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Procuring commercial-off-the-shelf software for Air Traffic Services systems in state-owned organizations: A client-centered case study in Spain

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ABSTRACT

This paper reports preliminary findings of a client-centered exploratory study on how Commercial Off-The-Shelf (COTS) software influences the procurement of Air Traffic Services (ATS) systems in state-owned organizations. Our work carried out an initial qualitative study on the case of the Spanish Automated Air Traffic Control System (SACTA) in ENAIRE, the national Air Navigation Services Provider (ANSP). As a result, we present an tentative model of the case where a series of emerging ideas is identified. These ideas constitute a client-centered conceptual framework that may help state-owned organizations understand some phenomena associated to the evaluation and procurement of COTS-based ATS systems.

1. Introduction

Air Traffic Services (ATS) systems constitute an essential support element of the Air Traffic Management (ATM) system. Such systems enable a safer and more efficient operation of air transit by integrating information from a variety of sources such as flight plans, Communications, Navigation and Surveillance (CNS) systems or aeronautical and meteorological information providers. In addition, modern ATS systems automate routine functions, thus contributing to a reduction of the operator workload. Hence the importance of acquiring proper ATS systems and optimizing its performance throughout its life-cycle.

Commercial Off-The-Shelf (COTS) software has proved to be one of the principal factors influencing decision making when it comes to the procurement of new Information and Communication Technology (ICT) systems or upgrades for legacy systems.

COTS software is commercial software that can be built into and integrated within other software projects. It has been widely studied in the general domain given the supposed benefits they offer to speed up the development process and reduce overhead costs. Some studies focused on proving the advantages of COTS software solutions over bespoke ones (Blanchette, 2005; Morisio et al., 2002). According to those studies, COTS solutions do not always reduce the investment of time and effort required to successfully complete the project, rather they change the way the project has to be handled. Greater focus has been put on the integration issues of COTS software such as detection and solution of interoperability problems (Wile et al., 2010; Couts and Gerdes, 2010).

COTS software is starting to become commonplace also in the field of safety-critical applications. Safety-critical systems are those systems whose failure could result in loss of life or significant damage to the environment. The need to establish specific guidelines to ensure the suitability of COTS software components for safety-critical applications was already identified by Kohl (1999) along with the shortage of empirical research in the field. Two main problems with the integration of COTS software components into large safety-critical systems were identified by Dawkins and Kelly (1997): a) potential systematic errors can be introduced by poor integrations of COTS software; and b) difficulties to meet the requirements of the safety case. The use of COTS software within safety-critical domains is supported by Wetherholt (2009), who

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concluded that some modifications in the software assurance and safety approaches need to be done in order to ensure the successful assurance of COTS-based products.

Aviation is a good example of a safety-critical environment where the research on COTS software is still very limited and focuses mainly on airborne systems and certification processes (Alford, 2001; Ferrell and Ferrell, 2001). Although COTS software could become an economical alternative to bespoke software for aviation systems, thorough planning is needed to reduce re-certifications.

Research on COTS software for ground-based ATS systems is extremely scarce and tackles very specific applications such as the selection of operative systems (Pierce et al., 1999). The case study conducted by Kesseler (2008), which analyzed a COTS-based ATS system, could not corroborate the expected benefits of COTS software. This study also evidenced how the management style can dramatically influence the outcome of the project. Kesseler (2004) analyzed and compared several safety-critical software standards and guidelines, including the previous editions of the main standards widely used for the development of aeronautical airborne systems (DO-178/ED-12) (RTCA/EUROCAE, 2012a) and ground-based systems (DO-278/ED-109) (RTCA/EUROCAE, 2012b). Both standards consider the use of COTS-based systems. In Europe, Commission Regulation (EC) No 482/2008 lays down software safety assurance requirements to be met by Air Navigation Services Providers (ANSPs) through a Safety Management System (SMS) (European Commission, 2008). This regulation is based on the EUROCONTROL Safety Regulatory Requirement addressing software in ATM systems (ESARR 6) (EUROCONTROL, 2002). EC No 482/2008 leaves in National Supervisory Authorities' hands the decision to accept alternative means of compliance to support the safety case of COTS software integrations. Nevertheless, the European Aviation Safety Agency (EASA) continues to expand its responsibilities in the ATM field and new extensive regulatory material on ground-based ATM systems is underway (EASA, 2014). It is expected that the European Commission will soon draft new related implementing rules to amend or even replace EC No 482/2008. Subsequently, EASA should promulgate its own Acceptable Means of Compliance (AMC) and Guidance Material (GM) partially based on ED-153, the most commonly used AMC to EC No 482/2008 (EUROCAE, 2009).

Despite the evident relationship between the performance of the ATS system and economic development, the impact of COTS software on the procurement of ATS systems by state-owned Air Navigation Services Providers (ANSPs) is a topic that has not been studied in the literature yet. This paper aims to help fill the research gap in this area by introducing the results of our initial approach to the issue of COTS software for ATS systems in the Spanish Air Navigation Services Provider (ENAIRE).

2. Case approach

2.1. Case selection

State-owned ANSP raise a particular interest insofar as public money is directly or indirectly at stake. The Spanish Automated Air Traffic Control System (SACTA) was developed for ENAIRE in 1984. SACTA comprises a fully integrated network of ATS automation systems at Area Control Centers (ACCs) and Control Towers (TWRs) (civil and military), enabling seamless interoperability among them. A key factor contributing to the success of this bespoke system, developed from-scratch by the Spanish company Indra, is the fact that SACTA is in operation at every single Spanish ATS facility, thereby avoiding the problems that arise when dealing with different ATS systems from different providers. The Automation Division of ENAIRE, which is based at the headquarters in Madrid, centralizes the software verification, validation and strategic management of SACTA across the entire Spanish territory, standardizing decisions and studies on potential integrations of COTS software.

Over the last few years, new regulatory scenarios and a recession economy have been putting state-owned ANSPs under pressure to reduce costs in order to confront new models of competition while maintaining or even improving safety levels at the same time. In Europe, one of the main aims of the Single European Sky (SES) initiative, promoted by the European Commission, is to prevent existing public ATS monopolies by facilitating the set-up of new free market models. The emergence of new institutional models for the provision of air navigation services (Button and McDougall, 2006) and the SES initiative have led to the liberalization of ATS in Spain (Gómez Comendador et al., 2012), and so to the emergence of new privately-owned ATS/CNS providers which may represent tough competition to ENAIRE. The new ANSP might decide to replace SACTA with different ATS systems following a COTS strategy in order to reduce costs.

The following criteria, borrowed from the work of Oates (2006), justify the relevance of a case study about the impact of COTS software on the procurement of SACTA in ENAIRE:

- *Generalization*: Despite the peculiarities of SACTA and the impossibility to generalize results due to the adopted research methodology, the insights of this research may be of interest for other governmental or state-owned ANSPs and ATS systems providers.
- *Opportunity*: There is presently a lack of well-grounded methodology to support decision makers during the evaluation of new COTS software in an ATS context.
- *Convenience*: Many professionals conveyed their interest to analyze the impact of COTS software on their daily activities with SACTA from a scientific point of view.
- *Novelty*: The integrated network-centric model of SACTA makes the case unique.

2.2. Methodological approach

The exploratory case study is the methodology that best serves the objectives of this research. Our work followed a flexible use of the Paradigm Model (Corbin and Strauss, 2014), a conceptual analytical tool in the context of the Grounded Theory, which was used to create a simplified model of the case out of the qualitative analysis. We carried out an initial inductive analysis inspired by Grounded Theory, yet identifying some initial ideas as starting point (Robson, 2002). We also followed an interpretivist paradigm since the focus of our research was put on the understanding of the social context of the case rather than on technical details. The insights obtained may help tackle initial approaches to similar cases, but the outcomes cannot be generalized.

We conducted this preliminary study focused on the point of view of the client, the Automation Division of ENAIRE. It is expected that this first approach can shed more light on the matter than approaches focused on other main actors involved such as the Air Traffic Controllers (ATCOs) (end user), Indra (ENAIRE's current ATS systems provider) and potential future COTS systems providers. The results obtained from this client-centered approach will constitute a solid basis for further research on the way to an integral approach

of the case.

2.3. Data collection and analysis

We used semi-structured on-line interviews to collect data. Questions for respondents were developed after a preliminary interview to identify topics of importance. The first interviewee was recruited on a purposive basis and is an experienced middle manager with an extensive overview of the issue with COTS software within the organization. This manager suggested seven additional respondents, all at the same peer level, thus making up a total sample frame of eight individuals. The sample frame (population) comprises all the employees of the Automation Division of ENAIRE with decision-making responsibilities on COTS software in SACTA. Out of this sample frame we could individually interview five professionals on a consecutive basis between July 11 and August 24, 2014. Even though the sample size may seem far below usual recommended values in qualitative research (Creswell, 2007), it constitutes a 62.5% of the reduced population under study. Moreover, the sample frame was endorsed by the interviewees, who could not suggest further information-rich contacts. Interview transcriptions and final results were additionally member-checked (Creswell, 2007; Lincoln and Guba, 1985) by the respondents, thereby increasing the accuracy and credibility of the study. In this sense, Patton (2002) points out the importance of selecting proper sources of information and the quality thereof over the sample size. The ultimate aim is credibility and understanding rather than representativeness.

The respondents asserted during the interview that they did not feel subjected to any kind of pressure or influence that may condition the responses – at least provided that their identities remain anonymous. In order to preserve anonymity in the dissemination of this study, individual responses are not linked with participants' identities. Nevertheless, biased results cannot be completely discarded due to the social factor inherent to the initial nominations by the first respondent and the interviewing process itself.

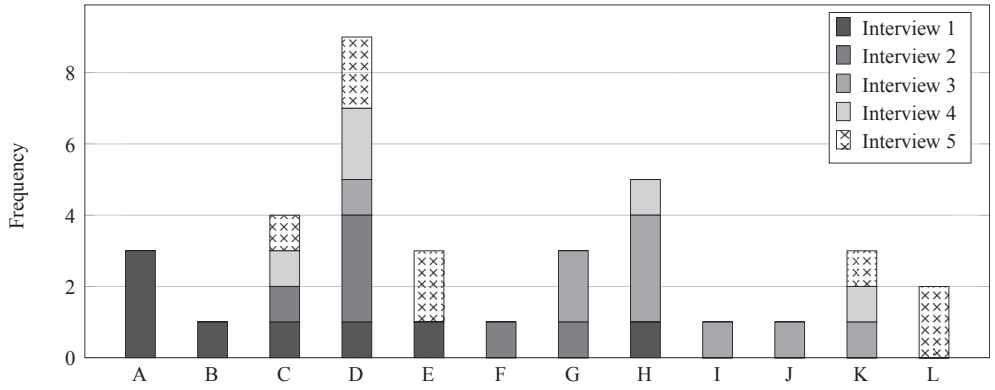
The transcription of the interviews constituted the input data for the qualitative analysis carried out with the aid of Computer-Assisted Qualitative Data Analysis Software (CAQDAS). Individual parts of the transcriptions were marked with a number of conceptual codes giving an idea of the underlying concept or theme (open coding). Basic frequency analysis was used to quantify the conceptual codes and thus be able to draw insights from the qualitative results. The observed frequency of the different themes was used as a plausible (but not unquestionable) indicator of the relevance of each code against the other. Finally, the interrelationships among conceptual codes were elicited by establishing networks and hierarchies with the different passages of the interview transcriptions marked with a given code (axial coding). Data saturation (Francis et al., 2010) could not be formally verified. However, most of the codes (eleven out of twelve) were elicited during the three first interviews, being some of them recurrent and setting an initial set of sufficiently interrelated concepts that fulfills the objectives of our initial approach to this case.

3. Results and discussion

The conceptual codes that arose from the interviews as well as their observed frequencies are shown in Fig. 1 in form of column chart. The results of the frequency analysis combined with the establishment of interrelationships among the conceptual codes are shown in Fig. 2, which depicts a simplified version of the Paradigm Model. This simplified view classifies the conceptual codes into conditions, actions and consequences. The radius of the circles containing the conceptual codes in Fig. 2 is directly proportional to the observed frequency of the related code during the interviews – the higher the frequency the larger the circle.

Hereinafter, we refer to the conceptual codes identified in Figs. 1 and 2 by including their references expressed as capital letters in parentheses.

The economic impact of COTS software integration (D) is the topic that arose from the interviews the most (see Fig. 1). In the



A- Limited flexibility in public procurement
B- Independent maintenance of COTS components
C- Established monopoly in the Spanish ATS system
D- Economic impact of COTS software integration
E- Reluctance to implement COTS software
F- Liberalization of ATS/CNS
G- Lacking interoperability regulations in Europe
H- Complexity of certification processes
I- Ambiguous definition of COTS
J- Role of service experience
K- Resistance to change
L- Deficient knowledge on COTS software

Fig. 1. Frequency of conceptual codes by interview.

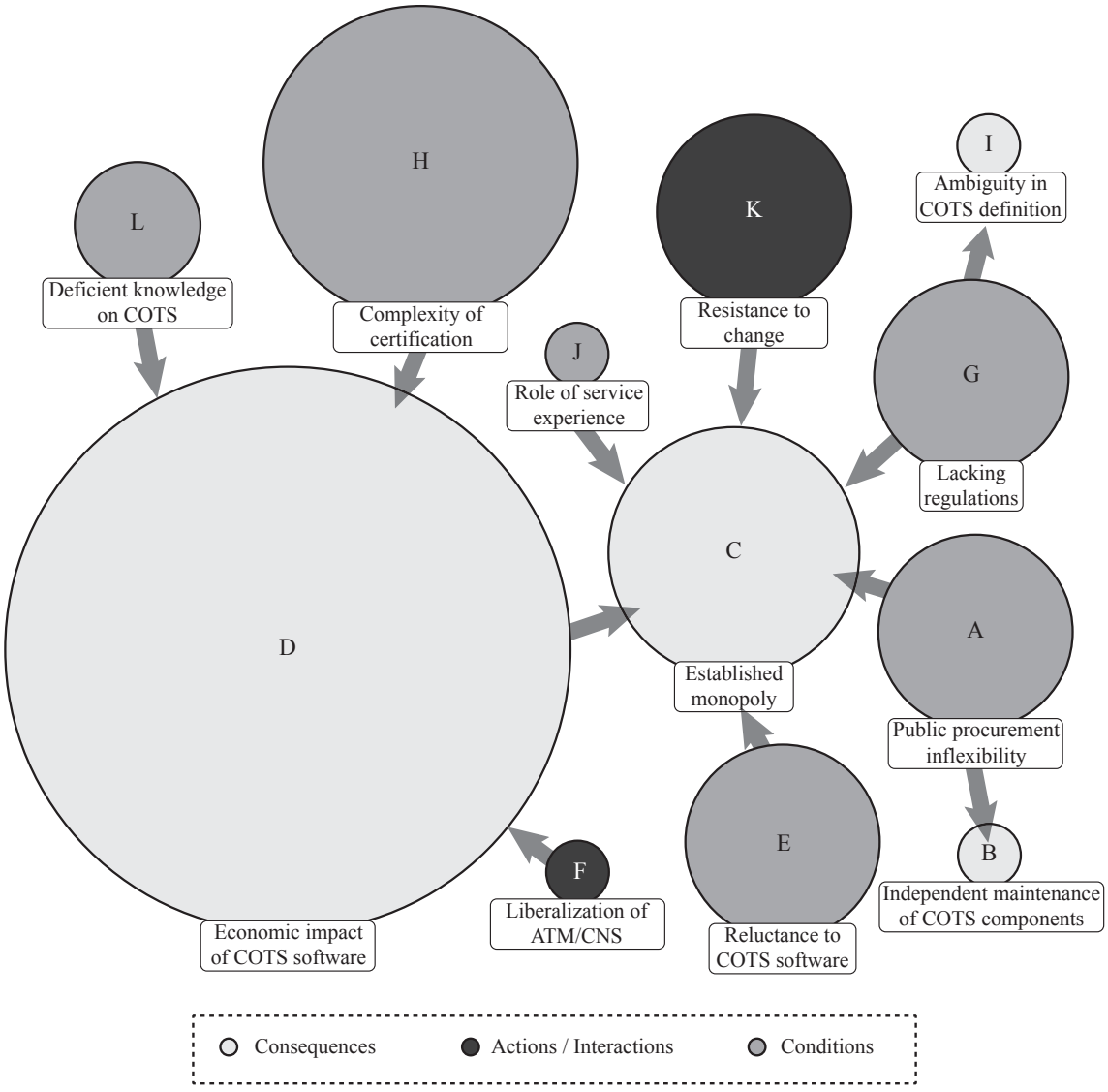


Fig. 2. Simplified Paradigm Model of the case.

light of the liberalization of ATS and CNS services (F), promulgated by the Spanish government in 2010, ENAIRE re-adapted many internal processes to accommodate a future increase in the integration of COTS software components. This denotes that ENAIRE had, and still has COTS software in foresight as a means of cutting down on expenses. On the other hand, the difficulties of cost estimation in COTS-based environments may account for the fact that no COTS software providing *operational functionalities*[1] has been yet integrated into SACTA. A poor understanding on COTS software (L) and the high complexity of the related certification processes (H) – the second-most mentioned concept – can hinder accurate estimations of the actual economic benefit (see Fig. 2). The integration of operational COTS software into a bespoke system like SACTA and consequent certification poses a great challenge as it triggers new safety assessments for the whole system. Some respondents found the certification criteria over-demanding and unrealistic to a certain extent. Moreover, the Spanish Aviation Safety Agency (AESA) accepts service experience as means of compliance for system certification (J). This also complicates the integration of new operational COTS modules since they cannot compete with Indra and SACTA in terms of proved service experience.

The absence of a consistent regulatory framework in Europe tackling the implications of COTS software in ATS (G) has led to some ambiguities even in the very definition of COTS software (I).

The network-centric model of ATS facilities that ENAIRE owns has the capability of making up for loss-making facilities by means of those producing benefits. However, an imminent further step of the liberalization process or a total privatization of the air navigation services in Spain would lead to a new scheme of ATS facilities where the self-compensation would no longer be possible. In that hypothetical context each ATS unit would strive to minimize expenses on their own, likely looking at COTS software as a way to reduce the costs associated to the ATS system.

The following themes or concepts turn out to be emerging ideas that we could not find in the literature:

- *Established monopolies in the provision of ATS systems* (C): The existence of a persistent natural monopoly in the provision of

[1] Functionalities directly accessible by the ATCO to facilitate the safe provision of ATS.

ATS systems in Spain hinders any integration of COTS software with operational functionalities. The current situation of ENAIRE raises the dilemma that on the one hand a cost reduction may be achieved by resorting to COTS software from other providers, but on the other hand the dependency on Indra as the provider of SACTA is very strong after a long experience together (K).

- *The lack of flexibility in public procurement complicates COTS software integration* (A): The Spanish legislation relating to public procurement seems to play an adverse role in the integration of COTS software into the ATS system due to its lack of flexibility to manage a multi-provider environment and the requirements that this environment imposes when it comes to maintenance contracts (B). These conditions may also benefit Indra and its natural monopoly with SACTA.
- *End user reluctant to a COTS-based ATS system* (E): When the part responsible to manage the procurement and development of the system does not correspond to the end user, the view of the end user tends to be overlooked. The analysis carried out in this research revealed that a transition from bespoke software with high adaptability into a COTS-based system with limited adaptability may be seen as an important downgrade, which would benefit the current monopoly. A further study focused on the end user may confirm this view.

4. Conclusions

We were interested in understanding how COTS software influences the procurement of ATS systems in state-owned organizations. To that end, we conducted an initial client-centered study on the Spanish Automated Air Traffic Control System (SACTA) in ENAIRE, one of the major European ANSPs.

The results revealed that some of the governing factors identified in our preliminary approach to the case are not new, for example the need to optimize resources in a liberalized ATS environment, the complexity of certification processes, the value of the service experience and the lack of knowledge about COTS software, being the difficulties of ENAIRE to accurately estimate the economic benefit of COTS software integrations in SACTA the most relevant factor. However, the inflexibility of the public procurement system, the existence of natural monopolies and the possible reluctance of the end user to change SACTA for a COTS-based ATS system are emerging themes that were identified through our research. All these factors seem to hinder the incursion of COTS software with ATS functionalities into SACTA, especially the persistence of an old natural monopoly due to the long record of experience between the provider (Indra) and the client (ENAIRE).

Based on these results, we assume that the concepts that emerged in this initial case study can be considered as a preliminary client-centered conceptual framework on the procurement of ATS systems in state-owned organizations. Nevertheless, further research is needed in order to confirm whether these emerging concepts represent global phenomena. A global and complete understanding of the case can be achieved through new approaches focused on the other main actors (end user, current and potential providers).

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