a combination of both social and technical. For this reason, the granularity of the definition of the actors is important while defining the actors and relationships between them. The radical approach of ANT on treating non-humans as the human actors, makes it explicitly dependent on the researchers choice what is to include or exclude. The suggested way to approach this problem is to follow the actors, and take the actors that are most influential in the formation of the network. Additionally, in IS research it is important to see the evolution of technology besides its social underpinnings. The formation of a network is a gradually happening process, where human and non-human actors interact towards a new technology. These interactions can be modelled and illustrated with the four stages of ANT translation, such as problematisation, interessement, enrolment, and mobilisation.

The post-ANT approach also changed the landscape for IS research and its graphical representation. This is mostly due to the increase in dynamics and complexity of the network representation. Concretely, ad hoc approaches are preferred rather than alignment, stabilization, and closure of the actors in the network. Yet, the graphical framework from Silvis et. al (2014) aims to simplify these complexities by standardizing the elements and the connections in the network. An additional ANT related issue is the priority given to the actors considered in the network. On some occasions, it becomes the case that the non-human actors be the

focal actor in the network due to its biased definition by the researcher. Furthermore, the degree of freedom given to the researcher when choosing the actors is wide, and this creates ambiguity on identifying the stakeholders. The researcher, end user of the technology, or some powerful stakeholders might also affect the structure of the network. This is mainly called as the managerialist bias [Silvis and M. Alexander(2014)].

Visualizing ANT is to understand the translation concept behind first, then to build upon the steps of an ANT approach. Socio-technical systems are becoming more and more complex to understand, as in the case of European ATM. It is crucial to introduce simple graphical representations to make the analysis more understandable. The actors, their roles and relationships are the key for understanding a socio-technical change from an ANT perspective. The graphical network forms through the translations and relations between the actors rather than their structural network of connections. These relationships lie in the heart of ANT, and showing them in a neat graphical illustration is the best way for a research. Therefore, a specific syntax is needed to illustrate these concepts as also suggested by Silvis et. al (2014). Since ANT networks are dynamic, Silvis et. al (2014) proposes two distinct diagrams. First diagram is the ANT model, in which the actors, their relationships, and translations are depicted looking into a particular case in a particular time. The second diagram is for capturing the ANT models in different time frames.

The core syntax offered by Silvis et. al (2014) investigates the translation concept of ANT. Specifically, translation is the key idea of ANT to examine the actors and their interests. Thus, making translations visible is the ultimate aim on the ANT illustrations. This provides the viewer to examine the key actors in the network and relationships between them. Ultimately, the alignment of the actors are critical for the succesful adoption of new technologies. For this, Silvis et. al (2014) defines three types of actors [Silvis and M. Alexander(2014)]:

- **Source Actor:** The actor that is being translated
- **Target Actor:** The actor that is being translated for
- **Translating Actor:** The actor that translates the source actor for the target actor

An example to this classification stated by Silvis et. al (2014) is that Microsoft, as being a source actor, employs software engineers as target actors. In this relationship the source actor translates its objective towards its employers by using translating actors, such as competitive salary packages, hardware and software. All these process follow the four stage definition of translation concept of ANT. First, the translator actor converts the objective of the source actor to a form that the source actor understands. Then, the connection between the source and the target actor occurs if the alignment succesfully happens [Silvis and M. Alexander(2014)]. The following table provides the definition for the corresponding graphic symbol for each ANT concept:

ANT Concepts and Graphic Symbols

Concept		Definition	Graphic symbol
Source	Core concept	Any entity that is included in an ANT analysis	
Target	Core concept	Any entity that is included in an ANT analysis	
Translator	Core concept	Any entity that is included in an ANT analysis that translates between a Source and a Target	
Relationships	Core concept	Indicates the relationship between a Source, Translator and Target	
Black box	Complex ANT concept	A black box is a well-established network of allied actors that is so strong that the assemblage is counted as only one actor	
Action at a distance	Complex ANT concept	Action at a distance identifies an actor that can act upon another that is far away from itself (physically or conceptually)	
Main research foci	Pragmatic extension	Actors that directly have a bearing on the primary purpose of the research	
Exemplary instances	Pragmatic extension	Actors that do not explicitly form part of the empirical dataset, but which she believes might nevertheless form part of the actor-network	

Figure 2.11 – ANT concepts and graphic symbols [Silvis and M. Alexander(2014)]

As also illustrated in the Figure 2.11, there are 4 core concepts representing the three different types of actors (source, target, translating) and the connections between them. Beyond that, there is also the representation of a black-box, which is the rigid form of a network of alliances. Hence, it is regarded as a single actor and shown as a box in the representation. Additionally, the difference between local and global actors is depicted within the actors at a distance representation. There might be a number of actors who can act on the overall network without being directly connected or translating with specific actors. Actors at a distance targets to represent these actors in the network. Furthermore, in order to differentiate the actors that are in the scope of the research, two concentric circles are used for the representation. The actors that are not direct part of the research are shown as a cloud representation. The sample illustration for electronic health record applications are provided below:

Actor-network theory conceptualizes any socio-technical change in four moments or stages: problematisation, intersement, enrollment, and inscription. The literature, before Bengtsson et al. (2013) does not define clearly the network or visualize it. Several examples of illustration has been used by Latour and Callon on various topics previously. Yet, a concrete framework encompassing ANT elements has not been offered. Until now, simple frameworks that visualize relations between the actors, and their translations are offered. Additionally, models and supportive visualizations are used whenever appropriate in the research narrative. By a comprehensive literature review, Bengtsson et al. (2013) pointed out a gap that ANT concepts are not very well mapped into the visualization. Concretely, visualizations are mainly used as a picture of relationships between the actors, and do not focus on the transformation process by time.

Graphical representations of ANT analysis help researcher to showcase their work and point

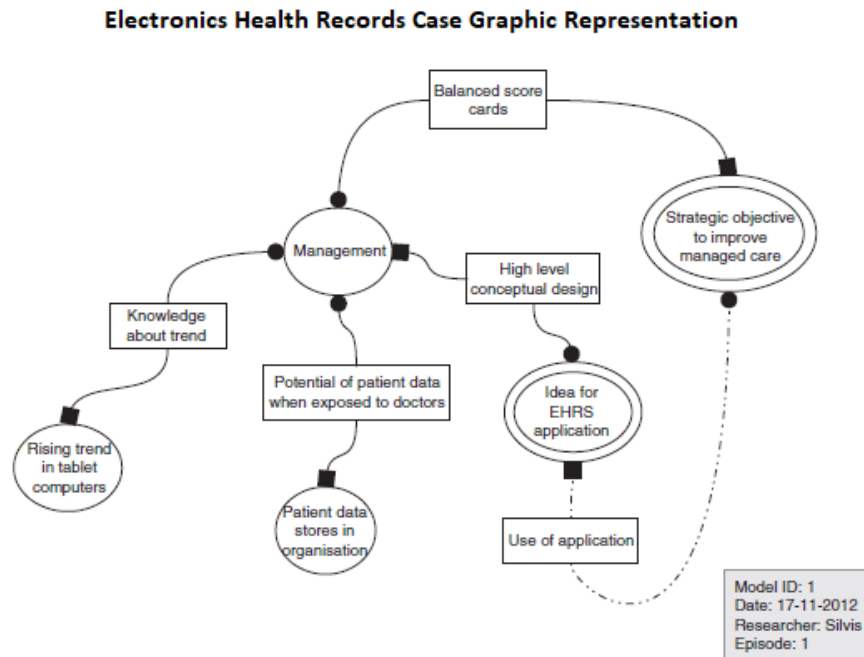


Figure 2.12 – Electronic Health Records case ANT representation [Silvis and M. Alexander(2014)]

out the network of relationships in the analysis. This gap has also been identified by Bengtsson et al. (2013), where they pointed out a systematic way to visualize ANT approach [Bengtsson and Lundstrom(2013)]. For this reason, Bengtsson et al. (2013) introduced the notion of ANT-maps as a visualization tool, directly mapping to the key concepts of ANT. The approach is to study the case of particular individuals related to the information systems initiative of a Swedish media house. Specifically, they analyzed and conceptualized the strategy for social media and open innovation initiatives. Various forms of data, such as interviews, meetings, observation and documentary analysis are collected. Similar to Silvis et. al (2014), the study focused on the key concepts of ANT and the representation of them in graphical form. Rather than using circles, Bengtsson et al. (2013) preferred to use differentiated dots to represent the same concepts. The connection between the dots represent the translation process.

Faraj et. al (2004) carried out an extensive study of the development of web browser technology. The study examines the complex process of the evolution of the web browser technology based on the archival data between 1993 and 1998 using ANT approach and graphical representation. In addition to the translation process of ANT, Faraj et. al (2004) introduced the processes of inscription, translation, and framing to examine the actors and the relations between them. This is previously illustrated in the ANT research section of the literature review. In this section, we can examine how Faraj et. al (2004) illustrated the case of web browser technology development. The following figure specifically provides all the graphical representation of the case under investigation.

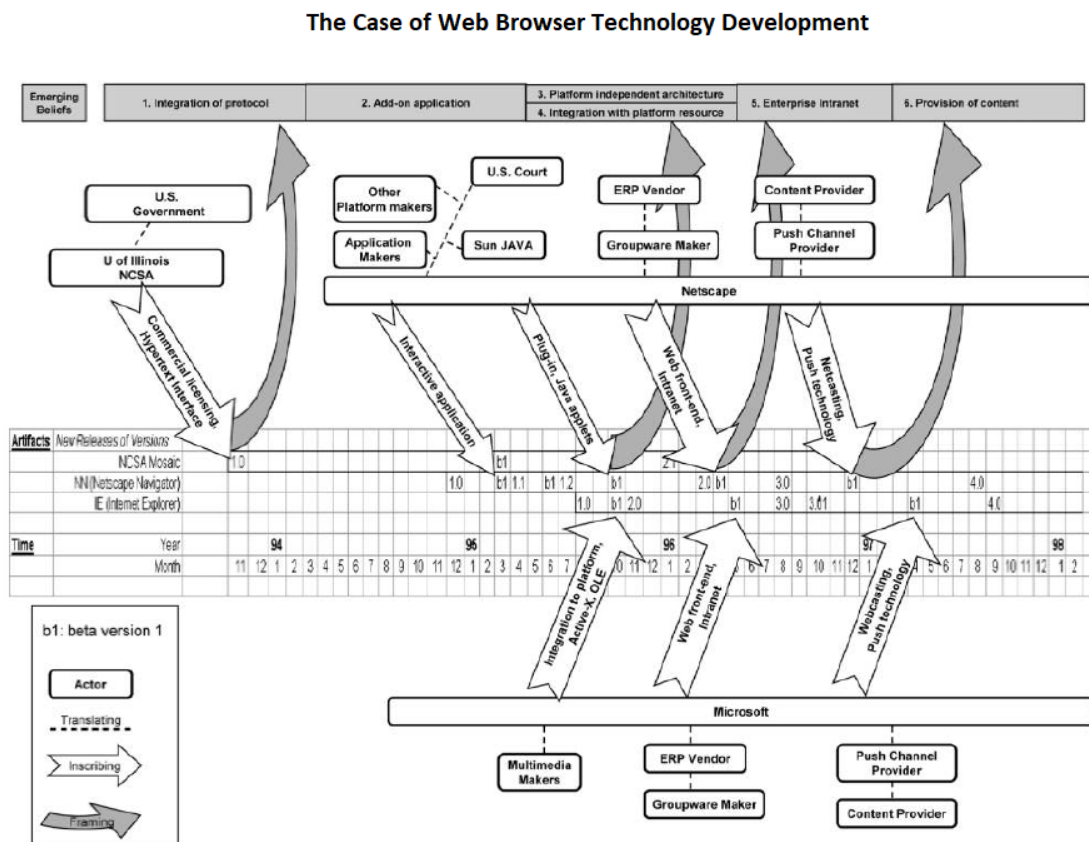


Figure 2.13 – The case of web browser technology development [Faraj et al.(2004)Faraj, Kwon, and Watts]

Different from the previous graphical representations of ANT, Faraj et al. (2004) uses three distinct connections. First is the regular connection between the actors to represent the translations between them. The translations can be seen as a dashed line between the actors, who are represented as square boxes. The second connection, namely the inscriptions, of actors towards certain artifacts are represented by the white arrows. These inscriptions can be understood as the transformation of the belief of human actors towards certain artifacts. The final connections are the grey arrows, which represent the framing of the actor’s translation. By this, an actor’s belief crystallizes and takes shape. Mainly, if the inscriptions are successful and the actors are aligned, then the technology development becomes successful. This is created by the crystallization of some of the technological artifacts regarded as the inscription. The graphical description of Faraj et. al (2004) covers most of the ANT concepts in a highly detailed way.

A similar representation of an ANT framework has been used by Awa et. al (2016) to understand ICT adoption in small service businesses [Awa et al.(2016)Awa, Ukoha, and Eke]. The study used qualitative means of data collection, such as unstructured and structured interviews.

2.7. Graphical Syntax for Network of Actors

The interplay between the human and non-human actors are depicted using the translation, inscription, framing, and stabilization stages as also the case with the depiction of Silvis et. al (2004). Yet, in this study the graphical representation stay basic, only listing the actors and the stages of analysis. The key human, and non-human actors are illustrated using the following figure.

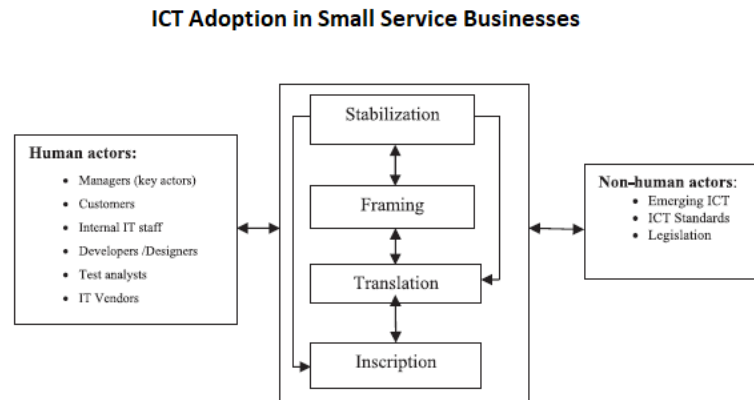


Figure 2.14 – The human and non-human actors in ICT adoption in small service businesses [Faraj et al.(2004)Faraj, Kwon, and Watts]

Following the previous framework, Eze et. al (2017) proposed a similar ANT inspired framework to examine the roles of actors in the technology adoption process of small and medium services enterprises in the UK. The study also uses the four ANT concepts of inscription, translation, framing, and stabilization. The structure of the study is nearly the same as Awa et. al (2004) and the graphical illustration of the ANT framework is depicted in the following Figure 2.15.

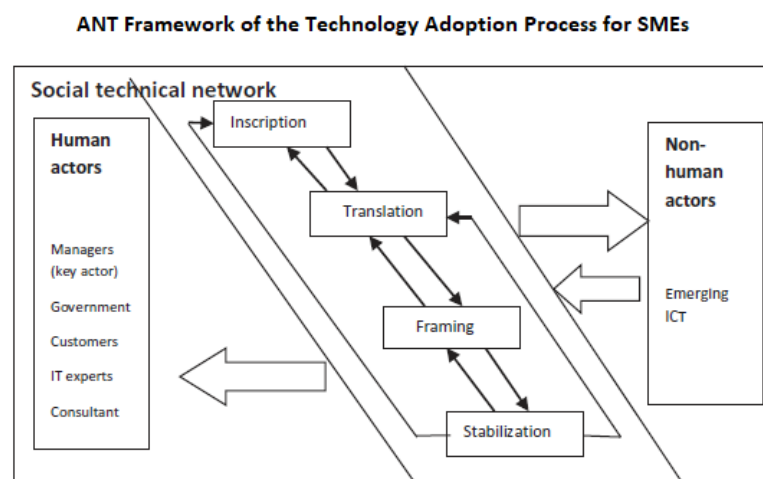


Figure 2.15 – The ANT framework of the technology adoption process of small and medium services enterprises in the [Eze et al.(2018)Eze, Chinedu-Eze, and Bello]

Furthermore, Eze et. al (2017) provided an illustration of the roles of the actors in the technol-

Chapter 2. Literature Review

ogy adoption process. These include classification of the actors according to their function in the processes of inscription, translation, stabilization, and framing. Concretely, the illustration presents the roles of the actors as themes. In inscription, small medium enterprise managers are regarded with the themes of innovativeness, empowerment, and monitoring. Whereas the government encompass the themes of funding, and research. In the translation phases, SME managers translate into their functions of empowering, monitoring, and controlling. Governments are treated as having collaborative support and funding in the translation phase.

Oh et. al (2005) carried out an analysis of the alliances between mobile carriers, banks, and other related actors in Korea. Specifically, the connection between the banking industry and the mobile carrier technologies is investigated. The study concludes that the technology plays an important part in the shape of the ANT network, and the inscription of the interests of the actors are dependent on the translation of the customers' interests [Oh and Lee(2005)]. As can be seen in Figure 2.15, the ANT graphical representation is similar to Silvis et. al (2014), where actors are represented as circles, and the translation connections are arrows from source to target actors. Specifically, the focal actor is differentiated by a box representation in the network. The banks, mobile carriers and telecom companies are the focal actors for this research. The 3 phases of the technology adoption process in depicted with the differing actors acting on the network. In the case of framing, similar to previous phases SMEs have the monitoring and controlling functions, while the role of government changes to legislation. Finally, in the stabilization phase SME managers have all the previous roles, while training is added to the role of the government. This is illustrated in the following Figure 2.16.

Computerized support tools for the representation of the ANT network has been introduced by Bots et. al (1999). This is to support the decision makers, allowing them to understand the factors affecting the whole network. Bots et. al (1999) mainly focused on the policy analysis, stakeholders, decision makers and their dynamic relationships. The strategic thinking of the actors are the key elements for the building of the computer support tool for ANT. Concretely, the decision of the actors drive the network to follow certain policies. Hence, the main aim of the model is to reflect on the capability of understanding of the decision makers' actions. Bots et. al (1999) made a clear distinction between the actors, which are human and the factors affecting them. The computerized tool allows the user to input them distinctly as actors, and factors. Similar to previous representations the actors are represented by circles and the relationships are illustrated as arrows between the actors. The width of the arrow defines the power of the relationship between the actors. In the dynamic actor analysis the plus or minus near the arrows indicate either a positive or negative relationship between the actors. An example of the computer support tool of Bots et. al (1999) has been provided as in Figure 2.17.

2.7. Graphical Syntax for Network of Actors

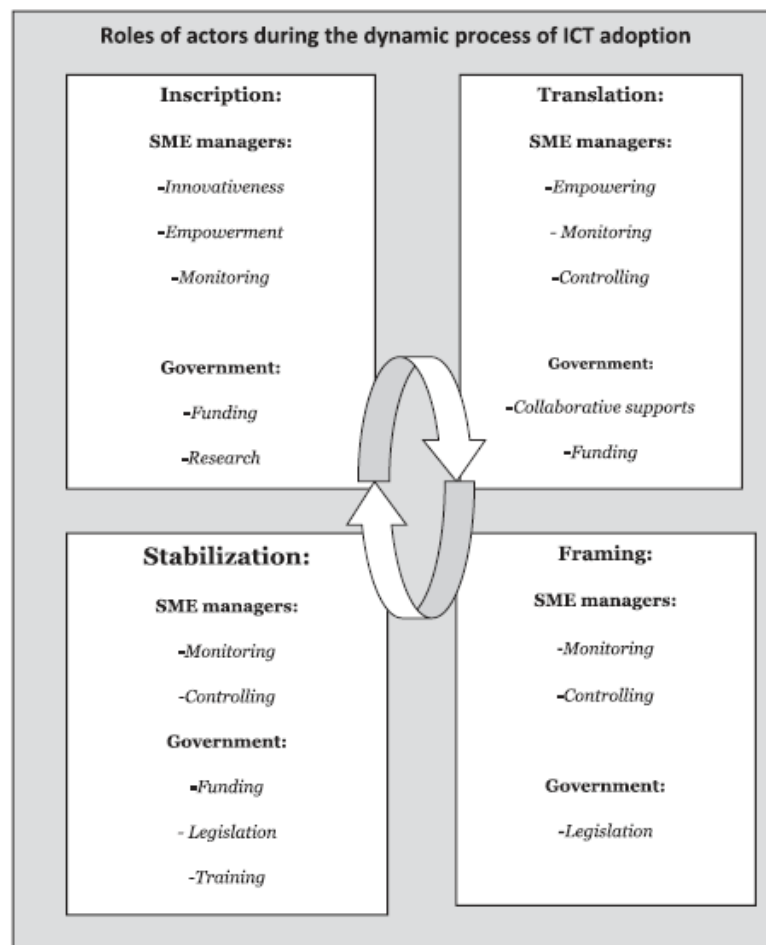


Figure 2.16 – Roles of actors in ANT technology adoption framework [Eze et al.(2018)Eze, Chinedu-Eze, and Bello]

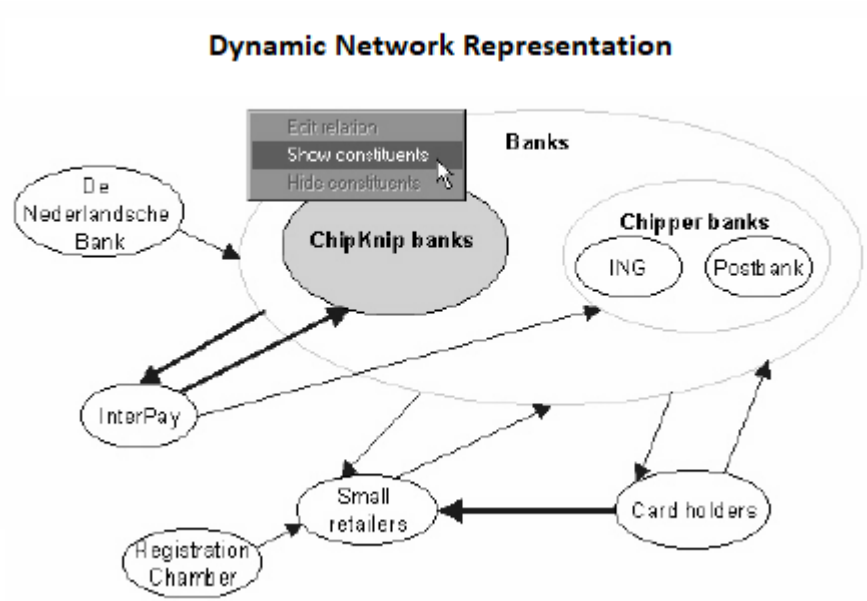


Figure 2.17 – Dynamic actor representation with computer support tool [Bots et al.(1999)Bots, Van Twist, and Van Duin]

3 Research Design

This chapter includes the description of research design by stating the research paradigm, research methods, and strategy. This research builds on two specific case studies, specifically looking into the technology adoption process of virtual centre and flight-centric operations. A conceptual framework for examining technology adoption for European ATM is defined using a combination of stakeholder theory and inspirations from actor-network theory. Specifically, the evolution of the conceptual framework during the research process is explained, focusing on its use in the case studies. First, the research paradigm is presented outlining the perspective that this thesis approaches to the research problem. Second, the chapter presents the case study structure, including the interview and case study protocols that are used throughout the research. Finally, this chapter provides the research strategy in each phase of the research process.

3.1 Research Paradigm

This research uses a combination of stakeholder theory and concepts borrowed from actor-network theory as a tool to tackle the research problem. Thus, the ontological standpoint is relativist, where it is assumed that reality is socially constructed. Multiple interpretations of reality is possible and treated subjectively. The researcher's view for what constitutes knowledge, known as epistemology, is interpretivism. By this, we mean that social phenomena includes subjective meanings. Thus, the problem should be analyzed qualitatively and specifically for the cases at hand. The two case studies, under investigation, are selected using participant observation and documentary analysis. Then, initially a conceptual framework is designed to understand technology adoption in the context of European ATM. By time, the conceptual framework has evolved with minor updates, affected by both the collection of data and researcher's opinions.

This thesis treats stakeholder theory as the backbone of its research design. The concepts and elements from ANT supports the stakeholder theory in the conceptualization of the technology adoption process. These ANT concepts are mainly the translation of actors' interests,

Chapter 3. Research Design

factors, and obligatory passage points affecting the adoption process. The definition of the stakeholders is based on the Freeman's initial definition, while also treating non-human actors of ANT as factors affecting the technology adoption process. For this reason, this thesis relies on the theoretical assumptions of stakeholder theory in defining and clearly separating the actors and the non-human actors of ANT regarded as factors. Yet, the interpretive nature of the research leaves an open door to understanding the factors, and how these factors translate some of the actors' objectives, even in various cases affecting actors themselves. The Figure 3.1 illustrates the parts of the theories that are adopted from both stakeholder theory and actor-network theory to form the research strategy.

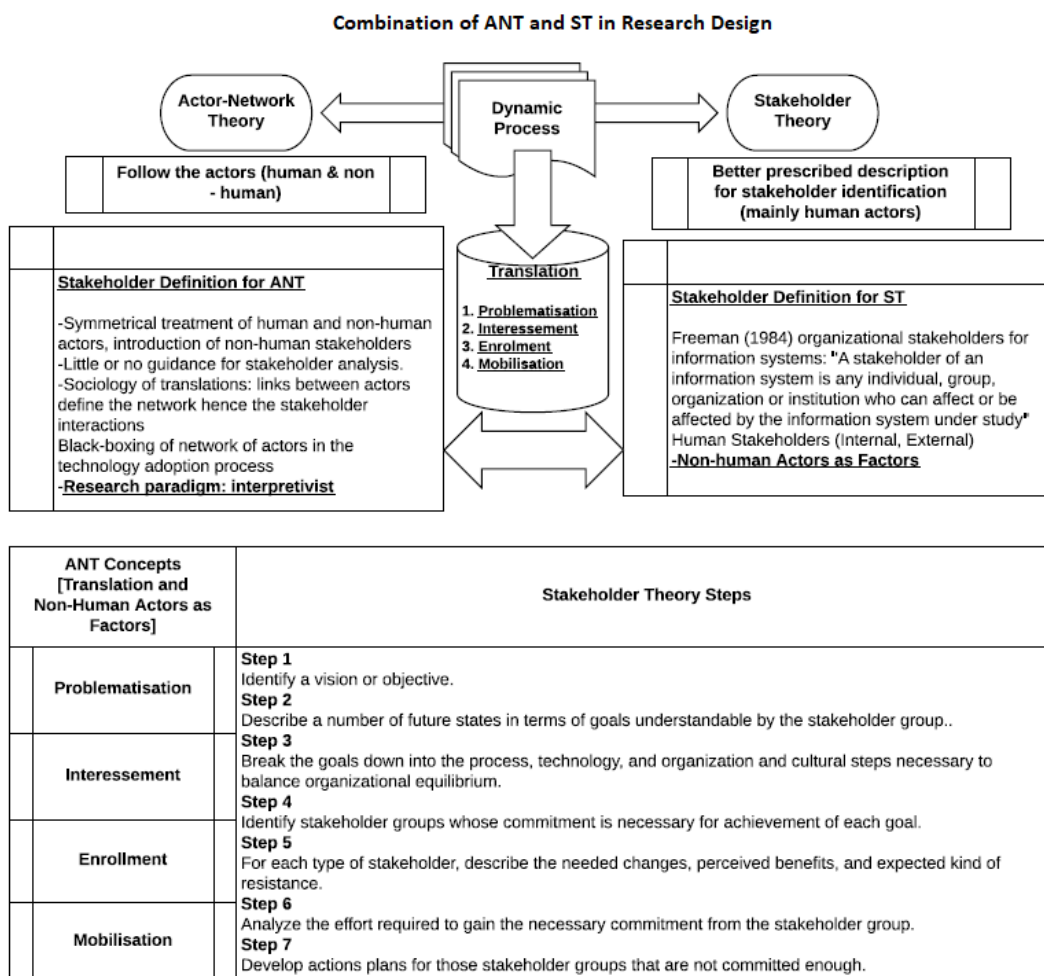


Figure 3.1 – Combination of Actor Network Theory and Stakeholder Theory - Research Paradigm

With regards to their research paradigm, both stakeholder theory and actor-network theory incorporate various approaches. Donaldson and Preston (1995) identifies that stakeholder theory encompasses very different research strategies, methodologies, and appraisal criteria [Donaldson and Preston(1995)]. The most prominent approach is the descriptive, instrumen-

tal and normative stance as defined by Donaldson and Preston (1995). Stakeholder theory is regarded as descriptive, since the organization is seen as a heterogeneous collection of actors' interest that have an intrinsic value. It is also instrumental in understanding the roles and objectives built inside of a framework consisting of the stakeholders and their relationships [Mishra(2013)]. Moreover, the normative value of stakeholder theory holds onto the definition of stakeholders as having intrinsic values considering their objectives [Rose et al.(2018)Rose, Flak, and Sæbø]. Donaldson and Preston (1995) explains that these three distinct approaches are mutually supportive and open to broad level of research paradigms. Additionally, the interpretive argument of stakeholder theory has been extensively used in dynamic and iterative identification of stakeholders in their own context [Pouloudi et al.(2004)Pouloudi, Gandechea, Atkinson, and Papazafeiropoulou]. Pouloudi suggests that ANT has useful tools to interpret the actors and artifacts within stakeholder analysis especially in IS research domain. The similarities between ANT and stakeholder analysis in interpretive approach has been pointed out by Pouloudi (2006) as follows:

- The first property of stakeholder analysis is setting the context and time frame, which is also clearly defined for both human and non-human actors defined in ANT.
- The second property is the identification of the stakeholders and relationships between them. ANT also emphasizes the translations between the actors, where their objectives are transformed during the process of linking between them. ANT additionally focuses on the properties of the network and how this network functions as a whole.
- The third property is related to the technical artefacts and the importance of them in the overall functioning in the network. There is a fundamental difference regarding ANT's approach of treating non-human artefacts as actors, while stakeholder analysis clearly only focuses on human actors as stakeholders.

Friedman (2004) supports the contribution of Jones and Wicks (1999) stating that the representation of alternative accounts of stakeholders also shows the interpretivist side of stakeholder theory. In organization studies, organizational realities are constructed by observation and beliefs that can be subjectively interpreted. A convergent stakeholder theory containing all these different research paradigms is difficult. Hence, different perspectives also make the stakeholder theory remain a creative and evolutionary approach to the research problems. Stakeholder identification and engagement is also a topic of discussion among researchers. Ackerman and Eden (2011) suggests the use of interpretivism in stakeholder theory by pointing out three challenges for the management of stakeholders as follows [Gregory et al.(2020)Gregory, Atkins, Midgley, and Hodgson]:

- Identification of the stakeholders is an interpretive task for the specific context and situation, rather than assuming that generic stakeholders act similarly.

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- The relationships between stakeholders are dynamic and multifold, hence needs an in depth analysis for each stakeholder.
- Stakeholder management strategies allow to determine the time and ability to evaluate each stakeholder's significance.

Pouloudi et. al (2016) approves the interpretivist view by presenting concrete steps for stakeholder analysis in the context of information systems. This framework is widely adopted in IS research to identify the stakeholders and the dynamic relationships between them. Moreover, Pouloudi et. al (2016) identifies one of the key challenges in information systems development being the creation of aligned interests between business strategy and information systems strategy. Misalignment in the perspectives of stakeholders creates major barriers for the development of information systems. Thus, understanding these different perspectives of stakeholders' objectives using an interpretive approach is crucial. Alongside, Pouloudi et. al (2016) converges to find a framework for the interpretive analysis of the stakeholders. Consequently, it is mentioned that the stakeholder analysis should be dynamic, context-dependent and iterative. In this way, stakeholders could be captured within better depth and detail focusing on their different perspectives, and how they translate each others' objectives. These steps are summarized as follows [Nancy et al.(2016)Nancy, Currie, and Whitley]:

- The set and number of stakeholders are context and time dependent.
- Stakeholders may have multiple roles.
- Different stakeholders, even within the same group, may have different values and perspectives, which may be explicit, implicit or hidden.
- Stakeholder roles, perspectives and alliances may change over time.
- Stakeholders' relations and power matter in the shifts in their roles, perceptions and alliances.
- The definition of stakeholder groups for inclusion also represents boundaries of exclusion and marginalisation.

The sixth step has recently been added to Pouloudi (2016) framework by Gregory et. al (2020) in order to define the boundary for the stakeholders. This boundary acts as filter to select the stakeholders critical for the decision-making process inside the network of objectives. Gregory et. al (2020) argues that the boundary critique could be solved by investigating the drivers and barriers to change in the case of the use of new technologies. This is also highly correlated with our framework, where also barriers for technology adoption are investigated. Additionally, Gregory et. al (2020) warns that only considering the internal stakeholders is dangerous. Hence, the defining and evaluating the boundary of stakeholders in each phase of the research is important for stakeholder engagement.

There are uses of stakeholder theory supported with interpretive case studies in technology study literature. One example is the study of technology integration solutions (TIS) adoption by Kamal et. al (2011), where stakeholders are explored within their dynamic roles in the technology adoption process. It has been stated that the interpretive approach allow the researcher to get close with the stakeholders, investigate their perspectives, and blend them inside a single framework. This is also supported by stakeholder theory being a very pluralistic field of research having a wide spectrum of theoretical perspectives. The use of interpretivist paradigm within stakeholder theory has been supported by social construction of stakeholders, as in the case of institutional theory. Scherer et. al (2011) argues that intepretive approach of stakeholder theory allows the researcher to guide a practical research purpose, while also constructs the stakeholders' interests without taking them for granted as hard coded facts. This practical approach allows the researcher to capture the roles and relationship of actors in their own context, and find meanings of their actions identifying the situation of dependency and domination. The researcher is an active part of the interpretation process, in which the subjective meanings take form with the collected data, and interpreted inside the conceptual framework.

Walsham (1997)' s explanation of interpretive paradigm guided by a conceptual framework suits well in our research strategy. Walsham (1997) states that the use of theoretical concepts is important to guide interpretive research [Walsham(1997)]. Creation of an initial framework helps the researcher to formulate methods for research design and data collection. Later, this framework could be modified according to available data with possible modification of the selected theories in some cases [Vashist et al.(2011)Vashist, McKay, and Marshall]. Abdel-Fatah (2009) supports that development of e-government applications is becoming more than just technical solutions, and emphasizes the use of an interpretive framework in IS research. Moreover, the study argues that various fields of social, political, cultural, economic, and environmental affect the development and provision of e-government systems. For this reason, Abdel-Fatah (2009) offers to use of interpretive paradigm to evaluate the e-government systems and the relevant stakeholders. This is mainly due to the fact that interpretivist paradigm will provide a better dynamic approach than the other paradigms for evaluating IS systems.

In a following study, Walsham (2006) points out the importance of doing interpretive case study research in the IS domain. First, the study states that the fieldwork is the fundamental basis of interpretative research [Walsham(2006)]. Walsham (2006) summarizes them into four categories: choosing a style of involvement, gaining and maintaining access, collecting field data, and working in multiple sites if possible. The study maintains that being a neutral observer is key for an interpretive researcher, rather than trying to change the landscape as in the case of an action researcher. Second, maintaining access to the relevant research site is crucial for the interpretivist researcher, besides having good social skills. Third, the interpretive study should rely on qualitative data in the form of interviews, participant observation, and documentary analysis. It is best to support data collection with multiple methods in order to interpret and validate the results of the research. Following these suggestions, Walsham

(2006) continues with the importance of the use of initial theory in interpretive research to guide the data collection and analysis. Yet, Walsham (2006) also argues that the deliberate choice of theory should rely on the researchers' interests and the context. Since the researcher becomes the observer, who knows the most suitable approach to interpret the phenomena under investigation. The insightful choice of the theory would help the researcher to execute a successful interpretive case study. Regarding data analysis, Walsham (2006) points out that the establishment of the data-theory link provides the researcher a roadmap for data analysis. Reporting and concluding the interpretive study follows and describes all stages of the case study as similar to a case utilizing any other research paradigm.

Following an interpretivist research paradigm, the nature of the research is qualitative, and relies mainly on understanding the main actors, their objectives and relationships between them while the actors align their interests on the adoption of two specific technologies, virtual centre and flight-centric operations. The data collection of the two cases builds on three distinct qualitative methods of interviews, participant observation, and documentary analysis. Both the interview and case study protocols are designed to represent the interpretivist approach of ANT and stakeholder theory. These two technologies are selected because of their disruptive nature on the current conventional ATM provision in Europe. In order to understand the technology adoption process in European ATM, initially a conceptual framework is designed. Concretely, the conceptual framework interprets how these technologies are perceived from the various actors involved, and how they align, and form networks to adopt these technologies. Following the actors, the research also pointed to a number of non-human actors, which are referred as factors and barriers affecting the technology adoption process.

3.2 The Conceptual Framework

In this section, we will get back to the research problem at hand, and explain the approach of the conceptual framework, combining various ideas from both stakeholder theory and actor-network theory. The conceptual framework for technology adoption is initially built using a combination of participant observation and documentary analysis. The main driver for the conceptual framework is the misalignment of the interests of actors towards adopting new technologies. This is evidently observed considering any new or disruptive technology, since not all the stakeholders in European ATM have the same objectives towards adopting new technologies. Hence, observing this misalignment as a participant observer, the research focused on interpreting the actors, their roles, and relationships between them. Furthermore, the misalignment is not only due to technical reasons or challenges, there are political, economic, legal, and social factors affecting the whole technology adoption process. As a matter of fact, the conceptual framework combined all these observations under a single roof.

The need to design a conceptual framework emerged from the fact that there is a lack of socio-technical perspectives in technology adoption research. Mainly, the previous technology adoption literature investigated how users adopt certain technologies. The recent

3.2. The Conceptual Framework

developments in technology are immense, affecting and ultimately disrupting the roles, and objectives of the actors. Not only the users, but also all the stakeholders who have a stake at a certain technology is affected by this disruption wave. Thus, understanding technology adoption becomes more than merely examining the users' perspectives, rather evolves into a collective alignment of all the actors involved in the phases of the technological change.

This research aims to understand how and to what extent the emerging technologies, specifically virtual centre and flight-centric operations be adopted by the relevant actors in the European ATM. In order to investigate this research problem, first the actors and their interests towards adopting these technologies should be investigated. Second, it is crucial to examine the alignment of actors around these technologies, while the actors are positioning themselves on the network. Concretely, the actors form a network of interests, where each of them defines their roles according to their objectives. These interests are molded by various factors, which are categorized under technical, economic, social, political, and legal. The conceptual framework treats these categories as the factors affecting the technology adoption process, which is also referred as non-human actors in ANT terms.

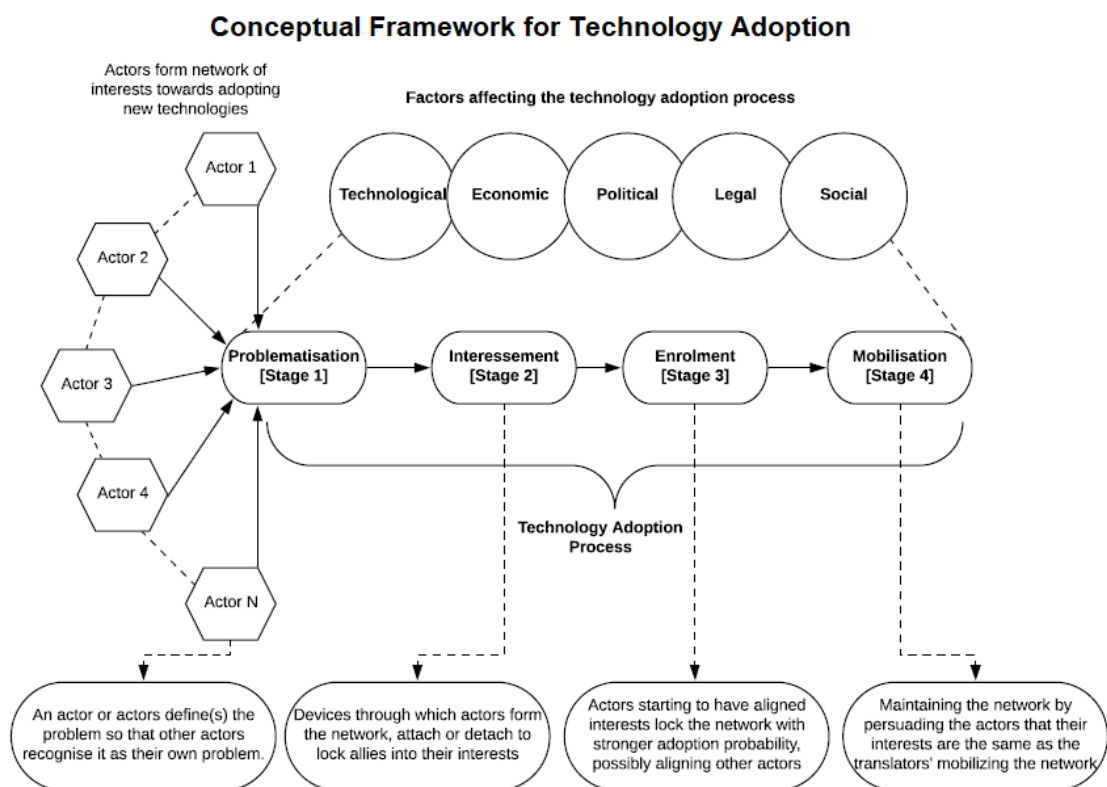


Figure 3.2 – Conceptual Framework for Technology Adoption

The conceptual framework adopts the definition of actors from the stakeholder theory and the stages of translation and factors affecting the technology adoption process from the actor-network theory concepts. The translation has four distinct stages, starting with prob-

lematization, as illustrated in Figure 3.2. In this phase, the focal actor(s) define their problem and relate to the interested actors. In our case, problematization is looking to the actors in European ATM, which drives and relates to the adoption process of the two distinct technologies. The second phase, intersement, represents the definition of common interests between actors while they adopt new technologies. Here, the actors start to define common objectives to adopt new technologies and get together to follow a common roadmap. The third stage, enrolment, consists of the collection of aligned interests of actors, forming of locked network structure. In the case of adoption, if the common interests between the actors lock in, then they start to have more probability for successful adoption. The final stage, mobilisation, is reached when the network between the actors stabilize, and lock-in. Then, the actors mobilize to attract more adopters or new actors to make the network stronger.

Actor-network theory also offers a term called obligatory passage point (OPP), which is a converging point of a majority of the actors in order to form the network of interests. Generally, an OPP forms in the problematization phase, where all the actors try to relate themselves into the defined problem. The OPP defines the scale of the problem, such as its locality and globality. The decision to pass the OPP should come from the focal actors with the support of all actors. The stability and the structure of the network also affects the properties of the OPP. Inspired from the study of Luomaaho et al. (2010) on investigating the translation in the case of corporate communications, the framework incorporated the factors affecting the adoption process, such as technical, economic, political, legal, and social [Luoma-aho and Paloviita(2010)]. These factors affect all the stages of the adoption process as we have described as the stages of translation. This provides the conceptual framework and the research design a socio-technical view on the technology adoption process.

In short, the conceptual framework targets to understand the actors, their roles and relationships in the technology adoption process. While understanding the actors, for the specific technology, the framework evaluates the network of interests between the actors towards adopting new technologies in the form of four translation stages. During the adoption, there are technological, economic, political, legal, and social factors affecting the actors and their overall objectives in the network. The conceptual framework acts as a guide through each phase of the research, starting from its design, moving into data collection, analysis, and finally reporting. The case study design is also guided directly by the conceptual framework in its data collection, analysis and reporting stages.

3.2.1 Participant Observation

This research initially starts with participant observation. This section summarizes the initial observations that are reflected on both case studies. Then inside each case study, participant observation for the specific technology is presented. The researcher is positioned in EUROCONTROL, which is a neutral, non-profit organization managing the European air traffic network. Within the 3 year professional experience in EUROCONTROL, the researcher worked

in various tasks ranging from business cases, cost-benefit analysis, building technical specification, and management of technological solutions. Additionally, EUROCONTROL drives the research for the SES, introducing new technologies inside the complex European air traffic management. This strategical position allowed the researcher to observe all the major actors, their roles, and interactions under a single roof. Even the selection of the cases are guided primarily by the participant observation, supported by documentary analysis. This section will focus on participant observation and its contribution to this research as the preliminary method of data collection for the two case studies.

Morgan et. al (2017) notes that many case study research lack in incorporating the unique contribution of observation data. Participant observation is powerful in combination with other multiple sources of evidence in case study research [Morgan et al.(2017)Morgan, Pullon, Macdonald, McKinlay, and Gray]. The richness of observing a phenomenon in its real-life setting is unique. Field notes and memos are used to track the observations done related to new technologies and their adoption in European ATM. The initial purpose of the participant observation is to examine the new technologies in European ATM. Before even the thesis topic is finalized, the researcher started to get acquainted with his working environment in EUROCONTROL. Following the research topic decision to investigate the technology adoption, then the participant observation focused more on the candidate technologies and their adoption by the relevant actors in European ATM.

The first observation of the researcher is the discovery of the existence of a huge number of technological solutions under the SES umbrella. This creates a confusion for the first time observer in European ATM on what to select which technologies to study for the cases. In the beginning, it is problematic to decide which technologies or solutions are the most promising. By time, it has been observed that the majority of the technologies or the solutions are either minor upgrades of the previous technologies, or just additional functions to the legacy systems. Yet, there are a number of technologies or solutions that diverge from the others by their disruptive nature. These technologies not only offer an improvement for the target objectives of the SES, but also shifts the paradigm of European ATM from legacy technological systems to service-based architectures. Among these, the initial focus is on investigating the technologies that have the potential to defragment the European ATM by switching to service-oriented architectures. Upon investigating the change in business models that the technologies offer, virtual centre and flight-centric operations are selected as the possible candidates for the case studies. The selection is approved by the meetings and events that the researcher attended and reinforce the selection of technologies for the case studies.

The power of the participant observation becomes more evident in examining the actors. Given the institutional complexity of the European air traffic management, it is crucial for a researcher to be part of an actor just to understand what is going on inside the air traffic domain. The exchange of feelings between the actors, how they utilise different perspectives on the same subject directly reflect on the misalignment of the actors and their objectives. Not all the actors in European ATM have the same objectives towards adopting new technologies.

Notably, the second observation is that there exists a misalignment between various actors towards adopting new technologies in European ATM. Consequently, the actors' interests or motivations can be quite different from each other and often attached to various factors. Hence, the third main observation is that the technology adoption is not just a technical decision of the airspace users. There are various factors ranging from political, economic, legal, and social affecting the objectives of the actors. The categories are emerged from the field notes from the meetings, events of the stakeholder discussions. The main categories are five, including the technical, of course the categories are not mutually exclusive, combination of them are possible, such as socio-political, or socio-technical, etc.

Following the actors, identifying them, and understanding their main motivations, it has been identified that there are challenges or barriers considering the adoption of new and disruptive technologies in European ATM as the fourth main observation. In the case of virtual centre, and flight-centric operations, which disruptively alter the business models of the main actors in European ATM, these barriers are extremely apparent and also voiced by the actors. Yet, this makes it crucial to define these barriers and point them before they challenge the adoption of these new technologies.

The four key observations lead into the search for a theoretical background to examine further, and reflect on the research design. Concretely, the conceptual framework is inspired from these observations. First, there exists a need to understand which technologies are able to shift the paradigm of the European ATM. For this reason, this thesis focuses on two case studies of virtual centre, and flight-centric operations. Second, the actors form a network of interests towards adopting new technologies. Accordingly, the network is affected by the aligned and misaligned objectives of the actors. Additionally, there exists phases of adoption explained in four stages of translation. Third, there are potentially existing factors affecting the technology adoption process categorized under technical, economic, political, legal, and social. Finally, during the adoption of new technologies, there are the possibility of barriers and obligatory passage points to be overcome for successful technology adoption.

In order to explain these observations inside a single conceptual framework, this research adopted theoretical and practical approaches from both stakeholder theory and ANT. Thus, the framework acts as an initial guide for the research, its design and strategy. Embedded inside, there are the observations originating from being a participant as a professional in the workplace. Furthermore, the observations are supported by the theoretical foundations without being too constrained. The approach of the conceptual framework is to keep simple and generic, while being powerful enough to explain the technology adoption at the same time.

3.2. The Conceptual Framework

Main Themes of Participant Observation	Supporting Evidence [Field Notes, Memos]	Related & Reflected Part of Conceptual Framework
<p>1. Selection of Technologies for the Investigation in Case Studies – New and Disruptive Technologies in European ATM</p>	<ul style="list-style-type: none"> - There exists a vast number of new technologies that the SES and the ANSPs focus for service-based architectures. - Among these technologies, virtual centre and flight-centric operations have disruptive nature and potentially change the business models of actors towards adopting service-based architectures. <p>Related Events</p> <ul style="list-style-type: none"> • 8th Florence Air Forum (21 OCT 2016) – Disruptive Technologies in European Air Traffic Management • 9th Florence Air Forum (15 MAY 2017) – The Single European Sky Performance Scheme • Field notes from work experience in Eurocontrol • IOD@DSNA – Innovation Open Days at DSNA 	<ul style="list-style-type: none"> - Unit of Analysis - Technology Adoption Process Case Study 1: Virtual Centre Case Study 2: Flight-Centric Operations
<p>2. Actors or Stakeholders – The relevant actors – Existence of misalignment between actors towards adopting new technologies</p> <ul style="list-style-type: none"> - Roles and Relationship of Actors 	<ul style="list-style-type: none"> - Initially, the researcher got acquainted with the following actors and their initial objectives • EUROCONTROL (Researcher location) • SESAR-JU • SESAR Deployment Manager • ANSPs • Air Traffic Controllers (ATCOs) • Air Traffic Controller Unions • Manufacturing Industry 	<ul style="list-style-type: none"> - Definition of actors - Technology Adoption Process - Network of actors' translation of objectives
<p>3. Technology Adoption Process</p> <ul style="list-style-type: none"> - Factors Affecting Technology Adoption 	<ul style="list-style-type: none"> - Technology adoption is a slow and challenging process in European ATM. It is a dynamic process involving all the actors in the chain of the network. It is crucial to analyse the roles, relationship of the actors towards technology adoption - There exists a number of factors categorized under technical, political, social, economic, and legal 	<ul style="list-style-type: none"> - Technology Adoption Process - Factors Affecting Technology Adoption Process (Technical, Political, Economic, Social, Legal)
<p>4. Barriers and Challenges in Technology Adoption</p>	<ul style="list-style-type: none"> - There exists barriers or challenges for the adoption in new technologies in European ATM - Defragmentation of European airspace, previously faced stiff challenges in the case of FABs, and Centralised Services 	<ul style="list-style-type: none"> - Factors Affecting Technology Adoption Process (Technical, Political, Economic, Social, Legal) - Obligatory Passage Points

Figure 3.3 – Relationship Between Participant Observation and Conceptual Framework

3.3 Case Study Design

This research uses case studies to examine the research problem. The two case studies investigate separately the adoption of two new technologies in European ATM: virtual centre and flight-centric operations. Specifically, the researcher is interested in understanding the technology adoption process, the actors involved, roles of the actors, the relationships between them, and the network of translations that they form. These two cases are selected because of their disruptive nature on the current conventional ATC and business models of the main actors in European ATM. These technologies does not only bring substantial changes in the technical and operational areas, but also on economic, social, political, and legal areas. This is what makes special to study these technologies, and actors revolving around them.

Decision to use case study as the main method stems from the research question itself. This research investigates "how" and "to what extent" new technologies, in particular virtual centre and flight-centric operations be taken up and ultimately adopted by the relevant actors in European ATM. For this reason, it is suitable to carry out a case study research to explore this contemporary phenomenon within its real-life context, as also suggested by Yin (2016) [Hollweck(2016)]. The case studies are supported by multiple types of data collection, interviews, participant observation, and documentary analysis. Concretely, the aim is to triangulate multiple sources to come to terms with results that have significance. This methodological path provides protection also for the validity by maintaining chain of evidence. The interpretive nature of case studies is also an important factor for the researcher to select case studies as the main methodology. Compared to other methods, Yin (2016) suggests that the use of case studies depends on three factors: form of research question, control of behavioral events, and focus on contemporary events. Yin (2016) compared the five main research methods (experiment, survey, archival analysis, history, and case study) within these factors to show the optimal use of case studies. The case study method is mostly suitable when the research question is in the form of how and why, does not require control of behavioral events, and focuses on contemporary events. Moreover, Yin (2016) states that the essence of a case study is to try to illuminate a process or set of decisions, answering why and how they were implemented and with what result [Hollweck(2016)]. Here, the decisions can be taken from individuals, organizations, processes, or programs.

In the research design, selection and identification of the technologies for the two case studies, virtual centre and flight-centric operations, are based on participant observation, and documentary analysis. During the first year of the research, the researcher observed a plethora of new technologies, solutions, and projects in European ATM, while working at the same time in EUROCONTROL. Among these new technologies, majority of them are updates and improvements on the current legacy system structure of the European ATM. Yet, a few of these technologies have the ability to disrupt the conventional ATC and radically change the roles of the main actors. Virtual centre and flight-centric operations are the two candidate technologies that are observed to be in this category. These two technologies change drastically the business models of the main actors, mainly by enabling geographically decoupled solutions

in Pan-European scale. Additionally, these technologies are expected to shift the paradigm of the European ATM from legacy-based systems and services to service-oriented solutions and services. For this reason, the selection of technologies are straightforward after carefully examining the solutions and projects in SES, and combining the alignment of the main actors through the observation period. The unit of analysis for the case studies is the technology adoption process, where the thesis offers a conceptual framework as a guide to examine the technology adoption for these technologies. The underlying theory for the conceptual framework is derived from both the stakeholder theory and actor-network theory. Thus, the research design defines the logic that links the data to be collected to the analysis following the conceptual framework.

Yin (2016) suggests that a case study should assure its quality by focusing on four areas: construct validity, internal validity, external validity, and reliability [Hollweck(2016)]. Most multiple-case studies are generally more reliable than a single-case study. The access to the relevant data and its sources is important in the decision of the cases. The researcher is able to participate in the definition and adoption phases of these technologies. Additionally, there is documentary archive and supplementary interviews that the researcher is able to rely on both for the two cases. Moreover, the researcher attends to specific events with main stakeholders to follow discussions, and the main factors affecting the adoption process of these technologies. The research design on the case studies include a logical path, which is guided by the research question, follows three distinct methods of data collection, and thematic data analysis to reach conclusions. In order to systematically develop the research design for the case studies, this research initially decided on the four step process offered by Yin (2016) [Hollweck(2016)]:

1. Definition of the research question:

- How and to what extent will emerging technologies, in particular flight-centric operations and virtual centre be taken up and ultimately adopted by the relevant actors of European ATM?
 - Who are the actors that are involved in the technology adoption process in European ATM, specifically for the technologies, flight-centric operations and virtual centre?
 - What are the key roles or objectives of the actors in the technology adoption process?
 - What factors (enablers, inhibitors) influence the adoption process of new technologies? (technical, economic, social, legal, and political factors)
- What will the consequences of such uptake or adoption be on the process of implementing the Single European Sky?

Following the main research questions, using stakeholder theory, combined with actor-network theory approach, we want to investigate the following sub-questions:

- What are the implications of these technologies to the implementation of

the Single European Sky, and its high-level target objectives? (capacity, cost-effectiveness, safety, environment, defragmentation)

2. The unit of analysis of the case studies:

- The unit of analysis is the technology adoption process, specifically virtual centre for the first case study, and flight-centric operations for the second case study

3. The logic linking the data to the propositions:

- This research uses three methods of data collection for the case studies: qualitative interviews, participant observation, and documentary analysis. The qualitative data collected from the data sources are analyzed using thematic analysis to identify the actors, technology adoption process, and factors affecting the technology adoption process.

4. The criteria for interpreting the findings:

- The conceptual framework to understand technology adoption is specifically designed to interpret the qualitative data collected. Using a combination of stakeholder theory and ANT, the framework evaluates the actors, their relationships, and factors affecting the technology adoption specifically for the two cases. The main criteria is thematic evaluation of the qualitative data, by coding and interpreting the data. Identification of rival explanations and alternative methods are also presented in the analysis section of this thesis.

3.3.1 Case Study Protocol

Following the preliminary 4-step decision criteria for the case studies, the research design follows a structured case study protocol, which defines the detailed steps to follow for the two cases under investigation, as illustrated in Figure 3.4. The main benefit of using a case study protocol (CSP) is to specify the details on how to address research questions and objectives. Furthermore, a protocol helps in to relate the collected data to the research questions and recalling triangulation and validation processes. According to Yin (2015), case study protocol consists of five stages, regarding a positivist approach to the case study research [Yin et al.(2015)Yin, Dargusch, and Halog]: case study design, preparing for data collection, collecting evidence, analyzing evidence, and reporting case studies.

Providing a coherent CSP helps the researcher to develop a set of guidelines to structure and govern a case research project. Additionally, for multiple case studies, the integrity of the data collection, analysis and presentation stays intact throughout the project. As derived from the initial case research design by Eisenhardt (1989), CSP follows an adaptable guideline to carry out case studies. Eisenhardt's (1989) framework follows 7 steps. First and the most important is the selection of the appropriate cases and unit of analysis for the study. Second is the decision for the crafting instruments and protocols. Third, the researcher enters the field

and observe the case at hand. Fourth step is the data analysis with the proper methodology and tools. Following that, the hypothesis are shaped to find the links between evidence and theory. This is followed by the unfolding of the literature and comparing the case with the previous studies. Finally, closure is reached with a case study report with possible theoretical saturation.

Combining both CSP approaches of Yin(2015) and Eisenhardt (1989) into 6 steps, the case study protocol in our research design follows 6 steps, described as follows:

1. **Background:** The first stage is the background and literature review focusing on the specific technology under investigation. The first case investigates virtual centre, while the second case investigates flight-centric operations.
2. **Design:** The second stage includes the decisions for the properties of the case study, such as single or multiple case, flexible or closed, holistic or embedded, and further evaluation of the steps of research design: research questions, objectives, units of analysis, data analysis, interpretation and validation criteria.
3. **Procedures:** The third step is the decision for the theoretical and methodological background for the case studies.
4. **Research Instruments:** Collecting effective data is crucial for the processing of data, by using multiple sources and maintaining a chain of evidence.
5. **Data Analysis & Guidelines:** The determination of appropriate analysis strategy (theoretical propositions, conceptual framework, case descriptions) and analysis techniques (pattern matching, thematic analysis, logic-models, cross-case synthesis), regarding the three principles (all evidence should be considered, presenting the evidence separate from any interpretation, and exploring alternative interpretations).
6. **Conclusion & Reporting:** Identify the audience, define the structure early, and clearly present the results following the case study protocol.

The case study protocol initially starts with a background analysis for the technologies under investigation. In the scope of the research problem, the previous literature on the specific technology is investigated. The researcher collected documents from various meetings, events and workplace to examine the concept of operations and cost-benefit analysis related to the two specific technologies. Mainly, the archival data is in the form of technical or economic concept design and validation. Then, each case study protocol adopts the technology adoption conceptual framework. The third step is the procedures, where the cases are selected into two specific technologies. For both cases, the unit of analysis is the technology adoption process. The research instruments used in this research is mainly qualitative. The data is collected in the form of documentary analysis, participant observation and semi-structured interviews. The collected data is thematically analyzed with the help of a computer-assisted

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qualitative data analysis software (CAQDAS). The thematic analysis is guided by the conceptual technology adoption framework, which borrows inspirations from both stakeholder theory and actor-network theory.

Case Study Protocol - Initial Design

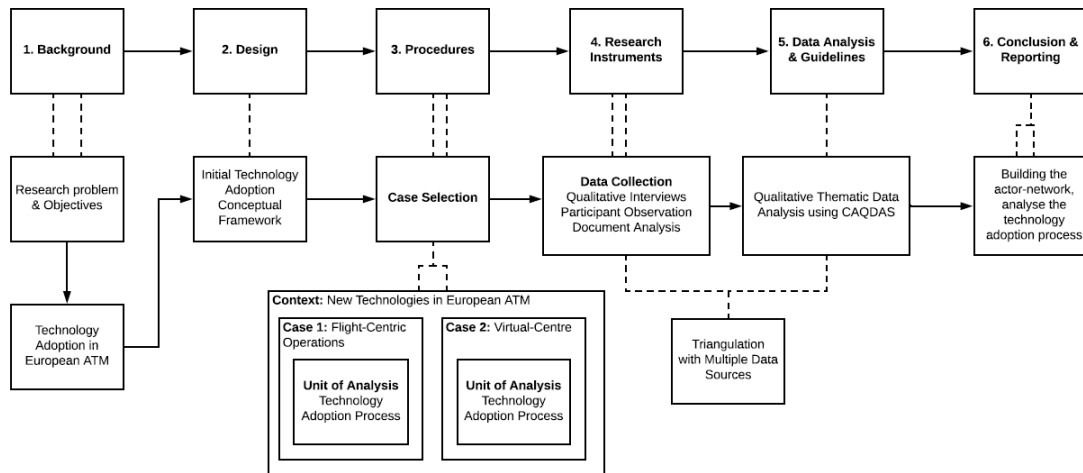


Figure 3.4 – Case Study Protocol

The components for the case study design relies heavily on the preliminary conceptual framework, which is directly guided by the theory behind. The construction of theory is essential for the case study to be effective. In this thesis, the case studies will show how and to what extent the two new technologies in European ATM (virtual centre, flight-centric operations) be taken up, and the factors (technical, social, economic, political, and legal) affecting the technology adoption process. This statement of the case studies implies that the cases will focus on identifying the relevant actors, their objectives, and relationships between them while they adopt new technologies. The rival theories, as of innovation diffusion, attempt to solve the technology adoption problem from the perspective of the user, without looking into the exact actors, and relationships, and evolving factors. Reviewing the literature, the conceptual framework, which combines ANT and stakeholder theory, is found suitable compared to other theories that approach technology adoption. This thesis does not use statistical generalization to move from case studies to theory. Rather, the cases are selected as a laboratory experiment from a trial of new technologies in European ATM. Concretely, the case studies use analytic generalization as a mode of generalization, where the empirical results from the case studies support and develop previously developed theory [Hollweck(2016)]. Within these two cases, if there is support to the replication of the results, then the results can be considered as more potent.

3.4 The Case Study Structure

Following the CSP, this section describes the case study structure, which outlines the content of the reporting for the two case studies. These guidelines act as a guide for the following two chapters of the thesis, where the analysis and the results of the case studies are presented separately for each case. The case study structure includes the following sections: case study purpose, introduction, case definition, unit of analysis, theoretical basis, procedures, research instruments, data analysis, and reporting.

3.4.1 Case Study Purpose

The aim of the two case studies is to understand how and to what extent will emerging technologies (case study 1: virtual centre, case study 2: flight-centric operations) be taken up and ultimately adopted by the relevant actors in European air traffic management (ATM). The two case studies follow the same case study structure. Only the context, being the technology under investigation, is different.

Following the main research question, the case studies specifically target to answer the related sub-questions:

- Who are the actors that are involved in the technology adoption process in European ATM, specifically for the technologies, case study 1: virtual centre, and case study 2: flight-centric operations?
- What are the key roles or objectives of the actors, and relationships between them in the technology adoption process?
- What factors (enablers, inhibitors) influence the adoption process of new technologies? (technical, economic, social, legal, and political factors)
- What are the implications of these technologies to the implementation of the Single European Sky, and its high-level target objectives? (capacity, cost-effectiveness, safety, environment, defragmentation)

By asking these questions, the case studies target to build a network of translations of actors' objectives towards the adoption of two technologies. The alignment between the actors will be analyzed using a graphical representation inspired from ANT. For each technology under investigation, the case studies follows the conceptual framework to present the actors, their roles, relationships, and the adoption stage. Furthermore, the factors affecting the adoption process will be incorporated inside the analysis, focusing on their level of affect on the adoption process. This includes understanding the possible barriers or challenges that the actors face during the technology adoption process. Overall, the case studies present the top view of the technology adoption process by focusing on the actors, their roles, and

relationships. By this, the aim is to provide all the relevant actors the current picture of the technology adoption, and recommendations to further improve the process.

The two case studies follow exactly the same case study protocol, only the technology under investigation changes depending on the case, as depicted in the previous case study protocol diagram in Figure 3.4. First, each case study starts with investigating the background and literature review for specific technology under investigation. Following that, the case studies include the design of the case study by providing the theoretical basis that guides the research methodology. This includes the presentation of the conceptual framework to investigate the technology adoption process inspired from ANT and stakeholder theory. Then, the case studies continue with data collection from multiple qualitative sources of interviews, participant observation, and documentary analysis. This is followed by the thematic analysis of the qualitative data in order to reach higher order themes. Finally, these themes are used to form the analysis technology adoption process in the form of graphical representation.

The holistic multiple case studies examine key technologies that have the possibility to realize the high-level objectives of the Single European Sky, as also stated as the key disruptive technologies in Airspace Architecture Study by SESAR-JU. The context of the case studies is purposefully selected from a number of SESAR solutions and projects. The disruptive nature of these technologies made them a candidate to investigate their adoption processes. These two technologies alter the objectives of the actors and introduce new business models and market opportunities. Yet, the adoption of these technologies face barriers, and need the alignment of actors' objectives and relationships. The key points of each technology is provided below:

Virtual Centre (Cloud-based ATC)

- Decoupling of air traffic management (ATM) data services, such as flight data, radar, and weather information, from physical controller working position (CWP)
- Virtually defragment the systems & services by using open service-oriented architectures
- Creation of virtual Single European Sky - virtually defragmenting key services
- Obtaining greater flexibility on the organization of air traffic control operations
- Seamless and more cost-efficient service provision to airlines and airspace users

Flight-centric operations

- Changing the conventional ATC into flight-centred structure by abolishing the geographical sectors
- Aircraft may be under the responsibility of the same ATCO across two or more geographical sectors, rather than handed over at sector boundaries

- A paradigm shift of ATC, where a flight is controlled from beginning to its end
- Changing the way ATCOs work and their situational awareness
- In Terminal Manuevering Area, non-geographical allocation of airspace, based on assigning arrivals and departures to distinct team of ATCOs

3.4.2 Introduction & Background

The case studies provide a background on the specific technology under investigation by focusing on the possible scenarios of adoption in the European ATM. Each case study reviews the relevant literature on the specific technology, presenting the actors involved, their roles and the relationships between them. Combining documentary evidence from technical validation report, operational service definition, and various presentations, the introduction presents an overall picture of the technology.

- Definition of the technology under investigation (case study 1: virtual centre, case study 2: flight-centric operations)
- Literature review of the specific technology under investigation using documentary analysis
 - Validation Report of technologies
 - Operational Service Definition of technologies
 - Presentations from the meetings, events and conferences

3.4.3 Case Definition & Design

The design of the case studies is holistic multiple-case, where there is a single unit of analysis, technology adoption process, within two distinct cases of new technologies in European ATM. Using multiple case design provides robust evidence than executing a single case study. In order to validate the conceptual framework for technology adoption, it is beneficial to design a multiple-case study, where we can compare and contrast the adoption of the two technologies. Yin(2015) suggest a replication, not sampling logic, for multiple-case studies. By this, the multiple case design investigates the possible test the same steps for the case research within two different contexts. This, in turn, provides compelling interpretation and results for the case studies.

Indeed, development of a rich theoretical framework in the preliminary stages of a case study research helps for the decision of the multiple cases. The conceptual framework states the steps to study a phenomenon under investigation, even ultimately converging on the case selection. Furthermore, it becomes the vehicle for generalization or replication through multiple cases [Yin et al.(2015)Yin, Dargusch, and Halog]. Throughout the case study, modifications

or updates can be done on the conceptual framework to enhance the theoretical and practical contribution to the topic.

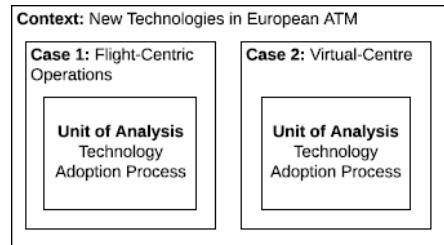


Figure 3.5 – Unit of Analysis

Unit of Analysis

The decision to select the unit of analysis is to decide on what constitutes a case. The unit of analysis for a case study can be anything under investigation, such as an individual, organization, event, or process, etc. Yin(2015) states that the guide to select the unit of analysis is to follow the the way the initial research question is formulated. Likewise, in this research, selection of unit of analysis follows directly from the research question, in which the case itself looks into the technology adoption process by asking a ‘how’ question. For the two cases under investigation, the unit of analysis is the technology adoption process. Further, in the context of new technologies in European ATM, the cases will look into specifically the virtual centre, and flight-centric operations. The theoretical basis for examining the technology adoption process is framed under a conceptual framework, and described in the following section. The changing parameter is the specific technology the case study examines, which are the two distinct technologies of virtual centre and flight-centric operations. This is illustrated in Figure 3.5.

3.4.4 Theoretical Basis & Procedures

This section presents the logic linking the data to the propositions by describing the theoretical background to support the data collection and analysis. As also previously described, the conceptual framework for technology adoption guides the theoretical basis of the case studies. Additionally, the interview protocol also is guided by the technology adoption conceptual framework. A combination of ANT and stakeholder theory is used as a theoretical basis, where the actors, their objectives and relationships between each other are the key points of the framework and of the case studies.

The need for a conceptual framework is evident for the case studies, since the framework guides both the design, execution, and reporting of the case studies. The conceptual framework is originated from the participant observation and the documentary analysis from the preliminary study. There is an apparent need for socio-technical analysis of the technology

adoption process and factors affecting it in the context of new technologies. In that sense, this research adopts theoretical standpoint from both the stakeholder theory and actor-network theory. The case studies adopt the definition of a stakeholder from stakeholder theory as similar to Freeman (1984)'s definition of a stakeholder being any group or individual who has a stake in the technology adoption process. Especially, when considering information systems, there are clear separations between the developer and the user of the technology as originating with Mumford's stakeholder definition [Pouloudi(1999)]. As the technologies are becoming more complex, a wide range of stakeholders started to get involved or affected by the information systems. Even external users started to have a word on the adoption of new technologies. Pouloudi (1999) suggests that stakeholder analysis should consider both organizational and interorganizational environment while taking stakeholders into account.

On the ANT side, there does not exist a clear separation between the human actors or stakeholders and the non-human actors. The ANT standpoint emphasizes the three basic principles of agnosticism (impartiality between actors engaged in controversy), generalized symmetry (the commitment to explain conflicting viewpoints in the same terms), and free association (the abandonment of all apriori distinctions between the natural and the social). Controversial as it seems, the ANT approach considers non-human actors and human actors affecting the network of relations, and having the same agency [Callon(1984)]. Given these assumptions, then Callon argues that there are four moments of translation, where the actors define their roles in perspective of each other. These stages, as also used in the technology adoption framework, are shown as described previously in the technology adoption framework.

Previous literature on stakeholder analysis has examples of combining stakeholder theory and ANT by rejecting the distinction between technical and social actors. Vidgens argues that the non-human stakeholders are equally as important as the human stakeholders [Pouloudi(1999)]. For Vidgens, the definition of a stakeholder becomes any human or non-human organization unit that can affect as well as be affected by a human or non-human organization unit's policy or policies. In a sense, this creates challenges in the identification of non-human stakeholders, while for human stakeholders identification is pretty straightforward. The same is true for the agency, and how could non-human stakeholders have agency is a challenging to answer. Even Vidgens in his study faces stiff challenges in understanding the non-human actors while assigning anthropomorphic properties. Yet, the study is able to overcome the problem by treating non-human actors as resources. Further in the discussion, Pouloudi (1999) does not advocate the symmetrical treatment of human and non-human actors, yet suggests to consider them separately.

Clearly, considering the previous approaches in stakeholder theory and ANT, this research keeps the separation between human and non-human actors. This is provided by limiting the stakeholders or actors as human actors, and treating factors affecting the technology adoption process as non-human actors. Hence, these factors translate the objectives of the stakeholders during the adoption process, the conceptual framework directly considers them in relation to the translation process. The factors affecting the technology adoption process are categorized

Combination of ST and ATN for Research Design

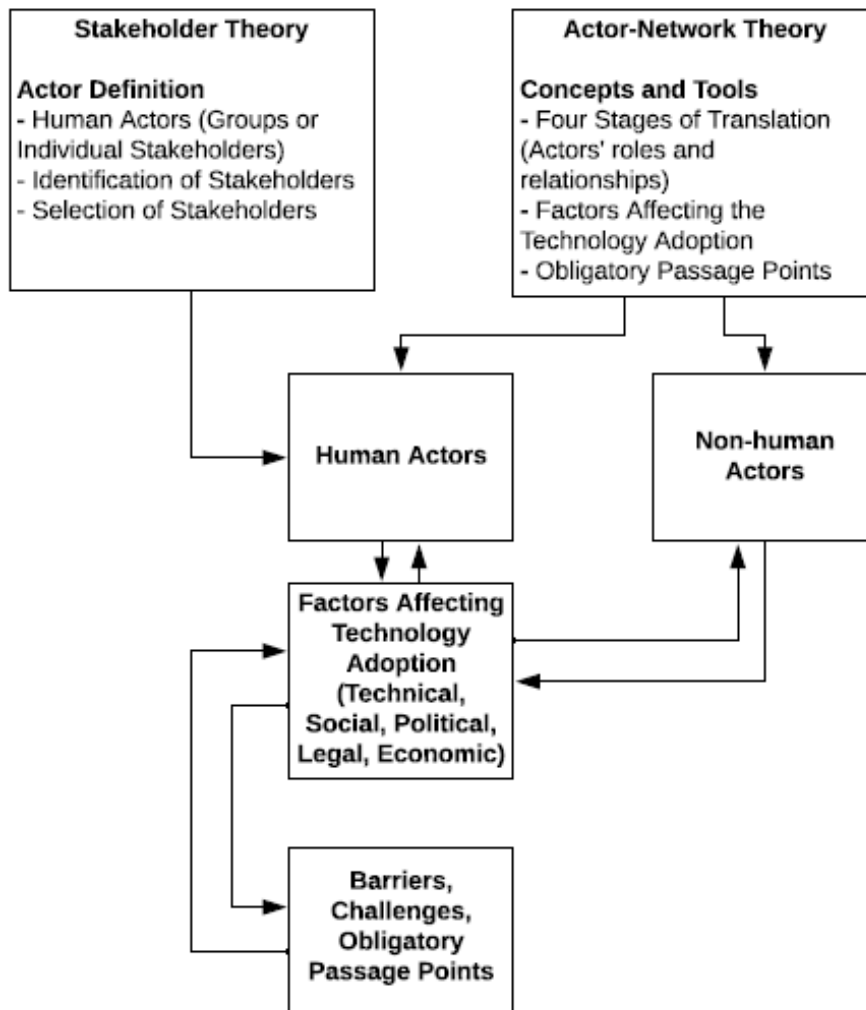


Figure 3.6 – Theoretical Basis for the Case Studies

under five categories: technical (technological), economic, political, legal, and social. These categories are derived using participant observation and documentary analysis in the first phase of the research. The separation between the categories is not totally exclusive, that there is possibility of a combination of the categorization of the factors, such as socio-political, and eco-political etc. Evidently, the definition of the stakeholders is adopted from stakeholder theory. This follows the identification and analysis of the stakeholders. Additionally, ANT concepts of translation, factors affecting the adoption process, and obligatory passage points aid the theoretical approach of the case studies. The technology adoption process is represented using four stages of translation, as adopted from ANT. These stages are called problematisation (Stage 1), interesement (Stage 2), enrollment (Stage 3), and mobilisation (Stage 4). The theoretical basis combining stakeholder theory and ANT is illustrated in Figure

3.6.

The main aim of this combined theoretical approach is to utilize best of the both worlds of stakeholder theory and ANT. This research treats technology adoption process as a socio-technical process, where the network of actors align to adopt new technologies. The human actors, either organizations, groups, or individuals form a network of interests towards adopting new technologies. Definitely, there might be also misaligned interests or objectives of the actors challenging the network. Specifically, these relationships appears on the four translation stages, where actors come together to translate their objectives and start forming a network. During this translation, there are obligatory passage points, challenges or barriers that the actors face while they try to adopt these technologies. Furthermore, the translation of objectives are affected by various factors during the adoption process. In our theoretical background, stakeholder theory acts as the definition and identification of the stakeholders, and ANT acts as the interpretive side of the technology adoption process. This research does not directly adopt ANT as a theory, rather various concepts and tools are borrowed from what has been previously proven effective in interpretation regarding the previous literature.

The phases of the technology adoption process are systematically adopted from Callon's work on the sociology of translation [Callon(1984)]. In that, Callon describes the four moments of translation, which then becomes the basis for the ANT approach. The problematisation stage consists of the definition of the identities and interests of other actors, which align with its own interests, creating obligatory passage points. By definition, an obligatory passage point is a situation that has to occur in order for all the actors to satisfy the interests of other actors. The second stage, interessement is where the focal actor(s) convince other actors to agree on and accept the definition of the focal actor(s). The third stage, enrolment, happens when an actor accepts the interests defined by the focal actor(s) and set out to achieve them through actant allies, which align with the actor-network. If all these stages are executed successfully, then actors ensure that they also represent other actors' interests, which is the mobilisation stage. Within these stages, the conceptual framework tries to understand the motivations and actions of groups of actors who form elements, linked by associations, of heterogeneous networks of aligned interests. In this context, we are specifically looking into the technology adoption in European ATM using the four moments of translation of ANT.

This research identifies steps to take throughout the two case studies following the conceptual framework as follows:

1. Identification of the stakeholders or actors

- (a) Identification of the main stakeholders in the technology adoption process specific to the case study or technology
- (b) Stakeholder as a human actor (organization, institution, individual, group) who can affect or be affected by the technology adoption of specific technology
- (c) Classification of core and side stakeholders according to their relevance and level

of influence in the adoption of specific technology

2. Roles and Objectives of the Actors

- (a) Investigation of the roles and objectives of the actors towards the adoption of specific technology
- (b) Classification of the roles of actors as critical, pushing, generic, decisive or passive roles in the technology adoption process

3. Relationships between the actors

- (a) Examining the specific relationships between the actors towards the adoption of the specific technology
- (b) Network of alliances, and creation of the steps related to the adoption as phases of translation (problematisation, intersement, enrolment, and mobilisation)

4. Factors Affecting the Technology Adoption Process

- (a) Examining the factors affecting the technology adoption process during translation of actors' objectives, categorized as follows:
 - i. Technological (Technical)
 - ii. Economic
 - iii. Political
 - iv. Legal
 - v. Social

5. Barriers, Challenges, and Obligatory Passage Points of the Technology Adoption

- (a) Investigating the blocking points of the adoption of the specific technology
- (b) Presenting them inside the conceptual framework of technology adoption

6. Impact on the Single European Sky

- (a) Understanding the impact on the high-level objectives of the SES, categorized as follows:
 - i. Cost-Effectiveness
 - ii. Capacity
 - iii. Safety
 - iv. Environment
 - v. De-fragmentation

3.4.5 General Procedures & Research Instruments

The case studies uses three qualitative sources of data collection: interviews, participant observation, and documentary analysis. Multiple sources of evidence guide the data collection in order to establish validity using triangulation. Additionally, multiple perspectives from the relevant actors are collected to form a uniform pool of qualitative data. This provides an unbiased approach to the case study, where the actors are observed from a neutral point of view.

Data Collection & Sources

Interview: The interview protocol is designed guided by the research questions, conceptual framework, and the theoretical basis of the research. Mainly, the semi-structured interview is designed to understand the relevant actors, their objectives, relationships between them, and the factors affecting the technology adoption process. A combination of purposeful and snowball sampling is used for the interviews. Specifically, the domain experts from the actors involved are interviewed to collect qualitative data for the case studies. A number of interviewees also supported the data collection by providing specific key informants to provide relevant data to the case studies. The interview protocol is presented in the following section.

Participant Observation: The researcher, being part of the Business Cases team in EURO-CONTROL, has around 3 years of professional working experience between July 2016 and August 2019. During this period, the researcher attended face-to-face meetings, workshops and events with stakeholders regarding the two technologies under investigation. Moreover, the researcher has the opportunity to follow up the actors, while working on tasks related to the projects. The participant observations are recorded using various methods of field notes, memos, and voice recordings.

Document Analysis: For each technology, there is a related SESAR project which follows its technical development with stakeholders. There are two main technical public documents for each project. First is the validation report (VALR), which contains the detailed description of the validation exercises and their results. The second document is the concept of operations or technical specifications, which presents the technical specifications related to each technology. Additionally, presentations from the specific related events, meetings, and conferences are used as a documentary archive.

- Validation Report (VALR)
- Concept of Operations and Technical Specifications

- Presentations from the events, meetings, and conferences

Triangulation: Three distinct qualitative data sources (interviews, documentary analysis, participant observation) are used to support the data collection of the case studies. Triangulation is key to gather meaningful insights from the collected data. Additionally, the case studies follows the below mentioned steps for the validity and reliability of the research:

- **Construct validity:** establishing correct operational measures for the concepts being studied.
- **External validity:** establishing the domain to which a study's findings can be generalized.
- **Reliability:** demonstrating that the operations of a study, such as the data collection processes, can be repeated with the same results.

3.4.6 Data Analysis Guidelines

Selection of the data analysis approach is crucial for the successful execution of a case study. The methods for case study analysis provide a systematic and rigorous roadmap for the generation of meaning from the collected data [Cruzes et al.(2015)Cruzes, Dybå, Runeson, and Höst]. Considering the research objectives, the theoretical basis and the conceptual framework, the analysis of the case studies is selected as thematic analysis in this research. Concretely, thematic analysis is a method for identifying, analyzing, and reporting patterns (themes) within data. This method is mostly suitable for interpretive case studies, where multiple sources of evidence converge into themes, either following a deductively or theoretically driven, or inductive approach. Our approach is to follow a theoretically driven interpretive case study, in which the conceptual framework guide the data analysis. Yet, on the reverse side, the themes from the data analysis update the conceptual framework without being totally restricted by the theory. This makes thematic analysis suitable for this research, being flexible method in the understanding of the rich data.

The collected data is analysed using a computer-aided qualitative data analysis software (CAQDAS), specifically NVivo software. The case studies follow the discrete steps provided by the 6-step approach to execute thematic data analysis as follows:

- **Step 1:** Becoming familiar with the data
 - Reading and re-reading the data in order to formulate the categories and themes within the collected data
- **Step 2:** Generate initial codes

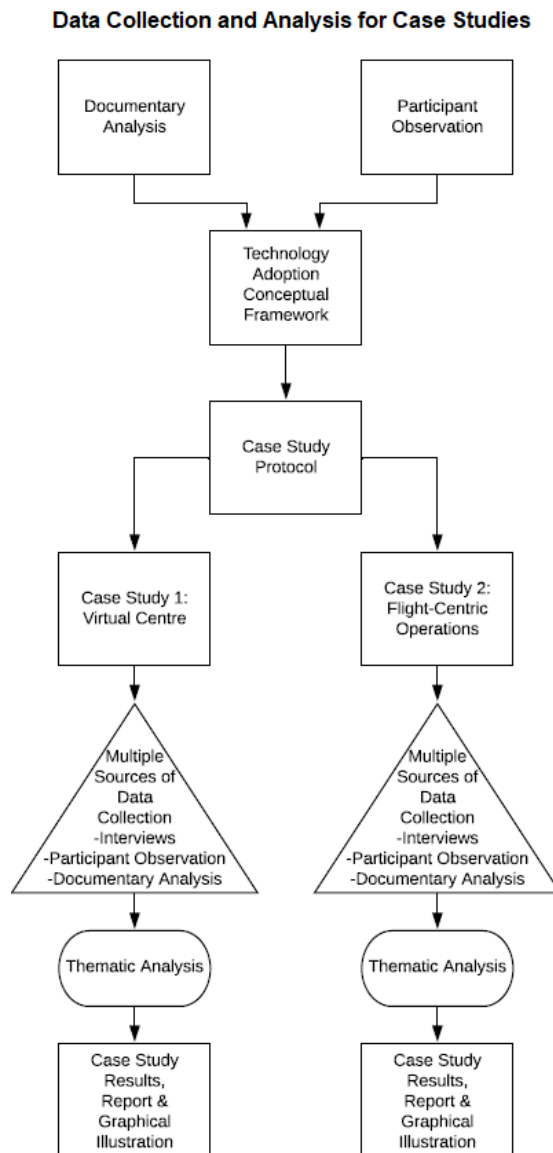


Figure 3.7 – Data Collection and Analysis for Case Studies

- The emergence of the first set of codes for review
- First pass of the collected data
- **Step 3:** Search for themes
 - Through review of the emergent themes to find and stabilize the categories and themes
- **Step 4:** Review themes
 - Review of the themes to understand the evolution of the emergent codes

- **Step 5:** Define themes
 - The finalization of the themes will occur through an iterative process.
- **Step 6:** Interpretation of the results
 - The actors, their relationships and objectives are described using resulting tables and graphical representation.
 - The stages of adoption is presented using the four stages of technology adoption process and graphical representation.
 - The factors affecting the adoption process is interpreted by categorization under technical, social, political, legal, and economic and presented using resulting tables and graphical representation.
 - The overall analysis is presented using the technology adoption conceptual framework.

Graphical Representation

Previously, in literature review chapter, the thesis presents various approaches on illustrating the network of actors and their relationships from ANT perspective. Yet, there does not exist a standardized and simple way of representing the actors, their roles, and relationships inside a single framework for the context of technology adoption. For this reason, this thesis offers a syntax for the representation of the actors, their relationships, stage of adoption, and factors affecting the technology adoption process. The conceptual framework for technology adoption is the starting point for the graphical representation that is used in this thesis. The Figure 3.8 provides the elements used in the graphical representation.

The graphical representation has 3 distinct section, as illustrated in Figure 3.9. The first section represents the actors, their roles, and relationships. Next, the second section illustrates the stages of technology adoption as problematisation, intersement, enrolment, and mobilisation. Finally, the third section provides the factors affecting the technology adoption process. The graphical syntax, defined in Figure 3.8, is used to build the overall graphical representation for the communication of the results of the case studies. As can be seen, the basis for this representation is the conceptual framework, where the graphical illustration presents the elements in the framework in detail.

3.4.7 Conclusion & Reporting

The reporting of the case study is the final closure of the results obtained through the data collection and analysis stages. Hence, this part of the case study uses the finalized themes from the data analysis to build the network representation of the actors and their interests. The ultimate aim of the conclusion part is to provide recommendations for enhancing the technology adoption process in European ATM, specifically for the two technologies under

3.4. The Case Study Structure






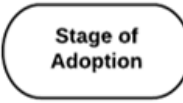



Graphical Icon	Name of Representation	Purpose in Illustration
	Actor Representation	-Representation of the actors or stakeholders in the technology adoption process
	Actor Relationship – Critical Role and Relationship	-Representation of a critical role and relationship in the technology adoption between actors
	Actor Relationship – Pushing Role and Relationship	-Representation of a pushing role and relationship in the technology adoption process between actors
	Actor Relationship – Passive Role and Relationship	-Representation of a passive role and relationship in the technology adoption process between actors
	Actor Relationship – Decisive Role and Relationship	-Representation of a decisive role and relationship in the technology adoption process between actors
	Stage of Adoption [Stage 1]: Problematisation [Stage 2]: Interesement [Stage 3]: Enrolment [Stage 4]: Mobilisation	-Stages of adoption is the ANT inspired part of the technology adoption framework, where the stages of adoption are represented by the phases of translation of the actors' interests
	Factors Affecting the Technology Adoption [Factor Category 1]: Technical [Factor Category 2]: Economic [Factor Category 3]: Political [Factor Category 4]: Legal [Factor Category 5]: Social	-Representation of the factors affecting the technology adoption during the stages of adoption -The radius of the circle changes with the level of influence on the specific stage of adoption
	Obligatory Passage Point - Passed	-Obligatory Passage Point-Passed represents a passed critical milestone
	Obligatory Passage Point - Blocking	-Obligatory Passage Point-Blocking represents a blocking critical milestone

Figure 3.8 – Graphical Syntax for the Illustration of Technology Adoption

investigation. The two case studies follow exactly the same reporting structure. The case study report includes two main steps to follow:

1. Identifying the audience:

- (a) The audience for the case studies is all the relevant actors who are involved in the

adoption process of the two technologies under investigation

- (b) Policy-making recommendations derived through the challenges affecting the adoption process targets the European Commission
- (c) The modelling of the technology adoption process will assist EUROCONTROL and SESAR-JU to reach their targets in the adoption of these two technologies

2. Development of compositional structure:

- (a) The background and literature review of technology under investigation
- (b) Description of the theoretical basis for the proposed technology adoption framework (case study design, methodology)
- (c) Presentation of actors, their objectives and relationships between them in the technology adoption process
- (d) Challenges or Barriers Affecting the Technology Adoption Process
- (e) Illustration of the technology adoption process using the technology adoption conceptual framework
- (f) Policy-making recommendations for the relevant actors

3. Following certain procedures:

- (a) Reporting starts within the data analysis stage of the case studies
- (b) The interviewees will stay anonymous throughout the research, rather the main actors, their objectives, and relationships are the focus of the cases.
- (c) Collecting review and feedback from the peer researchers and participants to the research for validity

3.5 Interview Protocol

This section presents the interview protocol that has been used as one of the main qualitative data collection method throughout the thesis. It is crucial to start with a well-designed interview protocol in order to have effective interviewing, collect effective data and make in-depth analysis. The interview protocol includes the design of the questions, procedural guideline for the researcher and the interviewee and the direction of the interview.

3.5.1 Preparing the Interview Questions

For this research, first I started with designing a preliminary study, where I become acquainted with my working environment, my colleagues and the air traffic management domain. My initial ambition is to understand what domain experts think about technology adoption in air traffic management, types of actors involved and their influence in the adoption process. For this reason, the interview questions in the preliminary study is short, generic, and open. The

main aim is to collect as much as preliminary data possible from the interviewees to form the detailed interview questions for the future case studies.

The main theme of the interview is the technology adoption in European ATM, as aligned with the main research question. The aims of the preliminary study are to understand the current digital technology trends in European ATM, the factors (enablers, inhibitors) for the adoption of these technologies and their implication for the implementation of the SES. Thus, the interview protocol has been designed to guide the researcher to point out the right questions within the limited time and resources. In the context of this research, the interview protocol is based on [Cooper and Crase(2016)]. According to Cooper, an efficient interview protocol should follow the following guidelines, which are also followed by this research:

1. Research should guide your questions
2. Use a script for the beginning and end of your interview
3. Questions should be open-ended.
4. Start with the basics for data collection
5. Begin with easy to answer questions and move towards ones that are more difficult or controversial
6. The phrase "tell me about.." is a great way to start a question
7. Write big, expansive questions
8. Use prompts to keep on track for each question
9. Be willing to make "on the spot" revisions to your interview protocol

For this research, choosing the right type of questions is important, since we are aiming to collect open, unbiased data of the projects and actors involved. Rather than asking specific questions, this preliminary study asks what and how questions related to the technology adoption and the relevant stakeholders.

3.5.2 The Interview Protocol - Preliminary Study

Initially, an interview protocol for the two case studies has been prepared. These include semi-structured interview questions, which drives the interview as an open discussion. The questions for the two different case studies are structurally the same, except the technology under investigation is different. The researcher contacted with the interviewee prior to the interview, providing the aim and abstract for the research, asking for an appointment for the interview. The first sample for the preliminary study is the team that I have been working in EUROCONTROL. This is purposefully sampled due to the fact that the preliminary study

would be a practice run for me to update the interview protocol and questions. Initially, the preliminary interview protocol included the following questions:

1. How and to what extent do you think that the latest technologies for European Air Traffic Management (ATM) will be adopted? What are the key actors in its take-up process?
2. What are the actors in European ATM that are involved in the technology adoption process? Can you also name any non-human actor (technology, regulation, standard, etc.) that is involved in the adoption process? What are the roles of each actor you mentioned in the technology adoption process?
3. What factors (enablers, inhibitors) influence the adoption process of flight-centric operations technology? What are the specific challenges?
4. What are the implications of this technology to the implementation of SES?

Each question in the interview protocol is designed to gather data in accordance with the conceptual framework of technology adoption. The first question aims to understand the participants' opinion on the latest technologies in European ATM. The preliminary study does not limit the investigation of the cases towards virtual centre and flight-centric operations. Rather, the question asks for a spectrum of new technologies that are able to change European ATM. The second question targets to find the actors that are involved in the take-up process. These are the main stakeholders in European ATM, with having various interests in the technology adoption process. The sub-question investigating the non-human actors, then discarded since it directly leads the participant to assume that there are non-human actors. Yet, the analysis makes the segregation of human and non-human actors through their translation of objectives inside the actor-network. For example, if a factor or artefact has an importance in the definition and shaping of stakeholders' network of interests, then these are considered as potential candidates for non-human actors. Consequently, the next question investigates the roles for each actor in the technology adoption process in European ATM. For experts, that specifically know the virtual centre and flight-centric operations, I tried to understand the specific roles in the adoption of these two technologies. For the participants that have a generic knowledge on new technologies, I focused on a broader role of actors in the generic technology adoption process.

The third question asks for the factors (enablers or inhibitors) affecting the technology adoption process in European ATM. Here, the aim is to understand the factors, categorized as technical, social, economic, legal, and political in the conceptual technology adoption framework. During each phase of technology adoption process, there are enablers and inhibitors, affecting the actors and their objectives in the adoption process. This is crucial to understand in order to model the blocking points and challenges specific to each technology under investigation. On the contrary, there might be enablers to support and enhance the process of technology adoption. The last question in the preliminary study aims to investigate the

implications of these technologies to the implementation of the SES. By this, we mean the implications on the high-level target objectives of the SES. These objectives are 3-fold increase in capacity, improving safety by a factor of 10, enabling 10 percent reduction in the effects that flights have on the environment, and the provision of ATM services to the airspace users at a cost of at least 50 percent less. These high-level target objectives are followed by the key objectives of the SES: restructuring the European airspace as a function of air traffic flows, creation of additional capacity, and the increase on the overall efficiency of the air traffic management system.

3.5.3 The Interview Protocol - Case Studies

After successfully implementing the preliminary study, it has been found that some of the questions should be clarified and updated. Getting feedback from the first participants, the interview protocol has been updated [Kvale and Brinkmann(2009)]. First, the interview protocol is divided into two for each specific case study. Second, the questions are divided under main topics (introduction & related experience, technology and its implementation, actors, their roles and relationships, factors affecting the technology adoption process, impact of the SES), and detailed sub-questions are included, where specific details are needed. Finally, the interview protocol is formalized including an introduction of research purpose, researchers background, and details of the interview process itself. This is due to fact that this finalized interview protocol will be used to reach various types of actors and collect data from them. The interview protocol is not actor specific, and included the same questions for each representative of the actors. Within each actor, the researcher would like to capture all the actors, and perspectives of the interviewees about the other actors. The main aim of the interviews remain the same as to understand the actors, their roles and relationships during technology adoption process. Additionally, the updated interview protocol aims to collect the data related to the factors that are affecting the technology adoption process categorized into technical or operational, economic, social, legal, and political. There is also an additional question to investigate the specific challenges or barriers for the adoption of each technology. The interview protocol is executed as follows:

The Interview Protocol - Case Studies

Location:

Date/Time:

Interviewer: Engin Zeki

Interviewee:

My name is Engin Zeki and, I am currently a PhD candidate at EPFL following the Management of Technology programme. The goal of my project is to understand the technology adoption process of new technologies in European ATM, specifically virtual centre and flight-centric air traffic control technologies. My initial aim is to conceptualize the technology adoption process in European ATM by collecting qualitative data from interviews with domain experts. Ultimately, this study will implement stakeholder theory combined with actor-network methodology to understand the technology adoption process as a collection of actors' interests, alignments, and network formation. The information collected from these interviews assist us to evaluate the technology adoption process using thematic analysis and validate our conceptual framework.

We value your opinions and insights for this interview as a domain expert. The face-to-face interviews will take approximately 60 minutes. The interview is semi-structured which follows a designed interview protocol to guide an open discussion with the domain expert. The consent form will be collected after the interview. If there are any questions related to the topic or the interview, please feel free to ask before the interview.

I will start by presenting my brief abstract for my PhD project, and then we will move on to the questions for guiding the interview:

This research focuses on emerging technologies in European air traffic management (ATM), specifically investigating technology adoption by the main stakeholders. European ATM consists of a highly fragmented aviation infrastructure, built and managed by actors with diverse interests. Rapid developments in information and communication technologies affects European ATM as also the case with other network industries. Air Navigation Service Providers (ANSPs) and the industry more generally started experimenting with digital technologies, such as Flight-Centric Operations/Sector-less ATM and Cloud-Based Services (Virtual Centre Air Traffic Control (VATC) & Cloud Flight Data Processing Systems). These technologies have the possibility to disrupt or at least change the current ANS provision. Nevertheless, we do not know the possible impact of these technologies on European ATM in general and the Single European Sky in particular. This PhD project will study the possible adoption of two emerging technologies: flight-centric operations and cloud-based ATC on European ATM. The following two questions will be answered in this thesis. The first research question is: How and to what extent will emerging technologies - in particular flight-centric operations and cloud-based services be taken up and ultimately adopted by the relevant actors of European ATM? The second research question is: What will the consequences of such adoption be on the process of implementing the Single European Sky? In order to analyse, understand and evaluate the technology adoption, this thesis takes a socio-technical approach using stakeholder theory combined with actor-network theory (ANT) methodology. Different from the traditional adoption research approaches, such as innovation diffusion, ANT focuses on how new technologies come into

existence and evolve. The processes of ANT packed into problematization, interessement, enrolment and mobilisation are used to explain the adoption of flight-centric operations and cloud-based technologies. The data is collected qualitatively through participant observation, interviews and document analysis. The interactions between the key actors are analysed for further recommendation on the adoption of these new technologies.

Introduction & Related Experience

1. In order to learn more about you before starting the interview, please provide brief information about yourself, your work experience and your expertise in the domain of European air traffic management.

Technology and Its Implementation

2. What are the key changes and developments that (case study 1: virtual centre, case study 2: flight-centric operations) bring to the European air traffic management?

Actors, Their Roles and Relationships

3. Who are, in your opinion, the actors/stakeholders that are involved in the technology adoption process of (case study 1: virtual centre, case study 2: flight-centric operations) in European ATM?
4. What are the roles of each actor you mentioned in the technology adoption process?
5. What are the relationships between the actors in the technology adoption process? How do you think that these relationships affect the process of technology adoption?
6. Who are the key actors that have the stronger force in the adoption process for (case study 1: virtual centre, case study 2: flight-centric operations)? There are some actors, which have the ability to promote/push the technology adoption process. These actors are critical for the creation and stabilisation of the relationships between the actors and are the drivers in the technology adoption process. On the other hand, who are the actors that inhibits/pull the technology adoption process for (case study 1: virtual centre, case study 2: flight-centric operations)?

Factors Affecting the Technology Adoption Process

7. What factors (enablers, inhibitors) influence the adoption process of (case study 1: virtual centre, case study 2: flight-centric operations) in European ATM?

- (a) What are the technical/operational factors influencing the adoption process of (case study 1: virtual centre, case study 2: flight-centric operations)?
 - (b) What are the economic factors influencing the adoption process of (case study 1: virtual centre, case study 2: flight-centric operations)?
 - (c) What are the social factors influencing the adoption process of (case study 1: virtual centre, case study 2: flight-centric operations)?
 - (d) What are the legal factors influencing the adoption process of (case study 1: virtual centre, case study 2: flight-centric operations)?
 - (e) What are the political factors influencing the adoption process of (case study 1: virtual centre, case study 2: flight-centric operations)?
8. What are the specific challenges/barriers for (case study 1: virtual centre, case study 2: flight-centric operations) to be adopted by the relevant actors in European Air Traffic Management?

Impact on the Single European Sky

9. What will the consequences of (case study 1: virtual centre, case study 2: flight-centric operations) be on the process of implementing the Single European Sky and its objectives?
10. If this technology is implemented, what do you think will be impacted for the target objectives of the SES?

3.6 Research Methodology

It is important to emphasize that there is a distinction between how the research methodology is utilized to interpret the past and future considering the two cases of technology adoption. Considering the past, ANT and ST provides the necessary tools to identify the actors, their roles and relationships in the adoption process, modeling the stages of adoption by looking into the factors, barriers and challenges affecting the process. For the future, the most probable scenario of the interaction of the actors are presented focusing on the likelihood of the behaviour of actors moving towards the stages of adoption. As for the two cases, mainly the first two stages of adoption, problematization and interestment are related to the past events, whereas the next two stages, enrollment and mobilization are related to the future.

The combination of ANT and ST provides a powerful approach to look into the historical progress of technology adoption. The cases of virtual centre and flight-centric operations provide an extensive overview of the formation of a network of adoption. The roles and relationships of actors are shaped by their behaviours in the past, affected by the factors, barriers and challenges during the adoption process. Initially, the idea or concept of the technology is

introduced by the focal actor(s) in the first stage of problematisation. Then interested actors carry the network further into the adoption stages of interest and enrolment through the progress of technology. This process generally is a multi-actor process, where each actor could perceive the technology from their own perspective. The combination of ANT and ST provides an extensive approach in understanding the historical progress of the adoption of these two technologies. By mapping the actors, their objectives and relationships in combination with the factors affecting them while they adopt new technologies, the methodology provides a concise historical picture for the technology adoption process.

Additionally, interpreting the past derives the backbone of the conceptual framework for the technology adoption. Concretely, actors reflect their objectives through their actions in the past in relation to a specific technology. Most of the connections between the actors, and the structure of the network relies on how they formed these relationships previously and under specific circumstances. Specifically, for technology adoption, the actors could play their generic roles, and additionally their specific roles for the technology adoption case under investigation. Furthermore, factors, barriers and challenges affecting the adoption could be directly attached to past events and milestones in the adoption process. Thus, it is straightforward to use combination of ANT and ST as a research methodology while looking towards the past. Considering the second stage of adoption, interest, where the interested actors join the network, the conceptual framework also relies on the interpretation of the previous events. In this stage, specifically for the two cases, a number of ANSPs join the network forming aligned interests with the focal actor(s). From a methodological point of view, the conceptual framework could effectively interpret the past events and incorporate inside the elements of the framework.

Of course, the interaction between the actors could change dynamically, according to their dynamic objectives while adopting a new technology. That constitutes the future part of the research methodology, where the research methodology aims to capture the most probable scenario for both of case studies. A number of actors could attach or detach to the network during the stages of adoption and progress through the stages of adoption. Thus, it is important to follow the actors in the future for further information on how do they position themselves inside the network, or whether they could solve the barriers or challenges associated to a specific technology. The methodology used in this thesis follows the most probable scenario that is derived from the convergence of the actors' objectives. This scenario is built to provide a future outlook for the adoption of the technology and further evaluate their roles, reiterate according to optimize the technology adoption process. Furthermore, it is important to note that the barriers in the third and final stages of adoption could be further evaluated from the current situation including the relevant actors that could be able to solve them. This is similar to examining risks related to the adoption process that could create significant barriers for the further adoption of new technology.

The future interpretation marks the switch between the third stage, enrolment, towards the final stage, mobilization. This passage is generally marked with the stabilization of the network

and mobilizing towards attracting more actors inside. There are also similar patterns in the adoption of technologies and solutions in the SESAR portfolio, in which first the ANSPs start the adoption process, then the political and regulatory actors come into the picture in the final stages. In these stages, new actors could attach to the network, or in the reverse side, some actors could detach according to their objectives and the roadmap of the adoption of new technology. Hence, there might exist deviations from the most probable scenario that the research methodology aims to present. In order to overcome these limitations, in the future research section, it is suggested to support the conceptual framework with quantitative models, such as system dynamics or agent-based models. Concretely, quantitative models provide simulation of scenarios under changing parameters, such as the interest of actors, their roles and relationship and the extent of the affect of the factors and barriers in the adoption process.

Additionally, identification of the barriers and challenges have important implications while constructing the future scenario. Not only they are related to past, but these challenges and barriers provide a hindsight for the future of the adoption. As an example, the lack of a market for virtual centre creates a significant barrier for the actors to move towards the third stage, enrollment, into the final stage, mobilization, in the technology adoption process. For successful adoption of the virtual centre, this marks an important milestone to be passed in the third stage, enrollment. As for the case of the flight-centric operations, a similar example could be the milestone of pre-requisite social and economic challenges affecting the adoption through the passage from third to final stage. Furthermore, the factors affecting the adoption could be reverse interpreted to derive scenarios for the future. In the future, if these factors change according to the dynamics of the technological landscape, then the stages could be updated to reflect the changes of the effects of the factors for the adoption.

As a conclusion for this chapter, the methodological implications direct towards a clear distinction between the past and the future interpretation. Looking towards the past is straightforward using the combination of ANT and ST as a research methodology. Interpreting the future includes the presentation of the most probable scenario, that the actors converge towards realizing their common objectives. Deviations from the most probable scenario is possible, in order to overcome these limitations in the future, quantitative models could form additional scenarios which could be simulated with parameterized values. Additionally, the possible quantitative models are described in detail in the future research section of the thesis.

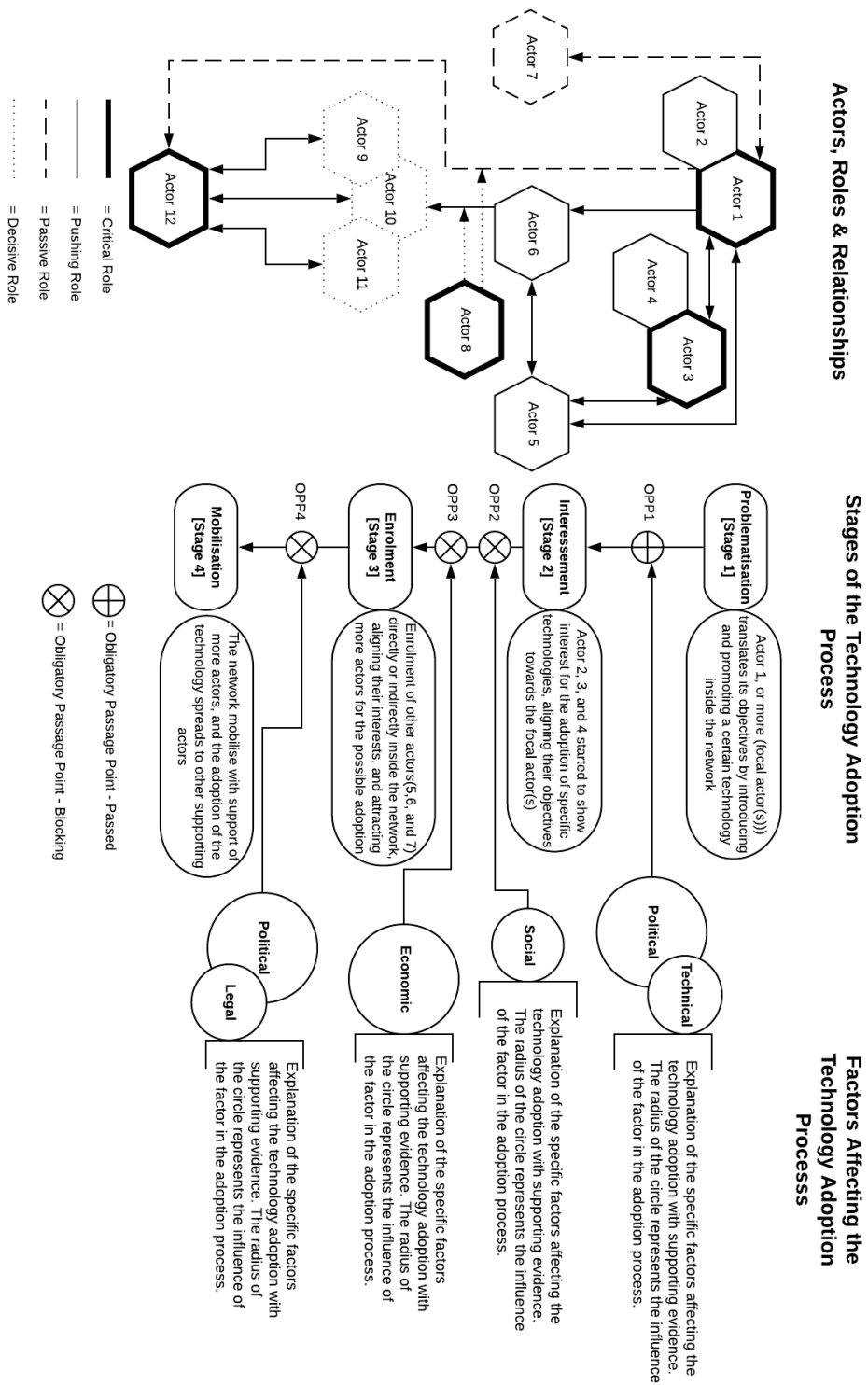


Figure 3.9 – Graphical Template for the Illustration of the Technology Adoption in European ATM

4 Guide to Case Studies

This chapter establishes the guide for the case studies by providing the common structures used inside each specific case study. As previously mentioned, participant observation in this research started even before the decision of the specific cases. Therefore, initially the actors and their interests are examined through their behaviour, not only on the adoption of specific technologies, but also through their mutual relationships between each other following the conceptual framework and tools. This includes their objectives, the alignment of their interests through their journey of adoption and how they perceive each other during this adoption process. The chapter reviews relevant actors, their generic objectives and relationships between each other in relation with the adoption of new technologies in the European ATM.

4.1 Actors and Their Interests

This section presents the actors that are involved in technology adoption process in the European ATM. In order to follow a systematic process, we have identified a method for the identification of stakeholders, adapted from the previous implementations of stakeholder theory. Pouloudi (2016) discretely pointed out the steps for the clear identification of the stakeholders in the case of technology adoption of information systems. Furthermore, these steps guide how the stakeholders can be categorized and segregated for their power, giving emphasizes on the identification of their roles, interests, perception and behaviour [Nancy et al.(2016)Nancy, Currie, and Whitley]. Stakeholder theory provides generic steps for the identification of the actors, yet never directly propose a stepwise approach for the identification of the stakeholders. For stakeholder theory, any actor that has a stake in the technology adoption process can be considered as a stakeholder. Correspondingly, actor-network theory also sets rather flexible ideas on how to identify the stakeholders. The main suggestion is to follow the actors as a researcher, and consider the ones that have the ability to form a network of translations and interests.

Pouloudi (1999) establishes a step-wise stakeholder identification framework relying on the

fact that there is a need to clarify the actors in the case of information systems [Pouloudi(1999)]. Reviewing the previous and current methods of stakeholder theory, the paper provides the initial concrete steps on the decision for the stakeholders in information systems. Interpretive stakeholder identification approach should be dynamic, context dependant, and iterative [Pouloudi et al.(2004)Pouloudi, Gandecha, Atkinson, and Papazafeiropoulou]. To put it another way, we need concrete steps to follow to identify the stakeholders, as both from a combination of stakeholder theory and ANT. Reviewing the previous literature Pouloudi (2016) sets these concrete steps in a 5 step approach as follows [Nancy et al.(2016)Nancy, Currie, and Whitley]:

1. The set and number of stakeholders are context and time dependent.
2. Stakeholders cannot be viewed in isolation.
3. Stakeholders may have multiple roles.
4. Different stakeholders (even within the same stakeholder group) may have different values and perspectives - these may be explicit, implicit or hidden.
5. Stakeholder roles, perspectives and alliance may change over time.
6. Stakeholder relations and power matter in the shifts in their roles, perceptions and alliances.
7. Stakeholders may be unable to serve their interests or realize their wishes.

As a matter of fact, the first principle defines stakeholders under a specific context and timeline. In this case, this thesis specifically looks into the adoption of two technologies in European ATM, virtual centre and flight-centric operations. Thus, the relevant stakeholders are the ones that have a stake in the technology adoption process of these two technologies. Even though the technologies under investigation are different, apparently the same actors in the European ATM interact for the adoption of new technologies as focused in the case studies under investigation. The timeline of the study is between 2016 and 2020, combined with a past, current and future outlook on stakeholders considering the length of the research for the PhD. The roles and behaviours of the stakeholders are captured within these timeline, observing the multiple roles and dynamic changes in their objectives. Following that, the second principle states that the stakeholders cannot be viewed in isolation. This is practically applicable that the objectives of the stakeholders exist in a complex multiple stakeholder environment. A vast number of stakeholders exist in European ATM, so the case studies limit the scope to the relevant stakeholder in European considering the technology adoption context.

Correspondingly for the third principle, the stakeholders under investigation may have multiple roles, including different translations of their roles given a specific technology. This section will present the generic roles of the stakeholders in the technology adoption process

without being context specific for each technology. The categorization of the roles are also provided in detail in the following section. The value of the analysis depends on the fourth principle, where different stakeholders may have different values and perspectives. In the technology adoption process, not all the stakeholders have the same interests and objectives. The objectives may also be affected by the various factors of technical, political, social, legal and economic. For this reason, we have categorized their interests according to their ability to push or pull the technology adoption process. By doing this, the misalignment between the actors are observed and presented in the case studies. The fifth principle focuses on the possible changes of roles, perspectives and alliances of stakeholders over time. Given the time period of 4 years, and the initial adoption process, it is observed that the generic roles of the stakeholders are steady and do not radically change over time.

In addition to the previous guidelines, Pouloudi (2016) emphasizes that stakeholder relations and power matter in the shifts in their roles, perceptions and alliances. Consequently, the relationships between the actors and how this affect the overall network are keys in our analysis. Hence, this is critical for the stages of the adoption of the actors, which is guided by the ANT perspective overall. Finally, the last principle states that the stakeholders may be unable to serve their interests or realize their wishes. This is apparent in the barriers and challenges that the stakeholders face during their adoption of new technologies. Often times, it is hard to form alliances for the actors to take up new technologies. It is not always the case that all the objectives of all actors are aligned. The constellation of the alignment of the actors' interests decide on the fate of adoption affected by a numerous number of factors though the adoption journey.

4.1.1 Identification of Stakeholders

This section presents the identification process of the stakeholder during the research. The identification of the stakeholders starts with the focal actor Eurocontrol, where the research started within this main network coordinating actor. Similar to other network industries, air traffic consists of a number of diverse actors, tightly working together in an ensemble, delivering a safety critical service to the passengers. Following the actors, the study managed to identify their roles, objectives and relationships between them. In this section, I will briefly present my initial discovery of the actors, focusing on their generic roles while they adopt new technologies.

Being in EUROCONTROL for this research, which is the ideal place to be due to the presence of multiple stakeholder collaboration model of the SES project, it was rather straightforward to connect with the other relevant actors. EUROCONTROL is one of the key players of the SES, hence is the forefront of the research, development, and adoption of new technologies in European ATM. Being there, it is a natural way to meet all the stakeholders involved in the adoption of new technologies. Constantly, there exists meetings with stakeholders, constructive discussions on new technologies, and opportunity to discover the actors in

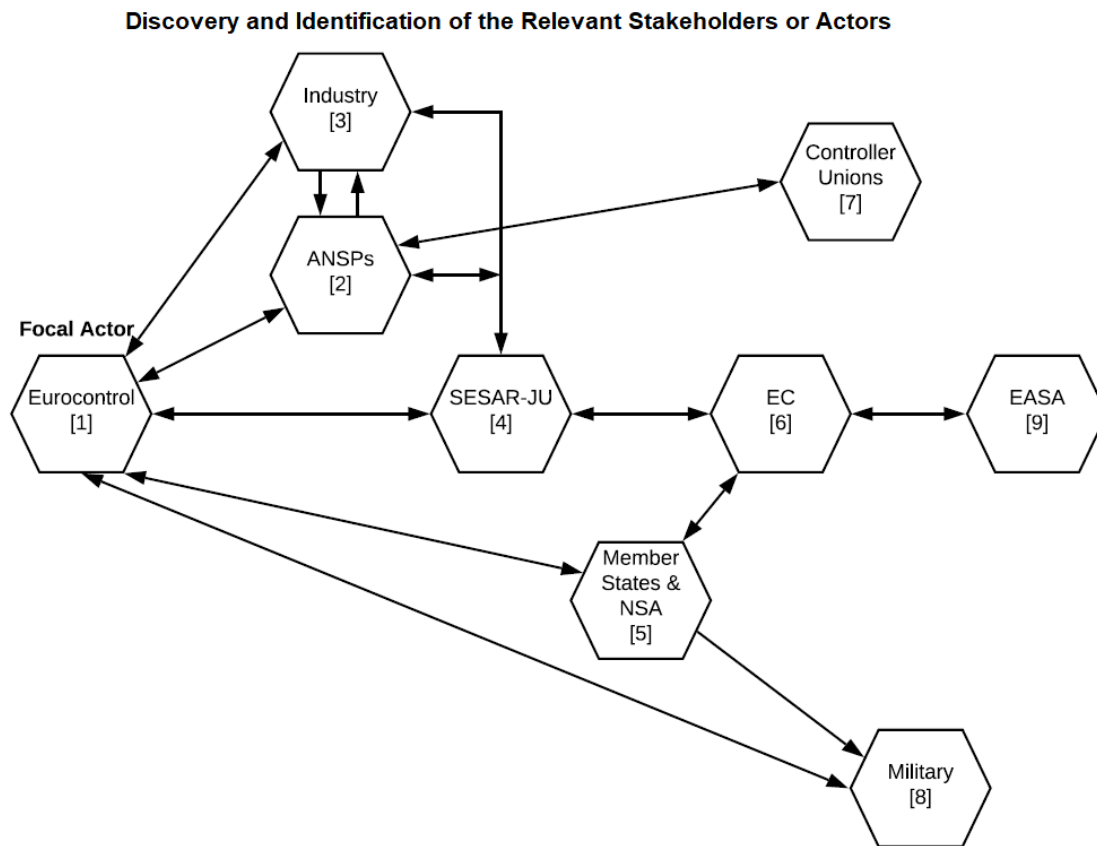


Figure 4.1 – Discovery and Identification of the Relevant Stakeholders or Actors

detail throughout the research journey. The first actor, arising naturally from the workplace, is EUROCONTROL. Then, the identification of the surrounding actors followed directly from the focal actor. As illustrated in Figure 4.1, the identification of the actors is connected to understanding all the actors that have a relationship with EUROCONTROL. The numbers in Figure 4.1 emphasize the order of discovery of the actors during the first year of the research. Initially, the inseparable pair of ANSPs and Manufacturing Industry have been identified as the major actors in the technology adoption process. This is followed by spotting the actor, SESAR-JU, which is a joint partnership between the European Commission and EUROCONTROL in order to make the SESAR project a reality in joint cooperation with industry, ANSPs and the EC.

Following the actors, during the key meetings the actors of the European Commission and representatives of the Member States have been identified. Getting to know the ANSPs in more detail, the importance of the ATCOs and the Controller Unions have been identified by the researcher as a powerful main actor in the technology adoption process. Within EUROCONTROL, there exists the Military representatives. Furthermore, a recent entity EASA is included in the scope of the research for the safety and standard regulation. Overall, these constitute the main actors that have a mutual relationship between each other during the research, development, deployment and adoption of new technologies. There are of course

4.2. Description of the Stakeholders and Their Objectives

other side actors, who are involved or indirectly affected by the adoption of new technologies. These actors are namely airports, airlines, aircraft manufacturers, and SESAR Deployment Manager. The side actors are discovered in the data collection phase with the main actors, where either they play a minor or passive role in the technology adoption process.

4.2 Description of the Stakeholders and Their Objectives

Before starting with the detailed description of the stakeholders involved in the technology adoption process in the European ATM, this section initially starts by describing the categorization of the roles of actors as in 5 main categories: pushing, critical, decisive, generic and passive. This categorization is derived from the thematic analysis of the combination of participant observation, documentary analysis and interviews. At the same time, the conceptual framework and the taxonomy of the case studies influence this categorization.

4.2.1 Categories of the Roles of the Stakeholders

In the technology adoption process, the actors in the European ATM represent their objectives in various categories of roles. After the coding process for the actors and their objectives, these roles are found to be converging under 5 main categories within the context of technology adoption. With attention to their specific importance in the adoption process, the name of the roles and the corresponding explanation is provided in Table 4.1.

These roles have a hierarchical level between each other, starting with the critical role as being the most favorable for the adoption of a technology, ranging towards pushing, decisive, and generic roles through passive role, which is the least favorable for the adoption. In the graphical representations, which are presented specifically in each technology adoption case study, the most prominent role of the actor is illustrated as actors could have multiple roles associated to them.

EUROCONTROL

EUROCONTROL is the European Organization for the Safety of Air Navigation, a supranational non-profit organization with 41 Member States, covering a larger European airspace than the European Union. The main responsibility of EUROCONTROL is the Network Management, which is role designated for a period of 10 years by the European Commission. EUROCONTROL manages the network in cooperation with the ANSPs, airports, airlines, and Military of its Member States. The organization is governed by an international convention, having two governing bodies of the EUROCONTROL Commission and the Provisional Council, and the Agency as the executive body. Considering the SES, the main mission of EUROCONTROL is to modernize the European ATM by researching, developing, and assisting the adoption of new technologies. The SES is initially launched by the European Commission in 2004 in order

Chapter 4. Guide to Case Studies

Name of the Role	Description of the Role
Pushing Role	A pushing role is an attribute attached to the corresponding actor when the objectives of the actor signal to accept, promote or push the adoption of a new technology. An actor with a pushing role is in favor of the adoption and tries to align their objectives with actors inside the network towards adopting a new technology.
Critical Role	A critical role is an attribute attached to the corresponding actor when the objectives of the actor carry critical importance in the adoption process of a new technology. An actor with a critical role is either one of the focal actors or have an objective which is important for the successful adoption of a new technology.
Decisive Role	A decisive role is an attribute attached to the corresponding actor when the objectives of the actor depend on a specific attribute or event. An actor with a decisive role decides to join the network of interested actors in the adoption process. The decision of the actor either promotes or inhibits the adoption process of a new technology.
Generic Role	A generic role is an attribute attached to the corresponding actor when the objectives of the actor originate from the generic objectives of the actor, not specific to a new technology under adoption. An actor with a generic role functions its objectives as usual without considering the technology adoption process.
Passive Role	A passive role is an attribute attached to the corresponding actor when the objectives of the actor does not directly affect the adoption of a new technology. An actor with a passive role does not actively promote or inhibit the adoption of a new technology, rather its objectives rely on watching and understanding the adoption of a new technology.

Table 4.1 – Description of the Types of Roles of Actors in the Technology Adoption Process

to reshape the architecture, respond to the capacity crunch, and raise the efficiency of the European ATM. A Pan-European approach is adopted to reach a number of high-level target objectives, these include:

- **Capacity:** Increasing the capacity 3-fold , aiming to reduce delays on the ground and air
- **Safety:** Improving safety by a factor of 10
- **Environment:** Reaching 10 percent reduction in the negative environment effects caused by flights
- **Cost-efficiency:** Decreasing 50 percent of the cost of ATM services provided to airspace users

EUROCONTROL also has the role of the Network Manager, which controls, and optimizes the overall ATM network of the Europe, by designating the optimal flight plan and routes for

4.2. Description of the Stakeholders and Their Objectives

flights. The SESAR programme has mainly be driven by the joint partnership with SESAR-JU. This also shapes the EU air traffic policy by following the initiative of the EC. Yet, it is also challenging to find aligned interests for all the Member states involved. Following these high-level target objectives, EUROCONTROL has specific roles in the adoption of new technologies in the European ATM. These roles are thematically analyzed combining both the participant observation and documentary analysis. The sub-themes emerging from the anaylsis then converged into main themes, and the roles are categorized as previously described previously in the section. The generic roles of EUROCONTROL in the adoption of new technologies in the European ATM is summarized as follows.

Air Navigation Service Providers (ANSPs)

ANSP is an organisation which locally provides the air navigation services for a specific airspace of a country. Mainly, ANSPs are state entities with a few exceptions of privatized shareholders. Based on the ATM Cost-Effectiveness (ACE) 2017 bench-marking report, there are currently 38 ANSPs in Europe, providing air navigation services for its Member States. Civil Air Navigation Services Organization (CANSO) represents the trade association of ANSPs. CANSO also needed to adapt to the changing regulatory environment brought by the SES [Baumgartner and Finger(2014)]. With the emergence of new technologies, ANSPs also need to adapt to the evolving needs of European environment. Mainly, ANSPs remain in between the users (airlines), owners (Member States), and employees (ATCOs).

The air navigation services can be generalized into three categories: ground infrastructure, commmunication, navigation, and surveillance (CNS) provision, and ATM. Since the main function of the ANSP is service provision, any new technology that affects the provision is considered by the ANSP. ANSPs are also responsible for all the necessary hardware, software, and maintenance to function any technology in order to provide these services. Responding to the performance scheme and pilot common project (PCP) requirements, ANSPs also adhere to the practices and recommendations of the EC. Baumgartner et al. (2014) argues that the efficiency of ANSPs are affected by two factors: current route-charging scheme, and sovereignty of airspace. The optimization of the route of flights is not the best given that the routes are charged according to the kilometer of the flight. The sovereignty of the airspace makes it harder for ANSPs to share information, data, and collaborate in new technologies.

In Europe, Air Navigation Service Providers is public or private organizations that are attached to each Member State, responsible for the service provision of air navigation services for the general air traffic. According to the ATM Cost-Effectiveness (ACE) report by EUROCONTROL, there exists 38 ANSPs in Europe providing services in the European airspace. ANSPs consist of the necessary infrastructure, hardware, software, management, technical and operational staff to provide the services. The operational staff is the ATCOs, who are the forefront of the air traffic control, directly working on the separation of aircraft from their controller working position (CWP). The main responsibilities of an ANSP includes the following distinct functions:

Chapter 4. Guide to Case Studies

- Air Traffic Management (ATM)
- Communication navigation and surveillance systems (CNS)
- Meteorological service for air navigation (MET)
- Search and Rescue (SAR)
- Aeronautical information services & management (AIS/AIM)

Considering the adoption of new technologies, ANSPs have diverse objectives, even locally inside a single ANSP. The management, technical, and operational staff might have different objectives when it comes to the adoption of new technologies. This creates a mixed opinion on the adoption of new technologies for ANSPs. Yet, it is crucial to understand the generic objectives of each category inside an ANSP in order to examine the specific motivation for each technology. Additionally, the airspace size and complexity that the ANSP handles directly influence the perspective of ANSP towards new technologies. Small, medium and big sized ANSPs react differently to the adoption of new technologies due to a number of factors affecting their decision-making process.

Airspace Users

Considering the adoption of the virtual centre and flight-centric operations, airspace users play an indirect role through defining the objectives of other actors. Specifically, airlines translates their cost-effectiveness objectives towards the definition of the SES and its high-level target objectives. By this, SESAR aims the realize the objectives of the SES on defining the solutions and projects that involve the adoption of new technologies. This indirect role of the airspace users translate inside the objectives of all other actors. Defragmentation, brought forth by this new technologies, also is a indirect objective of the airspace users, as it enables new business models that could lead to increasing cost-effectiveness. It can be observed that the cost-effectiveness objective of other actors are shaped by the initial aims of the SES programme. As the SES initially started as a consequence of the needs of the airspace users, these objectives indirectly translate through the approach of the SES and the research pillar SESAR.

Manufacturing Industry

The manufacturing industry is the main provider of the hardware, software and maintenance to the systems that provide air traffic services in the European ATM. Since the market functions in a monopolistic way, there is slow pace in the development and innovation of new technologies. Currently, legacy systems are in use providing conventional ATC services. Each ANSP has an industry partner, which provides them the necessary hardware and software to provide services. The fragmentation over the European airspace is apparent of the ground

4.2. Description of the Stakeholders and Their Objectives

systems and deployment. The interoperability between the flight data processing systems is limited due to the fact that the industry partners provide tailor-made solutions to each ANSP [Baumgartner and Finger(2014)].

The business interests of the manufacturing industry inhibit harmonization of the ground infrastructure. This is due to the fact that defragmentation would reduce the number of products in the market. Additionally, harmonization brings competition which is clashing with the monopoly structures of the manufacturing industry today. One of the main objectives of SESAR is to defragment the current fragmented infrastructure and service provision in Europe.

The manufacturing industry are the companies which provide the necessary hardware, software and services to the ANSPs. Mainly, the ANSPs partner with an industry manufacturer in order to provide their necessary air navigation services. For this reason, the relationship between ANSPs and the manufacturing industry is long-lasting, and mutual objectives between the two actors are established. In Europe, the main objective of the manufacturing industry is to maximize their profits by selling and providing as many systems as possible to the relevant ANSP partners. This creates monolithic giant industry companies, who are facing low competition, and have mixed opinions on the adoption of new technologies. Additionally, there also exists small to medium sized companies, recently new in the market, and interested in investing in new technologies. This creates a pressure on the current market players considering that the new technologies for the European ATM is emerging rapidly.

SESAR-Joint Undertaking & SESAR Deployment Manager

The SESAR Joint Undertaking (SESAR-JU) is a non-profit entity, created by European Commission and EUROCONTROL in 2007, with the objective of research and development for the modernization of the European ATM in the scope of SESAR. Specifically, the SESAR-JU aims to involve diverse stakeholders of ANSPs, manufacturing industry, airspace users, airports, professional organizations, and academia in the development of new technologies for European ATM. In the scope of the SESAR programme, SESAR-JU acts a supervisor for the technological projects and solutions following the roadmap of the SESAR Master Plan. The responsibilities include the following main tasks considering the modernization of the European ATM:

- Secure the appropriate funding for the SESAR Programme by combining and managing public and private funds
- Organise the technical research and development, validation and study work to be carried out concentrating all relevant R&D resources for the implementation of the ATM Master Plan
- Define and update the SESAR work programme, in accordance with work progress
- Ensure project involvement by stakeholders from the ATM sector (service providers,

users, professional organisations, airports, manufacturers, as well as the scientific community and institutions)

- Ensure consistency, efficiency and technical progress on all items of the work programme
- Supervise the activities to develop joint products identified in the ATM Master Plan
- Report on the development phase results, and prepare relevant actions for the implementation of these results

The Member States

The European states play a key role on the research, development, and deployment of the SES. First, the SES is funded by the EU within EC legislative. The design of the SES has been designated to SESAR-JU and EUROCONTROL. The Member States actually include a number of actors under its umbrella. Specifically, the ANSPs, and the Military functions under the responsibility of the Member States.

The National State Authorities (NSA), on the other hand, are independent regulators of the air transport security and economics. Yet, the policy function of the NSAs still remain in correspondence to the Ministry of Transport. Although airports are locally owned, they are regulated in a national level. A similar case is airports, where they are generally privately-owned, but regulated by the national regulator.

The primary interest of the Member States is that they want to make sure that the safety, security of air traffic are intact. Following that they support ANSPs and protect their political, social, and economic interests. Development of the airports is one of the key roles of the Member States, as the airports benefit the country in the mean of economic development.

The Members States also act as associates of the ICAO, and for the European states EUROCONTROL, where they represent their national interests and need to comply with the regulations and recommendations by these international organizations.

The European Commission

The European Commission is the executive body of the European Union and its Member States, representing their objectives and interests. The roles of the EC includes the decision-making, proposing legislation to the European law, while also managing the funds and overseeing the EU treaties. Each Member States is represented in the College of Commissioners, and the president is nominated by the European Council. The general roles of the EC is summarized as follows:

- Proposing new legislation

4.2. Description of the Stakeholders and Their Objectives

- Various European institutions are involved in the rule making process, such as the Council of European Union and the European Parliament along with the European Commission
- Regulations are proposed within the implementation area consisting of EU States, and published in the EU Official Journal.
- Directives are transposed before it is applicable in corresponding national legal order of the EU Member State.
- The EC has the right of initiative, which means that the new legislation proposed by the EC has to be passed by the Council and the Parliament.
- The legislation that has been passed by the European Community has priority over any national rule.
- Implementing EU policies and the budget
 - The EC has a supervisory role on the implementing and spending the EU budget.
- Enforcing European law
 - The EC and the Court of Justice is responsible for the assurance of the proper implementation of EU law in all EU Member States
- Representing the EU on the international stage
 - The EC represents its 28 Member States internationally on the negotiation of international agreements

In order to execute these functions through the EU, the EC has built a vast expertise in the preparation of a regulatory framework. The expertise comes from the assessment of the economic, social, political, and environmental impacts of the regulation and laws, assembling the right experts and teams, and implementing clear and efficient safeguards. Regarding civil aviation, the Directorate-General for Mobility and Transport (DG-MOVE) of the EC is responsible for EU policy on mobility and transport. Among the main responsibilities, the SES project and the modernization of Air Traffic Control is directly related to the adoption of new technologies in the European ATM. The EC manages the aviation area by generating a range of community regulations, directives and implementing rules. These include the regulation of accidents and safety issues in the scope of the European airspace. The Single Sky Committee, composed of two representatives from each EU Member State, assists the EC on the implementation of the SES.

The EC has direct relations to the main actors in the European ATM. Moreover, the EC has launched a number of these actors, such as SESAR-JU, and EASA in close cooperation with EUROCONTROL. The European Community also launched an aviation safety regulatory system, focusing on progressively covering the safety and performance of aerodromes, ATM and ANS services. This marked the emergence of a new aviation safety agency for the European Union.

European Union Aviation Safety Agency (EASA)

European Union Aviation Safety Agency (EASA) is established for as a separate safety specialized organization for the European Member States. Based in Cologne, having 32 Member States, EASA aims to standardize the certification for safety and environmental protection among its Member States. The main tasks of EASA includes the following main areas:

- Draft implementing rules in all fields pertinent to the EASA mission
- Certify & approve products and organisations, in fields where EASA has exclusive competence
- Provide oversight and support to Member States in fields where EASA has shared competence
- Promote the use of European and worldwide standards
- Cooperate with international actors in order to achieve the highest safety level for EU citizens globally

Controller Unions

A number of European and global professional staff organizations exist in order to support and protect the rights and social conditions of the ATCOs, ANSP staff and pilots. Among these, globally International Federation of Air Traffic Controllers' Association (IFATCA) and International Federation of Air Traffic Safety Electronics Association are the main ones. For the European case, European Trade Union Organization and the European Cockpit Association creates a platform for the coordination between the staff between the ATCOs and flight crews [Baumgartner and Finger(2014)]. These organizations mainly protect the social interests of the air traffic controllers (ATCOs) by establishing coordination with various European institutions.

These organizations are mainly non-profit and for the supporting the interests of the groups that are forming them. The main aim is to protect and safeguard the interests of the ATC profession. Additionally, they promote the safety, efficiency and regularity in International Air Navigation. As ATCO unions, they want to make sure that the safe and orderly systems of ATC is in development within having close cooperation with other international organizations.

Military

The military has the multiple properties embedded in a single actor. It is mainly an ANSP and airspace user with advanced authority and capabilities. Military provides service for its own airspace as an ANSP, while also uses the civilian airspace whenever it needs as an airspace user. Without the consensus of the military, it is challenging to progress with the SES. When it comes to accept and adopt new technologies, the military becomes a decisive actor. The first

4.2. Description of the Stakeholders and Their Objectives

priority of the military is to protect national sovereignty and security. There are many reserved areas in the European airspace, which makes inefficient for the civilian air traffic. The project Advanced Flexible Use of Airspace targets this by optimizing the airspace reservations of the military.

The military is a decisive player, where it might intervene with the SES process when it sees an effect on the either national sovereignty or security. In the future, new technologies surely create new issues related to the cyber-security legislation due sharing of data throughout Europe, or by enabling location independent services. Thus, the Military act as a decisive actor through the Member States and its corresponding local ANSP.

5 The Virtual Centre

5.1 The Concept and History

The virtual centre technology aims to defragment the provision of ATC by combining and standardizing the infrastructure, hardware and software between the European Area Control Centres (ACCs). Currently, there are 64 ACCs spread around the European airspace that provide ATC services for the aircraft locally. This creates a patchwork of solutions to develop, support, maintain these systems with low-level of information sharing between the systems. Based on the principles of open service-oriented architectures and backed by cloud-based infrastructure, virtual centre aims to virtually defragment the services by enabling location and infrastructure independent provision of the services. Establishing this needs pre-requisite technologies, such as a new digital communication infrastructure supported within a Wide Area Network (WAN). Concretely, the ANSPs would be able to subscribe to services in a plug-and-play fashion using common data centres defragmented in a Pan-European scale. Additionally, the virtual centre requires modifications in the working positions of the ATCOs in order to support the modernized service interfaces. The components of the virtual centre is illustrated in Figure 5.1.

The initial aim of the virtual centre is to reduce costs by combining two or more ACCs together. Skyguide, the Swiss ANSP, introduced the concept in 2014 with the ambition of combining the Zurich and Geneva ACCs into a single centre. By this, the procedures, hardware, and software between the ACCs would be standardized within a new open service-oriented architecture. Of course, this would require heavy initial investment for the ANSP in order to be an early adopter of the technology. The micro-problem of the Swiss ANSP, combining the two ACCs, is a general problem for the whole Europe, where fragmented ACCs deliver separate services within their predefined sectors. Hence, virtual centre is regarded as a role model for the defragmentation solution for the whole Europe. By this, the fragmented ACCs could be merged towards optimizing the use of the resources. Virtual centre relies on a 3 layer approach, which directly separates into data, application and services layers. Mainly, a cloud-based system would support the sharing of information between the ACCs, and ultimately ANSPs

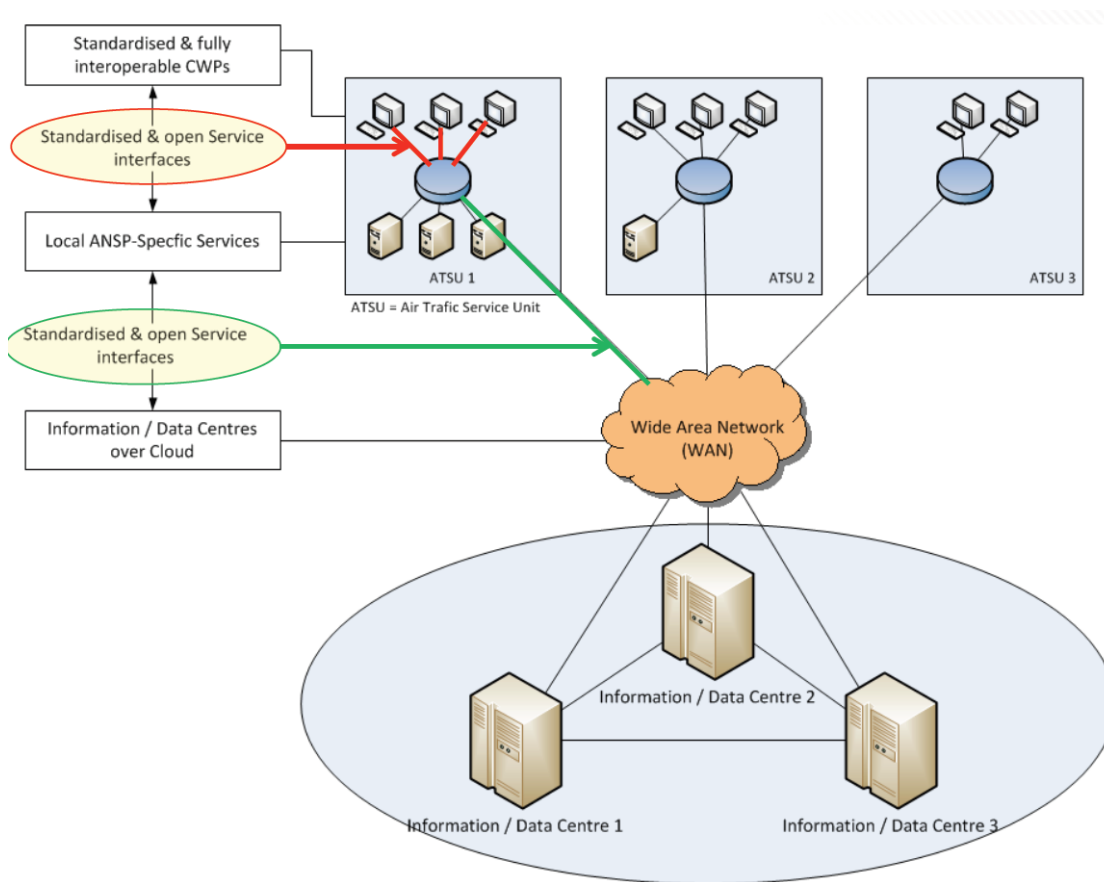


Figure 5.1 – Virtual Centre Model [Skyguide(2020)]

throughout Europe.

Currently, the implementation of the virtual centre remain local, initially defragmentation happens inside a single ANSP by combining its internal ACCs. Additionally, a number of contingency scenarios between ANSPs, where the delegation of airspace between ANSPs is considered. This requires further standardisation of all the procedures to support virtual centre technology between ANSPs. Additionally, rationalization of infrastructure is required to further introduce cost-effectiveness benefits. The virtual centre introduces radical changes inside the European ATM. First, the technology creates a paradigm shift from legacy systems towards service-oriented architectures in the European ATM. Second, it introduces radical changes in the business models of the actors, where location independent provision of services would be possible. Third, virtual centre could create the necessary momentum to virtually defragment the current fragmented provision of services in the European ATM.

5.1.1 Virtual Centre - Skyguide

Skyguide, the Swiss ANSP, carries the flag when it comes to the creation, adoption and spread of virtual centre. The initiative took shape in 2017, while Skyguide successfully completed Tranche 1 of Virtual Centre programme and move to Tranche 2. Within its small, but complex airspace, Skyguide tries to create the technical means for location independent air traffic control. In that Skyguide is a model for other countries if they have a tendency to adopt this technology. There is an apparent need in European ATM to shift its paradigm into service-based architectures.

The advancements on the technology side, with the possible disruptive technologies, are multi-fold. Yet, still ANSPs still use legacy technologies which are not future-proof. To reach to the target objectives of the SES, virtualization is one of the key solutions. Switzerland, in the case of Skyguide, has become the first adopter of the technology by directly embracing to combine Geneva and Zurich ATC into one seamless ATC. The virtual centre model is compatible with open-standard and service-based architectures, while also enabling System Wide Information Management (SWIM) concept. For this reason, the strategic investment of Skyguide is crucial for other adopters to form stable networks. However, Switzerland can not achieve these ambitions alone. Strategic partnerships are required for the adoption of technology. An innovative IT partner, with a new software and service, is needed. There are many pre-requisite technologies for virtual centre to happen, which makes it challenging to standardize. Moreover, the regulation is key for reaching the targets of virtual centre model.

The partnership with innovative ANSPs, industry partners and suppliers are the key elements for the extensive adoption of the virtual centre. If Switzerland successfully adopts the virtual centre technology, it will be an example to other European states. Klaus Meier, CIO, clearly states that they consider the inter-centre handover that happens between the Geneva and Zurich control centres a microcosm of what takes place above European Skies. Given that within the laboratory of Europe, Skyguide establishes to control Geneva and Zurich virtually from a single location, the other ANSPs would be interested in the technology. Moreover, this is a Single Sky system solution for the whole of Skyguide with ambitions to spread to the other countries of Europe. This technology has the potential to enable a harmonized and location-independent air traffic management system.

The virtual centre programme (VCP) directly aims to realize the Single European Sky ambitions set by the European Commission (EC). Yet, European states could not find a harmonized way out of their diverse interests. The functional airspace block (FAB) that Switzerland is in is FABEC, which is composed of Belgium, France, Germany, Luxembourg, Switzerland and the Netherlands. Skyguide proposed an initial hybrid architecture solution that creates a blueprint for the rest of the FABEC members. Since the solutions under SESAR is not tailor-made for each country, as in the case of Switzerland, every country researches for custom solutions for their needs. That is the main reason for Skyguide to create the virtual centre initiative, hence preparing a common operational concept (COC).

In order to create the virtual centre concept, Skyguide completed their dynamic roadmap. This roadmap includes the developments to enhance coordination with cooperating ACCs, improve conflict detection and achieve enhanced dynamic multi-sector planner. The COC also supports the target efficiency objectives for the Reference Period 3. It includes a revolutionary approach to shift the paradigm of flight data management from legacy systems to service-oriented architectures. Hence the mere definition of flight data processing system (FDPS) is changing. A traditional FPDS constitutes from route calculation, flight level allocation and sector-sequence calculation. The idea in virtual centre is to separate these functions into standardized services, and then defragment them among ACCs. They call it the new Flight Data Management (FDM) concept. For this, Skyguide takes an agile and exploratory approach for the progressive implementation.

With the implementation of virtual centre, there are substantial changes on how systems and people work. Specifically, ATCOs are affected by the new definition and use of the technologies. Skyguide points on the fact that new technologies will make the job of the controller very easier. However, it also requires to adjust the staff effort and training according to the new technologies. Skyguide manages to these changes by an initiative they call IT Software Factory. From the software side, a number of changes are to be implemented to enable virtual centre. First, they adopted an agile approach and implemented DevOps.

In the Vision 2035, Skyguide has established a solid approach to the future of European ATM. Among this vision, they include systems which are guided by artificial intelligence and machine learning to support ATM and its managers. The main part of the virtual centre is to be implemented in early 2020, with a possible disruption in the ATM market. This will place Skyguide as a data processor for other ANSPs and even work with neighbouring airspaces. Virtualization makes it possible a modern ATM system, which is location-independent with the absence the locked, or monolithic systems. Reducing duplication will create a single system, combining Geneva and Zurich, called System Switzerland.

Currently, Skyguide is reaching the second phase, Tranche 2 of the Virtual Centre (VCT2), of their programme. One of the key component is a tool, called CRYSTAL, to forecast the air traffic volume of a given airspace. The CRYSTAL tool is used to predict the staff's workload and peaks, additionally the organization of the ATC control room. This solution already exists in GVA airport and now migrated to Dubendorf to control the two centres. By this move, Skyguide tries to adopt a data-centric, open-service oriented infrastructure (SOI). The next step would be to implement New Route Handling (NRH) and Flight Data Management (FDM) systems. These systems will operationalize the functions in Dubendorf from a single system. Additionally, free-route airspace will be enabled by the harmonization of the airspace.

5.1.2 Virtual Centre - SESAR

The SESAR work on the virtual centre started with the introduction of the Virtual Centre Model concept by Skyguide. Initially, the benefits, possible use cases, and the service-oriented archi-

ecture of the virtual centre has been investigated. This lead to the creation of two projects in SESAR1 between 2014 and 2016, namely B 04.04 - High level architecture, initial service identification, feasibility and B 04.05 - Common Services Methodology. Following the progress on SESAR1, SESAR2020 detailed the projects for the virtual centre in SESAR2020 between 2016 - 2019. The enabling project is designated as the PJ16.03 - Enabling rationalisation of infrastructure using virtual centre based technology, and supported by other SESAR projects, such as PJ15 - Common Services and PJ10.06 - Generic' (non-geographical) Controller Validations.

In close cooperation with relevant ANSP and manufacturing industry partners, SESAR Solution PJ15.09 Common Services and PJ16.03 Work Station, Service Interface Definition & Virtual Centre are also aiming to implement virtual centre in the European airspace. The main objective is to defragment the ANSP infrastructure to reach into an interoperable, cost-effective and flexible service-oriented architecture. SESAR approaches the virtual centre under specific scenarios that are referred as use cases. Specifically, there exists 3 separate use cases regarding the virtual centre, namely Delegation of Airspace, Contingency and Rationalization of Airspace. The validation report for the PJ16.03 works on the following validation areas:

- **Service Orientation:** ATSU can subscribe to services.
- **Multi-vendors:** ATSU can subscribe to services offered by an ADSP. ATSU and ADSP have different suppliers.
- **Controller Working Position (CWP) Cross-validation:** CWP(s) developed by a vendor can subscribe to services offered by different vendors.
- **ADSP Cross-validation:** CWP(s) developed by different vendors can subscribe to services offered by one ADSP.
- **Remote Usage:** ATSU(s) can connect remotely to ADSP(s) through a WAN.
- **Quality of Service Expectations:** An initial estimation of Quality of Service indicators for the Virtual Centre concept can be obtained from exercise data.

Within these validation objectives, the SESAR project also identified some related limitations for the project. These include the following areas:

- Services and operations coverage.
- Demonstration of the cross-validation requires several runs and output of several exercises.
- Physical derivation was done using two different technologies.
- Operational scenario was with low traffic and demonstration of scalability is limited.

- Remote connections were done using VPN.
- Quality of Service limited to measurement and not aiming to set target figures.
- And technically the surveillance infrastructure was error-prone.

The Solution PJ.16-03 Workstation, Service Interface Definition & Virtual Centre Concept develops a concept for separating the Controller Working Position (CWP) from the datacentre where the data is produced. This lean and efficient use of ANSP infrastructure tackles the issues presented by fragmented European ATM systems and country-specific architectures, enabling Europe to move to an interoperable, cost effective and flexible service provision infrastructure. Decoupling of the CWPs should enable a more efficient use of the most valuable and expensive resource, the human. By enabling increased flexibility the ANSPs should better manage staffing for prevailing traffic conditions and assure service continuity.

The Solution PJ.16-04 Workstation, Controller Productivity deals with new methods of controller interaction with the Human Machine Interface (HMI), applying mature technologies from other domains to ATM. This will increase controller productivity, reduce workload, stress level and enable the use of SESAR advanced tools, safely facilitating performance based operations. Furthermore, the use of modern thin client technology and the processes for developing HMI solutions are investigated, aiming at more efficient CWP development and operation.

5.2 Actors, Their Roles and Relationships

This section presents the relevant actors and their roles in the adoption process of the virtual centre in the European ATM. First, the section describes the main and the side actors, focusing separately on the roles and interests of each actor. Second, the relationships between the actors are presented using the four moments of translation as described in the conceptual framework. Each actor also translates their objectives through connecting with other actors. The main actors are the ones that play an active role in the adoption of the virtual centre, while the side actors either have passive roles or indirectly affected by the adoption.

5.2.1 Air Navigation Service Providers

ANSPs play an important role in the adoption of virtual centre, first as being a potential user of this technology to provide air navigation services in the European airspace. Not all ANSPs in Europe have the similar size, complexity, and a corresponding interest in the adoption of new technologies. According to this difference, there exists a number of ANSPs interested in the adoption of the virtual centre, while others follow the progress. Yet, the disruptive nature of the virtual centre is expected to change the business model of the ANSPs, affecting the way that the ANSPs currently function. First, the description of the roles of the ANSPs are presented by analyzing the corresponding themes. Second, the first order relationships of ANSPs with the other actors are presented using the description of the conceptual framework.

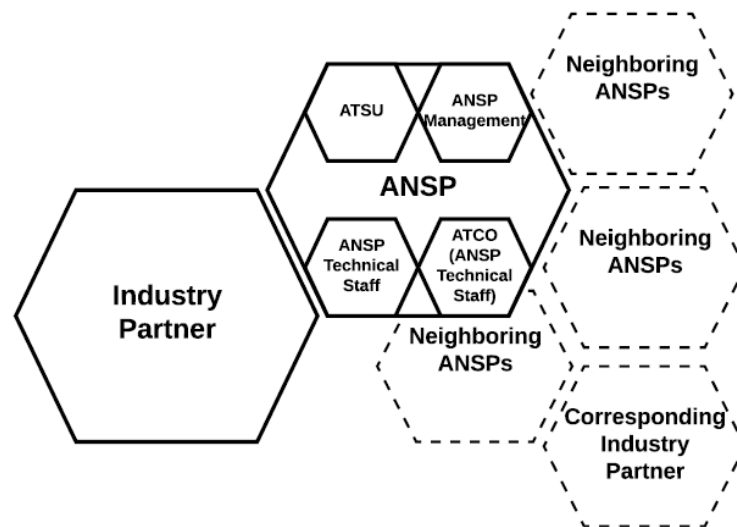


Figure 5.2 – Graphical Representation of ANSP and its First-Order Relationships

ANSPs partner with a manufacturing industry in order to realize new technologies, such as virtual centre. The ANSP-industry pair is inseparable, and there exists a first-order relationship between these two actors. The ANSPs itself constitute from Air Traffic Services Unit (ATSU), ANSP technical staff, ANSP operational staff and ANSP management, segregated according to their various roles played in the adoption of the virtual centre. ANSPs are also in direct relationship with their neighbouring ANSPs, both for the seamless cross-border operations and collective adoption and realization of the virtual centre. The neighbouring ANSPs additionally partner with an industry partner of their choice in order to adopt virtual centre. These actors are illustrated in Figure 5.2.

ANSPs have critical, pushing, decisive and generic roles in the adoption of the virtual centre. First, the roles for the overall ANSPs are presented. This is followed by the explanation of distinct roles for the ATSUs, ANSP technical staff, ANSP operational staff (ATCOs) and ANSP management respectively. These roles are supported by the evidence from both interviews, documentary analysis and participant observation where necessary. Starting with ANSPs is crucial, since investigating the main motivations of the ANSP helps to understand the objectives of the other actors. The critical roles of the ANSPs are presented as below:

- **Critical Role 1:** ANSPs need to make the business decision to adopt virtual centre.
 - The decision to adopt the virtual centre is mostly interpreted as an ANSP business decision by the ANSPs and also other actors . Some ANSPs have already started working on the adoption of the virtual centre, guided by the SESAR Project 16 - Controller Working Position and Virtual Centre Concept.
 - **Critical Role 1.1:** ANSPs need to connect to the virtual system with standardized

interfaces.

- **Critical Role 1.2:** Small ANSPs find it hard to allocate resources to the virtual centre project.
- **Critical Role 1.3:** The decision to adopt virtual centre should be opt-in decision.
 - * **Critical Role 1.3.1:** DSNA and Skyguide collaboratively work on the Cloud Co-Flight solution.
 - * **Critical Role 1.3.2:** DSNA, Skyguide, ENAV, NATS, DFS, and COOPANS are working together on the SESAR project of the virtual centre.
 - * **Critical Role 1.3.3:** NATS adopted a cloud-based approach for its data centres. The approach is more of a reduced hardware then operational change. NATS approaches the virtual centre in cumulative steps.
 - * **Critical Role 1.3.4:** Skyguide as an ANSP innovating and promoting the virtual centre. Skyguide tries to reduce costs by reducing fragmentation between its 2 centres. Skyguide aims to be a service provider for the virtual centre in the region.
- **Critical Role 1.4:** There should be a financial incentivization mode for ANSPs to adopt virtual centre.
- **Critical Role 2:** ANSPs have to create the initial market for the virtual centre either by themselves or in coordination with other regulatory actors, such as the EC.
 - Currently, there does not exist a market for the virtual centre or the provision of virtual services. There is a need for a market for the provision of the virtual services. Even an initial test market within a smaller scope for the virtual centre will aid the adoption of the virtual centre.
- **Critical Role 3:** Creating synergies for the adoption of virtual centre with EC - DG MOVE.
 - The ANSP or group of ANSP intend to create synergies for the new technologies, such as virtual centre in order to support and finance its development with proper funding mechanisms. For some of the digital technologies, this creates a momentum for the movement towards the digitalization and service-oriented architectures to be considered for the future of the European ATM system.
 - **Critical Role 3.1:** Triggered the rise of digitalization and virtualization, and the paradigm shift to digitalization and virtualization into ATM

Furthermore, ANSPs also appear as one of the strongest pushers for the adoption of the virtual centre in the European ATM, whenever there exists a business opportunity for them. Yet, for some ANSPs, mainly having small-medium size or complexity, they tend to follow the progress in the adoption. Looking into the pushing and generic roles of the ANSPs, we can see that there is momentum for the adoption of the virtual centre in the European ATM:

- **Pushing Role 1:** ANSPs and Regulators should collaborate on virtual centre
- **Pushing Role 2:** ANSPs partner with a suitable industry partner to adopt virtual centre
- **Generic Role 1:** Within ANSPs, operations and engineering need to work closely
- **Generic Role 2:** ANSPs trying to collaborate on a good will approach
- **Generic Role 3:** Change Management
 - **Generic Role 3.1:** Driving the required changes for the virtual centre in collaboration with other ANSPs
 - **Generic Role 3.2:** Standardizing the ATM data as in IT systems
- **Generic Role 4:** Implementing new technologies supporting virtual centre, and new digital communications (5G)
 - **Generic Role 4.1:** Building the necessary infrastructure, hardware, and software for virtual centre
 - **Generic Role 4.2:** Providing the information for training and regulatory work
 - * COOPANS is an example for remote training with its centre in Ireland
- **Decisive Role 1:** The business model of some ANSPs, especially small-medium sized and late adopters, could be disrupted by the new drastic business model change brought forth by the virtual centre.
 - **Decisive Role 1.1:** For some ANSPs it is hard to find a partner, both as a neighbouring ANSP and industry partner.
 - **Decisive Role 1.2:** Some ANSPs, especially small-medium sized ANSPs, find it hard to invest on virtual centre due to heavy initial investment required.
 - **Decisive Role 1.3:** ANSPs, that could not afford for the adoption of the virtual centre, could play a decisive role in the adoption.

Following the roles of the actor of the overall ANSP, we can investigate the roles of ANSP management. The virtual centre brings substantial changes also in the current paradigm of air traffic management. Eventually, this brings radical changes on how the ANSPs are managed and the corresponding management staff of the ANSPs. The roles of the ANSP management are presented as below:

- **ANSP Management**
 - **Generic Role 1:** Change Management Arising due to the Virtual Centre
 - * **Generic Role 1.1:** Finding the right key management people with the relevant know-how

- * **Generic Role 1.2:** Key management in the early adopting ANSPs try to adapt to implement virtual centre
- * **Generic Role 1.3:** Key management needs to consider change management on jobs and retirement due to changes brought by virtual centre
- * **Generic Role 1.4:** To have the right mixture of internal and external people to support the development of the virtual centre

ANSPs also include their technical and operational staff. The technical staff is mainly responsible for the support of the hardware and software that provides the air navigation services. These are experts specialized in all kinds of services that an ANSP provides. Additionally, there is operational staff, often referred to as ATCOs, who actually separate the aircraft from each other for a safe and seamless air traffic flow. Monitoring the position, speed and altitude, provided by radar, of aircraft from controller workposition, ATCOs maintain the flow of traffic by providing directions to the pilots by radio. ATCOs, being on the forefront of ATC, are an important actor inside ANSPs. They also separately form Controller Unions, which is treated as a separate actor in this analysis in the following part. The roles of the technical staff, and operational staff, ATCOs, being a local part of ANSPs, are as follows:

- **ANSP Technical Staff**

- **Pushing Role 1:** A number of ANSP technical staff could be a pusher as an ambassador for change
- **Decisive Role 1:** Could play a decisive role to adopt virtual centre due to change in social benefits or job availabilities
- **Decisive Role 2:** There exists mixed opinion on changes in the social benefits and the job structure because as also new type of jobs could also be created with virtual centre

- **ANSP Operational Staff (ATCO)**

- **Critical Role 1:** ATCOs could play a critical role in the adoption of the virtual centre, depending on how the specific virtual centre implementation affect their roles, working practices and social conditions
 - * **Critical Role 1.1:** Remote or location-independent provision of services could critically change the work practices and social conditions of the ATCOs
 - * **Critical Role 1.2:** Adaptation of the current roles of the ATCOs to the changes brought forth by the virtual centre is key for the change management
 - * **Critical Role 1.3:** Some ANSPs approach to the virtual centre without considering an effect on the reduction in the number of ATCOs

5.2.2 Manufacturing Industry

The essential partner of ANSPs to realize the virtual centre is the manufacturing industry. Mainly, the industry produces the necessary infrastructure, hardware and software in order to sell to ANSPs for the provision of the services of the virtual centre. In general, an ANSP partners with a single monolithic industry partner and procure necessary infrastructure, hardware and software from this single partner from a long period of time (5-10 years). This creates market conditions with low competition for the industry. Yet, for the emerging new technologies, such as the virtual centre, there are also investments for the enabling technologies from the small to medium sized industry manufacturers. These companies create possible competition for the provision of the services for the virtual centre. The industry and its first-order relationships are illustrated in Figure 5.3. Additionally, the roles of the manufacturing industry in the adoption of the virtual centre is summarized below.

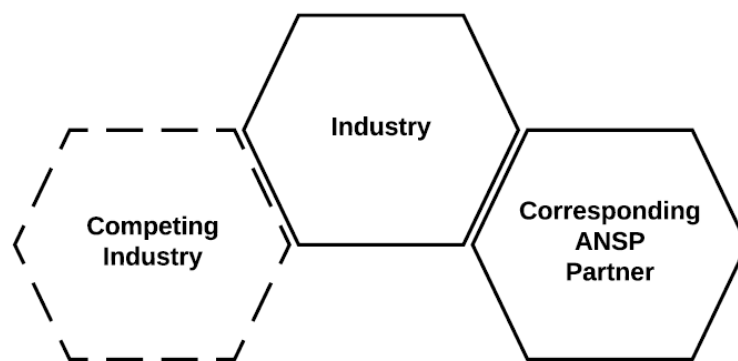


Figure 5.3 – Graphical Representation of Manufacturing Industry and its First-Order Relationships

- **Critical Role 1:** A part of manufacturing industry, partnering with ANSPs, started to adopt service-oriented architectures, supporting the virtual centre concept.
 - **Critical Role 1.1:** iTec provides support tools and inter-products to NATS
 - **Critical Role 1.2:** Thales have partnered with international organizations for similar kind of solution
 - **Critical Role 1.3:** Thales leads the virtual centre project in cooperation with EUROCONTROL and SESAR-JU within SESAR scope
 - **Critical Role 1.4:** Thales partners with ANSP alliance COOPANS for the development of virtual centre
 - **Critical Role 1.5:** Through SESAR ANSPs partner with the right industry partner to adopt virtual centre
- **Decisive Role 1:** Protecting their conventional business model until disrupted by the business model of virtual centre

- **Decisive Role 1.1:** Monolithic industry partners could be slow in transitioning from providing conventional systems to new systems that support virtual centre
- **Decisive Role 1.2:** The business model of the industry is based on delivering monolithic systems to many partners
- **Decisive Role 1.3:** ANSPs could guide the industry partners on providing infrastructure, hardware and software to support virtual centre
- **Decisive Role 1.4:** Depending on the benefits of the virtual centre, industry could aim to provide new infrastructure, hardware and software for the virtual centre
- **Decisive Role 2:** Part of industry is slow and tend to continue with provisioning of legacy systems
- **Generic Role 1:** Currently, there exists low competition for the manufacturing industry
 - **Generic Role 1.1:** The need for more players in industry to increase competition in the market
- **Generic Role 2:** Needs to move away from legacy CNS implementation
- **Generic Role 3:** Needs to invest in technologies that support virtual centre
 - **Generic Role 3.1:** CWP Cross-Validation - CWP(s) developed by a vendor can subscribe to services offered by different vendors
 - **Generic Role 3.2:** Industry will develop the technological enablers for the virtual centre and convince ANSPs to use it
- **Generic Role 4:** Industry initially aims protect their main revenue on providing conventional systems, at the same time investing on the new technologies
- **Generic Role 5:** Top management of the industry is familiar with the concept
- **Generic Role 6:** Middle management identifies the drastic business model change

5.2.3 EUROCONTROL

EUROCONTROL plays multiple roles in the adoption of the virtual centre. First, the organization provides the coordination and collaboration of the multiple actors inside the SESAR project. This, in turn, creates the necessary momentum and relationships between the actors to adopt new technologies, such as virtual centre. The second role is the Network Manager function assigned by European Commission to EUROCONTROL. The Network Manager also needs to adjust their management, operations and technical systems to the changes brought forth by the service-oriented architectures and the virtual centre. Moreover, EUROCONTROL acts as an ANSP considering the Maastricht Upper Area Control Centre (MUAC). The actor EUROCONTROL and its first-order relationships are illustrated in Figure 5.4.

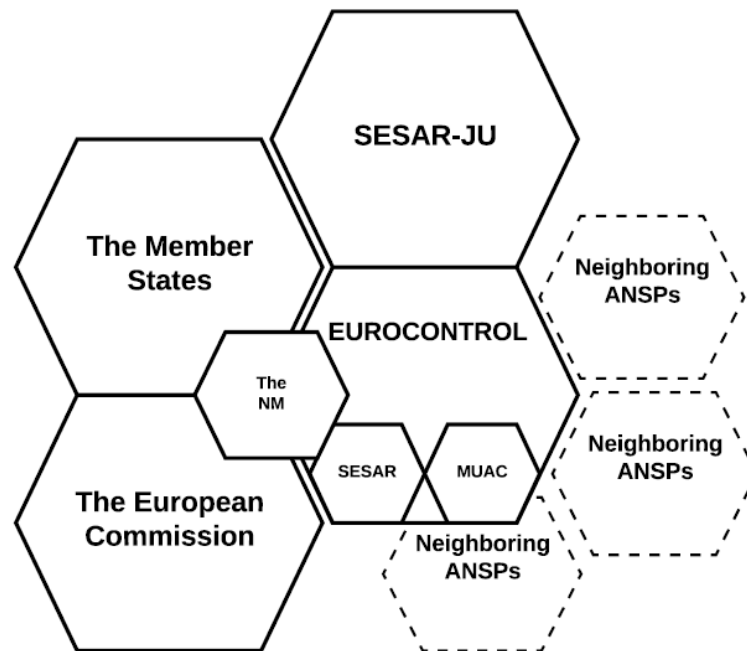


Figure 5.4 – Graphical Representation of EUROCONTROL and its First-Order Relationships

- **Pushing Role 1:** Providing the management of infrastructure, strategic, and technical development including and beyond the European network
 - **Pushing Role 1.1:** NewPENS will be a facilitator for the adoption of new technologies
 - **Pushing Role 1.2:** The model of sharing of infrastructure in MUAC is a successful example for the virtual centre
 - * **Pushing Role 1.2.1:** MUAC already provides a number of services using a kind of service-oriented architecture to neighbouring countries
 - * **Pushing Role 1.2.2:** MUAC is a pioneer for the possibility of a cross-border ATC in Europe
- **Pushing Role 2:** EUROCONTROL can become the data service provider for the new services in a service-oriented architecture
 - **Pushing Role 2.1:** EUROCONTROL is a candidate to provide services to ANSPs enabled by new technologies
 - **Pushing Role 2.2:** EUROCONTROL's data sharing model with Slovenia is a candidate for service-oriented architectures
- **Pushing Role 3:** Promoting the use of standardized enterprise architecture in Europe, such as System Wide Information System (SWIM)

- **Pushing Role 3.1:** Common Services offered by EUROCONTROL is an enabler for virtual centre
- **Pushing Role 3.2:** Political reasons affect the feasibility of the solutions that include defragmentation of ATCOs
- **Pushing Role 4:** Virtual Centre is a candidate to solve the delay and capacity issues
- **Generic Role 1:** Roadmapping for the new technologies such as Virtual Centre in SESAR
 - **Generic Role 1.1:** Coordination between the actors with a non-dominant role and moderate speed
- **Generic Role 2:** Within the SESAR framework, supporting the virtual centre concept and evaluating the possibilities
 - **Generic Role 2.1:** The EC also supports the deployment of SES with the support of SESAR
- **Generic Role 3:** Oversight of the development and deployment of the virtual centre
 - **Generic Role 3.1:** The Network Manager is also a candidate for oversight
- **The Network Manager Role**
 - **Decisive Role 1:** Depending on the future evolution of the Network Manager, the NM could position itself according to the progress of the virtual centre
 - * **Decisive Role 1.1:** Consultation of NM is needed for the virtual centre since there is a technical and business impact of virtual centre
 - * **Decisive Role 1.2:** NM will carry on the role of demand-capacity balancing for the virtual centre
 - * **Decisive Role 1.3:** The Network Manager might gain the airspace designer role, organizing the airspace, optimizing the cross-borders with the virtual centre
 - * **Decisive Role 1.4:** From a political point of view, there are challenges associated to the new roles due to sovereignty of airspace

5.2.4 SESAR-Joint Undertaking & SESAR-DM

SESAR-JU supervizes the actors under the SES project in order to coordinate the efforts through the research, development and deployment phases of a SESAR project. SESAR-JU has been specially created by the joint cooperation of the actors EUROCONTROL and the EC to carry out the task to realize the ambitions of the SES. Virtual centre is perceived as one of the enablers for the SES and lately it has been emphasized also in Airspace Architecture Study. The coordinating efforts of the SESAR-JU put this actor in the side of the pushers, where many of the roles of SESAR-JU in the adoption of the virtual centre are in the category of pushing

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roles. Furthermore, SESAR-JU actively works with the ANSPs and the industry to create the necessary momentum for the SES project and its relation with the virtual centre. The actor SESAR-JU and its first-order relationships are illustrated in Figure 5.5.

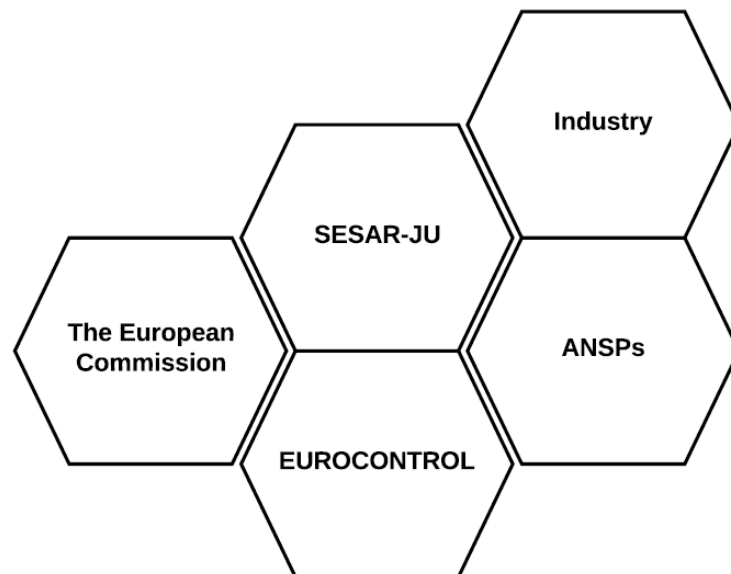


Figure 5.5 – Graphical Representation of SESAR-JU and its First-Order Relationships

The pushing and generic roles of the SESAR-JU in the adoption of the virtual centre in the European ATM is summarized as follows:

- **Pushing Role 1:** Supporting and guiding research and development for the adoption of the virtual centre
 - **Pushing Role 1.1:** Through SESAR, standardization of the current and future needs of the virtual centre
- **Pushing Role 2:** Providing exposure with public relations
- **Pushing Role 3:** Airspace Architecture Study suggests the integration of new technologies, such as the virtual centre
- **Generic Role 1:** Defining the roadmap for new technologies is Airspace Architecture Study (AAS)
 - **Generic Role 1.1:** 3 pillars in AAS promotes virtual centre - free-route airspace, location independence, communication and navigation services as a service
 - **Generic Role 1.2:** AAS defines a new actor called ATM Data Service Provider (ADSP)
- **Generic Role 2:** Supporting the concepts brought forth by the innovative ANSPs into and realize their ambitions

Additional to the development aspects of the SESAR-JU, on the deployment side SESAR-DM could attach to the network of actors on the final stage of adoption, mobilization, for further deployment of the Virtual Centre in the Pan-European scale within their area of responsibility. Since, SESAR-DM is mainly responsible for the deployment of the solutions under the SESAR framework, The generic roles for SESAR-DM listed as below:

- **Generic Role 1:** Supporting the deployment of the Virtual Centre in coordination with the SESAR-DM partners, including SJU, ANSPs, airlines, airports, military and EURO-CONTROL
- **Generic Role 2:** Following the deployment roadmap as presented in the European Master Plan
- **Generic Role 3:** Under the SESAR framework, management of the deployment of new technologies in synchronization with European ATM stakeholders

5.2.5 The European Commission

The European Commission acts as a regulator for driving the changes brought forth by the virtual centre. These include the management of the other actors, such as SESAR-JU and EUROCONTROL in order to realize the goals for the Pan-European approach of the SES project. As an ultimate aim of defragmentation in Europe, the EC guides the actors through the modernization of the European ATM. Virtual centre is one of the key enablers for the defragmentation of the systems and services throughout Europe. Additionally, the EC manages proper funding of the virtual centre, possible creation of an initial market, legal and regulatory requirements for a service-oriented architecture. This places the EC as one of the critical actors in the realization of the SES project.

- **Critical Role 1:** Regulating the changes driven by virtual centre
 - **Critical Role 1.1:** Creation of the regulatory and institutional framework
 - **Critical Role 1.2:** Increase adoption of virtual centre by setting implementation rules
 - **Critical Role 1.3:** Consolidation of other actors, specifically ANSPs, within a transversal view
- **Pushing Role 1:** The EC can push through creating a mandate for the adoption of the virtual centre
- **Decisive Role 1:** On condition that virtual centre creates a new monopoly
 - **Decisive Role 1.1:** Regulation of the virtual centre to increase competition for ATC provision in the European airspace

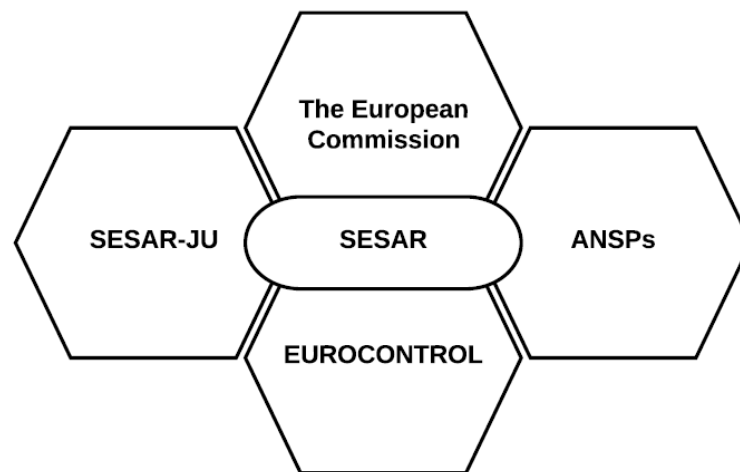


Figure 5.6 – Graphical Representation of The EC and its First-Order Relationships

- **Decisive Role 2:** The performance scheme targets should also target to aim future delegation of airspace
- **Passive Role 1:** Similar to other SESAR projects or solutions, funding the virtual centre inside the SESAR framework
 - **Passive Role 1.1:** Through SDM, Projects involving new technologies should be given priority in funding
- **Passive Role 2:** Keeping track of the progress of actors in the research and development of the virtual centre
- **Passive Role 3:** Understanding the evolution of the virtual centre concept
- **Generic Role 1:** EC needs to help with the definition of an insurance scheme for legal liability issues with the support of EASA
- **Generic Role 2:** Creating the market environment for the virtual centre
- **Generic Role 3:** Managing the virtual centre by setting EUROCONTROL as the technical agency
- **Generic Role 4:** Putting performance targets in place based on the requirements of the airlines
- **Generic Role 5:** The EC with the support of EUROCONTROL and SJU is planning to move forward with AAS in SES3

5.2.6 Military

The Military acts both as an ANSP for the military operations and training, and also as the actual military of each Member State at the same time. Mainly, the military airspace is a reserved area and the Military also experiment with different new technologies. Virtual centre and flight-centric operations are not totally new concepts for the military. Remote training and control is possible for the military drones and also night operations happen in similar conditions to flight-centric operations. Yet, military plays a critical role on the adoption of the virtual centre. EUROCONTROL also have a special division aiming for the civil-military cooperation. The division works with Military on enhancing airspace capacity, flight efficiency, military mission effectiveness and civil-military interoperability with reduced costs in the scope of the SES. Concretely, the Military has first-order relationships with the Member States, ANSPs, and EUROCONTROL as illustrated in Figure 5.7.

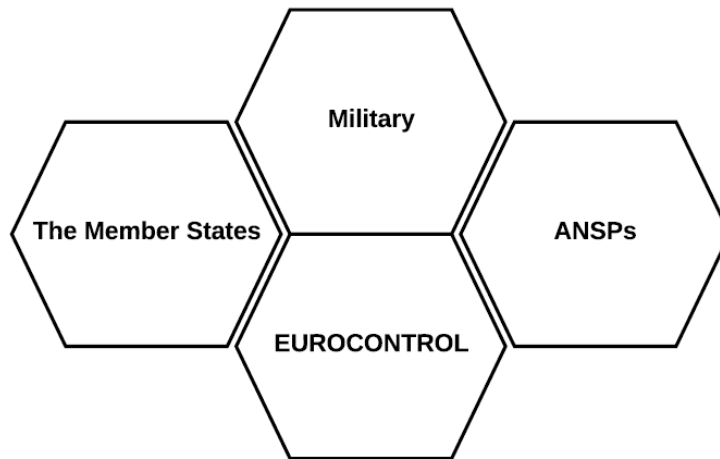


Figure 5.7 – Graphical Representation of the Military and its First-Order Relationships

- **Critical Role 1:** Military decides on the implementation by either accepting dynamic airspace management or not
- **Generic Role 1:** Military has some specific requirements within the virtual centre, depending on its level of implementation
- **Generic Role 2:** Application of virtual centre and flight-centric operations is familiar for military, yet safety assessment is paramount

5.2.7 Controller Unions

There are five organizations that represent the ANSP operational staff: global professional organizations, such as International Federation of Air Traffic Controllers' Association (IFATCA) and International Federation of Air Traffic Safety Electronics Association, European Trade

Union Organization (European Transport Workers' Federation), the European affiliate of the global professional pilot association (European Cockpit Association), and ATCO union coordination platform of Air Traffic Controllers European Unions Coordination (ATCEUC) [Baumgartner and Finger(2014)].

These organizations are mainly non-profit and aim to support the interests of the groups that are forming them. The main aim is to protect and safeguard the interests of the ATC profession. Additionally, they promote the safety, efficiency and regularity in International Air Navigation. As ATCO unions, they want to make sure that the safe and orderly systems of ATC is in development within having close cooperation with other international organizations. In the specific case of the virtual centre, controller unions aim to protect the jobs, salaries, workplace and social conditions of the ATCOs on the possible adoption of this technology. In the ATCO side, the virtual centre is considered as a disruptive technology, altering the usual way of working for the ATCOs, especially with location independency. Eventually, this creates a possible change in working conditions of ATCOs which are not uniformly distributed in Europe. In the remote provision of services, the work of ATCOs could be delivered location independently anywhere from Europe, so there is expected increase in the competition for ATC provision on the condition that the safety levels stay the same.

In particular, Controller Unions are a decisive actor on the adoption of the virtual centre. This is because of the fact the ATCOs are the direct users of the technology. Their opinions affect the other actors, especially ANSPs towards adopting the virtual centre. If in the case of remote or location-independent ATC, virtual centre could drastically change the conventional way of ATC provision and how ATCOs usually works, depending on its implementation and level of influence on the ATCOs. Consequently, the change management for the virtual centre should also include ATCOs adaptation to the new technology. Necessary training and change management should be delivered before the virtual centre is operational. On condition that ATCOs and Controller Unions are involved in the adoption of the virtual centre, they also emphasize the fact that it would be beneficial for both sides for the successful adoption of the virtual centre. Accordingly, the Controller Union has first-order relationships with the ANSPs as illustrated in Figure 5.8.

- **Critical Role 1:** Controller Unions protect the interests and social well-being of ATCOs
 - **Critical Role 1.1:** ATCOs and Controller Unions being defensive on the adoption of virtual centre
 - **Critical Role 1.2:** Change of social conditions due to location independency of ATCOs
 - **Critical Role 1.3:** Remote or location independent ATC provision could alter the roles of ATCOs
 - **Critical Role 1.4:** Evaluation of the drastic changes in the work practices of ATCOs under virtual centre configuration

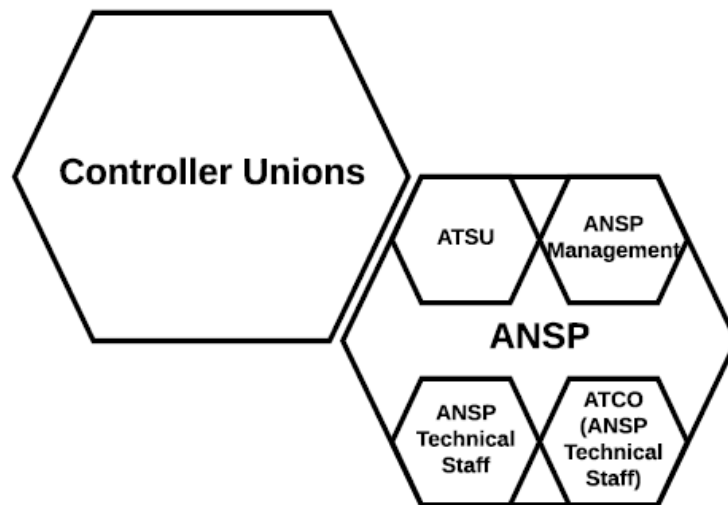


Figure 5.8 – Graphical Representation of Controller Unions and its First-Order Relationships

- **Decisive Role 1:** Getting involved in the change management and creation of the new concepts for the virtual centre
- **Decisive Role 2:** Depending on how the virtual centre solution implemented inside an ANSP, the position of ATCO changes

5.2.8 EASA

European Union Aviation Safety Agency (EASA) is established for as a separate safety specialized organization for the European Member States. Based in Cologne, having 32 Member States, EASA aims to standardize the certification for safety and environmental protection among its Member States. The main tasks of EASA includes the following main areas:

1. Draft implementing rules in all fields pertinent to the EASA mission
2. Certify & approve products and organisations, in fields where EASA has exclusive competence (e.g. airworthiness)
3. Provide oversight and support to Member States in fields where EASA has shared competence (e.g. Air Operations , Air Traffic Management)
4. Promote the use of European and worldwide standards
5. Cooperate with international actors in order to achieve the highest safety level for EU citizens globally (e.g. EU safety list, Third Country Operators authorisations)

Following this main tasks, EASA plays a key role on the assessment of the safety of the virtual centre. Consequently, this is supported by the standardization of the systems and actors,

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such as ADSPs by specialized certification for the virtual centre. Moreover, the licensing of ATCOs under the location independent virtual center configuration is highlighted as one of the main roles of EASA in the adoption of the virtual centre. These roles of standardization and certification could be established by the specific regulation of the EC in correspondence to the successful adoption of the virtual centre. EASA is also perceived as an actor who is helping in oversight of IT regulation on the virtual centre. This includes a transversal component, which covers a number of actors including the Member States, the EC and the ANSPs. Concretely, EASA has first-order relationships with the the Member States, ANSPs, and the EC as illustrated in Figure 5.9.

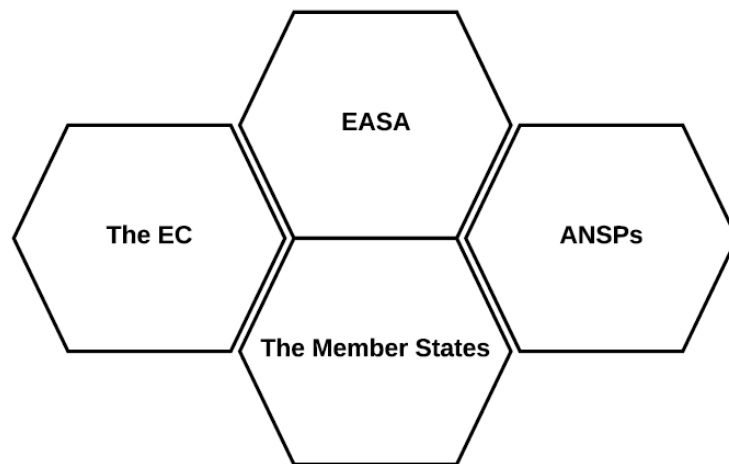


Figure 5.9 – Graphical Representation of EASA and its First-Order Relationships

- **Critical Role 1:** National and international safety regulation for virtual centre
 - **Critical Role 1.1:** EASA team up with EC to provide the necessary regulation and safety assessment
 - **Critical Role 1.2:** Learn with ANSPs the changes that virtual centre brings to create proper regulation
 - **Critical Role 1.3:** Regulators should enforce collaboration between ANSPs
 - **Critical Role 1.4:** Making sure that virtual centre is safe, secure and provide the claimed benefits
 - **Critical Role 1.5:** Regulation implies that virtual centre shall not create a new monopoly
- **Generic Role 1:** EASA doing the standardization for the multiple stakeholder ADSP certification
- **Generic Role 2:** Promoting industry regulation and rule-making

- **Generic Role 3:** Helping in oversight of IT regulators to regulate virtual centre. Oversight has also a transversal component on how the content is used.
- **Generic Role 4:** Definition of a new way to assess safety and compliance regulation

5.2.9 New Emerging Actors

The virtual centre additionally creates a possibility of disruption with the introduction of a disruptive technology in the European ATM. Since the ATM provision is decoupled from both from location and the service provider, with virtual centre, it becomes possible that companies other than ANSPs provide these services in a competitive environment. In a service-based architecture, these services could be provided remotely under competitive rules. Under these conditions both the ANSPs and the manufacturing industry are expected to be disrupted by the introduction of the new actors, possibly originating from other network industries, such as IT and telecommunications. This is highly correlated with the previous disruptions happened, and currently happening in other network industries. The slow pace of the ATM in adopting new technologies make the situation for a possible disruption even more likely to happen in the future.

For the provision of these services, a new entity, called ATM data service providers (ADSP) is also proposed by AAS study carried out by SESAR-JU. Consequently, a shift in the model of service provision in the areas of flight data processing functions (correlation, trajectory prediction, conflict detection and resolution), and arrival management planning is expected. In the future, these services are expected to be provided by harmonized, and defragmented ADSPs overall Europe. Additionally, ADSPs, when operational, will also cover ATM data services that aid in the virtual defragmentation of the European air traffic system. This is enabled directly by the adoption of the virtual centre, where the service provision is decoupled from ANSPs, and new actors could also be able to provide services in the European ATM.

The big IT giants and telecommunication companies, such as Google, Amazon, Facebook, Microsoft could also see an opportunity of penetration into the ATM market with the adoption of the virtual centre. Already, some of these companies working on the flight tracking, or other services in the air traffic domain. Within the enabling of competition for the services, these companies become able to enter the competitive market, providing services cheaper than the most of the current actors due to their huge volumes of data processing capabilities. The cloud-based systems are used in IT and telecommunications decades before than air traffic. Hence, with the introduction of the new actors, there will be a need to shift the way of regulating these new actors and the new way of provision of services. For this reason, new actors also arise in the regulation, specialized in IT, both standardizing the provision of services across Europe, while also checking the required safety levels.

New service providers also come with their own industry, possibly disrupting the current manufacturing industry in the European ATM. The monopolistic nature of the ATM industry

is expected to be disrupted if these services are opened to competition. In a competitive environment, the service-oriented architectures enable the provision of services, and decoupling of the necessary hardware and software, and infrastructure from location and provider. The IT giants have already long and established relationships with their corresponding industry partner. In the case of possible disruption of ANS services, the industry is also expected to be disrupted. Furthermore, new way of provision of services create the need for a new way of managing these with new actors. It is likely that a new technical operational manager is created within the operations of the virtual centre. This actor is responsible for the technical coordination between the various actors that provide services inside a service-oriented architecture. These new actors possibly penetrating the European ATM market is illustrated in Figure 5.10.

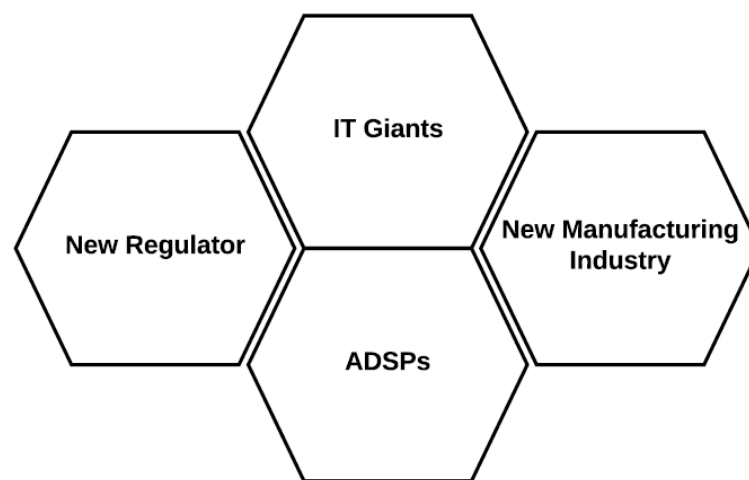


Figure 5.10 – Graphical Representation of the new emerging actors and its First-Order Relationships

- **ATM Data Service Provider (ADSP)**
 - **Critical Role 1:** ADSP Cross-validation - CWP(s) developed by different vendors can subscribe to services offered by one ADSP
 - **Critical Role 2:** New service providers are expected to provide even the current services offered by SITA and ARINC for CNS
 - **Critical Role 3:** The business model of ANSPs are currently changing with the aim of reducing costs
 - **Critical Role 4:** Potentially MUAC or Skyguide are candidates for being an ADSP
 - **Critical Role 5:** The ADSP pioneers have a chance to show that virtualization is possible
- **Big IT Giants (Google, Amazon, Facebook, Microsoft) & Telecommunication Companies**

- **Passive Role 1:** Reluctant to move due to legal and political barriers
- **Generic Role 1:** Standardisation of virtual centre
- **Generic Role 2:** Disrupt the current ATM environment by offering services
- **Generic Role 3:** Organize the traffic as a major transport organizer while optimizing the traffic flows

- **New Manufacturing Industry**
 - **Generic Role 1:** Frequentis is a candidate providing modular systems with open interfaces

- **New Technical Operational Manager**
 - **Generic Role 1:** Providing the management of infrastructure, strategical, and technical development beyond the European network

- **New IT Regulator**
 - **Generic Role 1:** Regulation of the European ATM under the provision of services in virtual centre configuration

5.3 Factors Affecting the Adoption of the Virtual Centre

The adoption process of the virtual centre is affected by various factors categorized under political, social, technical or operational, economic and legal factors. In each phase of adoption (problematization, interestment, enrolment, mobilisation), these factors play an important role guiding the objectives of the actors. Hence, it is crucial in our analysis to examine these factors, the affected actors, and the stage of adoption that the factor is affecting the adoption. This section first presents the specific impact of factors analyzed under the 5 categories. Second, guided by the conceptual framework to build up on to see the big picture affecting the overall adoption, the section finally provides the overall impact of the factors on the adoption of the virtual centre.

By looking to the comparison of the importance of the factors in the adoption of virtual centre, it has been found that the social and technical or operational factors affect the adoption equally in the first place after coding and thematizing the findings. This is followed by the economic factors being in the third place, followed by legal and political factors in the fourth and fifth place. Notably, the adoption of the virtual centre indeed is affected by various factors rather than just being technical. Specifically, the impact of the social factors are as crucial as the impact of the technical or operational factors. This makes the key point of the analysis that it is crucial to investigate the factors other than the technical in order to examine the adoption of the virtual centre. Although being a technical solution, the virtual centre alter substantial areas in other factor categories.

5.3.1 Social Factors

Starting with the social factors emphasizes the fact that the virtual centre brings radical changes on the side of the ANSPs, mainly affecting the ATCOs as being the operational staff, and additionally technical and managerial staff. In fact, these changes are related to the two properties of the virtual centre technology. First is the location independency that with virtual centre, ATC would be provided practically anywhere in the world without being constrained by the location. The second is the drastic changes in the work practices of the ANSP technical staff, operational staff (ATCOs) and management that the virtual centre brings. Specifically, these changes are a consequence of a the paradigm shift towards the legacy system-based solutions, that the ATM world is accustomed to, towards service-oriented architectures.

The shift towards service-oriented architectures radically alters the work practices of ANSPs. Correspondingly, most of social factors are related to the actors of ANSPs and Controller Unions. The ATCOs are used to work from location dependent ATSUs, delivering ATC services for the local service providers from their unique controller working positions. Now, with the virtual centre, this fact is totally abolished, where it becomes possible to license the ATCO for multiple locations anywhere in the Europe, and controlling from a remote location. Of course, this brings resistance from the operational staff of the ANSPs and the Controller Unions for the adoption of the new technology. Furthermore, with the new services and service delivery models available, the management and the technical staff of ANSPs need to adapt to both technical and cultural changes brought by the virtual centre. To summarize, all of the social factors are summarized in the Table 5.1, pointing out the relevant actors and the stage of adoption.

In particular, there exists two critical social factors affecting the adoption of the virtual centre. First is the misalignment between the top and middle management of ANSPs throughout Europe in the adoption of the virtual centre. This is also highly correlated with the heavy initial investment needed for the creation of the virtual centre. Even though the middle management is interested to adopt new technologies, such as virtual centre, and burden the change, the top management might not be always interested on relying on a new technology that includes risk and involve big investment. The second critical factor is the resistance of ATCOs arising from the changes brought by the virtual centre. Practically, the way the ATC delivered today is totally changing with the virtual centre. Of course, the ATCOs will be the one who are directly affected in terms of work practices, change of salaries, possible reduction in the number of ATCOs. Moreover, the virtual centre increases the dynamic flexibility of the allocation of ATCO resources for sectors. Especially, this can reduce the number of ATCOs for cost-effectiveness purposes in some areas.

5.3.2 Technical or Operational Factors

On the technical side, the virtual centre transforms both the infrastructure, hardware and software of the current ATC and ANS systems. Actually, the changes that virtual centre brings as

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Social Factors	Stage of Adoption	Relevant Actor(s)
Critical Factor 1 - Fragmented top and middle management throughout Europe affecting the adoption of virtual centre	Problematisation	ANSPs
Correct people at correct moment are needed for the necessary changes for the virtual centre	Problematisation	ANSPs
Some people are open for the change for the virtual centre	Problematisation	ANSPs
Critical Factor 2 - The resistance of ATCOs due to change in the work practices brought forth by the virtual centre	Problematisation	Social Actors
SF1 - ATCOs may resist by pulling out the safety flag	Interessement	ANSPs(ATCOs)
SF2 - Union driven processes resist to change	Interessement	Controller Unions
Having an open dialogue with staff associations will help	Interessement	Controller Unions
SF3 - ATCOs and staff in ANSPs have fear of loosing their working place	Interessement	Controller Unions
Explanation and discussing the possible changes that virtual centre brings with ATCOs	Interessement	Controller Unions
Possible change of their salaries due to location independency enabled by the virtual centre	Interessement	Controller Unions
SF4 - Transition towards standard IT solutions, accessible know-how compared to current highly specialized	Enrolment	ANSPs (Technical Staff, Operational Staff, Management)
SF5 - Licensing or rating of ATCO under virtual centre configuration	Mobilisation	ANSPs(ATCOs)
Currently ATCOs physically move to dense traffic areas to support	Mobilisation	ANSPs(ATCOs)
Expensive part including the re-training of ATCOs and staff for the virtual centre	Mobilisation	ANSPs(ATCOs)
The need for over training due to changing practices brought by the virtual centre	Mobilisation	ANSPs(ATCOs)
25 percent increase in work force before optimal operations	Enrolment	ANSPs(ATCOs)
SF6 - Change in the work practices of the ATCOs	Enrolment	ANSPs(ATCOs)
SF7 - Cultural differences affect the work environment	Enrolment	ANSPs(ATCOs)
SF8 - Age and relevance of the managers to the new technologies	Problematisation	ANSP(Managers)
SF9 - The balance between human-centric and system-centric approach should be found	Problematisation	ANSPs

Table 5.1 – Social Factors Affecting the Adoption of the Virtual Centre

a technology is unprecedented compared to any other new technology in European ATM. This is due to the fact that it is not just an update or improvement on the previous legacy systems used in European ATM. Uniquely, it is more of a major overhaul, leaving behind the legacy systems, and move towards a completely new service-based architecture. Yet, the size of the change creates also confusion towards even finding a common definition between the actors. Each ANSP approaches the solution from their perspective. For some, switching to cloud-based services rather than a full virtual centre solution is more feasible. Especially, a number of ANSPs treat the virtual centre concept as the a solution for their rationalization of airspace. Indeed, in the initial phases of its adoption it is rather perceived as a local defragmentation of their systems and services for ANSPs.

The technical and operational factors affecting the adoption of the virtual centre is multifold. These range from the technical enablers to support the realization of the virtual centre to the latency and cyber-security issues attached to the sharing of safety critical data. Since the technology is very new and outside from the ATM domain, it is hard to find and recruit staff with the relevant knowledge and expertise of the virtual centre. A few of the ANSPs, such as Skyguide and NATS, heavily invest on the realization of the virtual centre with the adaptation of the staff in mind. The technical changes required to shift from current legacy systems to service-based architectures are vast. Yet, current technologies from different domains, such as cloud-based systems or emerging technologies, such as block-chain is also signaling for the right direction for the European ATM of the technical change. Correspondingly, there also exists bottlenecks in the implementation of the virtual centre, including the frequency congestion which is a critical topic considering European ATM. This needs further validation if the virtual centre makes it better or worse for the frequency congestion problem, focusing

5.3. Factors Affecting the Adoption of the Virtual Centre

Technical or Operational Factors	Stage of Adoption	Relevant Actor(s)
Critical Technical Factor 1 - Different deviations from or approaches to the virtual centre concept	Problematisation	All
Inclusion of terms in the definition such as service-orientation is a discussion topic	Problematisation	All
Lacking of a common definition of the virtual service services	Problematisation	All
Tailor-made solutions for virtual centre implemented by each ANSP	Problematisation	ANSPs
The industry partners design, develop, and deliver separate non-interoperable systems to ANSPs	Problematisation	The Manufacturing Industry
Critical Technical Factor 2 - Not all ANSPs have the same expertise on virtual centre concept	Enrolment	ANSPs
OF1 - Labour based approach of ATCOs reduces flexibility	Interessement	ANSPs(ATCOs)
OF2 - Motivational behaviour could hinder the adoption of virtual centre	Interessement	ANSPs(ATCOs)
OF3 - Allocation and price of the network under full ATC operations	Interessement	ANSPs
OF4 - Operational factors depend highly on the specific use case of virtual centre	Problematisation	All
OF5 - Sharing of richer data in virtual centre than currently used in legacy systems	Enrolment	ANSPs
TF1 - Costly locked systems, not agile and resilient to adapt to change in operational requirements	Problematisation	ANSPs
TF2 - Technology enables you to realize virtual centre	Problematisation	ANSPs, The Manufacturing Industry
TF3 - Latency issues	Problematisation	ANSPs, The Manufacturing Industry
TF4 - Cyber-security issues	Problematisation	ANSPs, The Manufacturing Industry
TF5 - New data models helping virtual centre to become a reality	Problematisation	All
TF6 - Technical failures of ANSP affecting the whole system	Mobilisation	All
TF7 - Emerging technologies can help the adoption of the virtual centre, such as block-chain	Mobilisation	All
Satellite communication technology is also an enabler for the virtual centre	Mobilisation	All
TF8 - Lack of specialized workforce with relevant technological expertise	Enrolment	ANSPs, The Manufacturing Industry
Hard to find specialized young experts	Enrolment	ANSPs, The Manufacturing Industry
TF9 - Checking if virtual centre have an impact on the congestion of frequencies	Problematisation	ANSPs, The Manufacturing Industry
TF10 - Risk on services and operations coverage	Problematisation	ANSPs, The Manufacturing Industry
TF11 - Demonstration of the cross-validation requires several runs and output	Problematisation	All
TOF1 - Setting up operational processes according to technical enablers to realize virtual centre	Problematisation	ANSPs, The Manufacturing Industry

Table 5.2 – Technical Factors Affecting the Adoption of the Virtual Centre

also in risks on services and operations coverage.

Considering the critical technical factors affecting the adoption of the virtual centre, the first factor is the existence of different deviations from the original virtual centre concept. The concept originating from Skyguide has been modified by several ANSPs during the initial phases of the adoption process. Currently, there exists 3 use cases or scenarios of the virtual centre, namely Rationalization of Infrastructure, Contingency and Delegation of Airspace. The rationalization use case relies on the internal defragmentation of the ANSPs, where several ATSU are combined into one and served by a new actor ADSPs. The ADSPs are connected to each other functioning between several ANSPs. Consequently, the Contingency use case specifically aims to use the virtual centre as a switching option between ATSU that can act instead of each other in the case of an incident of a failure. In this case, the standardized interfaces between the ATSU make it possible for the location independent control of airspace. The last use case of delegation of airspace is a dynamic allocation of ATC between several ATSU as in the case of the original virtual centre concept. The abundance of the several interpretations of the virtual centre makes it harder to standardize the virtual centre adoption among various actors. In the second place, an additional critical factors related to ANSPs is that not all of them have or be able to gather the same expertise required for the adoption of the virtual centre. This is in terms of the management, technical and operational staff in the research and development phases of the project. Accordingly, the technical factors are

pointed out in Table 5.2 within the relevant actors and stages of adoption.

5.3.3 Economic Factors

Economic factors constitute a great number of critical factors pointing out that the actors are, at the same time, driven and hindered by their economic objectives. Yet, proper incentivization mechanisms for the adoption of the new technologies, such as the virtual centre is not in place. Additionally, ANSPs operate under cost recovery system, and most of them are public monopolies without any competition for the provision of the services. The virtual centre directly alters this point that it enables the competition for the services that the ANSPs currently deliver. Moreover, the manufacturing industry is used to sell the hardware or software supplying the longevity of the legacy systems. Hence, the virtual centre disrupts the current business models both ANSPs and the manufacturing industry. The provision of the services are decoupled from both the location and the systems. Indeed, this comes with the creation of the new actors, named as ADSPs, which are intermediary service providers between ATSU and ANSPs. The ANSPs can also play this role adopting the virtual centre, but for those ANSPs who are late or could not adopt the virtual centre, they are expected to be disrupted by the creation of ADSPs.

Certainly, the ultimate aim of the virtual centre is to defragment the European ATM and reach to reduction of costs. The economic objective has been targeted by several actors who are under the SES umbrella. The EC is setting the cost-efficiency targets for the SES, and virtual centre is an enabler to reach this objectives within a new business model. Yet, also on the downside the adoption of the virtual centre might bring reduction of jobs, which can be seen alternatively by various actors. The Member States politically might not be in favor of the reduction of the jobs, assisted by the Controller Unions. Additionally, the initial cost of setting up the virtual centre is perceived to be higher than expected for ANSPs. This can be a result of radical changes and new infrastructure needed for the implementation of the virtual centre. For the ANSPs which can not burden the weight of the adoption of the virtual centre, there are risks involved with the possible disruption of their business models.

The virtual centre is a key technology to enable the competition for the provision of the air navigation services in Europe. However, currently the market for the services using virtual centre does not exist. This is emphasized as the biggest critical economic factor affecting the adoption of the virtual centre. Even a small test market for those ANSPs that decide to adopt the virtual centre might help the adoption of the virtual centre. Indeed, a functioning market is crucial for the actors to switch towards a new technology. Furthermore, proper funding and incentivization for the early adopters are also interpreted as critical economic factors. ANSPs get motivated to adopt new technologies on condition that they can seize proper funding from the EC or SESAR. This is a way of cost-recovery for the heavy initial investment required by the virtual centre. Additionally, a realistic assessment of the cost and benefit in Pan-European scale is needed to prove the actors the promised cost-effectiveness targets of the virtual centre.

5.3. Factors Affecting the Adoption of the Virtual Centre

Economic Factors	Stage of Adoption	Relevant Actor(s)
Critical Factor 1 - Non-existence of market for the services created by virtual centre	Enrolment	All
Critical Factor 2 - Proper funding of the projects that use new technologies (virtual centre)	Interessement	SESAR-JU, The EC
Critical Factor 3 - Reducing the costs by reducing the staff, and management	Problematisation	ANSPs
Cost reduction due to location independency of ATCOs created by virtual centre	Problematisation	ANSPs
In the reverse case, number of supervisors needed is doubled, hence increasing costs in Langen	Problematisation	ANSPs
Mixed opinion for the virtual centre increasing cost-efficiency	Problematisation	ANSPs
Critical Factor 4 - The EC are setting cost-efficiency targets that forces ANSPs to adopt new solutions such as virtual and cloud services	Problematisation	The EC, ANSPs
Critical Factor 5 - Loss of jobs and environment is both an economic and social factor	Interessement	ANSPs(ATCOs, ANSP Technical Staff)
Critical Factor 6 - Conducting of a realistic CBA is decisive for the economic benefits of virtual centre	Problematisation	All
EF1 - A new business model for medium-sized, smaller companies	Enrolment	The Manufacturing Industry
EF1 - Economic crisis or downturn affect the adoption	Enrolment	All
EF2 - Alignment of business cycle of customers and the airlines	Enrolment	All
EF2 - Disintegration of services from core ATC services	Problematisation	ANSPs
EF3 - Defragmentation of 68 ACCs into 4 or 5 ACCs in Europe	Enrolment	All
EF6 - A lot of investment done on virtual centre, yet more is needed	Interessement	ANSPs, The Manufacturing Industry, SESAR-JU, The EC
Certification cost is high for virtual centre	Problematisation	ANSPs
EF7 - Promised reduction of overall costs by 30 percent	Problematisation	ANSPs
Reduction of the cost of physical infrastructure and hardware	Problematisation	ANSPs, The Manufacturing Industry
EF8 - The initial cost of setting up virtual centre is higher than expected	Problematisation	ANSPs
On condition that the EC or the EU cuts the funds, then the adoption is degraded	Enrolment	The EC
The cost of infrastructure is really big	Problematisation	ANSPs, The Manufacturing Industry
Data processing centre, power supplies, fiber networks that is required for the infrastructure	Problematisation	ANSPs, The Manufacturing Industry
The retro-fit cost should be taken into account in airborne investment	Problematisation	All
There is no short-term gain, only long-term gain	Interessement	All
Fewer people travelling might be a benefit	Mobilisation	All
More aircraft on the sky is not a benefit	Mobilisation	All
EF9 - More risks are involved for the ANSPs that are not adopting virtual centre	Mobilisation	ANSPs

Table 5.3 – Economic Factors Affecting the Adoption of the Virtual Centre

Correspondingly, the economic factors are summarized in Table 5.3 within the relevant actors and stages of adoption.

5.3.4 Political Factors

Even though the virtual centre is a technical project, political factors affect nearly all stages of its adoption. This is due to fact that the adoption of new technologies in European ATM is safety critical and also include politically driven actors. Yet, the political actors, currently, have misaligned interest in the adoption of the virtual centre for a number of reasons. First, each Member State has a sovereign responsibility to control the airspace over their boundaries. This is guaranteed under the Article 28 of the Chicago Convention. The technological change that the virtual centre brings allows sharing of data and location independent ATC theoretically from anywhere in the world. The political misalignment of the actors are mainly originating from the sovereignty and safety arguments. Apart from that, political actors are affected by the political objectives from various actors. Yet, these actors have often conflicting interests towards the adoption of new technologies.

Second critical factor is the contingency and safety issues arising when the virtual centre becomes operational. The location-independency of the ANS provision opens up new challenges on how to assess safety of the operations and who will responsible in the case of failure.

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Political Factors	Adoption Stage	Relevant Actor(s)
Critical Factor 1 - Deciding on how the failures will be dealt with in case of virtual centre	Mobilisation	All
Changing role depending on the failure events and their effects	Mobilisation	All
Critical Factor 2 - Raising interests of the political actors in the adoption of the virtual centre	Interessement	Political Actors (The Member States, The EC)
Decision-makers are affected by the political objectives of other actors	Interessement	Political Actors (The Member States, The EC)
Political actors have different conflicting interests resulting in slow adoption of new technologies	Interessement	Political Actors (The Member States, The EC)
Public acceptance of virtual centre is challenging	Interessement	Political Actors (The Member States, The EC)
Critical Factor 3 - Sovereignty over the airspace	Enrolment	Political Actors (The Member States, The EC)
Realistic approach is to expect that small to medium ANSPs are served by the big neighbouring ANSPs	Problematisation	ANSPs
Critical Factor 4 - Political pressure on actors to move towards service-oriented architectures	Enrolment	Political Actors (The Member States, The EC)
Political drive should create the necessary synergies for the adoption	Enrolment	Political Actors (The Member States, The EC)
Critical Factor 5 - Real consolidated view on virtual centre is needed from a political position	Problematisation	Political Actors (The Member States, The EC)
PF1 - Big countries need to work together to move new technologies forward	Enrolment	The Member States
PF2 - Collaboration with other ANSPs is a political issue	Enrolment	ANSPs
PF2 - Change management for the political actors in the case of new technologies	Interessement	ANSPs
PF3 - Limited collaboration between ANSPs towards adopting virtual centre	Enrolment	ANSPs
PF4 - Politicians should be convinced on the issues of sovereignty	Problematisation	The Member States
PF5 - Sovereignty of a country over their national airspace affecting adoption of new technologies	Problematisation	Political Actors (The Member States, The EC)
PF6 - Early adopters or innovators need to get the funding	Interessement	ANSPs, The Manufacturing Industry
PF7 - Ecology is part of political responsibility that affect the organization of traffic	Interessement	Political Actors (The Member States, The EC)
PF8 - The location of the data centre and the service provision is important	Problematisation	Political Actors (The Member States, The EC)
PF9 - Political factors even lead to challenges in a number of defragmentation solutions	Problematisation	Political Actors (The Member States, The EC)
PF10 - The EC and the Member States need to restructure the vision for the SES	Problematisation	Political Actors (The Member States, The EC)
PF11 - The actors have different interests in creation of synergies politically	Problematisation	Political Actors (The Member States, The EC)
PF12 - The Member States and the ANSPs should collaborate local and Pan-European levels	Problematisation	Political Actors (The Member States, The EC)

Table 5.4 – Political Factors Affecting the Adoption of the Virtual Centre

5.3. Factors Affecting the Adoption of the Virtual Centre

Currently, each state is responsible for the safety of their operations in their own airspace. With virtual centre, location independent service providers could provide services from anywhere in the world. Hence, the safety assessment and international agreements should be updated in order to adopt virtual centre in a Pan-European scale. Yet, there is also political pressure on the actors to reduce costs. This has a positive affect on the alignment of the political actors on the adoption of the virtual centre, on condition that virtual centre brings economic benefits and dynamic flexibility of the resources.

A important issue involving many actors is the consolidated definition of the virtual centre concept. The virtual centre is perceived in various forms including cloud-based services, internal defragmentation of ANSPs, application of the service-oriented architectures. Political actors could facilitate the common definition of a virtual centre. This is carried out by SESAR-JU, EUROCONTROL and the EC in the form of SESAR projects, where multiple actors collaborate to define the concept and adopt it accordingly. Yet, this collaboration could stay limited due to the political factors as mentioned starting with the sovereignty of airspace. The Member States, in general, working closely with their own local ANSP, should also approach the virtual centre solution in a Pan-European scale. Unless there is financial incentivization mechanisms in place for the adoption of the virtual centre, there is limited alignment with the political interests. With the proper regulation and the collaboration with the EC, rewarding incentives for the early adopters might help the adoption of the virtual centre.

5.3.5 Legal Factors

Virtual centre brings substantial changes with its radical enabling of location independent service provision considering the legal structure. The current legal structure relies on the local provision of the services, with every Member State and its corresponding ANSP is responsible for safe and secure air traffic within its predefined national airspace. Oppositely, virtual centre, by its conceptual design, abolishes the need of service provision to be locked inside the local service provider. If the virtual centre is adopted in a Pan-European scale, then even an ANSP could subscribe to services from another ANSP. Ultimately, the market for the provision of the services could be disrupted by the new entrants. Yet, this brings a totally new understanding of these legal structure. In the virtual centre configuration, high-level of data sharing between the providers would be key.

An overhaul of the legal structure would mean that cyber-security, sharing of information between service providers, liability and safety issues would be the key topics for discussions for the adoption of the virtual centre. Early adopters, such as Skyguide, alter the law to allow sharing of data for cross-border operations. Yet, not all the Member States are interested on sharing of data and information due to national sovereignty and liability issues. Furthermore, liability issues appear within the safety concept of the virtual centre. A new way assessing the safety and security of virtual centre is needed to provide seamless cross-border operations with high-level of information sharing and automation. Concretely, the virtual centre could

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Legal Factors	Adoption Stage	Relevant Actor(s)
Critical Legal Factor 1 - Modifications in the law of the Member States are needed to share infrastructure and data	Enrollment	The Member States
Skyguide had to modify Swiss law for essential data sharing to work with DSNA on virtual centre	Enrollment	ANSPs
Critical Legal Factor 2 - Member States are hesitant to share data due to cyber-security reasons	Enrollment	The Member States
LF1 - Liability issues under accidents or emergency issues	Enrollment	ANSPs
LF2 - Liability of cross-border operations and failures	Enrollment	ANSPs
LF3 - The EC becoming the micro-manager of technical regulations	Enrollment	The EC
LF4 - Regulating a huge network industry with a few experts	Enrollment	The EC
LF5 - The legal framework make the ANSP care about staff	Enrollment	ANSPs
LF6 - Safety issues in the beginning stages of implementation of virtual centre	Enrollment	ANSPs
Safety is not a showstopper for the virtual centre	Enrollment	ANSPs
LF7 - Liability issues attached to the sovereignty of the national airspace	Enrollment	The Member States
The responsibility under the delegation of airspace is done from one ATSU to another	Enrollment	ANSPs
LF8 - The virtual centre has to be liable in terms of safety, order and efficiency in ICAO standards	Enrollment	ANSPs, EASA
LF9 - Data liability issues in the case of virtual centre and machine learning or artificial intelligence	Enrollment	ANSPs, EASA
The training of the artificial intelligence or machine learning algorithms are important	Enrollment	ANSPs, EASA
LF10 - Security issues in relation to cloud implementation of virtual centre	Enrollment	ANSPs, EASA

Table 5.5 – Legal Factors Affecting the Adoption of the Virtual Centre

definitely look at the cloud-based solutions in other network industries as a role model for the new legal framework.

5.4 Technology Adoption Process of the Virtual Centre

The adoption process of the virtual centre is a complex interaction between the multiple actors in the European ATM. This interaction is modeled using the four moments of translation of stages (problematisation, interessement, enrolment, mobilisation) as previously described in the research design chapter. This section specifically explains this process for the adoption case of the virtual centre guided by the conceptual framework. The findings are embedded in the analysis representing both the actors, relationships, stages of the technology adoption and critical factors affecting the technology adoption process. The adoption process of the virtual centre is summarized graphically using the notation of the conceptual framework in the end of the section. The actors and their relationships are categorized under critical, pushing, passive and decisive. The graphical summary shows the barriers as the obligatory passage point for each stage of adoption. Additionally, the factors are represented with spheres of influence, where the size of the circle emphasizes the impact of each factor category of technical, economic, political, social and legal. Overall, the adoption process is represented by summarizing the main actors involved, their objectives, stages of the adoption and the factors or barriers affecting the adoption of the virtual centre.

5.4.1 Problematisation [Stage 1]

The problematisation stage consist of the initial definition of a technology, with the introduction of a new concept of the virtual centre by an actor. In our case, this actor is the Swiss ANSP, Skyguide. Skyguide translates its objective of defragmenting between their two ACCs in Geneva and Zurich into a concept called the virtual centre model around 2013. The initial problematization phase starts directly with this definition. An idea comes into life and an actor adopts the idea with the objective of finding the relevant partners to realize this objective.

5.4. Technology Adoption Process of the Virtual Centre

The idea to adopt virtual centre comes with internal changes within the ANSP in management and technical staff initially. Then this is followed by finding the right manufacturing industry partner to produce the necessary hardware and software for the project. The new industry partner(s) are also from internal and external to the air traffic domain. Since the virtual centre is a new concept for the ATM, there is a need to find the suitable partner with the right expertise to realize the virtual centre.

Following this, Skyguide partners with other ANSPs, such as DSNA in the first place, to implement cloud-based services for the flight data processing (FDP) systems. Coflight cloud-based services is offered by DSNA in partnership with Skyguide, sharing FDP data between the two ANSPs. This can be regarded as the initial implementation of data sharing model for the virtual centre model between the two ANSPs. Virtual centre is based on implementing cloud-based services between ANSPs or ATSUs in order to defragment their technical and operational requirements. Hence, in the problematisation stage DSNA, another ANSP, joins to the objectives of Skyguide translating their objective into a cooperative model. This is important for the initial acceptance for the virtual centre, as even in the problematisation stage, there is interest from other actors to support the new technology.

Of course, introducing a radical technology, such as the virtual centre, comes with its challenges. The data sharing model between the two or more ANSPs is a legal and political challenge, which involves political actors, such as the Member States and the Military. The safety and security issues and sharing of critical civil and military data create a need to modify law in order to share data between Member States. This is due to the fact that the conventional law requires that the data generated or used shall originate in the Member State. In general, remote provision and location independent service provision are new concepts for the European ATM, this should be targeted both from a political and technical point of view. Eventually, the agreement between the neighbouring countries could easily solve the barriers for the further adoption of the virtual centre.

In order to solidify the objectives of the virtual centre, a realistic cost-benefit analysis is needed in the initial stages of the adoption. Each ANSP deciding to adopt the virtual centre locally implements their own internal analysis to assess the economic impact of the virtual centre technology. Skyguide investigating the current and future trends decided to adopt virtual centre even though there is heavy initial investment required for the realization of the new technology. Yet, an overall CBA covering the European airspace and more relevant actors appears as an obligatory passage point through the problematisation phase towards the second stage of interessement. In order to attract the interests of the other actors, a positive CBA is treated as a requirement. Furthermore, the success of problematisation phase depends on the technical synchronization of the investments and procedures among the interested actors for the virtual centre. The initial technical requirement is the standardisation of the systems between ANSPs in order to connect their services in a plug and play fashion. Another possible hindering barrier is the acceptance of the ATCOs and the Controller Unions. These two actors have the decisive role on the adoption of the virtual centre affecting the opinion

and objectives of other actors by either pulling or pushing the adoption process. This is due to the fact that the virtual centre is changing the work practice, conditions, salaries, and reduce the number of jobs available to ATCOs. Precisely, the barriers and critical factors affecting the first problematisation stage of the virtual centre adoption are provided as below:

- **Obligatory Passage Points**

- **Political Technical Obligatory Passage Point:** Political actors decide on the extend of the virtual centre implementation level
- **Economic Obligatory Passage Point:** Realistic CBA proving the economic benefits of the virtual centre
- **Technical Obligatory Passage Point:** Synchronization of all investment and procedures for the virtual centre among actors
- **Social Obligatory Passage Point:** Controller Unions have a decisive role on the adoption process due to change in social conditions (jobs. location independency, salaries, work practices)

- **Critical Factors Affecting the Technology Adoption Process**

- **Economic**

- * Cost-effectiveness
- * Location independency benefits
- * Cost-efficiency targets of the EC
- * Realistic CBA
- * Requirement of heavy initial investment

- **Technical**

- * Deviations and variations of the virtual centre concept
- * Tailor-made solutions of ANSPs
- * Industry delivering monolithic non-interoperable systems

- **Social**

- * Decisive role of ATCOs and Controller Unions
- * Fragmented management in Europe
- * Lack of experts in virtual centre concept

- **Political**

- * Sovereignty of airspace
- * Consolidated view on the virtual centre

5.4.2 Interessement [Stage 2]

The second stage of the adoption is called interessement and, as the name suggests, in this stage new actors start to get interested with the adoption of virtual centre and try to align their objectives with the focal actors. There, it is observed that the supranational actors, such as EUROCONTROL and SESAR-JU incorporated the virtual centre concept inside the scope of the SESAR project. With the support of a coalition of ANSPs including COOPANS, NATS, ANS-Czech, DFS, ENAV, and ENAIRE and the relevant industry partners, this stage marks the attraction of all the interested actors inside the adoption of the virtual centre. Here, the importance of the supranational actors on creating the collaboration and coordination between the actors is emphasized. EUROCONTROL and SESAR-JU defined a common roadmap for the adoption for the virtual centre both in including the virtual centre in specific SESAR projects and also providing the actors the Master Plan and the AAS.

The joining forces of these interested actors are guaranteed by the proper funding mechanisms for the adoption of the virtual centre. Yet, there exists economic barriers related to heavy initial investment required to adopt virtual centre for ANSPs. In order to solve this, there should be financial incentivization mechanisms supported by the regulators to reward early adopters. Additionally, during the collaboration stage, the actors face technical barriers. First, the technical compatibility between the switching data service providers should be solved. Moreover, the actors, especially ANSPs state that the virtual centre is seemingly becoming more complex than what it thought to be in the beginning. This affects the initial cost and benefit estimates of the ANSPs and their economic targets on the adoption of the virtual centre.

The virtual decoupling of the air navigation services from the ANSPs and location-independence attract new actors inside the ANS market. These new actors include the ADSPs, IT giants and new industry and regulator supporting these two disruptors. These actors are expected to penetrate the ANS market during the ending phase of the interessement stage. Yet, they are not currently involved within the interests or objectives of other actors. Moreover, the tight regulation of the ANS market and the monopoly of the ANSPs providing the ANS services make it harder for the new actors to penetrate the ATM market. On the other hand, the definition of the ADSP has been established by the supranational actors and the EC. This marks the realization and possible creation of this actor, serving to ATSUs independently of the location. By time, ANSPs also evolve into ADSPs or ANSPs could aid the creation of the ADSPs by separating and virtualizing their service provision with location independency. On the other side, new actors could also act in the form of ADSPs and raise competition for the provision of the ANS services.

Currently, the adoption of the virtual centre is in the middle of the interessement and enrolment stage. The supranational actors manage to attract ANSPs, the industry partners in order to form common objectives and roadmaps towards the adoption of the virtual centre. The SESAR projects aim to deploy virtual centre in a Pan-European scale by 2030, yet some

of these ANSPs are already adopting the virtual centre, such as Skyguide, DSNA and NATS. Yet, a common definition for the virtual centre concept is crucial for the further adoption of the concept by other ANSPs. In this stage, the push from the actors of SESAR-JU and EUROCONTROL decide on the fate of the adoption with the rewarding incentive mechanisms for the early adopters of the virtual centre. In order to do this, the political actors should be convinced and their interest for the virtual centre should be aligned. Conflicting interests of the political actors, originating from the social factors, such as change in social conditions of ATCOs and technical staff of ANSPs affect the adoption of the virtual centre. The Member States could easily affect the objectives and interests of their ANSPs on the adoption. In this case, they directly became decisive actors for the adoption process. Additionally the change management on the ATCO side is crucial. The virtual centre can be perceived as a disruptive technology for the ATCOs, since it directly affects their work practices and conditions, even ultimately change of social conditions for the ATCOs. Accordingly, the barriers and critical factors affecting the second interestment stage of the virtual centre adoption are provided as below:

- **Obligatory Passage Points**

- **Economic Obligatory Passage Points**

- * Proper funding of the virtual centre by the relevant actors
 - * Creation of incentivization mechanisms for the early adopters

- **Technical Obligatory Passage Points**

- * The decision for the creation and supervisory authority of ADSPs
 - * Technical compatibility between switching data service providers
 - * Virtual Centre concept is more complex than what it seems in the beginning.
 - * Performance issues in the case of rationalization of airspace
 - * Cyber-security might be a hindering issue for the adoption of the virtual centre

- **Critical Factors Affecting the Technology Adoption Process**

- **Economic**

- * Proper funding of new technologies (virtual centre)
 - * Reduction in workforce

- **Political**

- * Possible misalignment of political actors
 - * Challenges in public acceptance of virtual centre
 - * Political objectives of aviation stakeholders affect political actors
 - * Conflicting interests of political actors

- **Social**

- * Change of social conditions of ATCOs
 - * Change of social conditions of ANSP technical staff

5.4.3 Enrolment [Stage 3]

The enrolment stage marks the locking of the interest of the aligned actors and the switch towards the operation virtual centre through Europe. This stage looks into the timeline between, today, 2020 and 2030. In this stage, the market for the provision of services supported by the virtual centre is expected to be established. Concretely, on condition that this market is operational then large number of ANSPs could operate under the conditions of the virtual centre. Notably, this is perceived as the responsibility of the EC to either create this market or promote the creation of the market by incentivizing other actors. The creation of this market will eventually attract new actors from the interestment stage to compete for the provision of the air navigation services. This will eventually lead to drastic changes on the political and legal side in order to allow these new actors to penetrate the market.

In the legal side, sharing of data and services force modifications of law of the Member State in collaboration with the ANSPs. This will be followed by a new approach to certification for the ATCOs working under the services provided by virtual centre configuration. Hence, the remote provision of ATC allows ATCOs to work location independently, this should be certified in a new way to protect the safety and conditions of the service. Here, the safety actor EASA is expected to play a role on the standardization and safety assessment of the virtual centre before and during operations of virtual centre. On the technical side, when the virtual centre is operational, depending on the CNS technology used, there would be frequency congestion issues and the modernization for the voice communication in European airspace might be needed.

Enrolment of actors in the virtual centre configuration depends also on the promises of the virtual centre. If the early adopters prove the benefits of the virtual centre on the defragmentation and cost-efficiency, more ANSPs will be involved in an operational virtual centre. The number of services available also depends on how many ANSPs, or new actors join and be able to operate under virtual centre configuration. In this case, Skyguide, and a few more early adopters plays an important role on showing the benefits of the virtual centre. If the virtual centre configuration becomes successful in Europe, the late-adopting ANSPs would have no choice but to collaborate with a neighbouring ANSP that have the virtual centre capability. This would eventually natural defragmentation of the system. Moreover, with the creation of the ADSPs or penetration from the other actors, the air navigation services could be served from a few sources, rather than each provider for each state. Concretely, the barriers and critical factors affecting the third enrolment stage of the virtual centre adoption are provided as below:

- **Obligatory Passage Points**

- **Legal Obligatory Passage Point**

- * Modifications in law is required to share infrastructure and data
 - * Certification of ATCOs under remote configuration of ATC

- **Economic Obligatory Passage Point**
 - * Creation of an initial market for the virtual centre supported by service orientation
- **Political Legal Obligatory Passage Point**
 - * Regulators should enforce collaboration between ANSPs due to sovereignty issues
 - * Certification of ATCOs under remote configuration of ATC
- **Critical Factors Affecting the Technology Adoption Process**
 - **Legal**
 - * Modifications required in law for sharing data
 - * Reluctance to share data due to cyber-security
 - * Challenging to share sensitive Military data
 - **Political**
 - * Sovereignty of airspace
 - * Political pressure to adopt service-orientation
 - * Creation of a political drive for adoption
 - **Economic**
 - * Non-existence of a market for virtual centre
 - **Technical**
 - * Frequency congestion and modernisation of CNS

5.4.4 Mobilisation [Stage 4]

In this final stage of mobilisation, the EC plays an important role as a regulator, yet currently stays passive as an actor. Assessing the realistic benefits of the virtual centre from the early adopters, the regulator might decide to promote the adoption of virtual centre and open the ANS market for competition. This is very similar to what happened to other network industries with the liberalization of services. In that respect, the virtual centre possess a high disruptive value. The EC is an actor with connections and influence on other actors, such as the Member States, ANSPs, EUROCONTROL and EASA. On the other side, it is hard to align the political objectives of the actors due to the sovereignty of airspace argument. The Member States have the sole responsibility of their airspace and the data generated in their systems. Not only a paradigm shift in technology, but also in legal and political perspectives are needed for the successful adoption of the virtual centre.

Mobilisation includes the attraction of new actors and solidifying the network of actors into aligned objectives with regards to the adoption of the virtual centre. It marks the timeline

5.4. Technology Adoption Process of the Virtual Centre

after 2030, where virtual centre is mainly operational within the early adopting ANSPs, and possibly ADSPs. This stage includes the penetration of the market by the new actors, possibly from other network industries of IT and telecommunications. Coupled with high-levels of automation, and the rise of artificial intelligence, it is expected that the European ATM systems are connected seamlessly in a virtual centre configuration. Still, political and social factors are expected to affect this final stage of adoption. Depending on the decision of adoption of the major actors in the European ATM, sovereignty of airspace remains as a challenging political factor. In the case of failures the political responsibility is hindering the further adoption of the virtual centre. Within this time frame, the role of ATCOs is expected to shift into a managerial task, with the operations automatized as most as possible. A new type role, such as Air Traffic Manager is expected to be shaped. This is definitely a challenging social factor for the mobilisation of the virtual centre.

- **Critical Factors Affecting the Technology Adoption Process**

- **Political**

- * Sovereignty of airspace
 - * Dealing with failures in case of virtual centre

- **Social**

- * Cultural and work practice change of ATCOs

Virtual Centre - Technology Adoption Process

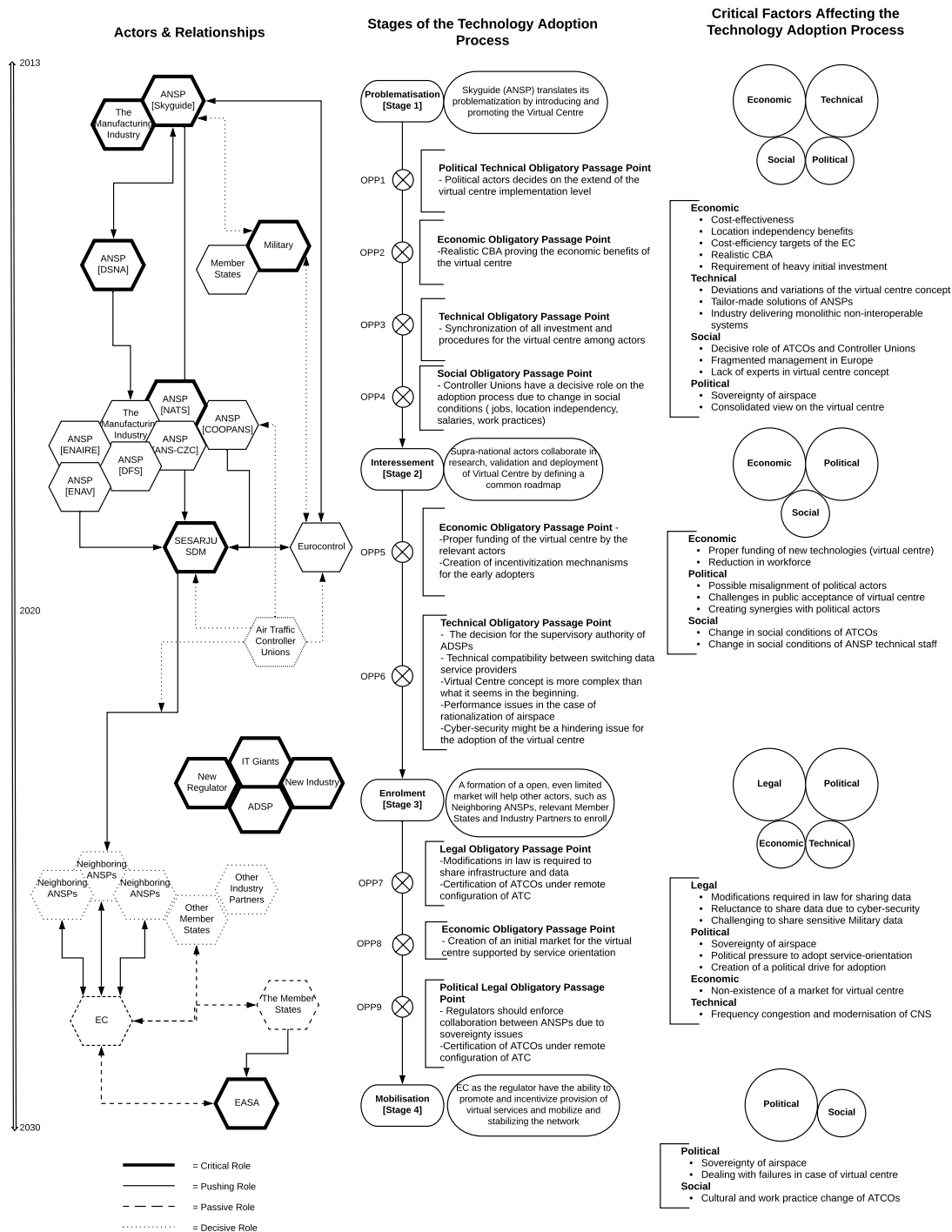


Figure 5.11 – Virtual Centre Technology Adoption Graphical Representation

6 Flight-Centric Operations

6.1 The Concept and History

Initially named as the sectorless ATM, flight-centric operations faced a number of changes in its definition, context and concept. The key element of the technology is to be able to move from conventional sector based operations towards a sectorless airspace control, ultimately merging all the sectors by focusing on the flight itself. The concept is first officially introduced by Duong et al. (2001) to handle increasing traffic in a complex airspace, while also keeping the safety at check [Duong et al.(2001)Duong, Gawinowski, Nicolaon, and Smith]. In order to solve this problem, a number of initiatives, Free-Flight in European Air Traffic Management Program (EATMP), User-Preferred Routes, Autonomous Aircraft Operations, and Flexible Use of Airspace are created by various actors in the European ATM. Yet, previously there does not exist a predefined formula for the overall management of change in the airspace sectorization. Addressing this problem, Duong et al. (2001) offered the decentralisation of the airspace sector control towards a trajectory-based flight control. Henceforth, this brings substantial changes in the work practices of ATC and ATCOs, regarded as a revolution rather than an evolution. Back in 2001, two possible options are considered for the sectorless ATM. First is the location independency of the ATCO as an ATCO being attached to an airline. Second is the evolving role of ATCOs towards a real-time dynamic flow manager.

Following the initial definition of the concept, Riviere (2004) further continued to validate the route network for sectorless ATM and built optimized techniques [Riviere(2004)]. Moreover, these validations insisted on the need to introduce new practices into ATC, while moving away from the traditional sector based approaches. Riviere (2004) suggested that sectorless ATM shifts the paradigm of ATC in discrete steps. In order to reach trajectory-based operations, the airspace should be redesigned with optimal routes, both optimizing the network, traffic and flows at the same time. These changes could be implemented by a complete overhaul of the current airspace structure, where a new method of network optimization, Trunk Route Generation, is offered as one of the possible solutions. Yet, Riviere (2004) suggested that more evaluations have to be carried on to validate the route network structure. Correspondingly, two

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issues have been identified for sectorless ATM. In terms of extension and level of allocation, the user, ATCO, should be taken into account for further evaluation. Additionally, fast-time simulation using real data could aid the validation process for sectorless ATM.

The sectorless concept gained traction by the joined contribution of DLR and DFS [Korn et al.(2009)Korn, Edinger, Tittel, Kugler, Putz, Hassa, and Mohrhard]. Korn et al. (2009) examined the feasibility of the concept, pointing on en-route ATC efficiency increase by 100 percent. A bigger portion of the airspace, including the whole German airspace, extending into the European airspace, is considered for the real-time simulations. The physical requirements for ATCOs in sectorless operations are defined as a new controller working position (CWP) providing the necessary support tools for the sectorless control. Consequently, this should be supported by reliable coordination tools for the ATCOs working under sectorless rules, assisting the situational awareness level of the ATCOs. Furthermore, Korn et al. (2009) summarized the foreseen benefits of sectorless ATM as follows [Korn et al.(2009)Korn, Edinger, Tittel, Kugler, Putz, Hassa, and Mohrhard]:

- The traffic load can be easily distributed in a very balanced way over the controllers on duty.
- Airspace capacity is no longer restricted by sector capacity. Instead, it is expected to increase ATCO efficiency of up to 100 percent.
- It offers an easy way to implement contingency actions since controllers can take over aircraft regardless of which center they are currently working for.
- Coordination actions between adjacent sectors are no longer necessary. The amount of voice communication between the aircraft and ATC are reduced. There are no handover and identification communications necessary.
- SESAR (or NextGEN) concept elements, like business trajectories, can be easily incorporated in this concept since the ATCO will have in mind the entire flight of his aircraft. ATCO is only supposed to interfere in case of conflicts. The better the individual business trajectories are coordinated with each other, the less difficult will be the job of the ATCO.
- As the airspace structure (sectors, airways, etc.) are no longer necessary, a direct-to based traffic organization can be envisaged.
- ATCOs will immediately see what their control actions will mean to the aircraft. A closer relationship between controllers and aircrews will be established. The ATCO could be regarded as an additional (temporary) aircrew member taking care for conflict free routing.

Furthermore, Korn et al. (2009) identified the changes needed to implement sectorless operations. The necessary communication method between a pilot and a sectorless ATCO is a

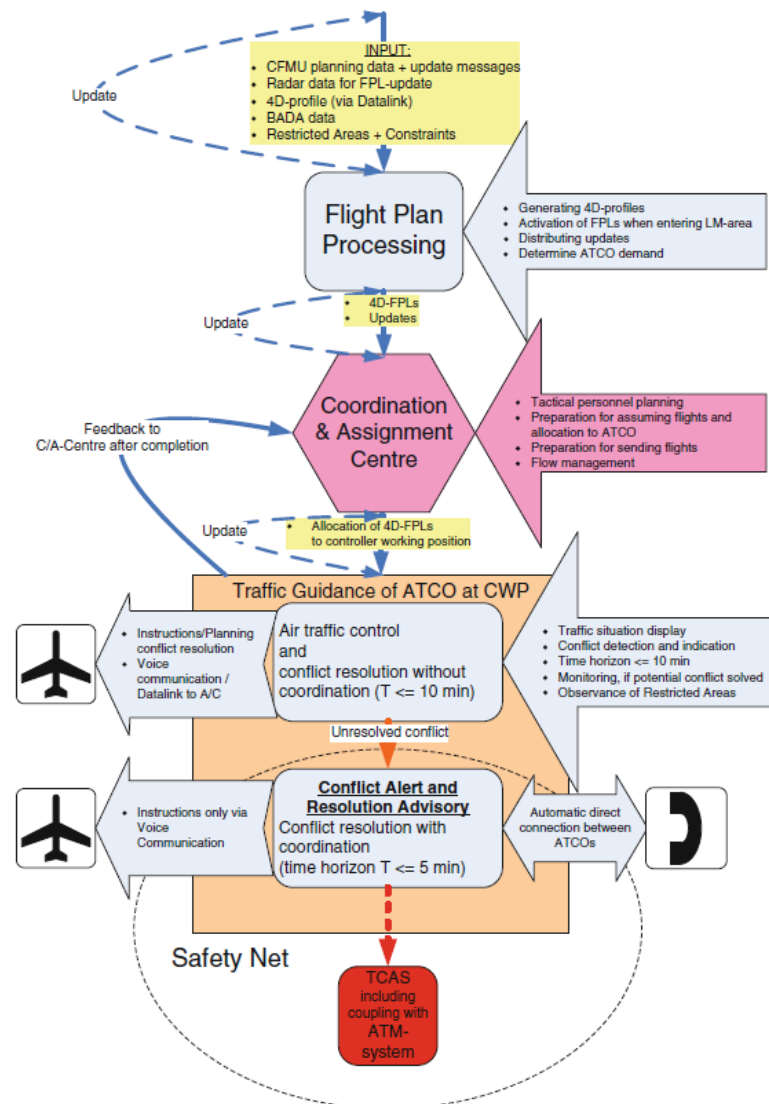


Figure 6.1 – Graphical Representation of the Conceptual Operations under Sectorless ATM configuration [Korn et al. (2009) Korn, Edinger, Tittel, Kugler, Putz, Hassa, and Mohrhard]

pre-requisite during the control of the flight. Apart from technical changes, the work practices of ATCO also change. The crucial one is the coordination between the ATCOs in the cases of conflict and resolution. This should also be supported with the adaptation of the flight rules for the case of sectorless ATM. Another point is the assignment of workload, and corresponding workload on the sectorless ATCOs. Assessing the feasibility of sectorless, Korn et al. (2009) proposed an experimental setup for sectorless ATM within the scope of their validation exercises. Respectively, first the operational concept is developed, then followed by a proof of concept simulation, which included a new definition for sectorless human machine interface (HMI) for ATCO, and support tool development. The results of the validations show that the sectorless ATM is a promising concept with manageable changes of the work practices

of ATCOs. Furthermore, ATCOs suggested the need for pre-defined rules for conflict detection and resolution in sectorless ATM. Notably, the study points out that the organisational, economic, and regulatory view should be discussed for the future adoption of sectorless ATM [Korn et al.(2009)Korn, Edinger, Tittel, Kugler, Putz, Hassa, and Mohrhard].

Within a sectorless environment, a critical topic remains as balancing the ATCO workload according to the new organization of the airspace and merging of the sectors. Schmitt et al. (2011) examined the possible assignment of aircraft to ATCOs in sectorless configuration within a joint project between DLR and DFS, called Airspace Management 2020. The conventional sectorized approach and using smaller sectors to accommodate traffic have disadvantages. Thus, initially dynamic sectorization could solve the rigid structure of the sectors, allowing for more flexibility and better allocation of resources. Next, implementing sectorless operations, an ATCO could be responsible for a number of aircraft from its departure to arrival destination. Schmitt et al. (2011) is the first to conceptualize the concrete steps for operations under sectorless ATM configuration as depicted in Figure 6.1 [Schmitt et al.(2011)Schmitt, Edinger, and Korn]. Under various conditions of sectorless configuration, the efficiency is found to be similar to current conventional operations if an ATCO is assigned 3 aircraft, considering the German airspace. If ATCOs train to utilize better their workload and control more aircraft, then the benefits of the sectorless configuration increase. A dynamic configuration of the workload of ATCOs under specific level or complexity of airspace is key to reach the benefits of sectorless operations.

Upon evaluation of the feasibility and operational setup, five transition strategies towards flight-centric operations are offered by Birkmeier et al. (2014) [Birkmeier and Korn(2014)]. Concretely, the transition towards flight-centric operations is foreseen to be gradual by reducing the safety risks associated with its adoption. Thus, strategies for transition are important for a new technology, such as flight-centric operations. The five transition strategies are element-wise, aircraft-wise, time-restricted, area-restricted and top-down transition [Birkmeier and Korn(2014)]. In element-wise transition, initially introductory concepts related to sectorless ATM are deployed before the technology reaches maturity until full deployment. These include the conflict detection and resolution tools and upgrades in the data and voice communication technologies to support sectorless ATM. Therefore, this approach minimizes the safety risk by deploying new technologies step by step to support sectorless operations. The second type of transition, aircraft-wise, relies on the differentiation between sectorized aircraft and sectorless aircraft. Consequently, this approach follows the definition of new rules for the specific types of aircrafts and airlines operating under flight-centric rules.

Alongside, sectorless ATM could be implemented within a time-restricted transition. Initially, night-time operation is suitable for testing and verification of sectorless operations. Next, the extension could be made to cover the parts or entire time of the day according to airspace complexity and structure. Correspondingly, the training of ATCOs should be modified to accommodate the necessary workload for sectorless operations. Another transition strategy is to restrict the area of sectorless operations, first starting with merging of sectors and then

enlarging to ANSP airspaces. In these sectorless areas, new rules could be tested and matured before enlarging to bigger airspaces. Finally, as being also the most familiar transition strategy is to implement sectorless approach in top-down manner according to flight level. The top level consists of the least complex en-route operations which are suitable for sectorless operations at first trials. Moving down in the flight levels, the complexity and homogeneity change and sectorless ATM could be well verified within various flight levels. Of course, possible combination strategies exist and should be well-suited depending on the type, structure and complexity of airspace.

Additionally, Birkmeier et al. (2014) identified the key elements to enable sectorless ATM. First and foremost, an assignment centre is required for the assignment of aircraft from the flight plans to ATCOs working in sectorless configuration. Complementarily, sectorless ATM requires the necessary voice communication to support the ATCO along the trajectory of flight inside sectorless airspace. This could be established by increasing the coverage for the frequencies in a sectorless airspace. For controllers, a new traffic situation display, supported by sectorless controller tools and priority rules for conflict detection and resolution, is important to attract their interest for sectorless ATM solution. The benefits of sectorless ATM are stated as even ATCO workload distribution, flexibility and a possible capacity increase of up to 100 percent [Birkmeier and Korn(2014)]. These benefits are followed by the easy integration to other SESAR concepts and solutions and the switch to user preferred trajectories.

Sectorless ATM brings substantial changes in the way ATCOs work. In sectorless ATM, an assignment centre assigns aircraft to ATCOs working under sectorless configuration and rules. On duty, the workload could be distributed among the available actors, optimized within the airspace structure and complexity. A tiled display is provided in the frame of the DLR simulation for each ATCO that is responsible for 6 aircraft flying in the upper German airspace at the same time. Controller working positions (CWP) include a large screen assisted by areas of information for sectorless operations. Birkmeier et al. (2016) stated that there is a shift of tasks between the executive and planning ATCOs [Birkmeier et al.(2016)Birkmeier, Tittel, and Korn]. The executive controller is more responsible for the monitoring and tactical control, while automation takes over the planning tasks. Drastic changes happen with sectorless operations in the situational awareness of ATCOs, since now the focus shifts from a single sector to trajectory. Hence, this brings new possible configurations for the teaming of the ATCOs. Among these setups, executive and planner team, two-controller team, coordinator-executives team, and control-room team are regarded as the possible candidates. Yet, the geographical and structural differences of the airspace affect the setup of the teams, so a dynamic configuration and distribution of workload are suggested as possible solutions.

Recently, a collaborative study between DLR and Hungarocontrol assessed the feasibility of the flight-centric mode of operations [Martins et al.(2019)Martins, Finck, Mollwitz, Kling, and Rohács]. Specifically, the real-time simulation covered the upper airspace of Budapest Area Control Centre (ACC) between flight levels of FL325 and FL660. A human performance approach is taken to evaluate the ATCO responsibilities and tasks, looking in ATCO trust,

workload and situational awareness, and assess the properties of the CWP display under flight-centric configuration. Martins et al. (2019) reports that flight-centric operations drastically change the situational awareness of ATCOs, especially in high complexity airspaces. In order to accommodate the change in situational awareness, a refined definition for flight-centric operations should be put in place, coupled with specific filtering for aircraft [Martins et al.(2019) Martins, Finck, Mollwitz, Kling, and Rohács]. With the possible integration of automation, trust of ATCOs in the automated systems could become problematic to satisfy the safety requirements. Enhancing the conflict detection and resolution tools is key to increase the trust of ATCOs in the flight-centric configuration.

The limits of the current way of doing Air Traffic Control (ATC), using ground-based radars and splitting airspace into sectors, each staffed by a team of controllers, have long been highlighted. In busy parts of the airspace, it becomes unfeasible to achieve further increases in capacity by splitting sectors due to the added coordination between neighboring sectors and the scarcity of resources of radio frequencies. The flight-centric concept, sometimes also called sectorless ATC, has the potential to address these limitations by changing control-by-sector to control-by-flight. In this concept, a controller would control one or more flights along a significant portion of their trajectory, be this within a large en-route volume of airspace, from approach area to approach area or even eventually from gate-to-gate. This concept is under development in the scope of SESAR the European Programme for ATM modernization and is aimed for deployment by 2035+. The complementarity between the flight-centric concept and other SESAR innovations is under discussion.

This section also highlights advantages of this concept compared to current ATC. Results of validation for a block of airspace in Germany show that the concept has the potential to increase controller efficiency and airspace capacity. The impact of sectorless air traffic control on controllers tasks states that coordination with neighboring sectors is no longer necessary and that the introduction of conflict detection tools and other automatic support systems could relieve the controller of planning tasks, thus shifting the main tasks more towards tactic control and monitoring. There also exists ways to help the controller to exploit the benefits of sectorless control while retaining situational awareness. A preliminary safety assessment of the sectorless concept establishing safety requirements for the design of this concept is established.

Considering that sectorless ATM is likely to coexist with other ATM concepts, there are five different strategies for the introduction of sectorless ATM: element-wise, aircraft-wise, time-restricted, area-restricted, and top-down transition strategies. The use of a top-down transition strategy combined with an element-wise transition is suggested as it could limit the number of simultaneous changes whilst taking full advantage of long-term planning. This section continues with a comparison of the flight-centric concept against current conventional ATC. Following this, it then identifies changes in the ATC market structure enabled by this concept and the assumptions made in terms of availability of technologies and feasibility of the concept. Four business models are presented in the following section which is expected to shape with

flight-centric operations.

6.2 Actors, Their Roles and Relationships

This section presents the relevant actors and their roles in the adoption process of the flight-centric operations in the European ATM. First, the section describes the main actors, focusing separately on the roles and interests of each actor. Second, the relationships between the actors are presented using the four moments of translation as described in the conceptual framework. Each actor also translates their objectives through connecting with other actors. The main actors are the ones that play an active role in the adoption of the flight-centric operations, while the side actors either have passive roles or indirectly affected by the adoption.

6.2.1 Air Navigation Service Providers

Flight-centric operations bring substantial technical changes for the ANSPs towards adapting their current conventional ATC systems. Mainly, the controller working position (CWP), voice communication, and ATCO support tools need to be adapted before an ANSP starts to adopt flight-centric operations. This will, in turn, requires a heavy initial investment for the ANSPs, including the hardware, software, provision, testing and staffing costs for the ANSPs. Coordinating with an industry partner is key for ANSPs towards adoption of flight-centric operations. Already, DFS, Hungarocontrol and CzechControl partnered with their corresponding manufacturing industry to build the necessary technologies to support flight-centric operations. Moreover, interested ANSPs such as DSNA, ENAV, ANS-CR, ENAIRE and NATS collaborate on the further research and development under the SESAR flight-centric project PJ.10-01b. Initially, these ANSPs would decide on the implementation level and coverage for the first local implementation of flight-centric control. On condition that big and medium sized ANSPs start to adopt flight-centric operations, then the neighbouring small ANSPs would be also interested to adopt.

ANSPs play an important role in the adoption of flight-centric operations, first as being a potential user of this technology to provide air navigation services in the European airspace. Not all ANSPs in Europe have the similar size, complexity, and a corresponding interest in the adoption of new technologies. According to this difference, there exists a number of ANSPs interested in the adoption of the flight-centric operations, while others either choose to remain passive. Mainly, the decision to adopt flight-centric operations by ANSPs depends on the proof in the form of positive cost-benefit analysis, and the condition that the local ATC market of ANSP are not disrupted by another competitor. Hence, the management level of ANSPs could play a decisive role in the adoption process depending on the technical and economical feasibility of flight-centric operations. A critical key performance indicator for flight-centric operations is ATCO productivity, where if there is substantial benefits, then more ANSPs would join within the network of adopters. In order to implement and understand the necessary changes of flight-centric operations, ANSPs also collaborate with the flight crews.

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Important to realize is that ANSPs include technical and operational staff who play important role in the adoption process. The technical staff is responsible for the specification of the tools to support the flight-centric operations. These include the specification of conflict detection, resolution, and cross-border tools in coordination with the operational staff, ATCOs. Besides, the flow management staff reported to have a better probability of implementing the necessary operational changes related to the adoption of flight-centric operations. Yet, on the operational side, ATCOs have the decisive ability for the adoption process depending on the level of changes in their work practices. As for the generic requirements for the flight-centric operations, ATCOs provide the business requirements for ANSPs and industry partners, translating them into technical requirements. Part of their job is to execute the testing, and provide their opinions on the design of the future ATM systems.

In the case of flight-centric operations, the roles of ATCOs also shift dramatically. Automated support tools are expected to aid the flight-centric controller throughout the trajectory of the flight. Operational supervisors need to plan further for the overall traffic and conflicts in a relatively larger airspace than sectorized configuration. Executive ATCOs become responsible for a number of aircraft in a bigger airspace, which result into a change in situational awareness. Depending on how this change of situational awareness is handled using new support tools, ATCOs have a decisive role on the adoption of flight-centric operations. An additional factor is the balance of workload of ATCOs in the case of flight-centric operations. If the dynamic allocation of aircraft to ATCOs work towards increasing the productivity of the ATCOs, then ATCOs would support the adoption of flight-centric operations. In the case of local implementation, ATSU as a single unit could decide whether or not to switch to flight-centric operations.

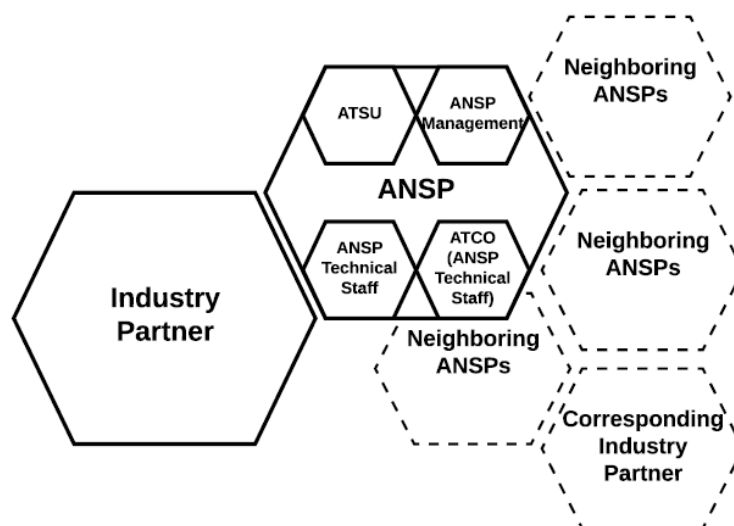


Figure 6.2 – Graphical Representation of ANSP and its First-Order Relationships

ANSPs partner with a manufacturing industry in order to realize new technologies, such

as flight-centric operations. The ANSP-industry pair is inseparable, and there exists a first-order relationship between these two actors. The ANSPs itself constitute from Air Traffic Services Unit (ATSU), ANSP technical staff, ANSP operational staff and ANSP management, segregated according to their various roles played in the adoption of the virtual centre. ANSPs are also in direct relationship with their neighbouring ANSPs, both for the seamless cross-border operations and collective adoption and realization of the flight-centric operations. The neighbouring ANSPs additionally partner with an industry partner of their choice in order to adopt flight-centric operations. These actors are illustrated in Figure 6.2.

ANSPs have critical, pushing, decisive and generic roles in the adoption of the flight-centric operations. First, the roles for the overall ANSPs are presented. This is followed by the explanation of distinct roles for the ATSUs, ANSP technical staff, ANSP operational staff (ATCOs) and ANSP management respectively. Starting with ANSPs is crucial, since investigating the main motivations of the ANSP help to understand the objectives of the other actors. The types of roles and explanations of the ANSPs are presented as below:

- **ANSP**

- **Critical Role 1:** ANSPs need to adapt their systems to the requirements of the flight-centric operations.
 - * **Critical Role 1.1:** The controller working position, specifically screen and supporting tools needs to be adapted for flight-centric operations.
 - * **Critical Role 1.2:** An initial strong investment is needed to adapt the current technologies and supporting tools.
 - * **Critical Role 1.3:** Provision, system design, testing, providing the staff effort for the flight-centric operations.
 - * **Critical Role 1.4:** Application of required changes in FDPS, and system coordination between sectors to support flight-centric operations.
 - * **Critical Role 1.5:** Coordinating with the industry partner in order to build a strong link to adopt flight-centric operations.
- **Pushing Role 1:** ANSPs will be interested in implementing flight-centric operations due to flexibility of the non-geographical ATCO.
 - * **Pushing Role 1.1:** DFS is working on the definition for the non-geographical ATCO in the context of flight-centric operations.
- **Pushing Role 2:** ANSPs try to collaborate by sharing their experiences in research projects and workshops.
 - * **Pushing Role 2.1:** DFS, Hungarocontrol, CzechControl, ENAIRE, DSNA, NATS, ENAV, ANS-CR and A6 Alliance are currently working under SESAR projects related to flight-centric operations.
- **Generic Role 1:** Deciding on the level of implementation of flight-centric operations (local or sub-regional).

- * **Generic Role 1.1:** Germany (DFS), Hungary (Hungarocontrol), Czech Republic (CzechControl) are adopting flight-centric operations locally.
- * **Generic Role 1.2:** If the big-medium sized ANSPs implement flight-centric operations, the small sized ones will follow.
- **Generic Role 2:** ANSPs link with the flight crews to implement the necessary changes required for flight-centric operations.
- **Decisive Role 1:** Switching to flight-centric operations on condition that the airspace control provision is not given to a competing ANSP.
- **Decisive Role 2:** ANSPs are interested with the idea if flight centric operations prove to bring benefits in ATCO productivity key performance area.
- **Decisive Role 3:** A number of ANSPs are not interested in the concept, not preferably adopting flight-centric operations.
- **ATSU**
 - **Decisive Role 1:** ATSUs can decide, locally by themselves, whether they want to switch to flight-centric operations or not.
- **ANSP Management Level**
 - **Decisive Role 1:** ANSP management can be decisive in the adoption of flight-centric operations if they see that the concept is not viable.
 - **Decisive Role 2:** On condition that the flight-centric operations bring benefits on ATCO productivity, the management could support the further adoption of flight-centric operations.
- **ANSP Technical Staff**
 - **Generic Role 1:** Specify the tools to support the flight-centric operations.
 - * **Generic Role 1.1:** Conflict detection and resolution, coordination between ATCOs for conflict, tools to coordinate between sector boundaries.
 - **Flow Management Staff**
 - * **Pushing Role 1:** Higher probability of understanding the concept and push for the adoption of flight-centric operations.
- **ATCOs (ANSP Operational Staff)**
 - **Generic Role 1:** Execution of the test, provision of the opinions on flight-centric operations and ATM system design with motivation to try new things.
 - **Generic Role 2:** Provision of the business requirements for flight-centric operations to a technical industry partner to build technical requirements.
 - **Decisive Role 1:** Depending on the benefits of the flight-centric operations, ATCOs could play a decisive role in the adoption.

- * **Decisive Role 1.1:** ATCOs can agree on how many aircraft they can handle and adaptive allocation of aircraft to ATCOs according to experience level.
- **Operational Supervisors**
 - * **Decisive Role 1:** Changing roles and responsibilities increased by flight-centric operations.
 - * **Generic Role 1:** Planning the full working environment adapted to flight-centric operations.
- **Executive ATCO**
 - * **Decisive Role 1:** Drastic change in the roles of the Executive ATCOs leading to a decisive role in the adoption.
- **Planning Allocator ATCO**
 - * **Decisive Role 1:** Drastic change in the roles of the Executive ATCOs leading to a decisive role in the adoption.

6.2.2 Manufacturing Industry

The manufacturing industry plays a key role in relationship with ANSPs to realize the technologies supporting flight-centric operations. Since flight-centric operations introduce substantial changes in the work practices and situational awareness of the ATCOs, the CWP, conflict detection and resolution tools, and automated support tools needs to be either adapted or manufactured by the industry for the ANSPs. Thales, Indra and Frequentis already started working in the research and development phases of these products to showcase the benefits in real-time simulations. Specifically, Frequentis is working on the new digital voice communication to enable flight-centric operations. Digital voice communication is able to solve the frequency congestion problem, allowing the control of bigger sectors and multiple aircraft at the same time. Yet, internal marketing, change management, human factors, and internal assessment affect the adoption process of the flight-centric operations. For some industry partners, that are producing the legacy communication systems, it will be harder to switch towards new digital communication technologies. The manufacturing industry and its first-order relationships are illustrated in Figure 6.3. Additionally, the roles of the manufacturing industry in the adoption of the flight-centric operations is summarized below:

- **The Manufacturing Industry**
 - **Pushing Role 1:** Based on the requirements of the ANSPs, provision of technology and control tools for flight-centric operations.
 - * **Pushing Role 1.1:** Thales, Indra supported by research institutes DLR (Germany) and CRIDA (Spain).
 - **Pushing Role 2:** Provision of the conflict detection and resolution tools to support flight-centric operations.

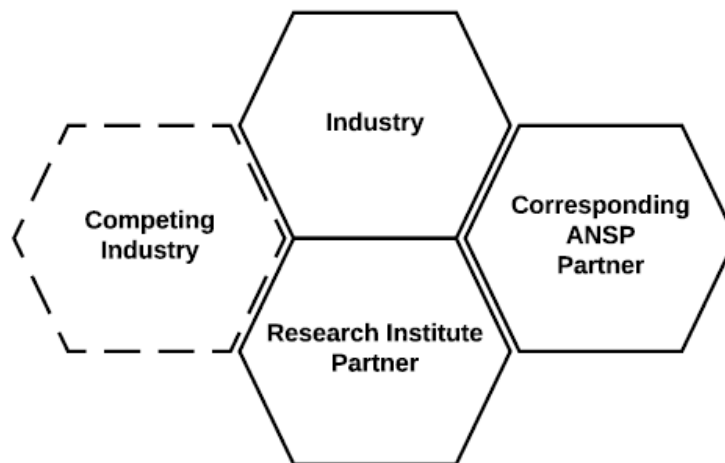


Figure 6.3 – Graphical Representation of Manufacturing Industry and its First-Order Relationships

- **Generic Role 1:** Innovative industry partners, such as Frequentis, developing new systems and tools supporting new voice communication for flight-centric operations.
- **Generic Role 2:** Together with ANSPs they provide the necessary implementation for flight-centric operations.
 - * **Generic Role 2.1:** Internal marketing, trainings, change management, human factors, and internal assessment.
 - * **Generic Role 2.2:** Provision of the technologies, infrastructure and Flight Data Processing Systems (FDPS) to ANSPs.
- **Decisive Role 1:** The industry partner that produces the legacy communication systems will not be interested in developing new digital communication tools.

6.2.3 EUROCONTROL

Considering flight-centric operations, EUROCONTROL plays multiple roles both as an ANSP, as the Network Manager and the Central Route Charges Office. The conventional route charging mechanism is based on the geographical sectors. Under flight-centric rules, the route charging mechanism should be adapted and EUROCONTROL is the critical actor for the adaptation of route charges in collaboration with its Member States and the European Commission. On the research and development side, the organisation leads the SESAR programme, building the roadmap as the Master Plan, and flight-centric operations is regarded as a key enabler to reach the SES target objectives. Housing the Network Manager, EUROCONTROL has a role to update the flight rules and network management according to new flight-centric rules. Even at later stages, a number of network services, such as a cloud database, could be deployed in order to coordinate the flight-centric operations. By this, the NM could take the role of the

capacity and frequency manager, assigning the adequate capacity and frequencies according to the load in the network. The actor EUROCONTROL and its first-order relationships are illustrated in Figure 6.4.

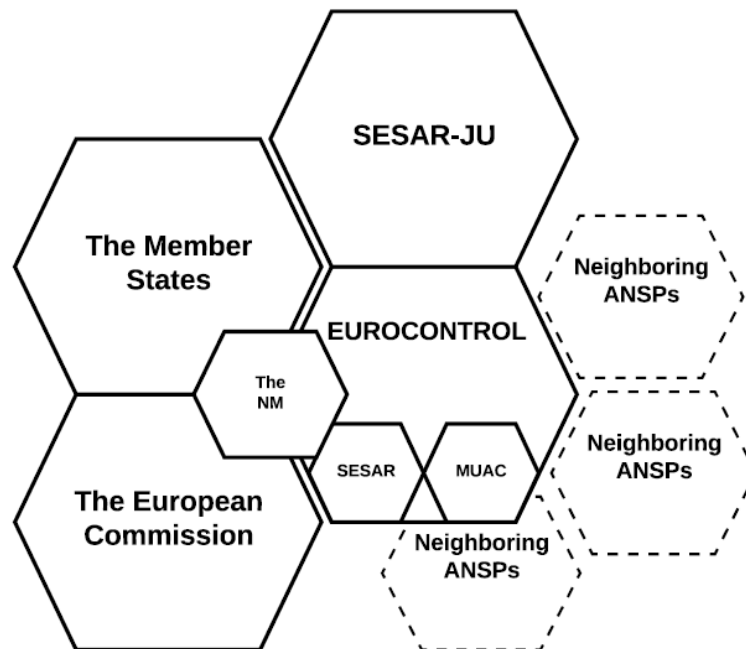


Figure 6.4 – Graphical Representation of EUROCONTROL and its First-Order Relationships

- **EUROCONTROL**

- **Critical Role 1:** Determination of the calculation for the route charges in the case of flight-centric operations.
- **Pushing Role 1:** EUROCONTROL, with other partners, provides the Master Plan as a roadmap for flight-centric operations..
 - * **Pushing Role 1.1:** Through SESAR in partnership with SJU, they provide the concept and the standard solutions.
 - * **Pushing Role 1.2:** SESAR in partnership with ANSPs can provide the solution, financing, and testing.
 - * **Pushing Role 1.3:** A number of SESAR solutions are looking into the ECAC-wide implementation of frequency management.
- **Generic Role 1:** Updating the flight rules and network management according to flight-centric rules.
- **Generic Role 2:** EUROCONTROL can provide the database for ANSPs related to flight-centric operations.

- **The Network Manager (NM)**

- **Critical Role 1:** The NM deciding on the local, sub-regional or regional implementation of flight-centric operations.
- **Critical Role 2:** In the later stages of flight-centric operations, close link between the NM and ANSPs should be established for coordination.
- **Critical Role 3:** The NM can be a key actor on the role of assigning capacity and frequencies over European airspace.
- **Pushing Role 1:** Sectorization planning to configure the network under flight-centric operations.
 - * **Pushing Role 1.1:** Arrange a best equipped, best served system by assigning extra slots for aircraft that are compatible with flight-centric operations.
 - * **Pushing Role 1.2:** London Heathrow airport is an example for the assignment of extra slots to aircraft that are MLS equipped.
- **Generic Role 1:** Business as usual service, demand-capacity balancing in a flight-centric environment.
- **Generic Role 2:** Specific optimization for demand-capacity balancing in flight-centric operations in required cases.
- **Generic Role 3:** Flight-centric operations modifying the network management functions by shifting paradigm from sectors to CWPs.
- **Generic Role 4:** Assigning the geographically reliable frequencies to the ANSPs adopting flight-centric operations.

6.2.4 SESAR-Joint Undertaking & SESAR-DM

SESAR-JU acts like a hub connecting multiple actors inside the SESAR projects, including ANSPs, the manufacturing industry, EUROCONTROL and the European Commission. Triggering interaction between the partners, the flight-centric operations is regarded as one of the key enablers for the SES in the Airspace Architecture Study. For flight-centric operations, SESAR-JU promotes the vision, research and development by also involving the social partners, ATCO in the design phase. This includes assigning the interested parties, ANSPs and industry as the champions of the projects and getting feedback from them to pursue the later phases of flight-centric operations. Additionally, SESAR-JU also leads the feasibility studies of the flight-centric operations, such as the cost-benefit analysis, which is crucial for partners to evaluate the benefits of flight-centric operations. The actor SESAR-JU and its first-order relationships are illustrated in Figure 6.5.

The generic roles of the SESAR-JU in the adoption of the virtual centre in the European ATM is summarized as follows:

- **SESAR-JU**

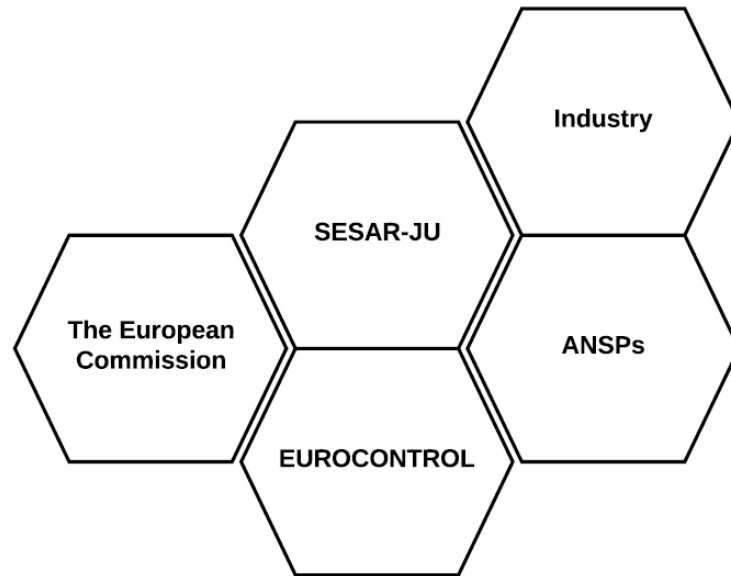


Figure 6.5 – Graphical Representation of SESAR-JU and its First-Order Relationships

- **Pushing Role 1:** SJU tries to promote flight-centric operations in cooperation with EUROCONTROL, ANSPs, the industry and public bodies.
 - * **Pushing Role 1.1:** Triggering the interaction between public partners in Europe, promoting the vision, research and development for the flight-centric operations.
 - * **Pushing Role 1.2:** Involving the social partners, ATCOs and Controller Unions, in the design of flight-centric operations.
 - * **Pushing Role 1.3:** Assigning the most interested ANSPs as champions for the development of the flight-centric operations and getting feedback from the champions of the projects.
 - * **Pushing Role 1.4:** Funding the project within all of its stages (research, development, and deployment).
 - * **Pushing Role 1.5:** Providing Airspace Architecture Study that supports flight-centric operations.
- **Pushing Role 2:** Updating the flight rules and network management according to flight-centric rules.

Additional to the development aspects of the SESAR-JU, on the deployment side SESAR-DM could attach to the network of actors on the final stage of adoption, mobilization, for further deployment of the flight-centric operations in the Pan-European scale within their area of responsibility. Since, SESAR-DM is mainly responsible for the deployment of the solutions under the SESAR framework, The generic roles for SESAR-DM listed as below:

- **Generic Role 1:** Supporting the deployment of the flight-centric operations in coordination with the SESAR-DM partners, including ANSPs, airlines, airports, military and EUROCONTROL
- **Generic Role 2:** Following the deployment roadmap as presented in the European Master Plan
- **Generic Role 3:** Under the SESAR framework, management of the deployment of new technologies in synchronization with European ATM stakeholders

6.2.5 The European Commission

The European Commission acts as a regulator on driving the changes brought forth by the flight-centric operations. These include the managing other actors, such as SESAR-JU and EUROCONTROL, to realize the goals for the Pan-European approach of the SES project. As an ultimate aim of defragmentation in Europe, the EC guides the actors through the modernization of the European ATM. Flight-centric operations is one of the key enablers for the defragmentation of the systems and services throughout Europe. Additionally, the EC manages proper funding and steering of the flight-centric operations, possible creation of implementation, legal and regulatory requirements for a service-oriented architecture. This places the EC as one of the critical actors in the realization of the flight-centric operations. Concretely, the EC has first-order relationships with the Member States, ANSPs, and EUROCONTROL as illustrated in Figure 6.6.

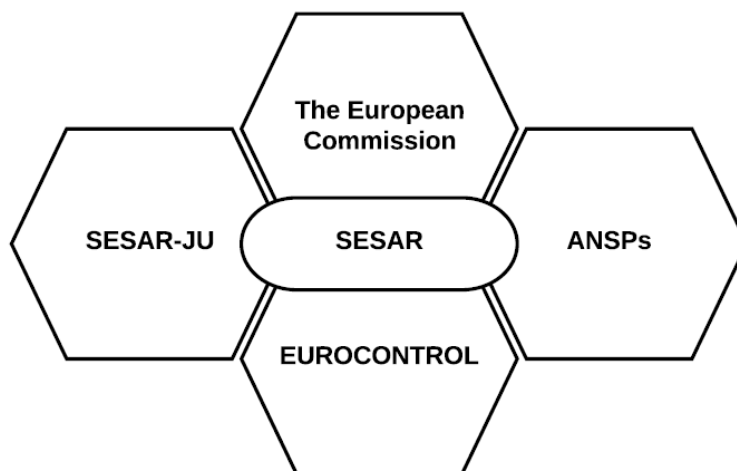


Figure 6.6 – Graphical Representation of The EC and its First-Order Relationships

- **The European Commission**
 - **Critical Role 1:** With SJU, the EC (DG MOVE) can promote flight-centric operations with proper steering and funding.

- * **Critical Role 1.1:** There are mixed opinions on how the EC can promote flight-centric operations by implementation rules.
- **Generic Role 1:** Preparation of a proof of concept, slowly resolving parameters and step-wise implementation on flight level.
- **Generic Role 2:** The EC may decide on the standardization and regulation of the work practices of ATCOs in flight-centric operations.
- **Generic Role 3:** Preparation and evaluation of the safety case for flight-centric operations with EASA.

6.2.6 Military

The Military is already familiar with the flight-centric concept, since it is using a similar approach for the night-time operations and training. The military has reserved airspace, which consists of mainly larger sectors than the civilian airspace. Thus the military ATCOs are used to the flight-centric concept. Hence, it is comparatively straightforward for the military to adopt flight-centric operations. Yet, it is important for flight-centric operations to either maintain or increase the safety levels for the military to adopt the concept. Currently, the military maintains its generic roles by following how other actors align towards the adoption of the concept. Concretely, the Military has first-order relationships with the Member States, ANSPs, and EUROCONTROL as illustrated in Figure 6.7.

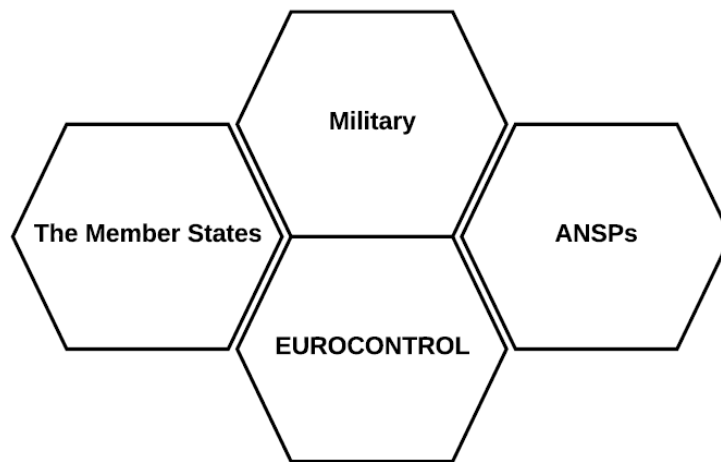


Figure 6.7 – Graphical Representation of the Military and its First-Order Relationships

- **The Military**

- **Generic Role 1:** Following the approach of the alignment of the actors for the adoption of flight-centric operations.
- **Generic Role 2:** Similar and familiar implementation for military under flight-centric operations in European airspace.

- **Generic Role 3:** Application of flight-centric operations is familiar for military, yet safety is paramount for successful adoption.

6.2.7 Controller Unions

In the case of flight-centric operations, controller unions have a decisive role on the adoption of this new technology. On condition that the flight-centric operations bring the promised benefits on ATCO productivity, while maintaining the safety and situational awareness levels, controller unions would be interested in the concept. For this reason, it is important to involve them inside the projects and discussion in the development stages of flight-centric operations. Since they are the end-users of the technology, they have a decisive role in the adoption process. Yet, controller unions aim to protect the rights, work practices and conditions of the ATCOs. In that manner, flight-centric operations possibly changes the work practices and situational awareness of ATCOs, which require new certification and training processes to put in place. Until these topics are addressed commonly between the ANSPs, there are still open points for discussion on how ATCOs will perceive the changes in work practices and situational awareness.

Specifically, these open points include the question of how to resolve of imminent conflicts in charge of different ATCOs in the same airspace. In practice, this requires the special management of multiple intents of ATCOs and reassignment of flights accordingly. The result of exercises with the ATCOs show that the mental picture of the ATCOs change while processing the traffic compared to conventional sectorized approach. There is also time and training required for the adaptation of ATCOs to the work practices of flight-centric operations. Another key point raised by the controller unions is a consistent criteria for allocation of aircraft to ATCOs. In the case of trajectory flows, it remains an open point on how to assign them in terms of complexity and sequencing. The reassignment of flights is a critical topic for both the ATCOs and the Controller Unions in the case of complexity and transfer of control in cross-border operations. In summary, Controller Unions has first-order relationships with ANSPs as illustrated in Figure 6.8.

- **Controller Unions**

- **Critical Role 1:** Discussing the potential, airspace area and the geographical licensing with the ATCO Unions
- **Decisive Role 1:** If they see a benefit for their workload and operations, then they are interested in flight-centric operations
- **Decisive Role 2:** Safety is a concern for the ATCOs in flight-centric operations
 - * **Decisive Role 2.1:** The effect of flight-centric operations on the situational awareness of ATCOs is critical

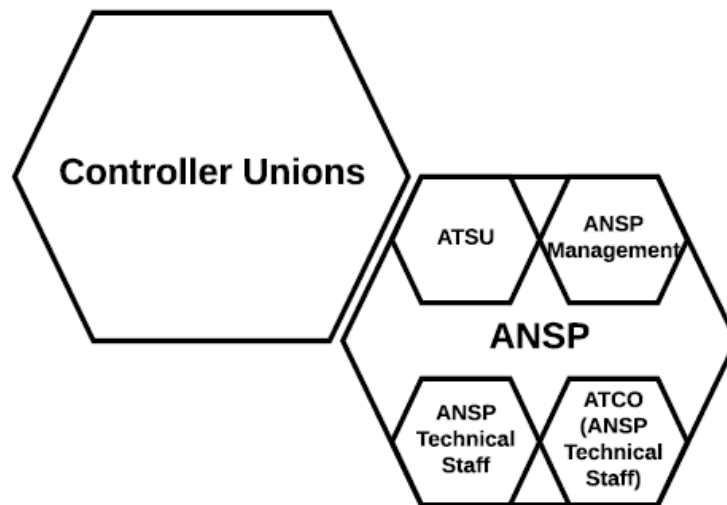


Figure 6.8 – Graphical Representation of Controller Unions and its First-Order Relationships

6.2.8 EASA & EUROCAE

EASA is an important actor for the standardization and regulation of the flight-centric operations. In particular, standardization includes the necessary certification, training of ATCOs and overall safety assessment for flight-centric operations. Specifically, in this standardization process, the EC and EASA are expected to work in collaboration to find the safest way possible for the ANSPs to adopt flight-centric operations. For the ATCOs, operating under flight-centric rules is completely different from the conventional sectorized approach. Additionally, conflict detection and resolution require new tools, resulting into new legal specifications. In the case of incidents or conflicts, there should be a standardized legal base between the ANSPs for flight-centric operations. Thus, an actor specialized in standardization, EASA, is suitable for the approval of the safety, standardizing the operations, certification and training by working in close cooperation with ANSPs to decide on the legal requirements of flight-centric operations. Accordingly, EUROCAE, European Organisation for Civil Aviation Equipment, would be responsible for the standardization of the digital communication technologies supporting flight-centric operations. Precisely, EASA has first-order relationships with the EC, ANSPs, The Member States and EUROCAE as illustrated in Figure 6.9.

- **EASA**

- **Critical Role 1:** EASA in coordination with the EC could provide the necessary regulation and safety assessment for flight-centric operations
- **Critical Role 2:** EASA assessing the safety of flight-centric operations
- **Generic Role 1:** Certification and licensing of the ATCOs under flight-centric operations

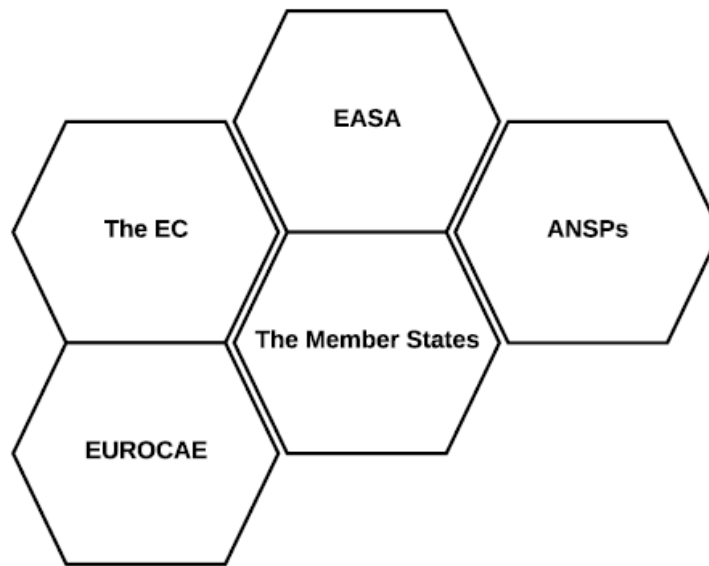


Figure 6.9 – Graphical Representation of EASA and its First-Order Relationships

- **Generic Role 2:** Legal assessment of the conflict detection and resolution under flight-centric operations
- **Generic Role 3:** Approval of the relevant authority to the flight-centric operations concept
- **Generic Role 4:** Working in close cooperation with ANSPs to decide on the legal requirements of the flight-centric operations
- **EUROCAE**
 - **Critical Role 1:** Standardization of the digital communication technologies that support flight-centric operations
 - **Generic Role 1:** Standardization of the flight-centric operations equipments on the ground and on-board the aircraft

6.2.9 The Member States

The Member States act mostly linked to the objectives of their corresponding ANSPs in the adoption process of flight-centric operations. Additionally, the Member States have political objectives, ensuring that the sovereignty of the airspace is secured. New technologies, including flight-centric operations, enable location independency of the provision of ATC and the ATCOs. In the future, it is expected that these changes will lead to new standardisation, legal framework and recalculation of the route charges throughout Europe. Of course, these radical changes in the provision of ATC are not always aligned with the political interests of the Member States. Concretely, sharing of information between the ANSPs is a critical political issue,

which needs to be legally addressed within neighbouring ANSPs. Initially, the Member States would be interested to adopt flight-centric operations as a local implementation, merging of sectors within an ANSP. By time, the systems, certification and training would be standardized by the coalition of actors, including EASA, the EC, ANSPs and corresponding Member States. Concretely, the Member States has first-order relationships with the Military as illustrated in Figure 6.10.

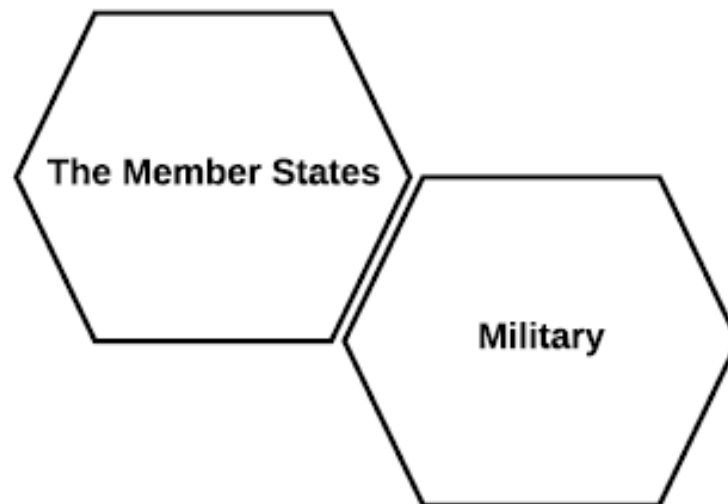


Figure 6.10 – Graphical Representation of The Member States and its First-Order Relationships

- **The Member States**

- **Decisive Role 1:** Calculation of the route charges in flight-centric operations is an issue for the Member States
- **Decisive Role 2:** Sovereignty over the airspace affecting political actors in adoption of new technologies
- **Generic Role 1:** With EASA, Certification and licensing of the ATCOs under flight-centric operations
- **Generic Role 2:** The Member States should join the frequency concept driven by flight-centric operations for further adoption
- **Generic Role 3:** Sharing of information between neighbouring ANSPs and Member States for flight-centric operations
- **National Supervisory Authorities**
 - * **Generic Role 1:** With other relevant actors, assessing and ensuring the safety of flight-centric operations
 - * **Generic Role 2:** Discussing with ANSPs and other actors for the flight-centric area and geographical licensing

- * **Generic Role 3:** Assessing the safety and testing of the new technology in relation to flight-centric operations

6.3 Factors Affecting the Adoption of the Flight-Centric Operations

The adoption process of the flight-centric operations is affected by various factors categorized under political, social, technical or operational, economic and legal factors. In each phase of adoption (problematization, interestment, enrolment, mobilisation), these factors play an important role guiding the objectives of the actors. Hence, it is crucial in our analysis to examine these factors, the affected actors, and the stage of adoption that the factor is affecting the adoption. This section first presents the specific impact of factors analyzed under the 5 categories. Second, guided by the conceptual framework to build up on to see the big picture affecting the overall adoption, the section finally provides the overall impact of the factors on the adoption of the flight-centric operations.

6.3.1 Social Factors

Flight-centric operations bring drastic changes in the work practices and situational awareness of the ATCOs. In this new concept, the ATCOs are shifting their focus from area limited sectors towards trajectories and ultimately the flight. This, in turn, creates a number of social factors affecting the adoption of flight-centric operations. In the first place comes the critical social factor of the change management of the ATCOs under flight-centric configuration. Concretely, flight-centric operations induce change in ATCO certification, location, salary and working hours. The way that these changes is handled by the ANSPs, and the ANSP management is critical for the adoption of the flight-centric operations. The involvement of the ATCOs in the initial problematization phase of the technology helps to minimize the risk associated to the drastic changes that the flight-centric operations bring.

Important to realize is that the ATCO productivity benefits of the flight-centric operations are still under investigation. Depending on the validations, ATCOs have a decisive role whether or not to adopt the flight-centric operations. Since, they will be the direct user of the technology, minimizing the uncertainty in the possible work practice change scenarios affect their opinion towards flight-centric operations. Furthermore, flight-centric operations introduce new, possibly automated, conflict detection and resolution tools to assist ATCOs. The trust and reliance of ATCOs for these automated tools affect their decisions towards adopting flight-centric operations. Correspondingly, the roles of ATCOs in this new concept change, even affecting their work location. Under flight-centric configuration, new setup of teams of executive and planning controllers emerge. Moreover, this will require new schemes of certification and training of ATCOs specifically for the flight-centric operations.

In general, the social acceptance of the new technologies by the social actors, such as the Member States, government, and controller unions, is challenging given that flight-centric

6.3. Factors Affecting the Adoption of the Flight-Centric Operations

Social Factors	Stage of Adoption	Relevant Actor(s)
Critical Social Factor 1 - Change management of ATCOs in the case of drastic changes brought by flight-centric operations	Interessement	ANSPs (ATCOs)
Certification, salary, and working hours of ATCOs are expected to change	Mobilization	ANSPs (ATCOs)
Decisive role ATCOs depending on the validations and benefits	Interessement	ANSPs (ATCOs)
Minimizing the uncertainty of possible scenarios by getting feedback from ATCOs	Problematization	ANSPs (ATCOs)
Reduction of channel switching might benefit ATCOs	Mobilization	ANSPs (ATCOs)
Mid-term Collision Detection Tool (MTCD) is perceived as beneficial by ATCOs	Mobilization	ANSPs (ATCOs)
The new role of ATCO, allocator of traffic, additional operational position, that allocates traffic to executive controllers	Interessement	ANSPs (ATCOs)
Additional extended ATC planners allocate the traffic based on workload and complexity	Mobilization	ANSPs (ATCOs)
ATCOs need to interact with each other uniformly among different ANSPs	Mobilization	ANSPs (ATCOs)
ATCOs are decisive on the adoption of more automation or tool support	Interessement	ANSPs (ATCOs)
SF1 - Calculation of the salary of ATCOs in different countries in flight-centric operations	Enrolment	ANSPs (ATCOs)
SF2 - The location of the ATCOs in flight-centric operations	Enrolment	ANSPs (ATCOs)
SF3 - Communication between the actors is important for the adoption of flight-centric operations	Mobilization	ANSPs (ATCOs)
SF4 - Better utilization of aircraft and flight crews due to reduced fuel and flight plan	Mobilization	Social Actors
SF5 - Social acceptance of new technologies affect the adoption of flight-centric operations	Enrolment	Social Actors

Table 6.1 – Social Factors Affecting the Adoption of the Flight-Centric Operations

operations alter the work practices of the ATCOs. These actors should be convinced that it is for the long-term benefit and productivity for the ATCOs to support flight-centric operations. Hence, the communication between the social actors, ANSPs and the manufacturing industry is key to further move towards the later stages of the adoption process. Specifically, cross-border operations need enhanced coordination with standardized technologies between the ATCOs located in different ANSPs. Further, the benefits of flight-centric operations increase by adoption within the neighbouring ANSPs, it is crucial to align the coordination between the adjacent units when the ATCOs control flight passing from another airspace of an ANSP. To summarize, all of the social factors are summarized in the Table 6.1, pointing out the relevant actors and the stage of adoption.

6.3.2 Technical or Operational Factors

Considering the technical factors, flight-centric operations rely on a number of critical pre-requisite hardware and software. First, a new voice communication, that can support multiple frequencies to support the flight centric area, should be put in place. This can be in the form of a totally new digital voice communication or the adaptation of the current legacy communication systems to support flight-centric airspace. Furthermore, EASA could work on the assessment of the safety, regulation and Pan-European level implementation of the flight-centric operations. Second, flight-centric ATCOs work within the support of the new conflict detection and resolution tools. Concretely, the trust of ATCOs to the automated tools depends on the safety and conflict resolution levels of these tools. Since the work practices of ATCOs change drastically in flight-centric operations, these tools aid in the shift towards flight-centric concept. Yet, it is critical that these tools are standardized between the ANSPs to support the cross-border operations to enhance the ATCO productivity. Moving towards a bigger airspace, the situational awareness of the ATCO change. Additionally, this needs the adaptation of the licensing, training and certification of the ATCOs working in flight-centric configuration.

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Technical and Operational Factors	Stage of Adoption	Relevant Actor(s)
Critical Technical Factor 1 - The deployment of the digital communications to support flight-centric operations	Mobilization	ANSPs, The Manufacturing Industry
Adequate frequency changes are foreseen for flight-centric operations	Mobilization	ANSPs, The Manufacturing Industry, The NM
The deployment of new type of radar should be discussed with EASA for specifications, law and regulation	Mobilization	ANSPs, The Manufacturing Industry, EASA
Some inspections should be done on local level and European level for the implementation covering safety	Problematization	ANSPs, The Manufacturing Industry, EASA
Critical Technical Factor 2 - Conflict detection and resolution tools	Problematization	ANSPs, The Manufacturing Industry
Critical Operational Factor 1 - Change of work practices and acceptance of ATCOs in flight-centric operations	Interessement	ANSPs (ATCOs)
Move to bigger airspace with reduced situational awareness than sectorized operations	Interessement	ANSPs (ATCOs)
The overall acceptability of the concept in terms of benefits, applicability, workability by ATCOs	Enrolment	ANSPs (ATCOs)
A big operational change which encompasses assessment of safety, and training	Enrolment	ANSPs (ATCOs)
TF1 - New technologies in the future can aid safety for flight-centric operations	Mobilization	ANSPs, The Manufacturing Industry
TF2 - Technical limits of the sectorization	Problematization	ANSPs, The Manufacturing Industry
TF3 - Use of assignment centre for the assignment of controllers progressively becomes automated	Enrolment	ANSPs, The Manufacturing Industry
A system that allocates aircraft to controllers based on workload and conflicts	Enrolment	ANSPs, The Manufacturing Industry
TF4 - Currently there does not exist an ATM system for full flight-centric solution from industry	Problematization	The Manufacturing Industry
TF5 - System coordination between adjacent ATSUs	Mobilization	ANSPs
TF6 - Advanced algorithms for communication, data resolution (CDR) and allocation of aircraft	Problematization	ANSPs, The Manufacturing Industry
TF7 - Impact of flight-centric operations on the ground infrastructure rather than airborne	Problematization	ANSPs, The Manufacturing Industry
Adaptation of the ground infrastructure for effective routing the cross-border coordination	Problematization	ANSPs, The Manufacturing Industry
OF1 - Overlap with free-route implementation across borders	Mobilization	ANSPs, The Manufacturing Industry

Table 6.2 – Technical and Operational Factors Affecting the Adoption of the Flight-Centric Operations

The main motivation of flight-centric operations is that the sectorized approach to ATC is limited in terms of performance, productivity and complexity. Coupled with the rise of automation in new technologies, the paradigm of ATC shifts towards merging of sectors, ultimately controlling an aircraft from its origin to destination. This is only possible with the introduction of new technologies from the manufacturing industry to support flight-centric operations. Maintaining or improving the safety levels of flight-centric operations would be possible with the introduction of specific technologies supporting an assignment centre, which allocates aircraft based on ATCO workload and traffic complexity. Yet, these new technologies are on the verge of development and need to mature to enable full Pan-European scale flight-centric operations. Concretely, this requires system coordination between adjacent ATSUs combined with advanced algorithms for communication, data resolution and allocation of aircraft. The technological impact of flight-centric operations is rather on the ground infrastructure than the airborne. Specifically, the adaptation of the ground infrastructure is required for the effective routing of the cross-border operations.

6.3.3 Economic Factors

For flight-centric operations to be adopted by relevant actors, a certain milestone is a realistic positive cost-benefit analysis (CBA) that shows the economic benefits of the concept. Notably, there is an initial phase CBA of the SESAR project 10-01.b which is providing the values that above a certain flight level in en-route, the CBA becomes positive. Yet, when the traffic complexity increases and the number of ANSPs adopting flight-centric decreases, the benefits could stay below the costs. Comparing the future conventional sectorized approach and the flight-centric operations, the main benefit comes from the key performance area of ATCO productivity. This is directly dependant on the level of implementation, and traffic complexity,

6.3. Factors Affecting the Adoption of the Flight-Centric Operations

Economic Factors	Stage of Adoption	Relevant Actor(s)
Critical Economic Factor 1 - The result of the validations and the CBA are critical for the adoption	Interessement	ANSPs, The Manufacturing Industry, SJU, EUROCONTROL
CBA should compare the future conventional environment with flight-centric operations	Interessement	ANSPs, The Manufacturing Industry, SJU, EUROCONTROL
EF1 - Validation of increase in ATCO productivity	Problematization	ANSPs (ATCOs)
How many ATCOs are saved over a period of time	Problematization	ANSPs (ATCOs)
EF2 - Calculation of route charges in flight-centric operations	Mobilization	ANSP(s), EUROCONTROL, The EC
EF3 - The economic benefits are currently calculated using low level tools and automation	Problematization	ANSPs, The Manufacturing Industry
In this case the benefits might be minimal or even negative	Problematization	ANSPs, The Manufacturing Industry
Flight-centric operations is feasible with high-level of automation	Problematization	ANSPs, The Manufacturing Industry
EF4 - All the factors that bring economic benefit would have to be quantified	Problematization	ANSPs, The Manufacturing Industry, SJU, EUROCONTROL
EF5 - Radical business model change for the ANSPs and the Manufacturing Industry	Enrolment	ANSPs, The Manufacturing Industry

Table 6.3 – Economic Factors Affecting the Adoption of the Flight-Centric Operations

so the results for the CBA is mixed in that sense. The validations show that flight centric operations bring the promised benefits on condition that the situational awareness of the ATCOs are supported with the new conflict detection and resolution tools. In the case of ATCO productivity, the key performance area looks into how many ATCOs are saved over a period of time in a given portion of airspace.

A point often overlooked is the method of calculation of route charges in flight-centric operations. In a Pan-European implementation of flight-centric operations where a flight is controlled by a single ATCO from its origin to destination, there emerges the question of then who will receive the money for the ATC service provided. Is it the percentage of airspace that the aircraft spent its time flying, or is it directly the charge based on the location of the ATCO that is controlling the flight? This have both economic and legal implications for flight-centric operations, which can be clarified more in the later stages of adoption, such as mobilisation. A number of actors, including ANSPs, EUROCONTROL, the EC and the Member States should be involved in the discussion to find an optimal way for the collection and distribution of the route charges.

In combination with virtual centre, flight-centric operations also bring radical changes for the business models of the ANSPs and the manufacturing industry. This is due to the fact that both technologies eliminate the location dependency and sector limitations of the ATCO. Certainly, this directly affects the current provision of the service which is locked in the national airspace. In this configuration, the ATC opens into competition and ANSPs could compete for the provision of the services for each other. Additionally, new actors in the form of IT giants, telecommunication and third party providers could be interested in the provision of the ATC. Consequently, this requires also changes in the future regulation of the ATC and the market for the provision of the ATC. In order to summarize, the economic factors affecting the adoption of flight-centric operations are summarized in Table 6.3.

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Political & Legal Factors	Stage of Adoption	Relevant Actor(s)
Critical Political Factor 1 - Sovereignty over the national airspace	Enrolment	ANSPs, The Member States
Cross-border operations require enhanced sharing of data and coordination	Enrolment	ANSPs, The Member States
Critical Political Factor 2 - The Europe wide adoption needs political decision in Member State (ANSP) level	Enrolment	The Member States
PF 1 - Calculation of the route charges in flight-centric operations	Mobilization	ANSPs, The Member States, EUROCONTROL
PF 2 - Increasing the geographical area for increasing benefits is a political decision	Enrolment	ANSPs, The Member States
PF 3 - Increasing ATCO productivity has political implications	Mobilization	ANSPs, The Member States
Critical Legal Factor 1 - Calculation of the route in flight-centric operations	Mobilization	ANSPs, The Member States, EUROCONTROL, The EC
Political issue in flights crossing the airspace	Mobilization	ANSPs, The Member States
Expensive versus non-expensive countries and the calculation of the route charge accordingly	Mobilization	ANSPs, The Member States, EUROCONTROL, The EC
Critical Legal Factor 2 - Safety argument needs to be strongly constructive	Problematization	ANSPs, The Member States, EUROCONTROL, EASA
Critical Legal Factor 3 - Cyber-security issues related to the new digital technologies (VoIP)	Enrolment	ANSPs, The Member States, EUROCONTROL, EASA
Critical Legal Factor 4 - Regulation of frequencies	Enrolment	ANSPs, The Member States, EUROCONTROL, The EC
LF1 - Certification of the ATCOs needs adaptation	Enrolment	ANSPs, EASA
Relevant SESAR projects also introduced the term non-geographical ATCO	Enrolment	ANSPs, EASA
Definition of a Single European ATCO license for flight-centric operations	Enrolment	ANSPs, EASA
Depending on the adaptation level, legal factors change	Enrolment	ANSPs, EASA
LF2 - Legal liability of the airspace beyond national boundaries	Mobilization	ANSPs, The Member States
Conflict resolution in case of different controllers controlling the same airspace	Problematization	ANSPs, The Member States
Assessment is needed for the criticality of the legal factors on flight-centric operations	Problematization	ANSPs, The Member States

Table 6.4 – Political and Legal Factors Affecting the Adoption of the Flight-Centric Operations

6.3.4 Political & Legal Factors

Technological changes brought forth by flight-centric operations have political and legal implications which affect its adoption in the large scale. The first critical political factor is the loss of sovereignty over the national airspace. Since each Member State and ANSP have a sovereign responsibility of the ATC in their own airspace, enabling ATC over the cross-border might create a political issue. This is due to the fact that the ATCOs would be able to control flights in a different airspace than their own national airspace. Additionally, this enables competition in the long run for the provision of ATC. Correspondingly, each ANSP would decide first on a local implementation of flight-centric operations, then politically align with the Member State for a Europe wide adoption of flight-centric operations. Notably, the benefits of the flight-centric operations increase with the number of ANSPs adopting and enlarging the overall airspace operating in flight-centric rules. The political decisions on the sovereignty and cross-border operations would affect the size and benefits of the flight-centric operations in the long run.

Furthermore, calculation of the route charges in flight-centric operations has also political and legal implications besides economic. The route charges carry a political value due to the economic benefits for the national ANSP and the Member State. Yet, currently each ANSP and its corresponding Member State have their own level of salaries for the provision of the ATC. Enabling location independent ATC, flight-centric operations alter the current structure of the ATC provision and route charges. Thus, there emerges a need for a redefinition of the legal

6.4. Technology Adoption Process of the Flight-Centric Operations

framework including the route charges and cost of ATC provision. Significantly, cross-border operations induce legal liability issues in the case of conflict detection and resolution. The responsibility of the ATCO controlling an aircraft in an airspace of a different country is still a question mark in legal liability terms. Additionally, flight-centric operations also need to make sure that the safety is not degraded by the enhanced reliance on the automation tools. Accordingly, a thorough legal assessment for the flight-centric operations is required to pinpoint the exact legal implications of the future implementation.

Safety is a critical factor both from a political and legal standpoint. Almost all actors agree that the safety argument of flight-centric operations should be strongly constructive. Mainly, the safety assessment should focus on the drastic change in the situational awareness of ATCOs and the reliance on the automated conflict detection and resolution tools. In like manner, new digital voice technologies, such as voice over internet protocol (VoIP), raise the importance of the cyber-security applications. The control, distribution and the regulation of new frequencies for the flight-centric control introduce new legal implications. The cost and the assignment of each frequency is still a debated topic, not only in ATM, but also in telecommunication domain. Hence, future regulation for the new frequencies to support new technologies, such as flight-centric operations, needs a thorough assessment for further adoption of the technology.

6.4 Technology Adoption Process of the Flight-Centric Operations

The adoption process of the flight-centric operations is a complex interaction between the multiple actors in the European ATM. This interaction is modeled using the four moments of translation of stages (problematization, interessement, enrolment, mobilisation) as previously described in the research design chapter. This section specifically explains this process for the adoption case of the flight-centric operations guided by the conceptual framework. The findings are embedded in the analysis representing both the actors, relationships, stages of the technology adoption and critical factors affecting the technology adoption process. The adoption process of the flight-centric operations is summarized graphically using the notation of the conceptual framework in the end of the section. The actors and their relationships are categorized under critical, pushing, passive and decisive. The graphical summary shows the barriers as the obligatory passage point for each stage of adoption. Additionally, the factors are represented with spheres of influence, where the size of the circle emphasizes the impact of each factor category of technical, economic, political, social and legal. Overall, the adoption process is represented by summarizing the main actors involved, their objectives, stages of the adoption and the factors or barriers affecting the adoption of the flight-centric operations.

6.4.1 Problematization [Stage 1]

The concept of the flight-centric operations, named initially as sectorless ATM, started within the experimental centre of EUROCONTROL in 2001. The main idea is to shift the paradigm

from the sectorized control of aircraft towards a trajectory based flight control. The problematization stage initiates by this definition where EUROCONTROL introduces the concept to the relevant interested actors. Consequently, DFS, the German ANSP, adopted the concept as being the first ANSP to improve the concept further with design elements and validations, supported by its research institute partner, DLR. The sectorless ATM concept matured, technical and operational requirements for the new technology started to take shape from 2008. This is followed by the feasibility studies, ATCO team configuration and the analysis of the changes of the situational awareness in flight-centric operations. Yet, flight-centric operations face a number of barriers from its transition from the definition, problematisation phase towards attracting the interest of the other ANSPs.

First and foremost, a cost-benefit analysis providing the realistic benefits of flight-centric operations on ATCO productivity is essential for the adoption of the technology. If in the case of the cost of the new conflict detection, resolution and automation tools are higher than expected, then less ANSPs would be interested to adopt in the long-term. The initial phase CBA shows that flight-centric operations bring benefits in low-medium level traffic complexity considering the local and Pan-European scale implementation. Yet, the initial cost of implementation of the supporting tools is high, such that in the first place only big ANSPs would be interested for the adoption. On the technical side, the manufacturing industry should deploy the new pre-requisite technologies, such as conflict detection, resolution and automation tools. Among the ANSPs, these tools should be standardized in order to enable cross-border operations to get the full benefits of the flight-centric operations. Moreover, the interested ANSPs should implement new voice communication technologies, such as VoIP, to increase the frequency coverage supporting flight-centric operations.

From a legal standpoint, the problematization phase includes the safety assessment of the flight-centric operations. The drastic change in situational awareness and the work practices of the ATCOs make the safety argument critical for further adoption of flight-centric operations. If the safety assessment shows that the flight-centric operations maintain or increase the current safety level, then more ANSPs would be interested to adopt the technology in the interestment stage. Additionally, standardization is important for the cross-border operations, and in the case of conflicts, a new legal framework would be needed to support flight-centric operations. New standard controller working position interfaces would be needed for neighbouring ANSPs that want to adopt flight-centric operations. Precisely, the barriers and critical factors affecting the first problematisation stage of the virtual centre adoption are provided as below:

- **Obligatory Passage Points**

- **Economic Obligatory Passage Point:** Realistic CBA proving the economic benefits of the flight-centric operations, cost of new conflict detection, resolution and automation tools
- **Legal Obligatory Passage Point:** Safety analysis has to done to reduce the reluctance to flight-centric operations, standardization of the solutions

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- **Technical Obligatory Passage Point:** New communication technology, such as digital voice (VoIP), is a pre-requisite technology, creation of new conflict detection, resolution and automation tools

- **Critical Factors Affecting the Technology Adoption Process**

- **Economic**

- * Validation of the benefits in ATCO productivity
- * Realistic CBA providing actual benefits
- * Strong investments are needed to realize flight-centric operations
- * Initial cost of new conflict detection, resolution and automation tools

- **Technical**

- * Standardized solution for flight-centric operations in Pan-European Scale
- * New voice communications supporting flight-centric operations, such as digital voice (VoIP)
- * Frequency coverage allowing the whole flight-centric area
- * New conflict detection, resolution and automation tools to support situational awareness of ATCOs

- **Legal**

- * Safety argument needs to be strongly constructive
- * Standardization of the technological solutions to support flight-centric operations

6.4.2 Interessement [Stage 2]

In the second stage, interessement, a number of ANSPs, including Hungarocontrol, ANS-CR, DSNA, ENAIRE and A6 alliance started to get interested in the concept of flight-centric operations. It is also important to note that these ANSPs are either neighbours of DFS, the German ANSP, or within close proximity to the German airspace. Furthermore, the concept is developed locally within the corresponding ANSPs, focusing mostly on research and validation of the feasibility. In this stage, the concept is officially adopted inside the SESAR project, called 10.01-b, consolidating and standardizing the solution for the interested ANSPs. Here, SESAR-JU and EUROCONTROL plays an important role in the further attraction and alignment of the interests of the actors by creating a common roadmap for the flight-centric operations. Initial conceptual development mostly relies on the local implementation of flight-centric operations within the airspace of a single ANSP, combining sectors into larger chunk of airspace. The validations include investigating the benefits of flight-centric operations on ATCO productivity by comparing various traffic complexities and flight-levels.

Of course, the effect of the social implications of the flight-centric on the work practices of ATCOs is apparent in this interessement stage. Concretely, ATCOs has a decisive role in the

adoption of the flight-centric operations as being the end user of the technology. Thus, some ANSPs, such as Hungarocontrol, involved ATCOs directly in the beginning of the conceptual phase of the flight-centric operations in order to develop the concept as specified by the ATCOs. Hence, this is beneficial to point out the social factors before they become a barrier for the further adoption of the concept. The change management of ATCOs is crucial to avoid the reluctance of acceptance for the new conflict detection, resolution, and automation tools. In flight-centric configuration, ATCOs need to work establishing higher coordination with each other, especially for cross-border operations. Yet, actors point on the existence of a number of open points related to social factors affecting the adoption of flight-centric operations.

On the legal side, actors in relation to the SESAR project, SESAR-JU, EUROCONTROL, ANSPs started working on the standardization of the new technologies to support flight-centric operations. Correspondingly, this includes the deployment of a wide area communication (WAC) system, and alternatively a satellite-based communication system. Currently, the stage of adoption is between the interestment and enrolment stages, and new technological enablers emerge during this phase of adoption. Yet, both from a technical and legal standpoint the standardization of the systems, supporting flight-centric operations, should be improved. In fact, it is crucial to align the working methods of ATCOs between different ANSPs in a combined airspace. As a legal obligation to maintain the safety levels, the tools between the ANSPs should work in a seamless manner to support ATCOs working in a flight-centric configuration. Additionally, possibly a new flight-centric certification for the ATCOs working under flight-centric will be needed to satisfy the minimum requirements to operate.

- **Obligatory Passage Points**

- **Social Obligatory Passage Points**

- * Controller Unions have a decisive role in the adoption process due to change in work practices and situational awareness (location independency, salaries, jobs)
 - * Increased coordination between the ATCOs for cross-border flight-centric operations

- **Technical Obligatory Passage Points**

- * Deployment of Wide Area Communication (WAC) supports flight-centric operations
 - * Satellite is also a possibility (low-earth orbit) in opposition to push-to-talk that is currently used in oceanic areas

- **Legal Obligatory Passage Points**

- * Standardization of the technological solutions to support flight-centric operations

- **Critical Factors Affecting the Technology Adoption Process**

6.4. Technology Adoption Process of the Flight-Centric Operations

– Social

- * Change management on the safety, conditions of the ATCOs is critical
- * ATCOs need to work in coordination with each other even under drastically changing environment
- * ATCOs are decisive to adopt highly automated solutions
- * Existence of a number of open points related to social factors affecting flight-centric operations

– Legal

- * SESAR with other partners can support standardization in flight-centric operations
- * Necessary to align the working methods of ATCOs in the combined airspace in flight-centric operations
- * Minimum set of requirements are foreseen to be standardized between ANSPs

– Technical

- * Investigating the exact enablers for the flight-centric operations to attract more actors

6.4.3 Enrolment [Stage 3]

The enrolment stage introduces the regulatory and national actors, such as the EC, EASA, the Member States and the Military, to the stage of adoption of flight-centric operations. Until this stage, the aligned ANSPs lock inside the network to adopt flight-centric operations by addressing the barriers affecting the adoption. In order to move with the adoption, mainly the social and technical barriers before the enrolment stage should at least be investigated or ultimately solved. Following that, the adoption of flight-centric operations mainly rely on the regulatory and national actors, introducing legal and political factors inside the network. Notably, the attraction of new ANSPs to adopt flight-centric operations depends on how the EC regulates the provision of ATC in the future, and also the standardization of the technologies, certification and working practices by EASA. Yet, still there are legal, political and technical barriers emerging in this stage of adoption. Moreover, the previous social and economic barriers reduce its impact until the enrolment stage, which is a relief for the successful adoption for the flight-centric operations.

Enrolling more actors inside the network of adoption involves the standardization of the technologies and systems supporting flight-centric operations. Indeed, this is practically possible by defining a common flight-centric operations license for ATCOs, possibly called a Single European ATCO license. Obtaining this license would enable an ATCO work in a flight-centric airspace by getting specialized training for flight-centric operations. In this case, MUAC could be a model for the certification and training due to the similar model they have for the combined control of Maastricht and Slovenian airspace. It is also important to note that training should be standardized between the flight-centric ANSPs to maintain the

same quality and safety level of ATC throughout the Europe. A solution for this is to create an open license scheme, where an ATCO would be able to select either a conventional sectorized license or a flight-centric license depending on the airspace and preference. Furthermore, ATSUs could decide, locally by themselves, whether or not to switch towards flight-centric operations.

Significantly, in this stage, the network of actors are affected by the political factors related to the adoption of flight-centric operations. The location independency and liberalization of cross-border operations brought forth by the flight-centric operations are misaligned with the sovereignty of airspace. As a result, national actors, the Member States and Military, have a decisive role for their ANSPs in the adoption of flight-centric operations. Additionally, it is not always the case that interoperability is available between the ANSPs. However, this might hinder utilizing the maximum benefits of the flight-centric operations in the long-term. From a technical perspective, the lack of interoperability limits the ATCO productivity under flight-centric operations. Since the size of the airspace would be limited, ATCOs could not be able to operate across borders of the neighbouring ANSPs. Precisely, the barriers and critical factors affecting the third enrolment stage of the adoption of flight-centric operations are provided as below:

- **Obligatory Passage Points**

- **Legal Obligatory Passage Point**

- * Definition of a Single European ATCO license for flight-centric operations.
 - * Definition of an open license to controllers is preferable to overcome this legal barrier.

- **Political Obligatory Passage Point**

- * Sovereignty of the Member States over their national airspace.
 - * Increasing complexity of systems between implementations of the ANSPs, Member States.

- **Technical Obligatory Passage Point**

- * Maximum limit of a controller in the flight-centric area can be reached.

- **Critical Factors Affecting the Technology Adoption Process**

- **Legal**

- * Definition of a Single European ATCO license for flight-centric operations
 - * MUAC can be a model for the certification of the ATCOs in flight-centric operations
 - * Coordination between ATCOs drastically changes compared to the conventional sectorized approach

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- * Training will pass on to the systems and tools in a standardized way for flight-centric operations
- * ATSU themselves might decide on the need of a separate licensing

– Political

- * Sovereignty of the Member States over their national airspace
- * Increasing complexity of systems between implementations of the ANSPs, Member States

– Technical

- * Technical limits and standardization of the cross-border operations, frequencies and communication

6.4.4 Mobilisation [Stage 4]

In order for the network to mobilize, in this final stage of adoption, the EC and EASA should work together to create a standardised legal base for flight-centric operations. First, this is to ensure that the safety levels are standardised between ANSPs that adopt flight-centric operations. Second, the definition of a Single European ATCO license for flight-centric operations would only be possible within a standardised legal base. This standard legal base includes the definition for the certification, training and operation of ATCOs in flight-centric operations. Additionally, it is critical to address the conflicts happening across border operations from both legal and technical perspectives. For this reason, the standardisation of the conflict detection, resolution and automation tools carries a critical value. The attraction and mobilisation of more actors would only be possible when this legal base is established by the regulatory and standardisation actors of the EC and EASA.

Another key point in the mobilisation stage is the misaligned political interests of the actors towards adopting flight-centric operations. Similar to almost all new technology altering the location dependency of the ATCO, hardware and software, flight-centric operations also face political factors affecting its adoption. The political factors are mostly linked to the national safety and security, economic objectives and change in work practices of the ATCOs. Additionally, the Member States aim to protect the social conditions of the ATCOs, by adapting the job and work practices when the conditions of the ATCOs change. A combination of virtual centre and flight-centric operations, as co-existing technologies, would enable the location independency of ATC, and equally the ATCO. The liberalization of ATC opens up the ATC market into competition, which also have political implications. Big ANSPs would be interested to provide the ATC for small to medium size ANSPs, which would lead to competitive prices for ATC through Europe. In summary, the critical factors affecting the third enrolment stage of the adoption of flight-centric operations are provided as below:

- **Critical Factors Affecting the Technology Adoption Process**

- **Legal**

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- * Related to the technical barrier, regulation should guide the standardization of flight-centric operations
- * Alignment of the cross-border operations between ANSPs

– **Political**

- * Possible misaligned interests of the neighbouring countries to implement flight-centric operations

6.4. Technology Adoption Process of the Flight-Centric Operations

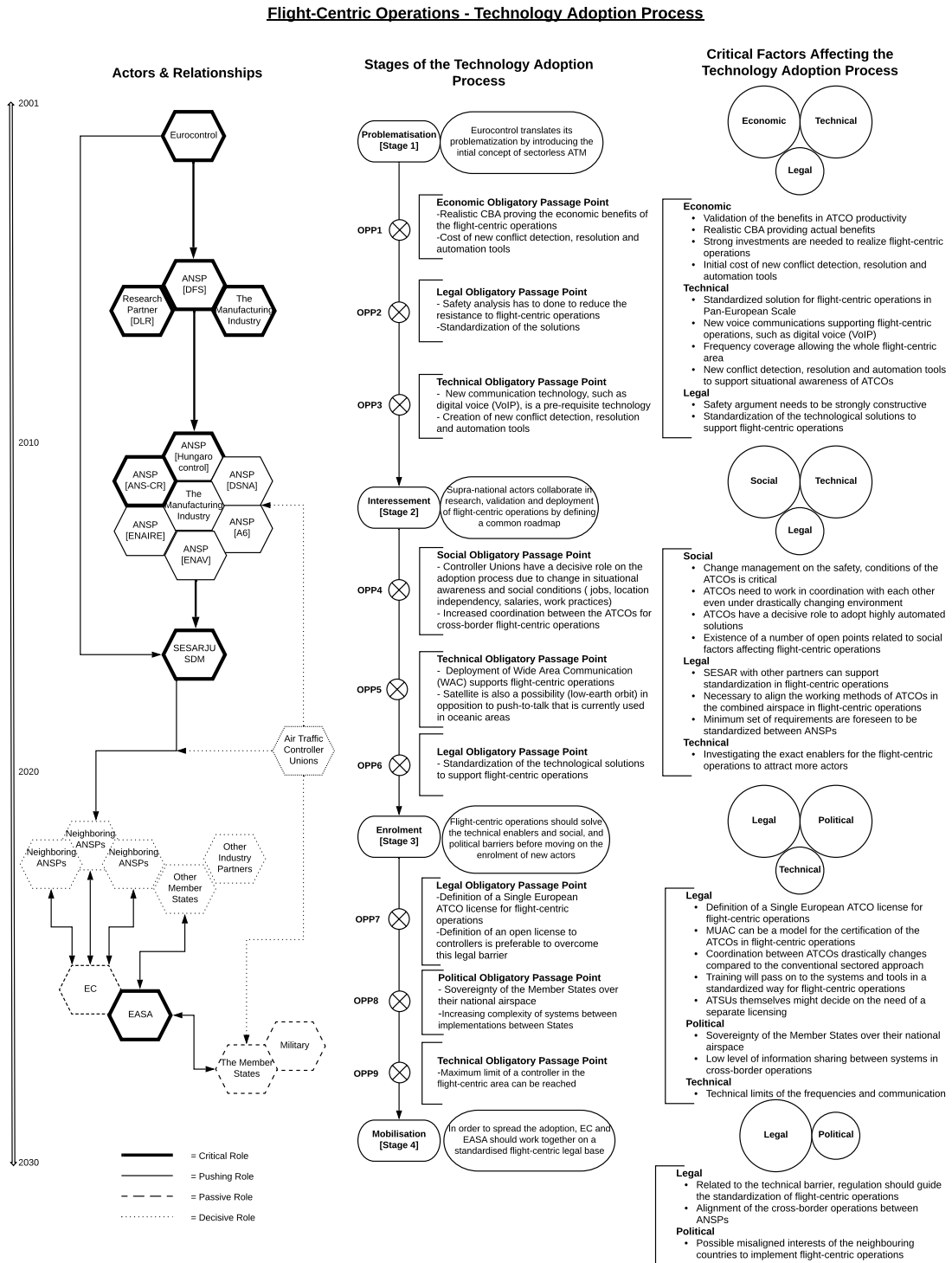


Figure 6.11 – Flight-Centric Operations Technology Adoption Graphical Representation

7 Analysis

This chapter provides the overall analysis for the two technologies of virtual centre and flight-centric operations. By interpreting the graphical representation obtained from the stages of the adoption, initially the outlook for the technologies are provided. Then, the chapter aims to explain the benefits of the two technologies in the implementation of the SES and the future of the European ATM. Finally, this is followed by providing the steps for the possible creation of the virtual centre and flight-centric operations with the suggestions for the relevant actors to overcome the challenges and barriers in the technology adoption process.

7.1 Overall Analysis of the Technology Adoption Process

In this section, the overall analysis for the virtual centre and flight-centric operations are provided by focusing on the results from the previous chapter. In each stage of adoption, there are specific challenges or barriers affecting the actors, guided by the factors affecting the technology adoption process. Specifically, this section will look into the adoption process with a current and future outlook.

7.1.1 Virtual Centre

The virtual centre could bring a total paradigm shift for the European ATM by enabling location independent service provision. By this, service provision will be liberalized and open to competition for any service provider which could satisfy the quality and safety levels. Currently, among interested ANSPs, only the ones that could afford the heavy initial investment of the virtual centre are able to adopt the technology. Apparently, this economic barrier requires further proof for the cost-effectiveness of the virtual centre by providing the relevant actors with a realistic CBA. According to the current implementation of the interested ANSPs, possible benefits would only appear after the service provision is virtualized and opened to competition.

From a technical point of view, virtual centre is similar to cloud-based services currently in

use within various network industries. The transition towards this type of services is inevitable in the long term strategy of the technological companies or organizations. Air traffic is one of the slowest network industry to adopt this technology and make this transition. Yet, what is more important than the technical is the synchronization of adoption and deployment between the ANSPs. The benefits of the virtual centre rely on the standardisation and the communication of the services between the adopting ANSPs. The more the number of ANSPs adopting virtual centre increases, the beneficial the transition will be. This is due to the fact that virtual services would only be adopted and used effectively only if a certain number of ANSPs make the transition.

A common roadmap to support the adoption of virtual centre is crucial, not only from a technical perspective as in the case of SESAR, but also a political agenda towards adopting new technologies for European ATM is crucial. Certain technologies that are promising for the long-term, such as virtual centre, should be supported by proper funding, incentivization mechanisms and creation of a market for the players to test their own strategies. The benefits for the virtual centre in the later phases could only be reached if the political actors are aligned with the technical actors in the European ATM. Here, virtual defragmentation requires the political actors to ease national sovereignty in order to share data and virtually defragment the services provided for the European ATM.

7.1.2 Flight-Centric Operations

Flight-centric operations aims to optimize the allocation of the ATCOs by changing the focus of ATC from a sectorized approach to controlling a trajectory of flight. Consequently, this is expected to change the work practices of ATCOs, assigning new roles to them, and changing the paradigm of situational awareness. In order to enable flight-centric operations, there are a number of pre-requisite technologies, such as new digital voice communications, controller support, conflict detection, resolution and automation tools. These pre-requisite technologies are important for the ATCOs to form their opinion towards the adoption of the flight-centric operations. Additionally, similar to virtual centre, flight-centric operations also require an initial heavy investment for the ANSPs that are interested to adopt the technology. This requires a realistic CBA considering local and Pan-European level of implementation of flight-centric operations.

From the analysis, an important point for the successful adoption of the flight-centric operations is to correctly manage the changes in the work practices of the ATCOs. Since flight-centric operations bring drastic changes in the work practices of the ATCOs, correct automated support tools should assist the ATCOs. Furthermore, cross-border operations require standardisation of the tools and technologies supporting flight-centric operations between the ANSPs. The benefits on the ATCO productivity would be visible when more ANSPs start to adopt flight-centric operations. Yet, this would also require new ways of standardizing the training and certification between the ANSPs. As mentioned previously, a single European

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license for the flight-centric ATCOs would be beneficial both for the ANSPs and the ATCOs. Here, a common roadmap to follow, as the case of the SESAR projects supported by SESAR-JU, EUROCONTROL, and the EC is important to realize the drastic changes of the flight-centric operations.

Realizing flight-centric operations also have political and legal implications, mostly related to the reassignment of the route charges. Under flight-centric configuration, the definition of the route charges should change to accommodate the trajectory of the flight, rather than that of the sectors that the aircraft passes through. Now, with ATCOs controlling aircraft for a trajectory, ultimately from its origin to destination, the route charge framework should be realigned either depending on the location of the ATCOs or the airspace that the aircraft passes through. In parallel, this will lead to a political discussion related to the national sovereignty argument if the ATCOs could control aircraft in another piece of airspace other than their national airspace. Yet, all the new technologies point towards data sharing and full integration between the ANSPs. This would ultimately require ANSPs and the Member States to ease their national sovereignty arguments.

7.2 Benefits of the Technologies for the Single European Sky

Looking into the technology adoption process, the actors also point out the benefits of these new and radical technologies to the implementation of the SES and the overall European ATM. Initially, the generic benefits of the technologies are provided by combining the analysis from both domain expert interviews, documentary analysis and participant observation. Following that, the benefits are categorized by specifically looking into the key target objectives of the SES and its high-level objectives. These categories are capacity, safety, environment, and cost-effectiveness. Additionally, defragmentation is added to the categories because of the highly fragmented structure of the European ATM and the ambitions of SES to defragment it.

7.2.1 Virtual Centre

The virtual centre is definitely a disruptive technology for European ATM. Not only the technological advancement brought forth with it is revolutionary for ATM, but also the radical changes in the services and the business models of the current actors. When the technology becomes operational, virtual centre is expected to alter the objectives of the major service providers in Europe. Collecting and analyzing the qualitative data from the domain experts, documentary analysis and participant observation, a number of possible future benefits have been identified in the case of successful adoption of the virtual centre. These benefits are preliminary in the sense that currently only qualitative data is available without the support of the quantitative data. Yet, still the qualitative identification of the benefits is important for the actors to realize and align their own objectives with the other actors in the European ATM.

The benefits of the virtual centre focus on the keywords of dynamic, flexible, digitalization, ser-

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Benefits of Virtual Centre

B1 - Dynamic Allocation - Flexible management of capacity to help other ANSPs

Moving one piece of airspace from one centre to another
Flexible allocation of ATCOs in cases of changing traffic

B2 - Creation of a new business model using digitalization

Europe being a front-runner in virtualization might also serve the other parts of the world
Not investing or adopting virtual centre is not beneficial for the future of the European ATM
A continuous innovation loop is needed for the virtual centre with sufficient workforce and modernization

B3 - Seamless exchange of services, data and ATC services

B4 - Helps medium-sized ANSPs to improve efficiency

B5 - Upgrading the infrastructure with implementing virtual centre

B6 - Reducing separation by improving predictability

B7 - Providing the level playing field for new services

B8 - More flexible organization of the airspace and centres

B9 - There should be a pragmatic way to show the benefits of virtual centre such as in congested traffic or specific events

Table 7.1 – Generic Benefits of the Virtual Centre

vices and virtualization. These keywords point towards defragmenting the current fragmented structure in the European ATM and reaching towards a service-oriented architecture. Being able to provide services location independently opens up new frontiers for the current and future actors regarding their business models. Hence, this creates competition for the future provision of the ATC and ANS services throughout the Europe. Arguably, choosing to avoid, or not to adopt virtual centre is not a smart move for the actors in the European ATM given the rapid rise in the ICT that supports cloud services. More importantly, the dynamic and flexible allocation of the effort of ATCOs through virtual centre allow dynamic capacity allocation. Yet, of course, the virtualization is totally new for the European ATM and sufficient workforce and know-how need to support the development and adoption of the virtual centre.

The current legacy systems are becoming obsolete, and minor upgrades of the hardware, software and infrastructure could not deliver the necessary changes to support new technologies. More flexible and seamless interconnected systems could create a level playing field for the new services. With the help of virtualization, the European ATM would be able to virtually defragment the ATC and ANS services. The medium-sized ANSPs could improve efficiency, while the small-sized ANSPs could subscribe to services supplied by the big ANSPs. In this way, the organization of the airspace and the centres would be gradually defragmented. In turn, the virtually interconnected systems could increase predictability, hence increasing capacity and reducing separation between aircraft. If, in the future, the benefits would be pragmatically proven with quantitative data for congested traffic, or specific complex airspaces, then the chances of attracting the actors' interests would be much easier.

Categorized Benefits of the Virtual Centre

Capacity

Capacity is one of the major problems for the European ATM due to its fragmented structure, congested complex airspaces and limited connectivity between ANSPs. These can be over-

7.2. Benefits of the Technologies for the Single European Sky

Capacity
C1 - Allowing more capacity in overload situations
C2 - Increased capacity due to standardized and defragmented systems
C3 - Doubling capacity can be achieved due to new applications reducing separation and increasing controller efficiency On the contrary physical separation is related to the aerodynamic properties of the aircraft
C4 - For some of the use cases of virtual centre increasing capacity is not the goal For the capacity problems on the ground, virtualization does not solve these problems
C5 - Being able to select and change the service provider for ANSPs will increase capacity in the long-term
C6 - Currently the ATCO capacity is not optimal for the en-route in increased traffic
C7 - The benefits of the virtual centre is not demonstrated quantitatively yet

Table 7.2 – Capacity Benefits of the Virtual Centre

come by the implementation of the virtual centre. By virtualization, the interconnected and standardized systems could deliver better capacity in overload situation. The dynamic and flexible allocation of ATCO effort allow to reach the optimal capacity of the ATCOs in a given airspace. Yet, not all the use cases of the virtual centre directly target to increase capacity. Some use cases aim to enable the rationalization or delegation of the airspace between ATSUs or ANSPs. These use cases indirectly contribute to the increase in capacity without directly affecting the current service provision. Furthermore, the benefits of virtual centre to the capacity is rather from the better utilization of the services and application to support the European ATM than the physical separation of the aircraft.

Cost-Effectiveness

Cost-effectiveness
CE1 - Efficient use of resources, dynamic resource allocation Using support cost and being in the flexibility of organizing the airspace better in virtual centre Dynamic resource allocation for ATCOs in increased traffic
CE2 - Less delays due to better dynamic and flexible management of airspace
CE3 - Estimated reduction in overall costs by 30 percent Reducing the European management layer translating into cloud-based services Reducing the staff in ANSPs by implementing the virtual centre Lowering the price of delivering virtualized ATM services
CE4 - Liberalization and competition of the market for the ATM services
CE5 - Remote Training Remote training can be delivered beneficially Remote training enables quick validation and training exercises location independently

Table 7.3 – Cost-Effectiveness Benefits of the Virtual Centre

Cost-effectiveness of the virtual centre is a topic still under discussion due to the initial heavy investment required for the ANSPs to research, develop and deploy. Additionally, a new workforce, specifically focusing on virtual centre, is needed to support the development of the

new technology. The economic benefits of the virtual centre takes shape after the heavy initial investment mainly in the areas of dynamic resource allocation, virtual defragmentation of the services, and optimization of the staff effort. Indeed, with the virtual defragmentation of the services, the market is expected to open to competition. As the case for the other liberalized areas of the European air traffic management, with competition, the cost of service provision is expected to reduce throughout Europe. In turn, this is also supported by the remote training which enables quick validation and training exercises to be done location independently. Additionally, the virtual centre directly affects the staff inside the ANSPs by reducing the European management layer with the defragmentation brought forth by cloud-based services.

Defragmentation

The key benefit of the virtual centre is by far the virtual defragmentation that is enabled by the cloud-based services. Even though the physical defragmentation of the European ATM system is challenging, the virtual defragmentation is possible with the support of the new technologies. By virtual defragmentation, even though the infrastructure and hardware stay fragmented as usual, the previous and new services could be migrated to the new cloud-based systems. This will, in turn, bring cost savings of economies of scale for each service provided by ANSPs. Consequently, this could be a role model for the European fragmentation problem by rationalization of infrastructure and airspace and closing the cost-effectiveness gap with the USA. By this, seamless exchange of data between cross-border ATSUs and ANSPs is expected to improve coordination between the centres.

Defragmentation

D1 - Virtual Centre as a role model for the European fragmentation problem

Rationalization of infrastructure and airspace overall Europe closing the gap with the USA

D2 - Development and sharing of various services enabled by the virtual centre

D3 - Defragmentation of the systems by economies of scale

D4 - Sharing of information and easily transfer sector from one ATSU to another

D5 - Cross-border implementation of virtual centre allows exchange of data, improving coordination between centres

D6 - The effect of defragmentation depends on the specific use case and ANSP of virtual centre implementation

D7 - Defragmentation in implementing one system with different configurations

COOPANS implemented a single system with different configurations for its members

Saving of costs due to implementation and testing by economies of scale

Right direction to take to implement virtual centre

D8 - Automation

Virtual centre allows the creation of a framework that provides more automation

Automation will start from the easiest services leaving the hard decisions for the management

New types of ATCOs, or even new automatization allows Air Traffic Managers

Table 7.4 – Defragmentation Benefits of the Virtual Centre

Environment

The effect on the environment directly depends on the airspace capacity and optimization of the routes. Hence, virtual centre enhances both of the areas, the expectation is that there will be less environmental impact due to less delays. Yet, this also depends on the changes of

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Environment

E1 - Less environmental impact since less delays

E2 - Positive effect on the environment due to having more direct routes, better organization of airspace, and less bottlenecks

E3 - Fuel efficiency does not change if the trajectory does not change

Table 7.5 – Environment Benefits of the Virtual Centre

the trajectories, if virtual centre only remains as a cloud-based service, connecting services of the ANSPs, then fuel efficiency does not get any better. Given that the virtual centre solves the bottlenecks of capacity in the European ATM, then there would be a positive effect on the environment.

Safety

The safety of the virtual centre is of paramount importance. Conventional safety approaches is not applicable for the virtual centre, where a new way of assessing safety and security of the systems supporting virtual centre could be put in place. For this reason, a shift of paradigm to assess the future cloud-based services could be investigated. Since the way the data coming to CWP of ATCOs changes in virtual centre configuration, cyber-security issues, such as protection of the network for critical data, arise. Moreover, the quality of the data should be sustained throughout the ATSU's connected to virtual centre. Mainly, this is due to better utilization of inter-operability between different systems in different ANSPs, but it still needs to be validated with common standards. The SESAR project related to virtual centre, PJ.16-03 does not report an improvement in the safety levels, rather priority is given to keep safety at the same level. The future assessment of the safety issue of the virtual centre is a critical element for the SES framework.

Safety

S1 - A totally new way of assessing safety is needed to validate safety of virtual centre

S2 - Conventional safety assessment approach is not applicable for remote provision of ATC

It should be validated with common standards

S3 - Safety improvement is not expected in the SESAR project, keeping safety at the same level is priority

S4 - Shift of change in safety focus due to the change of the system chain of data coming to ATCOs

Protection of the IP network for the critical data, cyber-security

The quality of the data the ATCOs have to be sustained

S5 - Critical on the current framework of the SES

Table 7.6 – Safety Benefits of the Virtual Centre

7.2.2 Flight-Centric Operations

Flight-centric operations brings a totally new paradigm for the ATCOs to control the flight from its origin to destination. The benefits for the flight-centric operations is still under discussion in a realistic comparison between the future conventional ATC and the flight-centric opera-

tions. The trade-off is the ATCO productivity versus the reduction in the situational awareness of the ATCOs. This is a critical topic for the flight-centric operations to prove its performance, human factor, and cost-effectiveness benefits. Additionally, from a CBA standpoint, in low to medium complexity airspace, flight-centric operations could bring benefits in the ATCO productivity. However, changing towards a high complexity airspace with various configurations of the ATCOs for flight-centric operations, the CBA could also result into negative. Similarly to virtual centre, flight-centric operations also require a heavy investment for the initial stage of adoption, and this would only enable the benefits to appear after a few years from its deployment. By itself, flight-centric operations does not alter the way of current provision of services. Yet, the change is rather on the work practices of the ATCOs and their productivity. According to the real-time simulations, the benefits mostly rely on the ATCO productivity, where ATCOs are responsible for a larger area or airspace rather than limited to sectors.

Categorized Benefits of the Flight-Centric Operations

Capacity

The initial aim of the flight-centric operations is to increase ATCO productivity, hence increasing capacity for a given piece of airspace with the same number of ATCOs. The capacity and cost-effectiveness can be regarded as the two sides of the coin. Concretely, the reduction of under-utilization of ATCOs by flight-centric operations increases the capacity of the overall network. Increase in capacity is also related to the flexible allocation of the airspace.

Capacity

- C1 - Increase of the capacity with the actors that support SESAR**
 - C2 - Increase of capacity should be tested in new concepts such as flight-centric operations**
 - C3 - Increasing capacity and cost-effectiveness are two sides of the coin**
 - C4 - Increasing capacity possibly with the same number of controllers**
 - C5 - Reduction of under-utilization of ATCOs boosts the capacity in the overall network**
 - C6 - Dynamic allocation of airspace gives dynamic flexibility**
 - C7 - Capacity increase needs to be further validated**
-

Table 7.7 – Capacity Benefits of the Flight-Centric Operations

Yet, the quantification of the benefits for the capacity should be further validated considering the different flight-levels and traffic complexities. This will allow the actors in the SESAR project either to support the further development and deployment of the flight-centric operations solution.

Cost-Effectiveness

A critical key performance area for the successful adoption of the flight-centric operations is cost-effectiveness. Theoretically, flight-centric operations is expected to reduce costs by increasing ATCO productivity. The theoretical assessment provides the overview of the ATCO productivity, but the practical assessment is yet to be done to provide proof for the cost-efficiency gains. Real-time simulations provides a quantitative assessment for the ATCO productivity gains, but still either they are limited for a specific airspace of an ANSP, or a flight-level with changing complexities. Indeed, changing flight-levels and traffic complexities directly affect the cost-effectiveness, accordingly the ATCO productivity. The gain for the ATCO productivity is expected to come from the better utilization of ATCOs under flight-centric configuration. Controlling a larger area of airspace, an ATCO is now responsible for a number of aircraft in an extended piece of airspace than the sectorized approach. Additionally, cost-effectiveness benefits appear profoundly when the adoption of flight-centric operations occurs in a larger area, ultimately in a Pan-European airspace. This is highly dependent on the reduction of the cross-border switches of pilots and ATCOs in flight-centric areas. Concretely, in order to reach the cost-effectiveness targets, ATCOs and pilots should be specifically trained for the drastic changes brought forth by flight-centric operations.

Cost-Effectiveness

CE1 - Reduced cost due to increase in ATCO productivity and reduction in environmental effects

Theoretical assessment is done for the amount of controllers saved, yet the hands-on operational experience is very important
 The reason for the need of fewer controllers in flight-centric operations is reduced under-utilization of ATCOs
 ATCOs will be able to work more easily in a larger area

CE2 - Changing flight levels will have different impact in cost

CE3 - The benefits are apparent when the flight-centric operations are adopted in a large area

A Pan-European approach is needed to gather most benefits

CE4 - Reduction of the workload across the boundaries in terms of clearances given to aircraft by ATCOS

CE5 - Support development of ATCOs better in flight-centric operations than in conventional sectorized operations

CE6 - Integration of drastic changes in the roles of pilots and controllers in the future

Table 7.8 – Cost-Effectiveness Benefits of the Flight-Centric Operations

Defragmentation

In parallel with the virtual centre, flight-centric operations also target defragmentation Europe-wide. By its conceptual design, flight-centric operations shifts the paradigm of ATC from managing traffic in a single sector towards managing a flight, ultimately through its whole trajectory. This is totally aligned with the defragmentation that the SES is looking after for the European ATM. Both horizontal (merging ANSPs), and vertical (between flight-levels) are possible with the introduction of flight-centric operations. Furthermore, cross-border operations include a complexity dimension which could be overcome by introducing flight-centric operations. Initially, an ANSP adopting flight-centric operations could defragment its internal sectors by merging the whole airspace under a single ANSP flight-centric area. Then the cooperation between the ANSPs is important for enabling cross-border flight-centric

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operations. A new regulation for the Pan-European adoption of the flight-centric operations might help for the smoother defragmentation of the European airspace.

Defragmentation

D1 - Defragmenting the sectors throughout Europe by flight-centric operations

D2 - Horizontal or vertical defragmentation of the sectors

D3 - Pilots will benefit from reduced workload and frequency change in flight-centric operations

Safety is also improved for the pilot

D4 - Help of the EC might be needed in the regulation side

D5 - In local ANSP implementation, the defragmentation is on the scale of defragmenting sectors inside an ANSP

D6 - Enabling defragmentation, but first defragment and then enable flight-centric

Increasing inter-operability between the ANSPs, hence promoting defragmentation

Table 7.9 – Defragmentation Benefits of the Flight-Centric Operations

Environment

The environmental benefits for the flight-centric is not apparent from the analysis with lack of additional benefits for the fuel efficiency. Only with the increase in ATCO productivity, indirectly if the routes are optimized and cross-border operations happen seamlessly, then there would be slight benefits for the capacity, hence the fuel efficiency.

Environment

E1 - Fuel-Efficiency

ATCO productivity may increase efficiency depending on the scale of flight-centric implementation

In free-route area there are no proven additional benefits on fuel-efficiency

Table 7.10 – Environment Benefits of the Flight-Centric Operations

Safety

Safety is a critical element for the acceptance of the flight-centric operations. Since there are radical changes involved within the work practices and situational awareness of the ATCOs, flight-centric operations shall maintain at least the same safety and security levels with the conventional ATC. A shift in paradigm for safety approach, including cyber-security, and new secure digital communications, are important for the adoption of flight-centric operations. Thus, the priority is not to increase safety levels, rather the aim is to keep the safety levels in an acceptable level while optimizing the ATCO productivity. Since flight-centric operations merge sectors and enhance cross-border operations, a totally new way of safety assessment is needed to further validate the effects on safety. Depending on traffic level, complexity and implementation, there needs to be a paradigm shift to assess safety for flight-centric operations. Further, the safety assessment of the flight-centric operations should be done in an upgraded way, both checking the safety of ATC under flight-centric operations, cross-border

operations, and cyber-security issues attached to its adoption.

Safety

S1 - A totally new way of assessing safety is needed to validate safety of flight-centric operations

Cross-border operations and trajectory based safety assessment should be priority

S2 - Cyber-security and situational awareness are critical factors

S3 - New digital communication for flight-centric operations has to be secure

S4 - Possible reduction of frequency changes could bring safety benefits

S5 - Priority is not increasing safety levels, rather keeping safety at the same level

S6 - Real-time exercises and simulations should be done to evaluate effects on safety levels

Table 7.11 – Safety Benefits of the Flight-Centric Operations

7.3 Creation of the Virtual Centre and Analysis

7.3.1 Virtual Centre

Upon further analysis of the stages of the virtual centre, the thesis provides a stepwise approach for the successful adoption of the virtual centre. By combining various approaches that the current ANSPs take to adopt virtual centre, a number of suggestions and recommendations have been summarized in the following section for the relevant actors in the European ATM. Starting from the conceptual framework of the virtual centre, down to creation of the core elements towards modern service-oriented architectures. A successful creation of the Pan-European virtual centre depends on the creation of synergies between multiple ANSPs switching towards service-oriented architectures. There are some critical features and steps for the successful creation of the virtual centre. Apparently, there is a need for a pioneer to show the benefits of the virtual centre, such as Skyguide or MUAC, to further attract the interest of the other ANSPs.

- **Creation of the Virtual Centre**

- **Step 1 - Conceptual Work by ANSP Management in Top and Middle Level**

- * Physical merging of sectors within ANSPs adopting virtual centre
- * Localization or consolidation of centres is secondary
- * One Sky by One System - Skyguide Approach to Virtual Centre
 - A service-oriented architecture with two ACCs
 - Operate as a single standardized system with two centres
- * In the beginning of implementation, there is less impact for ATCOs focusing on the positive benefits
- * First local ANSP solutions could be beneficial to try in congested areas

- **Step 2 - Creating the synergies around a virtualization solution**

- * ANSPs partnering with right industry partners for the development of the virtual centre
 - * Actors strategically position themselves to support the virtual centre
 - * There is a need for a pioneer, such as MUAC or Skyguide, on the implementation of virtual centre
 - * Defining who are the actors that are impacted by virtual centre
 - * ANSPs partners with manufacturing industry, also external system and software providers
- **Step 3 - Preparation of core elements by system architects**
- * Location independence of the systems and management of airspace
 - * Unnerving the core services and producing a digitalized overlay system
 - Layer allowing data sharing to provide new services
 - * Keeping the old systems and switch to new system in a step-wise approach
 - * Creation of a single cloud service with a single data set
 - Each node of the network provides a service that is symmetrical
 - * Rationalization of infrastructure, hardware, and software
 - Deployment of virtual centre (sector, local, national, Pan-European)
- **Step 4 - Creation of an idea of virtualization in multiple neighbouring ANSPs**
- * A big ANSP should support the development of virtual centre in support with small to medium ANSPs
- **Step 5 - Creation of a up-to-date and modern service-oriented architecture**
- * Feature 1 - No tight coupling
 - * Feature 2 - No point-to-point connection
 - * Feature 3 - No data duplication
 - * Feature 4 - Agile mode of delivery methodology
 - * Virtual centre becoming inter-joint with other new technologies such as Free-Route airspace and Flight-Centric Control
- **Step 6 - Creation of the stages (tranches) of virtual centre**
- * Tranche 1 - Setting the Scene
 - Tranche 1 Step 1 - Preparation of change management
 - Tranche 1 Step 2 - Creation of benefits really early in the adoption
 - * Tranche 2 - Building the Foundation
 - Tranche 2 Step 1 - Replacing the core systems by a service-oriented architecture (Current technology adoption stage)
 - Tranche 2 Step 1 - Migrating of first critical application - Sector capacity planning tool
 - Tranche 2 Step 2 - Starting to implement virtual centre in the least complex of airspaces

- Tranche 2 Driver 1 - The concept of merging the two systems in Switzerland
- Tranche 2 Step 3 - Step-by-step migration of core services from legacy to new systems
- Tranche 2 Step 3 - Safe migration of new functionality
- Tranche 2 Step 3 - Learning from mistakes and fixing, and stabilizing them
- * Tranche 3 - Focusing on operations and impact on airspace management
 - Tranche 3 Step 1 - Moving into more complex airspaces
- * Tranche 4 - Virtual defragmentation
 - Tranche 4 Step 1 - Defragmentation of core services throughout Europe
 - Tranche 4 Step 2 - Introducing competition for core services
 - Tranche 4 Step 3 - Implementing service-oriented architecture for flight data processing systems (FDPS)
- Step 7 - New actors will be able to penetrate the virtualized ATM environment

7.3.2 Flight-Centric Operations

Flight-centric operations has a progressive path of creation, initially starting from local implementation, ranging within various traffic complexities and flight levels. Next, an early adopting ANSP could be a role model for the neighbouring ANSPs to switch towards flight-centric operations. Yet, this needs pre-requisite technologies to be place, common deployment roadmap, and political incentivization mechanisms. There is also mixed opinion on how the ultra collaborative environment between ANSPs would work. Consequently, there would be a need for coordination between the NM and the ANSPs for synchronizing flight-centric operations. Upon the assessment of the quantitative benefits of the flight-centric operations, it would be beneficial to implement the technology where the traffic complexity and flight-level brings optimal benefits. Ultimately, the combination of flight-centric operations with virtual centre would bring the benefits from the defragmentation of the ATC and ANS services.

- **Creation of the Flight-Centric Operations**

- **Step 1 - Local ANSP Solutions**

- * One country or ANSP can be a model for others
 - Areas that include more under-utilized controllers can be a preferable start
- * MUAC can be a successful example for the implementation of flight-centric operations
- * ATSU could locally decide to adopt flight-centric operations
- * Allocation of staff, training, and regulatory issues will be adressed in high-level maturity of the project

- * Flight-centric is not necessarily out-of-border operations, local solutions are also feasible
- **Step 2 - Creation of the embryo of flight-centric operations**
 - * A flight-centric area which encompasses very high level airspace of neighbouring countries
 - An example could be an ANSP in collaboration with its neighbouring ANSPs
 - Maintaining proficiency for this top layer will be easier than lower and complex airspace
 - First starting with segregating flight-centric implementation to flight level between 325 and 385
 - Additionally the working conditions for ATCOs will be much easier with high level low complexity airspace
 - * If neighbouring ATSUs are interested in flight-centric operations, they can collaborate
- **Step 3 - Joining of other ANSPs (Member States) to the initial setup**
 - * This step needs political decisions, necessary budget, and a common deployment plan
 - * Sharing of information between ANSPs using additional hardware and 4D trajectory implementation
 - * There is mixed opinion on how the ultra collaborative environment between ANSPs would work
 - * Relationship between the ANSPs and the Network Manager is crucial in terms of flight-centric operations concept
 - A stakeholder agreement is needed to align the interests on flight-centric operations
- **Step 4 - Decision for the complexity for flight-centric operations**
 - * High-complexity traffic is not currently suitable for flight-centric operations
 - * The less complex the airspace, the more suitable is to implement flight-centric operations
 - * Hybrid operations between day and night switching of flight-centric operations
- **Step 5 - Combining flight-centric operations with other new technologies (Virtual Centre)**
 - * Standardizing the flight-centric operations within the SESAR framework
 - * Starting local and then moving to the transversal area by prioritizing certain enablers
 - * Flight-centric ATCOs that can work location independently
 - There are issues about where the location of these ATCOs will be and their certification, endorsement

7.4 Suggestions for the Improvement of the Technology Adoption Process

In this section, the thesis provides a number of suggestions and recommendations to raise the efficiency of the technology adoption process in the context of the specific technology for the relevant actors. These suggestions and recommendations are the by product of the analysis carried out in the previous section on the technology adoption process. Specifically, the barriers and challenges in each stage of the adoption process are reviewed to form these suggestions for the relevant actors. Additionally, the factors affecting the adoption process are considered within its circle of importance in the technology adoption process.

7.4.1 Virtual Centre

Virtual centre is a technology that brings substantial changes not only on the technical side, but also on the political, legal, economic and social areas. These changes happen only accompanied with the corresponding actors understanding and aligning themselves towards the technical changes brought forth by the virtual centre. Here, we will specifically look into what could be done further to increase the effectivity of the adoption of the virtual centre by providing specific recipes for the relevant actors. First is the funding and incentivization mechanisms to compensate the initial heavy investment required for the adoption of the virtual centre. Second, still the national sovereignty argument limits the data and service sharing between the ANSPs around the Europe. Third, creation of an initial test market specifically for the virtual centre would help the ANSPs examine the benefits of the virtualized services. Finally, specific regulation for the new technology, services and the market is required for successful operation of virtualization.

Funding, incentivization mechanism compensating initial heavy investment for virtual centre (ANSPs, The Manufacturing Industry, Member States, EC, EUROCONTROL, SESAR-JU)

Currently, it is an ANSP decision whether or not to adopt virtual centre, switch towards cloud-based systems, and service oriented approach. Only ANSPs, that could afford the heavy initial cost of the switch from legacy systems towards new virtualized systems, intend to adopt virtual centre for the moment. Given that the virtual centre delivers its promised benefits in the long-run for the European ATM, and if there is a consensus between the Member States and the supranational actors (EC, EUROCONTROL, SESAR-JU) towards the adoption of virtual centre Europe-wide, there should be a mechanism to incentivize, or possibly fund the early adopters. Additionally, this could be followed by attracting the support of the small to medium-sized ANSPs towards adopting the virtual centre. This could be achieved by conjoining some of the initial services with neighbouring ANSPs. Ultimately, the big ANSPs would also be interested to try virtual services with neighbouring small to medium sized ANSPs. Here, SESAR-DM

could play a key role on funding and incentivizing early adopters of SESAR technologies, such as the virtual centre.

National sovereignty issues related to data sharing, service orientation in European ATM (ANSPs, The Manufacturing Industry, Member States, EC, EUROCONTROL)

Virtual services increase the inter-operability between the ANSPs by enabling a standardized common platform of data sharing. Still, there are limitations on the standardization and sharing of data between the ANSPs, mostly linked to the national sovereignty argument. Virtualization and the benefits of the virtual services would be limited if there is no improvement in the levels of data sharing between the ANSPs. A solution to this would be to create a Pan-European legal base for the virtual services. A standardized platform where the ANSPs would consolidate data sharing between interested ANSPs would be beneficial for the European ATM. Indeed, the switch from legacy systems with limited inter-operability towards service-oriented architecture enabling highly-connected services would only be possible if there is more cooperation between ANSPs, and the Member States. Initially, neighbouring Member States could decide whether or not to share data for the virtualized services depending on the benefits and the criticality of the applications. Here, safety and cyber-security issues related to the sharing of data is at critical importance for the ANSPs. As more and more services switch towards virtual services, there would be increased need to ensure the cyber-security among the European ANSPs. Furthermore, in a consolidated data sharing model, EUROCONTROL could play a key role in providing a Pan-European platform for data-sharing, standardised using SWIM infrastructure.

Creation of a market to see the benefits for initial virtual services (ANSPs, The Manufacturing Industry, EC)

In order to validate the benefits of the virtual centre, an initial test market for the very first services is crucial to set up. These services would be the foundation of the service-oriented architecture for the European ATM. Currently, the ANSPs that are adopting the virtual centre are only able to use these services locally, defragmenting their local services inside. Yet, there does not exist a market for the ANSPs to provide virtual services for one another. There are some cloud-based services sharing, such as FDPS, among the neighbouring ANSPs in high traffic complexity regions. However, this stays limited for some of the services without the actual benefits of the virtualization. By virtualization, even ATC could be served location independently, theoretically from anywhere in the world. The requirement for an initial market is also important to examine the estimated benefits of the virtual centre. Moreover, introduction of virtual centre, specifically for cross-border operations, poses significant challenges for the current route charging mechanism. Under a virtualized configuration, the optimal route charge mechanism should be restructured to comply with the paradigm shift brought forth by the virtual centre.

7.4. Suggestions for the Improvement of the Technology Adoption Process

Specific regulation for the virtual centre (EC, Member States, EASA)

The services enabled by the virtual centre would not be location dependent. This requires reframing all the current regulation on service provision in the European ATM. With virtualization, ANSPs would be able to subscribe to any service provider that could operate within the appropriate technical and safety levels. The current regulation is based on the specific ANSP providing services only to the extent of the airspace of the Member State. With virtualization, an ANSP would be able to provide services even in place of other ANSPs. Here, the standardisation of services is crucial for the regulation to apply set the common interoperable regulation between the ANSPs. This new regulation should specifically target sharing of infrastructure, hardware, software, services, and data between the ANSPs. Ultimately, the aim of the new regulation should be enabling location independent ATC with the ancillary services to support it Europe-wide.

7.4.2 Flight-Centric Operations

Development of ATCO automation, support tools for flight-centric operations (ANSPs, The Manufacturing Industry)

Flight-centric operations rely heavily on the automated ATCO support tools, specifically for conflict detection and resolution. Rapid development of these tools is important for ATCOs to evaluate the performance of these tools compared to the conventional sectorized approach. These tools are currently under development by interested manufacturing industry partners of ANSPs. Following the development of these tools, a re-evaluation of the estimated benefits of the flight-centric operations would be investigated under real traffic within different traffic complexities and flight levels. Within these evaluations, the ANSPs, especially ATCOs would be either interested or not for the adoption of the flight-centric operations. More importantly, the changes in the situational awareness would be much prevalent in the real world exercises than comparing it in real-time simulations.

Pre-requisite technologies to support flight-centric operations (ANSPs, The Manufacturing Industry)

Enabling flight-centric operations requires certain pre-requisite technologies, such as new digital voice communication or VoIP, to be operational. The frequency congestion is a long-lasting problem for the general European ATM. Definitely, a new voice communication system is needed supporting more bandwidth to allow better communication between the ground and the air. Specifically, for cross-border operations or where the traffic complexity increases, this problem becomes more imminent. It is crucial to make sure that flight-centric operations would not introduce a new layer of complexity for the frequency congestion problem. Rather, it is more beneficial for flight-centric operations to use the new digital voice communication in order to accommodate the need for the additional bandwidth. By this, other new technologies,

such as virtual centre, would also benefit from the increased bandwidth for the location independent service provision.

Definition of a common roadmap among the relevant actors for flight-centric operations (SESAR-JU, EUROCONTROL, EC)

The adoption of flight-centric operations remain an ANSP decision. Within SESAR projects, SESAR-JU and EUROCONTROL support the research and development of flight-centric operations in close cooperation with ANSPs and the manufacturing industry. Yet, the local implementations of flight-centric operations have limited standardization between them, and the tools for the support of ATCOs are developed separately. The main benefits of the flight-centric operations is on the elimination of cross-border operations and switches. Yet, this is only possible with defining a common roadmap for the standardized implementation of flight-centric operations. Among the supra-national actors, SESAR-JU and EUROCONTROL is suitable for the assignment of the common roadmap for the ANSPs to follow. Actually, AAS is on the right track on supporting the common development of the flight-centric operations for the future architecture of the Single European Sky. Of course, the creation and development of a common roadmap includes all the aviation stakeholders within close cooperation with the supranational actors, such as the EC, SESAR-JU and EUROCONTROL.

Standardization of legal aspects, training, certification of ATCOs (ANSPs, EASA, NSA, EUROCAE, EUROCONTROL)

Similar to virtual centre, flight-centric operations bring drastic changes for the work practices of ATCOs, enabling an ATCO to provide services within multiple ANSP airspace. Indeed, an ATCO providing services in the airspace of multiple ANSPs would need to have a standardized training and certification procedure. Ultimately, a single European license for the flight-centric ATCOs would be beneficial in the long-run for the adoption of flight-centric operations. Yet, there is also the route charges issue that needs to be readressed in the case of flight-centric operations. The legal framework considering the new route charges should be reworked to consider the flight-centric areas and how to collect and distribute route charges for these specific areas. Additionally, for local and national standardisation of flight-centric operations, NSAs could work with their national ANSPs to support flight-centric operations. In the Europe-wide standardisation of flight-centric operations, EUROCAE could play a key role in consolidating the cross-border operations. Furthermore, for the restructuring of the route charge mechanisms for flight-centric operations, EUROCONTROL needs to implement required changes.

7.5 Conclusion for Analysis

Through observing the benefits and the possible steps for the creation of synergies for the adoption of these technologies, this chapter provides an overview of what could be learned from evaluating the adoption of these two technologies. First, the categorized benefits for the SES are provided in the case of successful adoption of the technologies. Following that, the concrete steps on how to reach a Pan-European scale adoption are summarized through evaluating the previous results from the technology adoption conceptual framework. Finally, the chapter provides suggestions for the relevant actors for increasing the efficiency of the technology adoption process.

Both of these technologies require heavy initial investments, and currently only the ANSPs that could afford the initial cost of adoption are interested. This could be supported by creating incentive mechanisms for the early adopters by the regulatory and political actors. For the virtual centre, the creation of an initial, even a test market, is critical for it to prove the benefits in capacity and cost-effectiveness. Considering flight-centric operations, a common roadmap to standardize the cross-border operations is crucial. Furthermore, flight-centric operations creates the opportunity to bring new business models and competition into en-route ATC. Both of the technologies rely on standardization between the ANSP and a number of pre-requisite technologies to be put in place. For a Pan-European scale adoption of the technologies, these challenges and barriers could be solved through the suggestions provided for the relevant actors in the European ATM.

The disruptive nature of these technologies introduce new procedures for the proper legislation and safety assessment. For the European ATM, safety is paramount. For this reason, a new safety assessment methodology including cyber-security, remote and location independent provision is needed. The regulatory actors could act towards observing other network industries on how to further evaluate the issues in relation to remote provision of the services. Yet, a paradigm shift is needed to evaluate the safety of these two disruptive technologies in the long term. Finally, the new legislation should prepare the grounds for new entrants to be able to compete in the market for the provision of ATC and ANS services.

8 Conclusion and Recommendations

This final chapter concludes the thesis by providing the synthesis, contributions, further recommendations and future work related to the thesis topic. The two case studies, virtual centre, and flight-centric operations are selected as the two promising technologies for the future of the European ATM. The ultimate aim is to investigate and explain the technology adoption process by looking to the big picture including the granularity of the actors, their roles and relationships between them. By this, the relevant actors are explored by looking into the roles in the adoption process in the guidance of the conceptual framework. A number of factors, including political, legal, economic and social are affecting the dynamic adoption process in the European ATM. Although the adoption problem is perceived to be on the technical side, the institutional environment are as important as the technical side surrounding the actors. For this reason, this thesis followed a socio-technical qualitative approach by combining various data sources to build up the picture surrounding the two important technologies in the European ATM.

8.1 Synthesis

This research targets to fill a gap in the literature where socio-technical research in the context of the European ATM is lacking. Both from a theoretical and practical perspective, there is definitely a need to understand the actors, their roles and relationships while they adopt new technologies for European ATM. Currently, the institutions and organizations remain on the side of understanding the technical or the economic perspective of these technologies. Yet, the main challenges and the barriers also remain on the political, legal, and social dimensions. Ultimately, the main aim of the thesis is to provide a socio-technical picture of the overall technology adoption process in the European ATM. Building upon the concepts derived from both ANT and ST, the conceptual framework paints this picture, still remaining simple to explain the adoption process on a single A4 page.

This dynamic picture of the technology adoption process is crucial for all the relevant actors in the European ATM. First, it could be the foundation to identify the challenges and barriers

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related to the adoption of new technologies, and how to solve them. Second, the current SESAR projects that follow virtual centre and flight-centric operations could benefit from the qualitative research results, besides the technical and economical impacts of these technologies. Finally, the conceptual framework could be updated with the latest information for the development and adoption of these new technologies, and provide a complete picture of the adoption process for all the relevant actors. Ultimately, the conceptual framework could be used as a strategical technology management tool to examine the technology adoption process in the European ATM.

Technology adoption in the European ATM is a complex interplay of actors, their objectives and relationships. Not only the technical and economical factors affect this interplay, but also the political, legal and social aspects matter. Even sometimes, these factors could become more important than the technical and economic aspects. In order to understand what is important is to include all these factors inside a single framework to evaluate the actual effects. Surprisingly, these factors create challenges or barriers for the actors during their way of adoption. Some of these challenges or barriers are not realized unless they become apparent for the actors. However, it is important to realize these challenges and barriers before they get in the way of the adoption, demotivating actors, or ultimately disrupting their objectives. Additionally, these factors are important for the alignment of the objectives of the actors for the technology adoption in the long-term.

Combining all these reasons, these thesis solves both a practical and theoretical problem. From a practical perspective, the European ATM needs a framework to evaluate the adoption of new technologies. Mainly, this is due to fact that the adoption process is becoming challenging, not all the actors are in the same page when it comes to the adoption of new technologies. Concretely, the new technologies, such as investigated in these thesis, virtual centre, and flight-centric operations have disruptive nature. Initially, these technologies alter the business models of the actors, where they make possible the location independent or remote provision of ANS and ATC services. This opens up new possibilities for the future provision of services for the European ATM. Ultimately, the market could be disrupted by new entrants in the form of third party providers, or outsourcing companies providing services instead of local provision of services by ANSPs.

Specifically for the case of technology adoption in the European ATM, this thesis provides a step-wise approach to further understand the emerging technologies. The method of using extensive case studies to understand the actors, their objectives, relationships combined with the factors is a valuable tool for pointing out the barriers and solving them in the future. This would both save time and money for the actors that are interested to adopt these technologies. Furthermore, the alignment of the actors could be observed throughout the stages of the adoption. If there is any misalignment between the actors, these could be solved prior to the actual adoption or deployment decisions. These complex behaviour could be understood with a qualitative approach, such as extensive case studies, as described in these thesis. The technology adoption could be optimized focusing on solving the challenges and barriers at

each stage of the adoption process. Observing the factors, these could be enhanced to increase the speed, efficiency and delivery of the technology adoption in the European ATM.

8.2 Limitations and Generalizability

The research methodology and the analysis carried out in this thesis have a number of limitations, mainly related to the future part and generalizability of the conceptual framework. First, there is a distinction between how the past and future are interpreted within conceptual framework for technology adoption. For the past, the conceptual framework builds a clear overview of the events including the actors, roles, relationships between them while also considering the factors and barriers affecting them through the adoption process. For the future, this framework relies on a qualitative approach where the most probable future scenario is built using the convergence of objectives of the actors. Considering the generalizability, it could be further supported investigating the adoption of emerging technologies in the European ATM. Similar patterns of adoption exist in other network industries, such as electricity, telecommunications and transport. Sampling new technologies and applying the conceptual framework to understand technology adoption for these industries would be beneficial to further increase the generalizability of the conceptual framework.

The initial limitation is the evaluation of the future scenario of the technology adoption for the two cases under investigation. This limitation is addressed utilizing the most probable scenario for future adoption of these two technologies. This most probable scenario represents the future behaviour of the actors, and their relationships mainly on the third stage, enrollment and final stage, mobilization of the technology adoption process. Of course, alternative scenarios could be considered, but this is possible within the future research when the quantitative input for the technologies is available, and these technologies get more mature, passing through the stages of adoption. For the most probable scenario, any change in the factors, barriers or challenges affecting the adoption process could be reverse interpreted to understand their affect into the adoption process. However, this also has limitations since the roles of the actors, and their relationships should be reiterated according to the latest situation of the network.

Yet, a quantitative simulation model, as also described in the future research section, could utilize the possible scenarios and simulate their output under parameterized conditions of the actors' behaviours, factors and barriers affecting them. This could help for the simulation of the alternative scenarios built for the adoption of the technology. For example, actors roles and objectives could be quantified and parameterized in order to evaluate the effects on the efficiency or rate of adoption of new technology. Furthermore, the affect of factors, barriers and challenges could also be quantified in order to simulate the overall effect on the changes of these parameters. As such, quantification of the concepts derived from the conceptual framework could help to support the limitations from the qualitative approach that is carried out in this thesis. As for an initial construction of the backbone for the ontology

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and syntax, this research adopts a qualitative approach in order to interpret and conceptualize the environment surrounding the technology adoption in the European ATM.

For the generalizability of this research, the two case studies mutually support each other through the formation of a conceptual framework for technology adoption. Furthermore, the generalizability of the technology adoption framework could be further increased with additional case studies of new technologies in the European ATM to support the conceptual framework. Iterations of the conceptual framework is possible from the updates derived from these future case studies. In the air traffic domain, there also exists similar patterns and interactions towards the adoption of new emerging technologies. Additionally, this thesis creates a generic backbone to study new technologies for the European ATM. In various regions of the world, the actors in the air traffic domain show similar network structure, including the types of actors, their roles and relationships. Of course, factors, challenges and barriers could be unique to the air traffic environment, as such that the European ATM has a fragmented air traffic structure compared to the other regions of the world. Considering the air traffic in the United States, the main difference is that the institutional governance, and regulatory bodies are centralised and there is only a single ANSP, Federal Aviation Administration (FAA), that is solely providing the services. This creates the main difference that there is expectedly less fragmentation, regulatory barriers for the adoption of new technologies. Having a single ANSP, FAA also is responsible for the Next-GEN project, which is similar air traffic research and development project as SESAR in the Europe. The fragmented structure of the European ATM could make the factors, barriers and challenges unique for the case of the technology adoption in the European ATM. Yet, the backbone of the conceptual framework, the generic descriptions make the approach generalizable to evaluate new technologies for other air traffic domains, such as the US ATM.

Considering the technology adoption in other network industries, there exists similar network industries to the air traffic, such as energy, electricity, rail and urban transport where there exists local provision of services. In these network industries, similar patterns exist when it comes to the definition of the actors, their roles and relationships. Of course, content and context-wise, there are differences between these sectors. However, the generic structure of the conceptual framework could be utilized to capture the technology adoption process in the industries. Additionally, in order to provide the generalizability for these sectors, extensive case studies could be carried out sampling new technologies from different network industries, to reiterate the conceptual framework and update it if necessary to further increase generalizability. This is also mentioned as one of the key points for future research section of this thesis.

In order to address these limitations and also increase generalizability, a number of case studies, both including from air traffic and other network industries could be carried out to investigate the applicability of the framework to other network industries. Initially, starting with the emerging technologies in air traffic, such as drones, satellite communication, and block-chain could be candidate case studies for future research. The findings from these case

studies could be used to update and reiterate the conceptual framework accordingly. From a methodological perspective, ANT and ST provide qualitative interpretation of the case studies, additionally quantitative models could support the generalizability with quantified inputs and outputs, parameterized for the scenario under investigation.

8.3 Theoretical and Practical Contributions

The previous literature on the technology adoption research focuses primarily on the behaviour and perception of the user, remaining user-centric. The approaches of ANT and ST brings out the combination of social and technical dimensions with the power of the qualitative research. In this way, the roles, social interactions revolving around the adoption of new technologies could be grasped from qualitative investigation. Previously, ANT offered ideas and concepts to examine how the new technologies come into existence and evolve. Combining these under a single conceptual framework to understand the adoption of new technologies is the initial contribution of this research. By this way, a complete picture of the adoption process of new technologies could be painted including all the actors, relationships and factors affecting them.

The adoption of new technologies in the European ATM is a socio-technical phenomenon. A number of distinct actors act through realizing their objectives, while getting aligned or misaligned depending on their aims. Yet, there is lack of research pointing out the adoption of new technologies in European ATM. Previously, possible scenarios and technologies for the future of the European ATM analyzed qualitatively by various researchers. However, as pointed out in the literature review section, extensive case studies to understand the specific adoption of new technologies is a first contribution to this topic from our knowledge. Now, the technology adoption cases of the virtual centre and flight-centric operations are contemporary topics. Crucially, it is important to point out all the actors, relationships and factors that affect these technologies through the adoption process.

The approach of using extensive case studies to understand the technology adoption process is lacking in the European ATM research. Generally, the technical and economic feasibility of the new technologies are investigated using qualitative and quantitative data. The case study research provides the in-depth look through each actor, and their roles in the adoption process. Eventually, this leads to a comprehensive understanding of a dynamic process of technology adoption. Without looking directly inside the specific cases, the analysis remains superficial, only providing generic results on understanding the new technologies. The new technologies alter also the objectives of the actors, and their relationships. Within the emergence of a new technology, actors position themselves inside a network towards the adoption of these technologies. The qualitative case studies could grasp these interactions between the actors, providing a complete picture of the adoption process.

Finally, the conceptual framework combines the concepts from ANT and ST in order to provide this complete picture of technology adoption in the European ATM. A case study guided by a

conceptual framework is a powerful researcher tool to provide practical recommendations for the actors in the European ATM. From a practical perspective, this thesis provides a step-wise approach to investigate the technology adoption process, as demonstrated in the two specific case studies. Critically, there are important factors, such as political, social and legal affecting the adoption process, besides technical and economic aspects. This is important to realize to increase the efficiency of the adoption process for the new technologies in the European ATM. The conceptual framework could be used to analyze any new technology, using a qualitative data collection approach. Additional quantitative approaches of assessment of the feasibility of the new technologies, this opens up new dimensions and advantages to increase the efficiency of the technology adoption process.

8.3.1 Theoretical Contribution

The previous literature on technology adoption either focus on the user side of the technology adoption, or rather look into the technical or economical aspects of the adoption process. Previously, ANT has been utilized by various researchers to understand how new technologies come into existence and evolve. Starting with Bruno Latour, Michel Callon, and John Law, the social aspects of the technology are incorporated inside the technical dimension. The emphasis is given on the mutual understanding of the social and technical dimensions together to build a complete picture of a technology with its actors and socio-technical environment surrounding it.

Following the steps of previous ANT researchers, Eze et al. (2018) [Eze et al.(2018)Eze, Chinedu-Eze, and Bello] provided an approach on using the ANT concepts to evaluate a technology adoption process. Yet, this remains on understanding and defining the actors and the stages of adoption, without looking into the factors, challenges and barriers in the adoption process. Moreover, the identification of stakeholders of ANT remains open by suggesting to follow the actors. For this reason, ST provides a guide for the identification of the stakeholders, where a step-wise approach to the identification of stakeholders is provided.

However, the previous research did not fully incorporated a framework, including the actors, their roles and relationships combined with the factors. In that manner, this study is a first attempt to combine the missing pieces into a single conceptual framework for technology adoption. Additionally, providing extensive case studies using the conceptual framework introduces a step-wise approach on how to explore the socio-technical environment, define the actors, observe the roles and relationships and determine the factors affecting the adoption. The definition of the actors are guided by the ST and the stages of adoption and social dimension are introduced from the tools of ANT. From a theoretical perspective, this introduces a new conceptual framework to evaluate the overall technology adoption process.

The stages of adoption, problematisation, interessement, enrollment and mobilisation encapsulate the necessary momentum for the technology adoption process. While understanding the factors at each stage of the technology adoption process is crucial to point out the barriers

and challenges associated to relevant actors. From this point of view, a theoretical contribution has also been made in incorporating the factors, challenges and barriers throughout the ANT translation stages of the adoption process. Previous research on corporate communications emphasized the importance of combining ANT tools with ST. Yet, it remains explanatory without the support of extensive case studies to back up the theoretical standpoint.

Spheres of factors and their influence on the adoption process is also an additional component in technology adoption research. The previous research pointed out the importance of factors, yet have not incorporated inside the technology adoption literature. Similar approaches are present in the corporate communications literature, where a single factor is considered through the stages of translation of actors' objectives. Yet, a comprehensive allocation of factors affecting the adoption process, emphasizing the importance by their size of sphere is missing. In that sense, the graphical representation of the factors at each stage of the adoption process is an additional component for the technology adoption framework.

8.3.2 Practical Contribution

More importantly, the conceptual framework could be used to further assess the adoption of the new technologies for the European ATM. Providing the challenges and barriers, the framework could assist the actors towards maintaining their objectives. Concretely, the actors could be able to pinpoint these challenges and barriers before they adversely affect the adoption process. The two case studies analyzes the two contemporary promising technologies, virtual centre and flight-centric operations in the European ATM. Some of the early adopters heavily invest in these technologies. For these actors, it is crucial to examine not only the technical and economic dimensions, but also the political, social and legal dimensions. The relevant actors could utilise the technology adoption conceptual framework as a strategical management tool to evaluate the adoption of new technologies in the European ATM.

Combining these challenges, barriers and factors affecting the technology adoption process, a number of suggestions for the relevant actors are summarized. These suggestions could potentially aid the adoption of these two new technologies. Specifically, for these two technologies, they have a disruptive nature to alter the objectives and business models of the actors. Consequently, they have the potential to enable the shift from legacy systems towards service-oriented architectures. For this reason, it is crucial to solve these challenges and barriers in order to progress the adoption of these two promising technologies. Gaining momentum towards adopting these two technologies is important for the future of the European ATM. Furthermore, the two technologies deliver dynamic resource allocation of both infrastructure, hardware, software and staff. Given the current situation in the European ATM, dynamic allocation is becoming a key property to reach towards efficiency.

Including all the actors inside a single picture from a socio-technical perspective is the ultimate practical contribution of these thesis. Mainly, previous research focuses on one or few actors and their behaviour towards new scenarios utilizing new technologies. In order to see the big

Chapter 8. Conclusion and Recommendations

picture, all the relevant actors who have a stake in the adoption process should be included. This enables to pinpoint all the challenges, barriers and factors affecting the technology adoption process. It is important to note that the results show political, social, and legal aspects could be as important as, or sometimes even more important than, the technical and economic aspects of the adoption. This is by itself an important conclusion to emphasize the importance of these factors in the technology adoption process. An actor introducing a new technology inside the European ATM should also check these beforehand in the feasibility studies. Combining all the theoretical and practical contributions, the following Figure 8.1 provides the overall summary for this section.

This thesis aims to fill a practical gap in the European ATM research, where there is a lack of socio-technical approaches to understand the adoption of new technologies. These new technologies have a disruptive nature, and it is strategically important for the actors to understand the different perspectives surrounding the adoption of new technologies. For the progress of the SES, the adoption of new technologies is critical. On one side, these new technologies are emerging rapidly, on the other side the institutional structure of the European ATM have complex dynamics when responding to the changes in the technology. Before investing on the specific technologies and solutions, it is important to evaluate the behaviour of the actors surrounding the new technologies. From a practical perspective, this thesis provides a complete framework for the evaluation of new technologies in the European ATM. Most importantly, the framework points out the factors affecting the technology adoption process, including the barriers that could affect the stages of adoption.

Currently, in European ATM research, the new technologies are perceived from mainly two perspectives, its technical and economic feasibility. However, this is not sufficient due to the rising complexity of the technologies and their effect on the social, political, legal dimensions. In that respect, this thesis emphasizes the practical importance of these dimensions besides technical and economic. Often times, the new technologies are shown to be technically and economically feasible, yet in the adoption process these technologies face important social, political and legal barriers. The practical significance of exploring these factors and barriers is important for the future of the SES and its implementation in the Pan-European scale. These barriers significantly affect the adoption and the perception of the actors in the network.

The two case studies, virtual centre and flight-centric operations, have also practical implications for the European ATM. Successful adoption of the two technologies could enable defragmentation. Specifically, the virtual centre enables virtual defragmentation by creating a virtual layer with standardized infrastructure, hardware and software on top of the fragmented physical layer. On the other side, flight-centric operations enable both vertical and horizontal defragmentation by merging of the sectors and aligning air traffic according to flight levels and traffic complexity. Defragmentation is one of the key objectives of the SES, evaluating the adoption of these technologies is important for all the relevant actors.

The conceptual framework for technology adoption could be further used to investigate emerg-

ing technologies in the European ATM. The generic structure of the conceptual framework for technology adoption allows further evaluation of candidate technologies in the European ATM. This could allow relevant actors to pinpoint the factors, relevant challenges and barriers in the initial phases of the creation of the technology. From a practical perspective, this could save time, investment and effort of the relevant actors for the selection, adoption and utilization of new technologies in the long term. Utilizing the framework, the relevant actors could see their position in the network and optimize their roles and relationships accordingly. This could increase the efficiency of the adoption process. The technology adoption is an important topic for the European ATM, since SES aims to adopt and deploy a number of solutions in a Pan-European scale. However, there exists slow or partial adoption of new technologies in the specific case of the European ATM. These reasons could be investigated using the conceptual framework presented in this thesis.

Understanding each phase of adoption is also important for the relevant actors in the European ATM. This could be used to create the necessary synergies to adopt promising technologies for the European ATM. From the case studies, it is apparent that each actor have a specific role in the adoption process. Some of these actors are relatively new, and purposefully created to push the momentum forwards for the adoption of these new technologies. The initial phase problematization mainly focuses on the definition of the idea of the technology by the focal actor(s). Identification of the early adopters in this stage has a practical significance, such that if these early adopters are supported relatively fast, then the efficiency of the technology adoption process increases. This is also mentioned in the suggestions for the relevant actors part of the thesis, where incentivization mechanisms are suggested for the support of the early adopters. The conceptual framework could be used to identify the early adopters and the interested actors for the technology and further support the adoption of the technology.

Moving through the stages of interessement and enrollment, it is beneficial to identify the actors that could further enlarge the network and increase the stability by attaching more actors for the adoption of the technology. This could also give the roadmap of the adoption on the attracting more actors inside the network. Especially, supra-national actors, such as EUROCONTROL and SESAR-JU could use the conceptual framework to evaluate the progress of adoption during the phases of development of technology. This could help these actors to build relevant strategies to further increase the rate and efficiency of adoption. Specifically, for the cases of virtual centre and flight-centric operations, it is rather important for the European ATM to increase the adoption in order to defragment the infrastructure, hardware and software. Additionally, these technologies enable the paradigm shift from legacy systems towards open service-oriented architectures.

Finally, this thesis provides an ontology for future system dynamics and agent-based models for the evaluation of technology adoption in the European ATM. The syntax provided in this thesis could be further utilized with quantitative input to build a scenario and simulation based models. This could also strengthen the evaluation of the future scenarios of adoption of the two technologies by the support of simulation. The definition of the actors, their roles and

relationships could be incorporated inside these models to further evaluate the behaviour of these actors under various conditions and parameters. The parametric evaluation of adoption of new technologies could also be incorporated for the factors affecting the adoption, where quantified inputs could be utilized for their parametric affect on the technology adoption process.

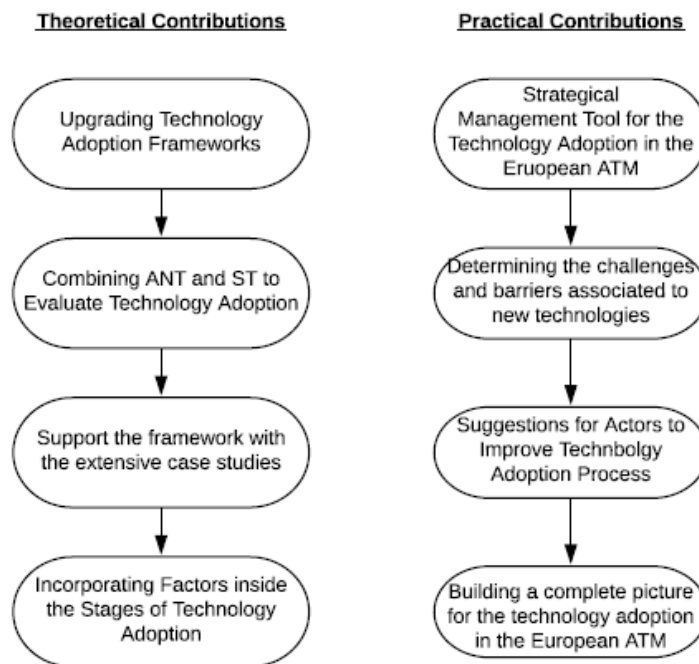


Figure 8.1 – Theoretical and Practical Contributions

8.4 Dynamism of the Technology Adoption Conceptual Framework

Providing a dynamic conceptual picture of the technology adoption process is important for understanding latest events affecting the actors. Considering the latest situation of COVID-19 affecting the air traffic in Europe and the globe, the actors adapt to the changing environment and update their objectives. Now, the objectives of the most of the actors is to survive economically, politically to maintain their local stability, and supporting social structure. Definitely, these will affect the economic, political, and social factors affecting the adoption of these new technologies. Concretely, we can look onto these factors in the technology adoption process picture, and interpret the affect of COVID-19.

Even though there is still uncertainty on the impact of the COVID-19, surely there is economical and political. Mainly, it will directly influence the economic decisions of the ANSPs, and the Member States, since the focus is shifting from new technologies to support airlines during these turbulent times. Yet, on the other side, such sharp changes in the traffic brought up the dynamic allocation of ATC, capacity and efficient resource allocation for all the air traffic

8.5. Importance of New Technologies for the Future of the European ATM

services. This could potentially open up new virtues, services, actors inside the European ATM. Considering virtual centre and flight-centric operations, both of these technologies support dynamic allocation of the effort of the ATCOs, even location independently. Potentially, if the economic barriers have been passed, then there is a chance of these technologies to be given a chance to test their potential to solve dynamic allocation.

In low traffic, it is easier to test new concepts without interfering or creating safety issues as in the case of normal to high traffic. This gives a chance for the European ATM to test new concepts and services, seeing the benefits on resource allocation. Currently, the estimated effect of COVID-19 would be long-lasting for the European ATM, this would signal that dynamic resource allocation for the staff of the ANSPs and airlines would be the biggest challenges currently and for the future. In that case, new technologies could help to foster this allocation dynamically. For example, maybe virtual centre could be used to allow ATCOs to work remotely in the future. In the low traffic scenario, flight-centric operations could optimize trajectory and lower the need off switches between sectors by merging sectors.

8.5 Importance of New Technologies for the Future of the European ATM

The future of the European ATM relies on the utilization of the best of the new technologies that could shift the paradigm of ATM towards legacy-based systems to service-oriented architectures. With the rise of digitalization, remote and virtual provision of services become possible. For long, these services are locked to physical location, and could only be served by the national ANSPs. Now, it becomes possible for a new service provider to provide services for ANSPs remotely. This would dramatically change the current way of provision of services, by allowing competition and virtual provision of services.

Virtualization is happening not only within air traffic domain, but also in other industries with the emergence of virtual, augmented and mixed reality technologies. This allows remote provision of services without the need of hardware and software to be located in the place of the service provider. This opens up totally new business models for all the actors involved in the process. For the European ATM, the actors need to adapt to this paradigm shift by realigning their objectives towards digital and virtual services. Currently, only a number of the actors started to adapt to these changes by adopting new technologies. This would be followed by either conjoining of the services of the ANSPs, or provision of these services by third party service providers.

In the future, the aircraft would likely to be treated as a data node in the network, connected to the rest of the cloud infrastructure. As more and more network industries evolve through optimizing their infrastructure towards digitalization, we will see totally connected, ultimately and sharing of real-time multi-dimensional data, as a similar concept to the internet of things. The new technologies enable service-oriented architectures without depending on the specific

location of the hardware and software. This property really introduces a paradigm shift for the European ATM. There would be shift of the behaviour of actors, new actors, new service providers, and new industry manufacturers in the future.

8.6 Recommendations

This thesis provides an overall look on the latest technology adoption in the European ATM by focusing on virtual centre and flight-centric operations. As new technologies come up into the picture of the European ATM, the conceptual framework would help to grasp the overall outlook for these technologies and actors surrounding them. Additionally, it is also important to frame each factor affecting the adoption of these new technologies. Given the current situation, the importance of digital and virtual technologies is rising to support the European air traffic. Thus, the results of this thesis would be able to support for the analysis of the technology adoption process. This is important for the strategical management of the new technologies that could support the future of the European ATM.

Further, new technologies for the European ATM could be analyzed using the conceptual framework that is the main contribution of this thesis. There is a practical gap to understand the qualitative aspects of the technology adoption process in the European ATM. Effectively, this research targets to fill this gap both from a theoretical and practical perspective. Practically, there are recommendations for the relevant actors to optimize the technology adoption process, specifically for the technologies under investigation. These cases represent a sample of new technologies that have the potential to shift the paradigm of the European ATM. Similarly, some of these factors, challenges or barriers affect also the adoption of the other technologies in the European ATM. Patterns of adoption of new technologies appear while also looking towards the adoption of new technologies in the European ATM.

Further improvement of the conceptual framework could be achieved by analyzing future new technologies for the European ATM, when they emerge and started to get adopted by the relevant actors in the European ATM. Additionally, the conceptual framework could be used as a basis for a system dynamic or agent-based model using quantified inputs for the behaviour and relationship of the actors. Then, what-if analysis of the scenarios of adoption would be possible in combination with the qualitative and quantitative environments surrounding the new technologies. For this, the adoption of virtual centre and flight-centric operations should reach the stage of providing quantitative data, such as real benefits, economic values, key performance areas and indicators.

8.7 Future Research

Starting with the update of the case studies, the technology adoption process for the future part could be further updated as the technologies mature and the adoption moves through the stages. A number of alternative scenarios could be built supporting the most probable

future scenario that is presented in this thesis. Moving through the stages, both the technology matures and the actors start to crystallize their objectives towards the adoption of these new technologies. A future investigation of the most probable scenario would be beneficial as a refreshment of the latest status of actors, their roles and objectives towards the adoption of these technologies. Additionally, update of the barriers and challenges are important for the relevant actors to evaluate the latest situation related to the technology. By time, some of these challenges and barriers would be passed, while some still block the adoption process. Consequently, it would be crucial to pinpoint the remaining barriers by time and factors affecting the adoption process through the passage from stages.

An important step for future research is the use of the syntax of the framework inside a quantitative simulation model, such as system dynamics or agent-based model. Concretely, this thesis provides the backbone for the model by modeling the actors, their roles and relationships during the adoption process. In combination with the factors affecting the adoption process, barriers and challenges, this creates an initial preparation for a simulation model that could be utilized with quantitative input, when it becomes available. What this could achieve is the simulation of scenarios with parameterized inputs for the behaviour of the actors. The roles and relationships of the actors could be causally modelled using parameterized values, and barriers, also factors could be quantitatively modeled in order to simulate the technology process as a whole. Consequently, this future model could achieve quantitative outputs, such as the efficiency and rate of adoption depending on the actor, their roles, relationships, barriers and challenges of the adoption process. Parameterizing these qualitative features, a number of possible scenarios for the adoption of these two technologies could be simulated. These simulations could be further used to evaluate and improve the efficiency of the technology adoption process.

For the third point, more case studies could further increase the generalizability of the conceptual framework of technology adoption. The two cases of virtual centre and flight-centric operations are purposefully selected as they are both new technologies and enable defragmentation for the European ATM. Additionally, there are also new emerging technologies such as drones, global satellite communication, and block-chain technology. In the future, these emerging technologies could be candidates as case studies using the approach presented in these thesis. From these case studies, convergence or divergence with the conceptual framework could be investigated for further solidification of the framework for technology adoption. In support of the framework, if there is any part for the update of the conceptual framework, these could be incorporated inside the framework. Even to further increase the generalizability within other network industries, specific technologies could be investigated from other network industries, such as electricity, post, rail, and urban transport. In turn, this could be beneficial to see the similarities or differences with the air traffic domain and further generalizability of the conceptual framework including other network industries.

Finally, as for the future research, it is becoming increasingly important to analyze technical and social together, while the line between the two becomes blurry with the rise of virtualization

and virtual services. Not only in air traffic, but also in other network industries, and even in our daily lives, there is increasing switch towards digital and virtual services. Henceforth, this makes the distinction between what is social and what is technical blurry. As for the future research, technology adoption could also evolve. It is becoming increasingly important to reflect the technological and social developments inside the conceptual framework, updating the changes and iterations through the evolution of technology. The fast-paced technological landscape reflects through its properties into a multi-dimensional and multi-disciplinary way. These affects could be further carried inside the conceptual framework to evaluate future technologies and their adoption. Guiding the actors towards adopting the new technologies in a strategic way, the conceptual framework could be utilized as a strategic management tool for the future adoption of new technologies.

8.8 Conclusion

One of the main challenges of the European ATM is to solve the overall fragmentation problem of infrastructure, hardware, software and institutions throughout Europe. For the European ATM to reach these target, there exists promising new technologies, such as the virtual centre and flight-centric operations. Even though the adoption of these technologies will happen progressively in the long-term, conceptually these technologies are able to shift the paradigm of the European ATM towards service-oriented architectures. By this, the local provision of the services evolve towards remote, location-independent provision of the services with new cloud and satellite based technologies. The ANSPs would be able to subscribe to services in a plug-and-play fashion. Ultimately, this would create a virtually defragmented layer of infrastructure, hardware and software.

The estimated benefits of these technologies show that there are improvements in various areas, such as capacity, cost-effectiveness and defragmentation. The succesful adoption of these technologies is important for the overall Pan-European efficiency. For this reason, this thesis aims to improve the efficiency of the adoption of these two promising technologies. First, a complete picture of the technology adoption process including the relevant actors is provided. Second, the challenges and barriers at each stage of the adoption are investigated. Third, factors are analyzed under political, social, legal, technical and economic considering all the possible main areas of influence focusing on their importance in the technology adoption process. Finally, the benefits of the technologies are summarized providing suggestions for the succesful adoption of these technologies.

As a researcher, my personal interest is to discover the new technologies in the European ATM, how they come into existence and get adopted by the relevant actors in the European ATM. Through this journey, I discovered that the technology adoption decision is not a one-off event, where the user of these technologies make the adoption decision. Rather, it is an interplay of actors' interests, objectives and relationships combined with the factors affecting them. Furthermore, political, legal and social factors affect the adoption process deeply besides

the technical and economic factors. Personally, I wanted to understand the actors, how they interact with each other towards adopting new technologies. I realized that the best way is to build a picture of their interaction towards adopting new technologies for the European ATM.

By providing the two extensive case studies for the virtual centre, and flight-centric operations, this thesis directly address the problem of how to get from a fragmented legacy European ATM system towards an open service-oriented architecture as illustrated in Figure 8.2. Compared to the legacy systems, an open service-oriented architecture offers sharing of infrastructure, hardware and software with location independent (remote) provision of services. ANSPs could be able to subscribe to preferred cloud services backed by satellite communication systems. Eventually, this would create high-level of coordination between the actors with increased sharing of data and information. More importantly, dynamic allocation of resources would be possible with this new architecture. Remote provision and virtualization of the services in the European ATM would help to defragment the overall system.

Paradigm Shift from Legacy Systems Towards Open Service-Oriented Architectures for the European ATM

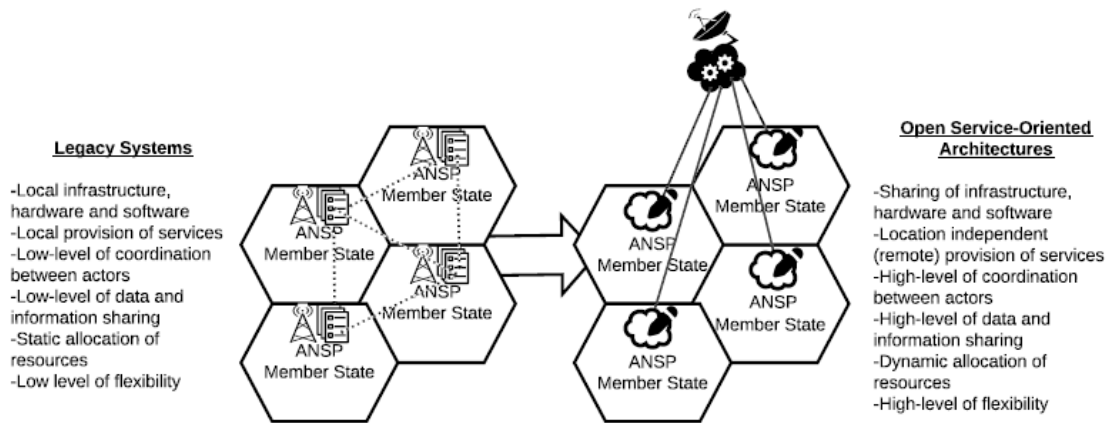


Figure 8.2 – Paradigm Shift from Legacy Systems Towards Open Service-Oriented Architectures for the European ATM

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