7-1-2013

Why Innovation In Air Navigation Services Is So Difficult In Europe? - A Study Identifying Current Obstacles And Potential Ict Enablers

Pablo Breitenmoser
ETHZ, Zurich, Zurich, Switzerland, pablob@ethz.ch

Ralf Abraham
University of St. Gallen, St. Gallen, Switzerland, ralf.abraham@unisg.ch

Markus Eurich
ETH Zurich, Zurich, Switzerland, meurich@ethz.ch

Tobias Mettler
Institute of Information Management, University of St. Gallen, St. Gallen, Switzerland, tobias.mettler@unisg.ch

WHY IS INNOVATION IN AIR NAVIGATION SERVICES SO DIFFICULT IN EUROPE? – A STUDY IDENTIFYING CURRENT OBSTACLES AND POTENTIAL ICT-ENABLERS

Breitenmoser, Pablo, ETH Zurich, Scheuchzerstrasse 7, 8092 Zurich, Switzerland, pbreitenmoser@ethz.ch

Abraham, Ralf, University of St. Gallen, Müller-Friedberg-Strasse 8, 9000 St. Gallen, Switzerland, ralf.abraham@unisg.ch

Eurich, Markus, ETH Zurich, Scheuchzerstrasse 7, 8092 Zurich, Switzerland, meurich@ethz.ch

Mettler, Tobias, University of St. Gallen, Müller-Friedberg-Strasse 8, 9000 St. Gallen, Switzerland, tobias.mettler@unisg.ch

Abstract

The Air Navigation Service (ANS) industry has not experienced many major technological innovations in the last decades. Despite its indisputable contribution to economic welfare, it relies on Information and Communication Technologies (ICT) that lag way behind their current technological potential. Yet, it is not well understood what exactly restrains ANS providers from introducing novel ICT systems despite the legacy ICT in use which reaches the end of its life-cycle. On the basis of an interview series with managers in the ANS industry, this study sheds light on the various barriers that hinder the diffusion of technological innovation. Our findings suggest that the stagnation in technological innovation cannot be ascribed to one single obstacle, but rather to intertwining political, economic, social and technological aspects. This study concludes by proposing ICT approaches to tackle the identified barriers. The analysis of obstacles and potential ICT enablers can support decision makers of ANS providers and can enable business transformations in the ANS industry. ICT researchers can use this study as a help for developing ANS technologies, and business researchers can focus on specific incentives to foster innovation.

Keywords: Air Navigation Services, Business Model, Diffusion of Innovation, Innovation Management, Technology-driven Business Transformation

1 Introduction

It may be unsettling to realize that while several airlines have recently launched in-flight Wi-Fi internet for their passengers, their pilots still communicate by analogue radio with ground staff. The discrepancy between passenger entertainment services and air navigation services (ANS) has one minor and one major reason. The minor reason is the reaction of the airlines to the sudden wide-spread use of smart phones and tablets: by offering wireless internet, they hope to gain more passengers based on the introduction of the new technology. The major reason is that technological innovation in ANS has been stagnating for decades. This stagnation is pushing the current information and communication technology (ICT) systems to its limits. The forecasts of the European air traffic management organisation Eurocontrol predict an annual growth rate of flight movements in Europe of 2.6 per cent until 2030, i.e. flight movements are assumed to double by 2036 (SESAR Joint Undertaking, 2012).

To deal with the projected increase in traffic, the ANS information systems will have to undergo technological improvements (SESAR Joint Undertaking, 2012, p. 30). The ICT in use restricts the amount of aircraft that can be served with ANS: the capacity limits have been reached, especially around busy airports (London, Zurich, etc.). The resulting queues inevitably lead to delays, additional environmental pollution and higher costs (European Commission, 2012).

In the light of such ICT limitations and the increasing demand for ANS, there is a strong need to transform the industry towards more adequate ANS provision. Since ANS is crucial to sustaining the economic welfare in Europe, air navigation service providers (ANSP), airlines, airports, and governmental, organizational and legislative bodies have started to discuss this problematic situation, but progress is slow. Yet, it is not well understood what exactly restrains ANS providers from introducing novel ICT systems. It is also not clear which ICT transformations would be able to foster effective innovation in the European ANS industry.

The goal of the study is to reveal obstacles that make innovation in ANS so difficult and to contribute to the understanding of the technology diffusion process in the ANS industry. We applied an empirical approach by conducting an interview series with representatives of the Swiss ANSP skyguide to identify innovation obstacles in ANS. On the basis of the identified obstacles, we propose ICT-based techniques to overcome some of these barriers. This techniques can contribute to actively push for changes of in the perception and behaviour of stakeholders with the goal to pave the way for enterprise transformations.

Organizations in the ANS industry are prime examples for High Reliability Organizations (HRO) – organizations, for which failures could have catastrophic consequences. In HROs, failures (e.g., plane crashes) affect multiple innocent bystanders and receive high media coverage. Therefore, safety is a paramount objective that is pursued via a systemic approach. HROs are constantly searching for ways to improve their safety. Before a (technological) change can be introduced to an HRO, it must pass comprehensive tests to ensure that it does not negatively affect system safety, availability and reliability. There are few, if any, studies that investigate enterprise transformation in HRO. This study is one of the first of its kind to address this challenge in an HRO and particularly in the ANS industry. Up to now, there is hardly any related work , because the ANS industry does seldom grant access to researchers.

2 Innovation in the Air Navigation Services Industry

The European Commission (EC) launched the Single European Sky (SES) initiative to handle the projected increase of flight movements. The SES ATM Research (SESAR) programme was launched as part of SES with the goal to develop a new generation of ANS that will be able to ensure the safety and fluidity of air transport in Europe and subsequently on a global scale.

The fragmentation of the European airspace has been identified as a major obstacle to achieve these goals. The formation of Functional Airspace Blocks (FAB) is planned to tackle this issue. FABs will lead to a different type of sectorisation: the airspace will be divided according to traffic flows and no longer according to national borders. Since a single FAB covers several countries, individual ANSPs (which are affiliated to a country) will have to collaborate more closely than they did in the past. This creates a high demand for interoperability between all the different ICT components and ANSP architectures that are now in use. Today's ANSP are monolithically integrated – both in their organizational as well as in their technological systems architecture – due to the slow development during the last decades.

Progress in implementing this transformation has been slower than expected. Besides technological obstacles, transformation in this industry is also hampered by political barriers like the fear of uncontrolled airspace infringements and the loss of national sovereignty; economic barriers, like the lack of liquidity for investments; and social barriers, like the loss of power of the unionized air traffic controllers (ATCO). In addition, the liberalization of the industry has led to different legal forms under which the ANSP of today operate. The legal form can range from traditional state ownership, through a variety of corporatized structures, to regulated private companies. Although legal setups have partially changed, the liberalization has not led to more innovation.

ANS industry studies about enterprise transformation are usually looked at on a case-by-case perspective. Case study evidence is organized as an intellectual capital portfolio and links are drawn to business outcomes for other organisations.

Scholars who have studied the impact of transformation, such as Button and McDougall (2006), assess the implications of the ANSP structure in correspondence with managerial approaches. Lewis and Zollin (2004) use management boards as a proxy for the correlation between the type of company (public vs. private) and its performance. Arvidsson et al. (2006) conducted a study, in which they determine the organizational climate with respect to transformation and innovation in order to investigate the organization's capacity to cope with transformation. These case studies contribute to understanding ANSP management in the light of "transformation", but do not provide information about barriers.

From a technological perspective, innovation in the ANS industry has a strong focus on optimizing Man-Machine Interaction, i.e. air navigation systems that heavily rely on human involvement. In the following, we identify the major subsystems and whether there are industry standards available for the information objects they process:

(1) Flight Data Processing (FDP): FDP processes flight plan data and is the biggest subsystem of the ANSP infrastructure. A flight plan is a standardized document that contains information such as aircraft origin, destination and planned trajectory (ICAO, 2001). The flight plans are filed before departure, but may be changed during the flight by an ANSP (e.g., to circumnavigate hazardous weather conditions). There is no defined common standard, yet development efforts of the SESAR program are underway towards a Flight Object Interoperability Specification (ED-133).

(2) Radar Data Processing (RDP): This system processes incoming radar data from several sources (which indicate an aircraft's altitude and speed) and presents the information to the air traffic controllers (Eurocontrol, 1997). With ASTERIX (All Purpose Structured Eurocontrol SuRveillance Information EXchange), a standard is available.

(3) Environmental Data Processing (EDP): This system processes environmental data such as meteorological data to ATCOs. With the Aeronautical Information Exchange Model, a standard is available.

(4) Communication (COM): This system provides air-to-ground (Pilot to ATCO) and ground-to-ground (ATCO to ATCO) communication capabilities. Communication may either be performed between humans (voice link), or between systems (data link). Standards for both communication types are available from the International Civil Aviation Organization (ICAO).

3 Transformational Perspective on ANSP Industry Innovation

In order to achieve a sustainable transformation of the ANS industry, there is a need, both to transform the ANS service provision and to address the needs of the single ANSP so that it can provide its service in the intertwined industry. The decision of whether to adopt or reject new IT architecture components is fundamental to ANSP enterprise transformation and the transformation of the industry. There are obstacles which hamper this process and which, to a certain degree, impede innovation and its diffusion.

For the sake of revealing obstacles to the introduction of innovations, we refer to the technology diffusion model of Rogers (1995) as an explanatory model. Given the lack properly publicly documented technological innovations in the ANS industry (SESAR, 2012), the model of Rogers provides an appropriate framework: It highlights the diffusion process of technological innovations, while also taking the effects of social factors into account; in this way, it does not represent a solely technocratic view. The technology diffusion model describes innovation diffusion by dividing the process into four specific stages (Fig. 1).

i. The knowledge stage defines the phase of learning of the existence of a certain new technology. This knowledge motivates an individual or an organization to learn more about how the innovation can be used in its environment. Finally, one’s knowledge of the technology is to be extended in order to gain an understanding of how and why it works.

ii. The persuasion stage is characterized by exploiting the information of the technology. It is an emotional phase, in which people and organizations conceive an opinion on an innovation. In this stage the involved party considers using the technology within its particular environment.

iii. The decision stage is the point where a technology is either adapted or rejected. This decision is based on the analysis of the potential political, economic, social and technological consequences of the innovation.

iv. The confirmation stage is the phase in which habits and practices change due to the adoption of the technology. Reinvention also occurs during this stage, with the goal of improving overall compatibility (Rogers, 1995).

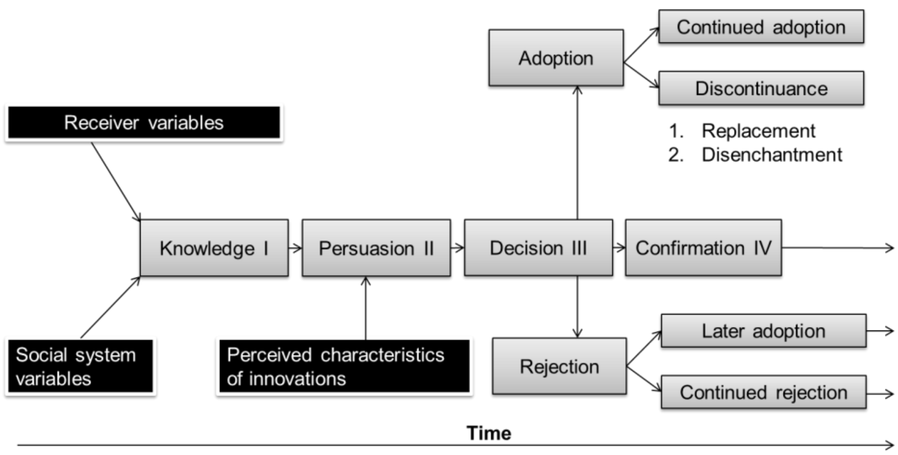

Figure 1. Simplified Technology Diffusion Model (Rogers, 1995)

4 Method

Not much related work has been done so far since the industry does not regularly provide access to researchers. The goal of this study is not only to understand the obstacles towards technology innovation that ANS enterprises face, but also to actively influence the perception and behaviour of stakeholders in the long run. Therefore, the study is based on a pragmatic epistemological approach, which is aiming for constructive knowledge that can be applied usefully in action (e.g., Goldkuhl, 2012; Goles and Hirschheim, 2000; Wicks and Freeman, 1998). The essence of pragmatic qualitative research lies in the interplay between actions and intervention: in order to alter certain aspects of reality, actions are required (Blumer, 1969). Knowledge (e.g., natural laws, social norms, empirical evidence) is essential to change reality into a desired end-state. In this sense, actions and their impact can also contribute to further cognitive clarification and development (Goldkuhl, 2012). This is in contrast to, for instance, positivist research which exclusively seeks to explain reality by using models (or a structure of relations) and which uses methods that emphasise the discovery of new knowledge and verify existing (structural) knowledge without actively distorting reality (Denzin and Lincoln, 2000).

As a first step in a larger research endeavour, we started our inquiry by getting a deeper understanding of the cognitive beliefs, perceptions, and plans of senior management and other personnel responsible for innovation and technology management at Skyguide, which is the ANSP of Switzerland. Skyguide has about 1,400 employees, including more than 540 civil and military air traffic controllers. Over 300 engineers, technicians and IT-experts are responsible for the development and maintenance of the complex technical installations and facilities. The operators of aeronautical data manage information to assure smooth air traffic.

Data was gathered by means of semi-structured interviews. In total, eight managers were interviewed which result in 30 interview hours (Table 1). Each interview began by asking broad questions about the status quo of the ANS industry, followed by asking more specific questions about the future development of the industry and the role of ICT to enable and support this change. A combination of focussed and open-ended questions was used. The latter were asked in order to ensure that a comprehensive understanding was attained. In doing so, we adhered to the approach advocated by Bouchard (1976), who explicitly calls for re-focussing during an interview. This provides a greater flexibility than completely structured interviews. To prepare for the interviews, we analysed a multitude of technical reports, internal presentations, project documents, annual reports, and press releases (Table 1).

Interviewee	*Main topics discussed*	*Documents analysed*
Chief executive officer (3h)	Vision and business model of future ANS industry	Annual report, internal presentations, press releases
Chief operations officer (2h)	Vision of future ANS industry and organizational change	Third-party commissioned technical report (European air traffic management master plan)
Chief information officer (4.5h)	Requirements engineering process and IT architecture	Third-party commissioned technical report (standardization in ANS-industry)
Head of change management (2h)	Innovation process and organizational change	Internal presentations
Head of safety, security, and quality (2.5h)	Perceived changes and future requirements for safe air traffic control	Third-party commissioned technical report (impact of SESAR)
Head of engineering and technical services (2h)	Innovation process and implementation roadmap	Third-party commissioned technical report (feasibility study for European air navigation services)
Project manager (8h)	Project goals, implementation roadmap, organizational change	Project documentation, internal presentations
External consultant (4h)	Industry Transformation requirements and Value Chain Impacts	Virtual Centre Business model, internal presentations
Chief executive officer (Skysoft) (2h)	Standardized Human Machine Interface (HMI) and service delivery for future ANSP	Project documentation, internal presentations

Table 1. Interview series (note: h = hour).

Data obtained was first analysed using open, axial and selective coding techniques (Urquhart, 2001). The extracted main statements and assertions were then grouped using STEP / PEST analysis (Political, Economic, Social, Technological) as a mental model (e.g., Mettler and Eurich, 2011) to determine specific areas for future interventions. In order to add to our findings, we led a focus group discussion involving key actors concerned with driving enterprise transformation and technological innovation at Skyguide. This included verifying the statements from the semi-structured interviews and the allocation of obstacles with the key actors in view of completeness and applicability for future work.

5 Findings

To group the statements and assertions, we use the concept of PEST / STEP as an analysis framework of macro-environmental factors. Peng and Nunes (2007) proposes the use of PEST analysis as a tool to identify narrower contexts and focus research questions around feasible and meaningful regional contexts. According to Mettler and Eurich (2011), STEP can be used as a mental model for determining specific areas of future interventions. We found a total of 11 obstacles to enterprise transformation in the ANS Industry: Three political, three economic, two social and three technological obstacles that could be assigned to the knowledge phase and the persuasion phase.

In Fig. 2, we map the identified obstacles to the technology diffusion model of Rogers (1995).

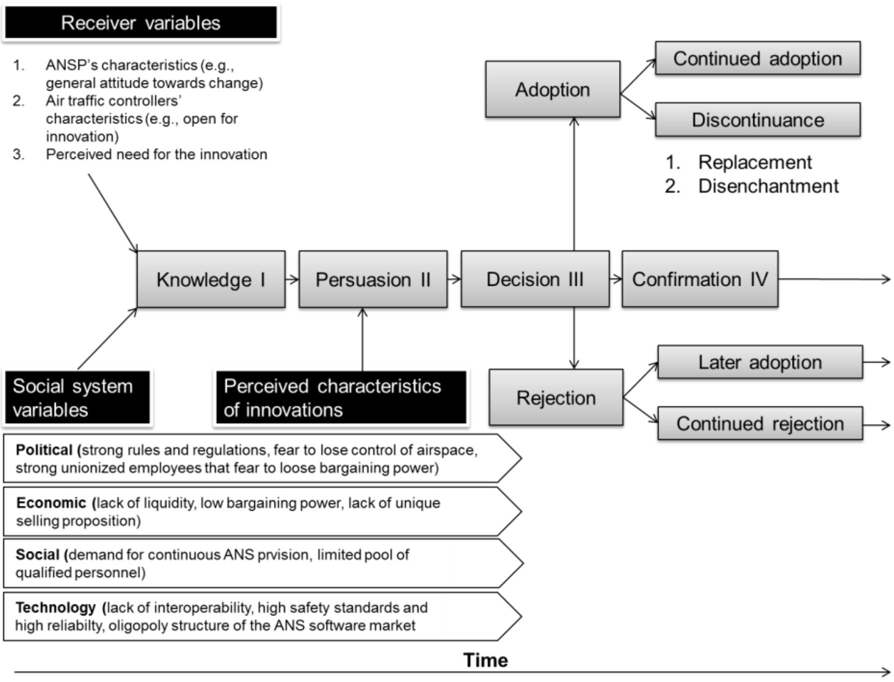

Figure 2. Technology Diffusion Model adapted to the ANSP Enterprise Transformation on the basis of Rogers (1995).

The study revealed that in all parts of STEP, the diffusion of innovation is bristled with obstacles to overcome. The mental states of the stakeholders that are described in the model of Rogers (1995) are generally influenced by one or several dimensions of STEP.

Politically, regulators need to understand how and why a technology works to build trust in the innovation and to get able to deal with changes in regulations (see section 5.1).

Economically, ANSP need to learn and understand what it means to operate under competitive conditions. Employees and management face change in the current mode of financing and purchasing (see section 5.2).

Socially, the creation of an idea how one could innovate under the highest expectation (safety) for continuous service provision while facing a limited pool of personnel is supposed to be aligned with political, economic and technological obstacles (see section 5.3).

Technologically, the study places the most emphasis on showing that ANS can be innovated to significantly increase capacity (see section 5.4) while maintaining or even exceeding current system reliability and safety levels.

5.1 Political obstacles to innovation

First, the strong rules and regulations: Historically, the ANSP are predominantly differentiated from one another according to national borders. Since this is the case for most ANSPs within Europe, they are regulated by both international and national rules and regulations. The obstacles are twofold. First, the rules and regulations in ANSP are complex. Being able to understand all the interrelated consequences an enterprise transformation could bring along is time consuming and would require a huge amount of domain knowledge in financial, political, as well as technological aspects. Second, the regulations include an explicit mission of an ANSP, which typically does not mention innovation.

Second, the fear of governments to lose control over their airspaces: Keeping sovereignty of its own airspace is historically a strategic political issue of highest interest. The government has the responsibility of dealing with airspace infringement. This is codified by the ICAO legal framework, which holds national states ultimately responsible for offering ANS services over their respective territory. Two questions will have to be answered before any nation would enter a discussion about its sovereignty: First, how will airspace control within a new functional airspace look like and second, what needs to be regulated if airspace sovereignty is not related to national borders. As the CIO remarked: "There are no big bang changes in our industry".

Third, the strong unionized employees fear losing bargaining power: Operating procedures are highly formalized and firmly anchored into ATCO. These factors put employees and unions in a very powerful position. Thus, ANSP unions are particularly interested in maintaining the status quo, which provides its members with safe jobs and a strong negotiating position with employers. Salaries of ATCO are very high compared to local average salaries. Therefore, enterprise transformation is regarded very sceptically and the fear of job loss and the loss of privileges, such as early retirement is present.

5.2 Economic obstacles to innovation

First, the lack of liquidity: ANSPs are often not-for-profit organizations (due to national regulations). Therefore, ANSPs operate close to the break-even point, with low profits. ANSPs are neither allowed to retain cash for future investments nor do they have access to the capital market for financing purposes. Therefore, ANSPs constantly lack liquidity for innovation and enterprise transformation. Investment for enterprise transformation must come from outside the industry and according to the present regulations, it can only come from governments.

Second, the low bargaining power of ANSPs: There are only few suppliers which dominate the market. Against the background of high investment and education costs, an ANSP will not purchase its infrastructure from another supplier once it has chosen its technology and its vendor: The ANSP is at the mercy of the decisions of its provider while the provider has little incentive to innovate. However, our informants are well aware of the dependency of their company from the big vendors, and they would like to see the situation changing. A project manager expressed this concern: "We want to buy components instead of systems". Currently, legislative bodies foster efforts to increase interoperability between systems from different technology vendors. Given the long system life cycles in the ANS industry, our informants expect the impact from these efforts to materialize only after considerable time.

Third, the lack of a unique selling proposition: An ANSP operates as a “connector and consolidator of information” with almost no unique selling proposition compared to other ANSPs. Currently, ANSs are almost interchangeable from the service perspective. In case of market liberalization, ANSPs will face difficulties in differentiating themselves from each other, which is likely to result in a reduction of ANSPs within a FAB.

5.3 Social obstacles to innovation

First, the high demand for continuous ANS supply: The need for continuous ANS provision leads to high pressure on ANSP management to ensure service supply with a very high reliability. Entire economies are affected when air traffic is interrupted, e.g. due to strikes. Service interruptions gain immediate and intense media coverage and are highly visible to the general public. Therefore, enterprise transformation can only take place if absolutely no negative effect to the continuous ANS supply can be guaranteed.

Second, the limited pool of qualified personnel: Applicants are either put off by unfavourable working conditions, e.g., shift duties on nights and weekends or they do not pass the recruiting tests due to the high cognitive demands: figures from Eurocontrol indicate a passing rate of around 6 per cent, not including medical conditions that may further reduce the candidate pool. Air traffic controllers cannot be easily recruited either, as they generally require a minimum of 2.5 years training. This makes it typically difficult for managers to take out ATCOs for strategic projects such as enterprise transformation.

5.4 Technological obstacles to innovation

First, the lack of interoperability: Every ANSP has its own monolithic infrastructure. To a large extent, this can be attributed to highly localized data provision which results in a limited data exchange. Currently, ANSPs in Europe run monolithic systems that integrate local data provision (e.g., meteorological, flight plan and surveillance/radar data) with ANS functionalities (e.g., conflict detection or flight trajectory planning). This results in tightly coupled systems at each ANSP which have very limited capabilities for automated data interchange. Existing systems have not been designed for interoperability and for taking advantage of modern communication infrastructure. This lack of interoperability reduces the area of enterprise transformation to the internal structure. As the CEO put it: "The passengers aboard an airplane see some data, for example time-to-destination, on their in-flight screens sooner than we do"

Second, high safety standards and high reliability: Modifications have to be thoroughly tested before implementation in order to meet safety requirements. They must be designed for backward-compatibility and integration into existing ICT. Therefore, enterprise transformation is an incremental and time consuming process.

Third, the oligopoly structure of the ANS software market: Since integrated systems demand a great deal of industry know-how, the market is shared between few highly specialised enterprises. Entrance barriers for new vendors are high due to heavy investment (and certification) cost. As one of our informants pointed out, the oligopoly structure is compounded by the fact that ANS is a niche market. Therefore, enterprise transformation does not stem from technology providers.

6 ICT approach to enable transformation in the ANS Industry

Although we stress that the technological implications must be seen in the overall industry context with all of its political, economic and social factors, based on our interviews, we pursue a technological approach to describing the barriers that need to be overcome or the obstacles that need to be avoided for enterprise transformation. Technology enablers help create the “knowledge” according to the diffusion model (Rogers, 1995), which represents the knowledge about an innovation in its earliest days and creates motivation to learn more about it. It seems that technology is the biggest driver of change in the field.

In order to gain interoperability between ANSPs, establishing a federated data provision layer where all connected ANSPs act as both data producers and data consumers is recommendable. Currently, data between ANSPs are exchanged primarily by voice communication (radio) and paper progress strips (physical paper strips that are printed out at each ANSP whenever an aircraft enters its airspace in order to track the aircraft). With centralized data provision, data available to one ANSP – e.g., the position and travel parameters of an aircraft such as speed and altitude – would become available system-wide immediately, instead of the time-delays as with the current architecture. The current, sequential data exchange model (Fig. 3 a) with a cloud-based, centralized data exchange model as proposed by the System Wide Information Management (SWIM) concept (SESAR Joint Undertaking, 2011) (Fig. 3 b).

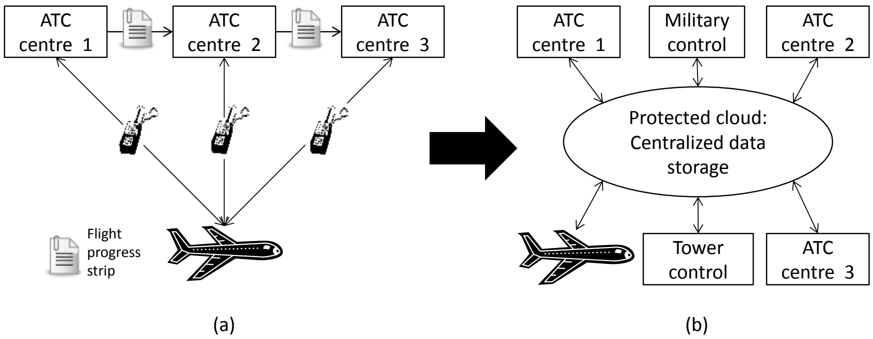

Figure 3. Sequential versus centralized data exchange.

SWIM implements the following principles: (1) Chronological decoupling of data provision from data consumption: As soon as data is available to any participant, it is fed into the protected cloud, where possible consumers can access it at any time later. All participants act as both data producers and data consumers. (2) Loose coupling between participants: Each participant feeds and receives data via predefined and publicly available standards (see section 2 for the standards defined for the data processing subsystems). (3) A common information model is used to enable data exchange and service definitions.

With standardization, electronic data interchange between aircrafts and different ANSP can be increased instead of relying on transmitting information via voice communication. This eventually paves the way for increasing automation and finally freeing capacity: For example, applying conflict detection components (support ATCO to avoid conflicts in the airspace), the capacity of a given sector could be increased. This would move the role of human ATCOs from handling routine tasks to managing exceptional situations.

Security requirements are paramount in any ANS technical system. In addition to providing the highest levels of system availability and data integrity, unauthorized access must be prevented at any time via adequate authentication components. In a network-centric model, unauthorized access naturally poses a higher risk than in offline systems. However, these challenges can be overcome, for example, by introducing trusted third parties or by relying on proven cryptography algorithms (Kandukuri et al., 2009; Sabahi, 2011; Zissis and Lekkas, 2012).

Eventually, the data cloud paves the way for a service-oriented architecture (SOA) (Huhns and Singh, 2005). This could break up the oligopoly structure of the ANS software market (Mueller et al., 2010). For technology providers, this means that the market entrance barrier regarding know-how would be lowered: In-depth expertise in monolithic integrated IT architecture would no longer be required. New technology providers could enter the field of ANS software, specialising on a single component like the Human Machine Interface (HMI). ANSPs would have the option of buying specific services instead of fully-integrated systems, which would decrease their dependency on monopolistic ANS software vendors, thus increasing an ANSP's bargaining power towards technology providers.

A service-oriented architecture (SOA) for ANSPs includes local ATC centres and site-depending infrastructure components (e.g. surveillance/radar equipment), connected via a (logically) centralized data layer (Fig. 4 a). By moving certain services to a centralized layer while retaining local centres, this architecture would not explicitly require any closing of a physical ATC centre.

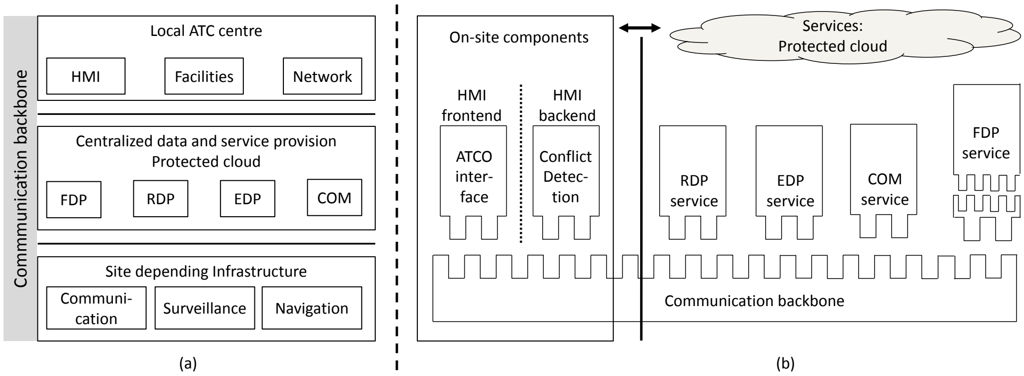

Figure 4. A service-oriented architecture for ANSPs.

Fig. 4 (b) shows a possible system architecture for an ANSP. The ANSP could use on-site HMI components, which may consists of a frontend (ATCO interface) and a backend (communication component) that receives RDP, EDP, FDP (connecting a legacy system via an adapter) as well as conflict detection services from external providers (Fig. 4b). Note that the conflict detection service can consume information from other cloud-based services such as FDP over the communication backbone. The enablers of such an architecture are centralized data provision as proposed by the SWIM concept (SESAR Joint Undertaking, 2011), and a communication backbone that defines interfaces for data exchange, to which all components adhere in an ATM system, including HMI and Data Processing Services.

In addition to cost-saving potential due to better systems maintainability and extendibility, SOA enables a greater degree of specialization: ANSPs can focus on a particular component of an overall ANS system and build specialized know-how in this area, while acquiring other system components from third parties. This may reduce the overall heterogeneity in ANS systems. For instance, if the diversity of HMIs is reduced to a few interfaces that are accepted and used by a great number of ANSPs, ATCOs working procedures and ATCO training could be standardized to a greater degree.

The key advantage of this architecture is that each ANSP can implement it within a timeframe that suits its own legacy situation. In other words, an ANSP can decide which components are to remain on-site, as an integrated system, and which services can be provided from the cloud. ANSPs with legacy systems, e.g. FDP systems, may be at the beginning of the transition to a SOA: FDP system would then receive RDP and EDP services from third-party providers, which would enable FDP to move from an integrated FDP component to a cloud-based FDP service. The separation of the integrated, on-site system parts from services provided via the cloud, and can be adjusted individually by each ANSP, as long as interoperability between ANSPs is provided via the communication backbone and the centralized data cloud (Fig 4b). Thus, existing investments can be protected and systems can be replaced only when they are approaching the end of their lifecycle. Safety and availability issues are less severe with an evolutionary change approach than with big changes.

In the diffusion model of Rogers (1995), providing an architectural blueprint of a SOA for ANS systems increases knowledge about technological innovation potential. By showing how technological obstacles can be overcome with a concrete architectural proposal that takes specific industry requirements (e.g., security and the need for evolutionary change) into account, the perceived characteristics at the persuasion stage are likely to be convincing from a technological point of view. This increases the likelihood of an adoption in the decision stage. ANSPs who reject the transition for the time being, e.g. due to financial constraints, have the possibility to opt for a later adoption.

The proposed ICT innovation has some implications for the business model of ANSPs: For instance, interoperability between ANS systems enables dynamic sector allocation, which, as a consequence, would allow for temporary shutdown of an ATC centre when other ANSPs are capable of managing this sector. Even though the dynamic sector allocation is a cornerstone to achieve SES cost-efficiency, it means that ANSPs are likely to lose some of their revenues, especially since their services would become increasingly interchangeable. Especially ANSPs of smaller states may have to look for new business opportunities, since they might be faced first with the threat that at least parts of their currently controlled airspace might be managed by a neighbouring ANSP in the future. For example, a new business model could focus on providing training services to external ATCOs from other ANSPs.

7 Conclusion and Outlook

The goal of this study is to reveal obstacles that make innovation in ANS so difficult and to contribute to the understanding of the technology diffusion process in the ANS industry. On this basis, ICT approaches are proposed to tackle the identified technological obstacles with the intention to actively influence the perception and behaviour of stakeholders. The findings show that reaching a decision point where technology is accepted (or rejected) in the ANS industry is bristled with obstacles to overcome different mental states of the involved stakeholders that are described in the model of Rogers (1995).

This study is one of the first to identify obstacles to innovation in an HRO. Whether the findings are generalizable to other HROs (e.g., nuclear power plants or hospitals) has to be investigated in further research. Still, the study provides a better understanding of technology adoption and diffusion in an under-researched domain and renders some new insights for both, industry ANSP decision makers and scientists. The identified obstacles may help practitioners define ICT strategies not only to tackle technical challenges, but also to consider the influence of political, economic and social stakeholders. Practitioners of the field may use the findings as an entry point to the creation of knowledge towards the development of ICT that enables enterprise transformation in the ANS industry.

The study has its limitations. It does not reflect the intertwining aspects of political, economic, social and technological aspects. Since this paper mainly focuses on ICT architecture to overcome technological obstacles, the implications of ICT architecture on the other PEST dimensions need further analyses. The concrete architectural proposal provides the discussion and negotiation vehicle to do so. Interview partners are members of one internationally recognized, yet small-sized ANSP. In order to validate the findings, interviews with other stakeholders from the ANS industry, for example representatives of ANS system providers and regulators, are needed.

Further research is required to better comprehend the industry-wide process of technology diffusion. In this sense, future work should also include the identification of additional innovation obstacles and look out for further enablers in the entire ANS industry. Additionally, enablers for economic, political and social obstacles need to be defined. Since no emphasis has been made considering the interfaces between stakeholders in the ANS industry, enterprise transformation aspect should be discussed under these aspects. Describing how incentive schemes could influence the ANS industry and its stakeholders could be a basis to describing requirements for increasing diffusion of innovation in this industry.

Finally, some more findings about successfully implemented solution designs would be of extraordinary value for deducing efficient and generalizable enterprise transformation mechanisms in an HRO environment. For these potential future endeavours this study can provide a substantial first step towards structuring the delicate and tricky situation of innovation management in the ANS industry.

References

Arvidsson, M., Johansson, C. R., Ek, Å. and Akselsson, R. (2006). Organizational climate in air traffic control: Innovative preparedness for implementation of new technology and organizational development in a rule governed organization. Applied Ergonomics, 37 (2), 119-129.

Blumer, H. (1969). Symbolic interactionism: Perspective and method. University of California Press, Berkeley, USA.

Bouchard, T. (1976) Field research methods: interviewing, questionnaires, participant observation, systematic observation, unobtrusive measures, In Handbook of Industrial and Organisational Psychology (Dunnette, M. Ed.), Rand NcNally, Chicago, pp. 363-413.

Button, K. and McDougall, G. (2006). Institutional and structure changes in air navigation service-providing organizations. Journal of Air Transport Management, 12 (5), 236-252.

Denzin, N. K. and Lincoln, Y. S. (2000) The discipline and practice of qualitative research, In Handbook of Qualitative Research(Denzin, N. K. and Lincoln, Y. S. Ed.), Sage Publications, Thousand Oaks, USA.

Eurocontrol (1997) Radar Sensor Performance Analysis. Doc. SUR.ET1.ST03.1000-STD-01-01.

European Commission (2012). Memo/12/774.

Goldkuhl, G. (2012). Pragmatism vs interpretivism in qualitative information systems research. European Journal of Information Systems, 21 (2), 135–146.

Goles, T. and Hirschheim, R. (2000). The paradigm is dead, the paradigm is dead...long live the paradigm: the legacy of Burrell and Morgan. Omega, 28 (3), 249-268.

Huhns, M. N. and Singh, M. P. (2005). Service-oriented computing: Key concepts and principles. IEEE Internet Computing, (January-February), 75-81.

ICAO (2001). Official definition, PANS-ATM Procedures for Air Navigation Services — Air Traffic Management [Doc 4444].

Kandukuri, B. R., Paturi, V. R. and Rakshit, A. (2009) Cloud Security Issues, IEEE International Conference on Services Computing, pp. 517-520.

Lewis, I. A. and Zollin, R. (2004). The Public to Private Continuum Measure and the Role of Stakeholder Boards as a Proxy for Markets in the Governance of Air Navigation Services: A Comparative Analysis. International Public Management Review, 5 (2), 52-77.

Mettler, T. and Eurich, M. (2011) What is the right service? A multi-criteria decision model based on 'STEP', Proceedings of the 2011 International Conference on e-Business, pp. 81-90.

Mueller, B., Viering, G., Legner, C. and Riempp, G. (2010). Understanding the Economic Potential of Service-Oriented Architecture. Journal Of Management Information Systems, 26 (4), 145-180.

Peng, G. C. and Nunes, M. B. (2007) Using PEST Analysis as a Tool for Refining and Focusing Contexts for Information Systems Resea rch, 6th European Conference on Research Methodology for Business and Management Studies, pp. 229-236.

Rogers, E. M. (1995). Diffusion of Innovations. Free Press, New York.

Sabahi, F. (2011) Cloud computing security threats and responses, 2011 IEEE 3rd International Conference on Communication Software and Networks (ICCSN), pp. 245-249.

SESAR (2011). WP 14 - SWIM Technical Architecture - Factsheet No. 01/2011.

SESAR (2012). The European ATM Master Plan.

Urquhart, C. (2001) An encounter with grounded theory: Tackling the practical and philosophical issues, In Qualitative research in IS: Issues and trendsEd.), Idea Group Publishing, London, pp. 104-140.

Wicks, A. C. and Freeman, R. E. (1998). Organization studies and the new pragmatism: positivism, anti-positivism, and the search for ethics. Organization Science, 9 (2), 123-140.

Zissis, D. and Lekkas, D. (2012). Addressing cloud computing security issues. Future Generation Computer Systems, 28 (3), 583-592.