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From traditional to professional Air Navigation Service Provider: a typology of European ANSP business models

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Abstract

This paper proposes a business model typology based on factor analysis of mixed data sourced from the 2016 Air Traffic Management Cost Effectiveness (ACE) benchmarking report, European air navigation service provider (ANSP) websites and annual reports. It provides ANSP management insight into the key strategic business model decisions to be made, their resulting models as well as how these business model decisions contribute to ATM/CNS profits. The findings suggest that ANSPs can benefit from increasing both their level of corporatisation as level of outsourcing. The paper can be used by ANSP managers to position themselves within the European air navigation services (ANS) landscape and as a discussion starter for future business model developments; or by ANS customers to better understand the strategic objectives of the ANSPs.

Keywords— air navigation service providers, business models, factor analysis, mixed data

1 Introduction

The European air navigation services (ANS) industry is currently facing many challenges as it is the last part of the broader aviation sector to be liberalised[1]. In the pre-COVID period, instrumental flight rules (IFR) movements in the EU-28 countries was predicted to grow by 13% from 2018 to 2025 (EUROCONTROL, 2019), causing pressure on the sector to reform to be able to handle this increase in traffic. The Single European Sky (SES) initiative from the European Commission initiates this reform, which advances ANSP competition, cost-effectiveness and innovation. While during the COVID crisis, the focus is on the revitalisation of commercial aviation, the challenges to reform European airspace will again attract attention in the post-COVID era.

Such challenges raise several questions for air navigation service provider (ANSP) management as well as for researchers. What are the strategic options available to ANSP management to cope with the faced challenges? Before new models for ANS provision can be developed, it is useful to gain more insight into the current business models deployed.

Previous academic research on the ANS industry has focussed mainly on effects of commercialisation and privatisation (e.g. Majumdar (1995), Steuer (2010)), pricing issues (e.g. Leal de Matos (2001), Bolic et al. (2014)), and more recently collaboration, consolidation and structural market reform is-

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[1] In 1978, the US launched the Airline Deregulation Act. The European equivalent followed in three packages in 1987, 1990 and 1993. Nowadays, practically all European airlines are private organisations operating in a single European market, while before liberalisation, they were state-owned and regulated via national regulatory regimes. In Europe, 73.5% of all passenger traffic in 2016 passed through an airport which was at least partly privately owned (ACI Europe, 2016). Before liberalisation, almost all airports were publicly operated and considered as national strategic assets.

sues (e.g. Adler et al. (2014), Tomová (2015)). While different authors have studied business models of airports (e.g. Kalakou and Macário (2013)) and airlines (e.g. Dewulf (2014)), there seems to be a research gap towards business model developments of ANSPs.

This paper proposes a typology of business models present in the European ANS market anno 2016-2019 and assesses its influence on ATM/CNS profit, in order to provide ANSP management with insights in their strategic options of coping with the changes in the market; and to provide airspace users a better understanding of ANSP's strategic objectives.

Although a business model approach is tailored to commercial and profit-maximisation-like businesses, it is also well suited to analyse the European ANSP landscape. There is indeed a visible trend towards more commercial activity which is likely to continue after the adoption of the SES 2+ package and beyond (Buyle et al., 2017; Tomová, 2016). At the same time, further liberalisation of the sector will require ANSPs to build a competitive advantage. Analysing the European ANS sector from a business model perspective is hence useful.

The proposed typology is based on factor analysis for mixed (cross-sectional) data sourced from the 2016 Air Traffic Management Cost Effectiveness (ACE) benchmarking report, ANSP websites and available annual reports. Since the ACE benchmarking reports focus on European monopoly en-route providers, ANSPs only providing terminal services[2] fall outside the scope of the paper.

The remainder of the paper is structured as follows: the next section discusses the definition of *business model* used for this study and presents the business model variables taken into account in the factor analysis for mixed data. Section 3 elaborates on the methodology, the number of factors that are used, as well as their interpretation. Section 4 presents the proposed typology, while Section 5 links the typology with ATM/CNS profits. Finally Section 6 summarises the implications for future business models and Section 7 concludes with the main conclusions and suggestions for future research.

2 The business model

There is a wide variety of definitions for the business model concept available in the literature. A currently popular concept used in organisations is the business model canvas of Osterwalder and Pigneur (2010). It is composed out of nine building blocks that describe how an organisation creates and captures value over its value chain: key partners, key activities, key resources, cost structure, value propositions, customer relationships, distribution channels, customer segments and revenue streams. However, these components do not lend themselves easily to be used in the monopolistic ANS setting as it proofs to be challenging to identify e.g. unique value propositions. Hence another, more flexible definition is needed.

A good starting point is the work of Amit and Zott (2001). They integrate different theoretical viewpoints of the firm into one business model concept. In their view, this business model consists of the content, structure and governance components of the transactions that create value for the firm. As this is a much more open definition it is easier to work with. Later work by Casadesus-Masanell and Ricart (2010) builds further on the definition of Amit and Zott (2001). They see a business model as a collection of choices made by the firm and the consequences linked to these choices. This paper relies on this framework of choices as it lends itself easily to be adapted to the context of the sector of interest, in this case, the European ANS industry. After having identified the essential business model choices, these can easily be quantified for further analysis.

After reading the discussion of the different choices and consequences below, it can be noted that besides a different definition is chosen as the starting point, each of the variables can be put in one of the boxes of the business model canvas of Osterwalder and Pigneur (2010).

Casadesus-Masanell and Ricart (2010) make a distinction between strategic (or policy) choices, asset choices and governance choices, as well as the

[2]The ANSPs only providing terminal services are often small in size (e.g. airport self-handling) and operational scope (mainly small regional airports). They are mainly active in the UK and Nordic countries.

strategy outcomes (or consequences) that follow from these choices.

2.1 Strategic choices

The strategic choices refer to those management decisions that affect all aspects of the firm operations. In this research, they are considered to be partially overlapping with the content and structure transactional components of Amit and Zott (2001). The specific choices are identified as the operational scope of the core ANS, innovation strategy, and whether the ANSP decides to cooperate with third parties or not.

2.1.1 Operational scope

The operational scope of the ANSP comprises the kinds of services offered. Initially, most of the national ANSPs only provided ANS to civil flights within their national airspace under the direct control of the national government. Over time some ANSPs started to extend their operations to more market-oriented commercial services. These ANSPs market their expertise in consulting services, open their air traffic controller (ATCO) training school to provide training to ATCOs of other ANSPs or actively bid for ANS contracts at airports in partly-deregulated markets. To stress that these services are offered in a market-like setting, they will be referred to as *marketable services* in the remainder of the paper. The majority of these marketable services are in the group of non-core services, while only the commercially offered terminal ANS could be seen as a core-service.

While in the past civil and military ANS were strictly separated, nowadays, more and more European countries realise that having two separate providers with each their infrastructure is inefficient. Therefore, in 2016, already fourteen out of thirty-seven national ANSPs integrated the military services into their product offer (EUROCONTROL, 2018).

Not only the kinds of services offered, but also where these services are offered changed over time. A small minority of ANSPs started to internationalise to some extent. Most often, this internationalisation of the ANS product offer is politically driven. In such cases, the government of a country delegates the provision of ANS in a part of its airspace to a neighbouring country. (EUROCONTROL, 2018) An exception to this case is HungaroControl (Hungary (HU)), which is remotely controlling the airspace of Kosovo (under a NATO mandate) (HungaroControl, 2019). NATS (United Kingdom (UK)), DFS (Germany (DE)) and Austro Control (Austria (AT)) to the contrary are actively making use of the opportunities created by the opening up of the terminal ANS market by actively acquiring service licenses at foreign airports within Europe. DFS and NATS do so via a subsidiary set up for this purpose. (NATS, 2019; FerroNATS, 2019; DFS, 2018; Air Navigation Solutions, 2018) For this study an ANSP is considered to be international if it offers en-route services in a considerable part of the territory of a foreign country (i.e. Croatia Control and SMATSA in Bosnia and Herzegovina[3], HungaroControl in Kosovo and Skeyes in Luxembourg) or offers terminal services at foreign airports, whether these are offered via subsidiaries (i.e. NATS and DFS) or the mother company (i.e. Austro Control).

2.1.2 Collaboration strategy

Many ANSPs are collaborating with other ANSPs or with technology providers in joint ventures or alliances. Alliances between ANSPs and a technology provider (i.e. iTEC and COOPANS) are initiated to share costs of technology development and to reduce the fragmentation of technology used in the European ANS landscape (iTEC, 2019; COOPANS, 2019). The joint ventures often have a more commercial focus. Examples include

- GroupEAD, a joint venture between ENAIRE (Spain (ES)), DFS (DE) and technology provider Frequentis, which is an aeronautical data management company operating on behalf of EUROCONTROL;
- European Satellite Services Provider (ESSP), a joint venture owned by seven European

[3]Bosnian airspace is currently no longer controlled by SMATSA and Croatia Control.

ANSPs (DFS, DSNA, ENAIRE, ENAV (Italy (IT)), NATS (UK), NAV Portugal and Skyguide (Switzerland (CH))) operating a satellite-based system for navigation. ESSP has a pan-European certificate to act as an actual ANSP;

- Aireon, a joint venture between NAV Canada, ENAV, IAA (Ireland (IE)), NAVIAIR (Denmark (DK)) and Iridium, that is setting up a system for space-based surveillance;
- Entry Point North (EPN), a joint venture between LFV, Naviair and IAA that provides ATCO training to third parties (other ANSPs have set up joint ventures with EPN for local training schools) (Entry Point North, 2019);
- Flight Calibration Services, a joint venture between Austro Control (AT), DFS and Skyguide that provides R&D, engineering, consultancy and inspection services for communication, navigation and surveillance systems (CNS) equipment (Flight Calibration Services, 2019);
- Frequentis DFS Aerosense, a joint venture between Frequentis and DFS subsidiary DFS Aviation Services for the development and commercialisation of a remote tower system (dfs, 2018);
- or Saab Digital Air Traffic Solutions (SDATS), a joint venture between LFV (Sweden (SE)) and Saab.

The last one not only sells the remote tower system, but they also intend to operate it from their centre in Sweden, which would make SDATS the first fully digital ANSP (sta, 2018).

In the analysis, the number of joint ventures and alliances in which the focal ANSP participates is split up by type of partners (ANSP-only, ANSP and supplier, mixed form).

Table 1: Variables influencing the ANSP business model

Strategic Choices	
Choice	**Variables**
Operational scope	Marketable service offer (yes/no)
	Military ANS integration (yes/no)
	International ANS services (yes/no)
Collaboration forms	Number of ANSP-only alliances
	Number of ANSP-supplier alliances
	Number of mixed alliances
	Number of ANSP-only joint ventures
	Number of ANSP-supplier joint ventures
	Number of mixed joint ventures
Innovation strategy	Horizon 2020 projects per 100 FTEs
	Remote tower operations (yes/no)
Asset Choices	
Choice	**Variables**
Factor inputs	Labour to capital ratio
Make-or-buy choices	Outsourcing of MET services (yes/no)
Governance Choices	
Choice	**Variables**
Ownership structure	% of government shares
	% of private shares
Corporate structure	Government department (yes/no)
	Common airport-ANS entity (yes/no)
	Independent company (yes/no)
Strategy outcomes	
Outcome	**Variables**
Cost structure	Cost share of staff costs
	Cost share of non-staff operational costs
	Cost share of depreciation costs
	Cost share of capital costs
Unit cost	Unit cost of terminal services
	Unit cost of en-route services
Revenue structure	Revenue share of terminal services
	Revenue share of en-route services
	Revenue share of marketable services
Unit revenue	Unit revenue of terminal services
	Unit revenue of en-route services

Source: own composition

2.1.3 Innovation strategy

The extent to which a firm contributes to innovation in the sector is often measured via its investments in research and development. Unfortunately, such data is not available for the European

ANSPs. This study hence relies on the number of Horizon 2020 projects (linked to Single European Sky ATM Research (SESAR)) per 100 full-time equivalents (FTEs) in which the ANSP is participating or has participated. All projects to which the ANSP contributed between 2014 and 2018 are included regardless whether they were finalised during the reference period or are still ongoing. Four of these projects started in 2015, one in 2017 and all others in 2016[4]. The correction for the number of FTEs is made to overcome possible bias since it is assumable that larger organisations have more means to participate in a higher number of projects than smaller ones. This normalisation, however, does not distinguish between two ANSPs each having the same number of FTEs and participating in the same project but contributing a different number of person-months. Such an approach would require reliable data on the person-month project contribution, which is currently not available.

Only half of the European ANSPs participate in Horizon 2020 projects. While some of those ANSPs only participate in one or two projects, most are active in a wide range of projects. However, when analysed in terms of projects per 100 FTEs, there is much more variation between the ANSPs. With six projects per 100 FTEs Oro Navigacija (Lithuania (LT)) scores the highest, followed by IAA (IE), LPS (Slovakia (SK)) and Naviair (DK) with between three and four projects per 100 FTEs. Only four ANSPs are taking up a leading role in these projects: ENAV (IT), DFS (DE), DSNA (France (FR)) and NATS (UK)[5]. (EU Open Data Portal, 2018)

While this study uses Horizon 2020 project participation, it should be noted that other programs might have existed before, or simultaneously with, the Horizon 2020 program and that ANSP innovation projects are not necessarily always sponsored by such large (European or national) government initiatives. Therefore, also the potential adoption of innovative solutions such as remote tower technology is taken into account in this study. It should be noted that both variables only measure the innovation effort, and not to which extent they contribute to cost reductions or revenue improvements.

2.2 Asset choices

There are two choices related to the assets used by the ANSP considered in this study. One is the labour to capital input ratio, and the other concerns the make or buy decision of support services such as meteorological services for air navigation (MET). The labour to capital input ratio is calculated by dividing the number of FTEs employed by the net book value of the fixed assets and corrected by the national capital goods price index as measured by Eurostat (2018). Six missing values for the price index are imputed via predictive mean matching. In predictive mean matching, regression-based predictions are made for the variable for which values are missing. In making the predictions, the regression coefficients used are randomly drawn from their posterior distribution. The procedure then looks for a set of observations for which the predicted values closely match the predicted value of the missing case, randomly selects one, and replaces the missing value with the observed value of the selected observation. The advantage of this method is that it does not require a Normality distributional assumption of the imputed variable. However, problems occur when extrapolation is needed or when the sample size is small. This issue is overcome by extending the data used for the imputation of the capital price index over a broader period (2002 - 2017). (White et al., 2011)

Note that only outsourcing of MET services is considered, as there is no publicly available and reliable data on the outsourcing of other kinds of services.

2.3 Governance choices

Most European ANSPs today are independent, but government owned, enterprises. Exceptions are NATS (UK), ENAV (IT) and Skyguide (CH). A consortium of airlines owns 49% of the shares in NATS, while 47% of the shares of ENAV are traded on the stock exchange. The other part is in the hands of the

[4] No projects started in 2014, the year in which the Horizon 2020 program of the European Commission was launched.

[5] Using the number of projects per 100 FTEs in which the ANSP has a leading role does not considerably change the factor interpretations.

government. For Skyguide, only a very small part of the shares (less than 1%) is in private hands. (EUROCONTROL, 2018)

The majority of the ANSPs might still be government owned, however, in many countries, the legislation already includes the option of private sector involvement, often with a golden share that remains with the government which stresses the strategic importance of the ANS industry.

The ANSPs which are not an independent company are either a government body (DSNA, PANSA, DCAC Cyprus, HCAA) or part of a common airport-ANS entity (Avinor, DHMI). Interesting here is that at the beginning of 2018, ANS Finland was split off from Finavia, the national airport operator in Finland. The Finnish government has, however, the ambition to integrate ANS Finland with traffic managers of other transport modes under the same holding. They believe this would stimulate digitalisation and create possibilities for the commercialisation of new services e.g. from increased data sharing. (EUROCONTROL, 2018; ANS Finland, 2018)

2.4 Strategy outcomes

The strategic, asset and governance choices have a consequence on the ANSP cost and revenue structure, which can be considered as the strategy outcomes. The operational scope, service offer decisions, asset choices, collaboration and innovation strategies of the ANSP determines its revenue streams as well as its cost structure. An ANSP that has a high labour to capital ratio and outsources non-core services is likely to have a different cost structure than an ANSP which is part of a common airport-ANS entity and has a low labour to capital ratio. In the end, costs and revenues will determine profits and part of the success of the business model. Profit maximisation is, however, not the only objective of an ANSP. As postulated by Adler et al. (2020), the ANSP objective function is a mixture of the maximisation of profits, consumer surplus and national interests. Consumer surplus and national interests are although more challenging to quantify and thus excluded here. ANSPs are furthermore subject to the SES Performance Scheme with binding performance targets in four key performance areas (safety, environment, capacity and cost-efficiency). This regulation has undoubtedly an influence on the *success* of the business model.

2.4.1 Cost structure

The cost structure is measured by calculating the cost shares of the gate-to-gate staff costs, non-staff operational costs, depreciation costs and capital costs[6]. These cost shares should add up to one.

The cost structure provides an idea about how the money is spent, but it does not tell anything about how much is spent. Therefore it is useful to take into account the unit costs of terminal and en-route services.

The unit cost of terminal services is calculated by taking the ATM/CNS cost attributable to terminal services and dividing it by the number of IFR airport movements (as reported in the ACE benchmarking reports).

The unit cost of en-route services is calculated in a similar way by dividing the ATM/CNS costs attributable to en-route services by the en-route IFR flight kilometres handled.

2.4.2 Revenue structure

The revenue structure is measured based on the contribution of each product to the operational revenue. ANSP operating revenues are composed of revenues generated by terminal charges, en-route charges and the marketable service offer.

According to the annual reports, fourteen out of thirty-seven ANSPs have revenues from marketable services ranging from 0.1% to 13% of the operational revenue. However, for four of them, these revenues contribute no more than 1% to the operating revenues and are hence neglectable. For only three ANSPs (ANS CR, NATS and LFV) marketable services have an operating revenue contribution of more than 5%.

Next to revenue shares, the unit revenues are also taken into account. These are measured by taking

[6] The total user cost of capital is calculated in the ACE benchmarking reports as the sum of the cost of equity and interest costs through the weighted average cost of capital.

the total revenues generated by terminal and en-route services and dividing them by respectively the number of IFR airport movements handled, and the number of IFR flight kilometres handled. The unit revenues are positively correlated with the unit costs, which is likely due to the price-cap regulation.

3 Factor analysis for mixed data

The choices and variables specified in Table 1 and discussed in the previous section, are quantified by use of cross-sectional data collected between 2016 and 2019 from the 2016 ACE benchmarking report published by EUROCONTROL (2018), ANSP websites and available annual reports. Information on Horizon 2020 project participation is taken from EU Open Data Portal (2018). The resulting dataset is a mix of quantitative and qualitative information. Since a cross-sectional approach is chosen, the dataset contains only one observation in time per ANSP and not multiple, as would be the case in a panel data approach.

This study relies on factor analysis, as opposed to e.g. cluster analysis, since it not only provides a ground to classify ANSPs based on their business model variables, but also provides insight in the main structures inherent in the dataset.

Previous studies in the air transport literature have used factor analysis to measure service quality (e.g. Wang (2007); Meng et al. (2010); Nameghi and Ariffin (2013); Bezerra and Gomes (2016)); to compose an index of air transport liberalisation (Piermartini and Fache Rousová, 2008) or travel and tourism competitiveness (Khan et al., 2017); to identify market segments based on user perceptions and service requirements for international air travel (Wen et al., 2008), air cargo (Chao et al., 2013) and airport ground access (Budd et al., 2014); to classify literature on low-cost carrier (LCC) pricing strategies (Costantino et al., 2016); or to compose a typology of LCC networks (Dobruszkes, 2006).

A factor analysis method for mixed data described by Pagès (2004) and implemented in R by Lê et al. (2008) is used to provide insight into the main components of the ANSP business model. This method is a combination of principal component analysis (PCA) and multiple correspondence analysis (MCA) in which the quantitative and qualitative variables are compared at an equal level. The knowledge gained from the factor analysis for mixed data is afterwards used to compose an ANSP business model typology.

Suppose that there are J variables: J^{quan} quantitative variables and J^{qual} qualitative variables. The data is stored in a matrix X in which the columns k represent the variables and the rows i represent the ANSPs. Each of the qualitative variables in X is split up in its separate levels such that the elements x_{ik} have numeric values if column k represents a quantitative variable and have a value of 0 or 1 if column k represents a level of the qualitative variables. The qualitative variables hence decompose in a total of K levels.

Each group of variables (quantitative and qualitative) are decomposed in eigenvalues λ and eigenvectors v. The eigenvalues can be ranked in decreasing order for each group, such that s represents the rank of the eigenvalue. The factor scores for the qualitative variables are then given by

$$F_s^{qual}(i) = \frac{1}{\sqrt{\lambda_s}} \frac{J}{\lambda_1^{qual} J^{qual}} \sum_{k \in K} x_{ik} G_s(k)$$

The factor scores for the quantitative variables are given by

$$F_s^{quan}(i) = \frac{1}{\sqrt{\lambda_s}} \frac{J}{\lambda_1^{quan}} \sum_{k \in K} x_{ik} G_s(k)$$

In which $G_s = X' D v_s$, with D the matrix with Euclidean distances between individuals. The final factors are given by

$$F_s(i) = \frac{1}{J} (F_s^{qual}(i) + F_s^{quan}(i))$$

The variables underlying the revenue, cost and ownership structure are measured as proportions of total operational revenue, total costs or the total number of shares. Each set of these proportions should add up to one. As suggested by Jolliffe (2002), the following transformation proposed by Aitchison (1983) is used for these kinds of compositional variables, to overcome bias in the correlations between them:

$$v_j = \log x_j - \frac{1}{p}\sum_{i=1}^{p} \log x_i, \quad j = 1, 2, ..., p$$

With p the number of variables that are part of the composition, x_j the original proportions and v_j the transformed values. For this transformation zero values of x_j are replaced by $(0.1)^{100}$.

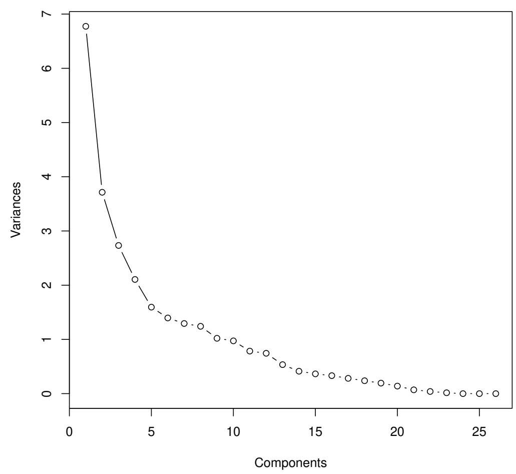
3.1 k factors

The goal of the conducted factor analysis for mixed data is to reduce the number of variables p to k factors that can be easily interpreted, while keeping as much of the original information as possible. Before these different factors found in the data can be discussed in detail, a decision should be taken about the number k of factors to keep for further analysis. Jolliffe (2002) discusses different methods to decide on k. Despite that hypothesis tests and statistically based decision rules exist, they are often found to rely on unrealistic distributional assumptions or are computationally demanding. The frequently used ad hoc rules-of-thumb seem to be most reliable in practice. That is to select those factors before the elbow in a screeplot or for which the eigenvalue is higher than 1.5. (Jolliffe, 2002)

Based on the elbow in the screeplot in Figure 1, five factors are kept. These five factors all have eigenvalues above 1.5 and represent 62.7% of the variance in the data. The first two factors account for 39% of the total variance, which is considerably more significant than the 95% quantile (24.3%) found by Husson et al. (2017, pp.228-229) in a study of ten thousand PCAs with independent variables of similar dimensions, indicating that there is a meaningful structure in the ANSP dataset. Table 2 provides an overview of the variance explained by each of the selected factors.

As the method relies on PCA, the number of retained factors does not influence the factor scores or the interpretation of the factors.

Figure 1: Screeplot of ANSP business model components



Source: own composition

3.2 Factor interpretation

For the interpretation of the factors, it is useful to look at the significant correlations between the quantitative variables and the factor scores. These are shown in Table 3. For the qualitative variables, Table 4 reports on the ANOVA estimates. No factor rotation was used.

When interpreting the factors, it is also useful to look at the ANSPs that are well projected on the respective factor and have an extreme score. Since a factor analysis is in fact an orthographic projection of the data points on a different coordinate system (the factors), the quality of representation can be measured by the squared cosine of the angle between the vector issued from the point representing the ANSP and its projection on the factor under investigation (Lê et al., 2008). An ANSP is considered to be *"well-represented"* if its measure of representation for the factor under discussion is in the highest quantile. The factor scores for these ANSPs are either on the high or low end of the spectrum.

Table 2: Variance explained by selected factors

	Corporatisation	Collaboration	Capital intensity	Outsourcing	Mixed alliances vs commercial focus
eigenvalue	6.77	3.71	2.73	2.11	1.60
percentage of variance	25.09	13.76	10.12	7.80	5.91
cumulative percentage of variance	25.09	38.85	48.97	56.77	62.68

Source: own composition

3.2.1 Level of corporatisation

The first factor reflects how corporatised each ANSP is. Highly corporatised ANSPs tend to act more like large independent commercial businesses. The factor contrasts the ANSPs which are partly privatised, have a marketable service offer, an international scope and engage in joint ventures, with those which are government departments and only offer ANS nationally.

There also seems to be a relationship between the level of corporatisation and the cost and asset structure of the ANSP. The more corporatised ANSP tends to have a higher en-route unit cost, lower labour to capital ratio, a higher depreciation cost share and a lower cost share for non-staff operational costs. The lower labour to capital ratio and higher depreciation cost share might be a consequence of the fact that corporatised ANSPs are exempted from government procurement rules, which makes it easier for them to invest in capital stock. With regard to unit costs there is no real consensus in literature what happens after corporatisation or privatisation. Some researchers (e.g. Sclar (2003)) argue that privatisation of ANSPs leads to a cost increase, others (e.g. McDougall and Roberts (2008); Poole (2007)) argue that unit costs decrease, while Dempsey-Brench and Volta (2018) concludes that ownership has no direct impact on cost structure or cost efficiency of ANSPs.

The five highest scoring and well represented ANSPs on level of corporatisation are NATS (UK), DFS (DE), Skyguide (CH), ENAV (IT), and LFV (SE). These are all ANSPs that operate as independent enterprises, have revenues from marketable services and participate in multiple joint ventures and alliances. Two of these provide ANS internationally (NATS and DFS).

The five lowest scoring and well represented ANSPs are HCAA (Greece (GR)), DCAC Cyprus (Cyprus (CY)), DHMI (Turkey (TR)), M-NAV (Macedonia (MK)), ROMATSA (Romania (RO)) and MATS (Malta (MT)). These ANSPs only provide regulated ANS in their national airspace and do not participate in alliances or joint ventures. DCAC Cyprus and HCAA are government departments, while DHMI is a common airport-ANS entity.

3.2.2 Collaboration and terminal efficiency

The second factor reflects to what extent the ANSP collaborates with others and innovates to reduce its terminal unit cost. The factor scores show high correlations (≈ 0.6 at $p < 0.001$) with the number of alliances in which the ANSP participates and to a lesser extent as well the number of Horizon 2020 projects in which the ANSP is involved per 100 FTEs (≈ 0.4 at $p = 0.022$). Investment in remote tower technology also results in larger scores on the second factor, while the terminal unit cost has a high negative correlation (≈ -0.7 at $p < 0.001$).

The high scoring ANSPs are LFV (SE), HCAA (GR), Naviair (DK), IAA (IE) and Avinor (Norway (NO)). Except for HCAA (which is not well represented in this dimension), all participate in three different alliances (Borealis, Noracon and either iTEC or COOPANS), have a terminal unit cost below or slightly above the European average and invest in remote towers.

LFV (SE), HCAA (GR), Avinor (NO) and Naviair (DK) have a cost structure in which a higher percent-

Table 3: Correlations between quantitative variables and factor scores

	Corporatisation	Collaboration	Capital intensity	Outsourcing	Mixed alliances vs commercial focus
en-route share	-0.913^{***}	0.017	0.022	0.091	0.313
terminal share	-0.911^{***}	0.012	0.021	0.093	0.317
marketable share	0.912^{***}	-0.015	0.021	-0.092	-0.315
labour ratio	-0.424^{**}	0.154	-0.335^{*}	0.262	-0.500^{**}
gov. shares	-0.546^{***}	0.247	-0.055	-0.660^{***}	-0.103
priv. shares	0.546^{***}	-0.247	0.055	0.660^{***}	0.103
H2020 projects	0.219	0.376^{*}	0.181	-0.267	0.376^{*}
capital cost share	-0.039	-0.450^{**}	0.700^{***}	0.005	-0.183
depreciation cost share	0.441^{**}	-0.359^{*}	0.211	-0.143	0.414^{*}
non-staff cost share	-0.400^{*}	0.350^{*}	-0.394^{*}	-0.031	-0.012
staff cost share	0.063	0.486^{**}	-0.642^{***}	0.113	-0.054
terminal unit cost	0.217	-0.748^{***}	-0.106	-0.136	0.036
en-route unit cost	0.419^{**}	-0.169	-0.718^{***}	-0.020	0.297
terminal unit revenue	0.066	-0.763^{***}	-0.081	0.028	0.204
en-route unit revenue	0.402^{*}	-0.136	-0.749^{***}	-0.056	0.233
ANSP alliances	0.228	0.597^{***}	0.350^{*}	-0.176	-0.053
mixed alliances	0.310	0.657^{***}	0.052	0.035	0.457^{**}
ANSP joint ventures	0.683^{***}	0.372^{*}	-0.013	-0.163	-0.012
supplier joint ventures	0.549^{***}	0.306	0.107	0.162	-0.061
mixed joint ventures	0.583^{***}	0.053	0.165	0.590^{***}	0.105

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Source: own composition

age of the total cost is due to staff and non-staff operational costs while having a lower percentage of depreciation and capital costs compared with the other ANSPs. IAA (IE) is a particular case, as it also scores quite high on the en-route factor, but has an average cost composition with around 60% of costs from staff expenditure, 20% of non-staff operational costs, 8% capital costs and 12% depreciation.

The five lowest scoring ANSPs that are also well represented are Sakaeronavigatsia (Georgia (GE)), Skyguide (CH), ARMATS (Armenia (AM)), MoldATSA (Moldova (MD)) and UkSATSE (Ukraine (UA)). None of them invests in remote towers or participates in alliances, while their terminal unit cost is above the European average (with Skyguide and Sakaeronavigatsia having the two highest terminal unit costs). At the same time, these ANSPs have a relatively high capital and depreciation cost share compared to the other European players. It is apparent that, except for Skyguide[7], this group is composed mainly out of ANSPs operating outside the scope of the SES regulation. This observation might be an indication that the SES initiative is spurring collaboration and technology innovations within the EU.

3.2.3 Capital intensity and en-route efficiency

The third factor could be seen as a proxy for the capital intensity and en-route cost efficiency. The well represented high scoring ANSPs on the third factor

[7]Switzerland (where Skyguide is operating) is participating in the SES initiative, despite not being an EU member, nor part of the European Economic Area.

Table 4: ANOVA estimates for qualitative variables

	Corporatisation	Collaboration	Capital intensity	Outsourcing	Mixed alliances vs commercial focus
not marketable	-2.320^{***}	-0.019	0.046	0.175	0.435^{*}
marketable	2.320^{***}	0.019	-0.046	-0.175	-0.435^{*}
national	-1.815^{***}	-0.031	0.437	0.459	-0.015
international	1.815^{***}	0.031	-0.437	-0.459	0.015
civil only	-0.467	-0.131	-0.080	0.492^{*}	0.197
military integrated	0.467	0.131	0.080	-0.492^{*}	-0.197
MET in-house	0.127	-0.625	-0.090	-0.655^{**}	-0.089
MET outsourced	-0.127	0.625	0.090	0.655^{**}	0.089
airport operator	-0.867	0.543	1.034	-0.384	0.305
gov. department	-1.244^{*}	0.550	-0.890	1.240^{**}	-0.667
independent	2.111^{**}	-1.093	-0.144	-0.856^{*}	0.361
no remote towers	-1.049^{*}	-1.108^{***}	-0.585^{*}	-0.050	-0.314
remote towers	1.049^{*}	1.108^{***}	0.585^{*}	0.050	0.314

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Source: own composition

are EANS (Estonia (EE)), IAA (IE) and LGS (Latvia (LV)). They are within the 25% ANSPs with the lowest en-route unit cost and revenue in Europe and have a capital cost share above or just below the European average. These three ANSPs are members of Borealis, an alliance between ANSPs which cooperate mainly on the en-route level via the creation of cross-border free route airspace. These ANSPs also invest in remote towers.

The lowest scoring and best represented ANSPs on the third factor are Skeyes (Belgium (BE)) and LVNL (Netherlands (NL)). These are the two ANSPs with the highest en-route unit cost and unit revenue. Both have amongst the 25% of ANSPs with the lowest capital cost share in Europe.

3.2.4 Level of outsourcing

The fourth factor reflects to which extent the ANSP outsources part of its services. ANSPs scoring high on this factor are more likely to focus on civil ANS (i.e. outsourcing of military services), outsource MET services and participate in mixed joint ventures (i.e. outsourcing innovation and infrastructure development while retaining influence)[8]. The low scoring ANSPs to the contrary are more likely to keep MET in-house, have integrated military and civil services and participate less in mixed joint ventures.

The best representing ANSPs with a high level of outsourcing are NATS (UK), ENAV (IT), Skyguide (CH) and DSNA (FR). Most of them outsource MET (except ENAV) and do not offer military services (except Skyguide). All participate in mixed joint ventures.

The best represented ANSPs with a low level of outsourcing are AustroControl (AT), SMATSA (Serbia (RS)) and HungaroControl (HU). They do not participate in mixed joint ventures, provide MET in-house and SMATSA also in-sourced military ANS.

[8] When considering the number of H2020 projects in which the ANSP has a leading role, instead of all H2020 projects in which the ANSP participated, the number of H2020 projects also has a high correlation with this factor.

3.2.5 Mixed alliance participation vs commercial focus

The fifth factor contrasts ANSPs, which focus on mixed alliance participation (i.e. participation in COOPANS or iTEC) with those which focus on employing commercial activities. ANSPs that tend to do both or neither one of them have less extreme scores on this factor. The positive correlation with the number of Horizon 2020 projects per 100 FTEs, might be explained from the fact that a Horizon 2020 project often also involves technology suppliers. The negative correlation with the labour to capital ratio, however, is likely due to the extreme value for HCAA (GR). This might explain why both the high and low scoring ANSPs have a labour to capital ratio, which is not so outspoken to one of the two extremes.

High scoring and well represented ANSPs are Oro Navigacija (LT), LVNL (NL), Croatia Control (Croatia (HR)) and IAA (IE). All of these participate in mixed alliances (iTEC or COOPANS) to share the cost of development of a shared ANS system, while none of them has a marketable service offer. Oro Navigacija, Croatia Control and IAA also have a high number of Horizon 2020 projects per 100 FTEs.

The low scoring and well represented ANSPs are HCAA (GR), SMATSA (RS), EANS (EE), ANS CR (Czech Republic (CZ)) and LPS (SK). None of these participates in mixed alliances, but except for HCAA, all have a marketable service offer.

3.3 Robustness

Robustness of the factors is checked by evaluating the impact on the results of excluding one of the ANSPs from the dataset. Except for the removal of HCAA (GR), the interpretation of the factors remains the same, while the actual loadings and scores might vary. In this aspect, it is interesting to look at the contribution of each ANSP to the different factors. This is calculated as the square of the individual's factor score value on the dimension of interest divided by the sum of squares of the factor scores of all individuals (Husson et al., 2017).

The contribution for the i-th individual to the s-th factor is given by

$$Ctr_s(i) = \frac{F_{is}^2}{\sum_{j=1}^{I} F_{js}^2}$$

in which F_{is} is the score of individual i on factor s and I is the total number of individuals.

Three ANSPs contribute considerably (more than 20%) to one of the factors. These are Skeyes (BE) and LVNL (NL) for the capital intensity factor (27%), and HCAA (GR) for the mixed alliances vs commercial focus factor (25%). The high contribution of HCAA might be due to its extreme value for the labour to capital ratio (22.44 compared to 5.36 for the second largest value). Skeyes and LVNL have the highest en-route unit costs in Europe, which might explain their large contribution to the third factor.

4 Business model typology

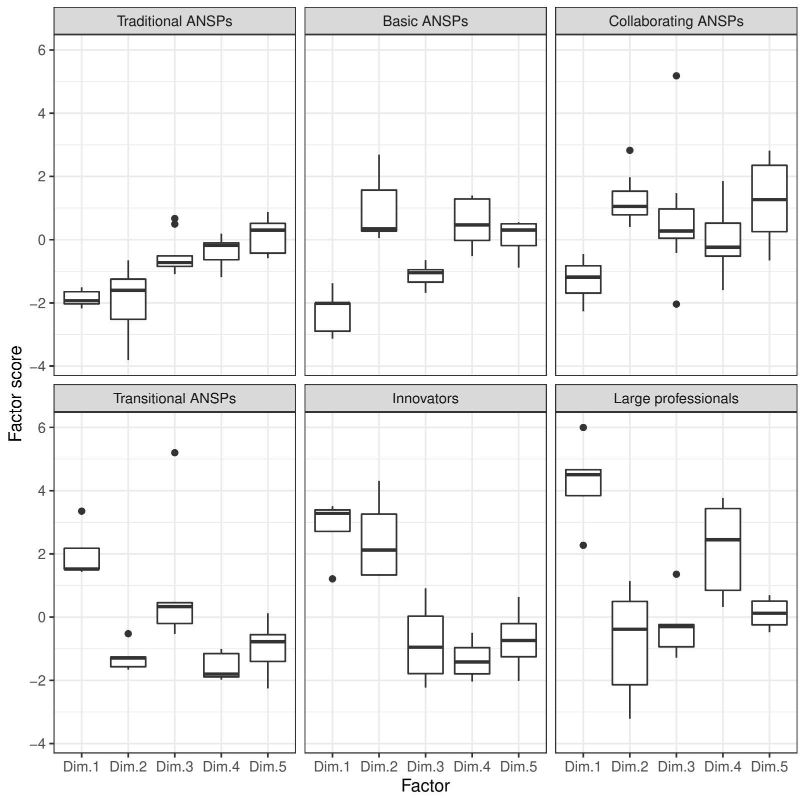
Based on how the ANSPs score on each of the five factors, different groups can be distinguished: The traditional ANSPs, basic ANSPs, collaborating ANSPs, transitional ANSPs, innovators and the large professionals. Table 5 presents the business model groups and their members, Figure 2 the factor scores for each group, and Table 6 the mean differences in factor scores for each model. Table 7 provides an overview of the main characteristics of each business model in the typology.

4.1 The traditional ANSPs

The traditional ANSPs are located in the outskirts of Europe and focus on the provision of the basic (regulated and core) ANS. They have a low level of corporatisation; however, they are all independent entities which do not offer international or commercial services, nor participate in joint ventures.

Although they do not have the lowest terminal and en-route unit costs, their cost structure seems to be represented by a larger en-route cost share. This is mainly because their traffic mix is composed primarily out of overflying traffic. As these ANSPs are

Figure 2: Visualisation of the factor scores in each business model



Source: own composition

typically based in lower-wage countries, they furthermore take advantage of the lower wages by employing a slightly higher labour to capital input ratio. At the same time, since their wage expenses are lower, these ANSPs have a relatively high capital cost share, which contributes to the higher score for the capital intensity factor.

Most of the traditional ANSPs have an in-house MET department and limit their ANS to civil airspace, which results in an average level of outsourcing. These group of ANSPs does not collaborate in mixed alliances, nor has a commercial service offer, hence the average score for the last factor.

These ANSPs are Albcontrol (Albania (AL)), ARMATS (AM), BULATSA (Bulgaria (BG)), Sakaeronavigatsia (GE), MoldATSA (MD), MATS (MT), ROMATSA (RO), Slovenia Control (SI) and UkSATSE (UA). All of them have their geographic market outside of the EU or in newer EU Member States, which might suggest that the transition in business models is at least partly induced by the SES initiative.

4.2 The basic ANSPs

Most of the basic ANSPs have a lower level of corporatisation than the traditional ANSPs since they are either a government department or a common airport-ANS entity. Only one ANSP in this group

Table 5: The six ANSP business models and their members

	Model	ANSPs
m1	Traditional ANSPs	Albcontrol, ARMATS, BULATSA, Sakaeronavigatsia, MoldATSA, MATS, ROMATSA, Slovenia Control, UkSATSE
m2	Basic ANSPs	DCAC Cyprus, LGS, Avinor, PANSA, DHMI
m3	Collaborating ANSPs	ANS Finland, DSNA, Croatia Control, IAA,Oro Navigacija, M-NAV, LVNL, NAV Portugal
m4	Transitional ANSPs	Skeyes, ANS CR, HungaroControl, LPS, SMATSA
m5	Innovators	Austro Control, LFV, Naviair, EANS
m6	Large professionals	NATS, ENAIRE, ENAV, Skyguide, DFS

Source: own composition

Table 6: Mean differences of factor scores

Models	Corp.	Collab.	Capital	Outs.	Mixed
m2-m1	−0.422	2.953**	−0.641	0.874	−0.069
m3-m1	0.626	3.226***	1.210	0.367	1.066
m4-m1	3.865***	0.705	1.542	−1.214	−1.100
m5-m1	4.685***	4.433***	−0.314	−0.990	−0.844
m6-m1	6.121***	1.146	0.211	2.516***	−0.007
m3-m2	1.047	0.273	1.852	−0.507	1.135
m4-m2	4.287***	−2.248*	2.184	−2.088*	−1.031
m5-m2	5.106***	1.480	0.327	−1.864*	−0.775
m6-m2	6.543***	−1.807	0.852	1.643°	0.062
m4-m3	3.240***	−2.521**	0.332	−1.581*	−2.166**
m5-m3	4.059***	1.207	−1.524	−1.357	−1.910*
m6-m3	5.496***	−2.080*	−0.999	2.150**	−1.073
m5-m4	0.819	3.728***	−1.856	0.224	0.256
m6-m4	2.256**	0.441	−1.331	3.731***	1.093
m6-m5	1.437	−3.287**	0.525	3.507***	0.837

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\circ}p < 0.1$
p-values according to Tukey (1949) HSD method

Source: own composition

operates as an independent entity. Just as the traditional ANSPs, they do not have an international or commercial service offer and limit themselves to the provision of the basic (regulated and core) ANS. However, they score slightly better for the collaboration and capital intensity factors. Some of them invest in remote tower technology and participate in alliances in an attempt to reduce terminal and en-route unit costs, while the traditional ANSPs do not. Most of these ANSPs belong to those with the lowest terminal and en-route unit costs in Europe.

Apart from an occasional exception, all of the basic ANSPs outsource MET and military ANS which results in a slightly higher level of outsourcing compared with the traditional ANSPs.

The basic ANSPs are DCAC Cyprus (CY), LGS (LV), Avinor (NO), PANSA (Poland (PL)) and DHMI (TR).

4.3 The collaborating ANSPs

ANS Finland (Finland (FI)), DSNA (FR), Croatia Control (HR), IAA (IE), Oro Navigacija (LT), M-NAV (MK), LVNL (NL) and NAV Portugal (Portugal (PT)) fall in the category of the collaborating ANSPs. Although there is no clear significant difference in factor scores with the basic ANS providers (see Table 6), they are considered here as a separate group because of their focus on mixed alliance participation and higher capital intensity. All of them are a member of either iTEC or COOPANS, in which they, together with a technology provider, save on system development costs and increase the interoperability of the systems used. Such a clear focus on mixed alliance participation is absent in the traditional and basic ANSPs groups. The innovators and large professionals, however, also collaborate with others, but the difference is that those focus more on the commercial service offer.

The collaborating ANSPs have a slightly higher level of corporatisation than the previous two groups (although not clearly significant, see Table 6) as some of them participate in joint ventures. However, just as the traditional and basic ANSPs, none of them has a commercial service offer and except for one, do not have an international service offer. Similarly as the basic providers, the collaborating providers score high on the collaboration factor. The majority of them participate in Horizon 2020 projects, with Oro Navigacija and IAA having among the highest number of projects per 100 FTEs in Europe. One out of two collaborating ANSPs invests in remote tower technology, while LVNL, Croatia Control, Oro Navigacija, IAA and NAV Portugal are a member of either iTEC or COOPANS.

Except for DSNA, the collaborating ANSPs have a terminal unit cost below the European average. The group is more mixed concerning the capital intensity and en-route efficiency factor as well as the level of outsourcing, with, e.g. LVNL having the second largest en-route unit cost in Europe and DSNA having the largest score on the level of outsourcing.

4.4 Transitional ANSPs

This group of ANSPs is composed of Skeyes (BE), ANS CR (CZ), HungaroControl (HU), LPS (SK) and SMATSA (RS), which are in the phase of transitioning from the traditional and basic models to the more corporatised and commercial models. They hence have a higher level of corporatisation compared with the previous groups mainly due to their broader scope of operation, as they have a small commercial service offer while all previous ANSPs have not. Some of these ANSPs also manage a considerable part of a foreign en-route airspace.

All of them score low on the collaboration and terminal efficiency factor as well as on the capital intensity and en-route efficiency factor. Their terminal unit costs are above the European average, while the en-route unit costs are more spread with Skeyes having the highest en-route unit cost in Europe. None of the transitional ANSPs currently participates in alliances or invests in remote tower technology at the time of data collection, but this is expected to change in the near future.

Concerning their level of outsourcing, none of the transitional ANSPs participates in mixed joint ventures, and most tend to in-source MET. ANS CR and SMATSA have in-sourced military ANS.

4.5 The innovators

The innovators have a high level of corporatisation and score high on the collaboration factor. They have a commercial service offer and are active in several joint ventures. Most of them are participating in either iTEC or COOPANS as well as Borealis. All invested in remote tower technology, and most have participated in around 2.5 Horizon 2020 projects per 100 FTEs.

Their level of outsourcing is rather low since most of them have in-sourced military ANS and provide MET in-house.

These ANSPs are called innovators since they have innovated both their business model as technologies used. The new technologies developed are often also commercialised.

These ANSPs are Austro Control (AT), LFV (SE), Naviair (DK) and EANS (EE).

4.6 The large professionals

The large professionals have the highest level of corporatisation amongst the European ANSPs. They also have a high level of outsourcing and have an average score on the mixed alliance participation factor, since they both participate in mixed alliances as have a marketable service offer.

This group consists of NATS (UK), ENAIRE (ES), ENAV (IT), Skyguide (CH) and DFS (DE). All of them offer commercial services and, except for ENAIRE and DFS, are partly privately owned. Most of them outsource MET and are not integrated with the military ANSP. All of them invested in ESSP, the European Satellite Services Provider, and two of them have a stake in Aireon, the joint venture that invests in and commercialises space-based surveillance. NATS also holds a 50% stake in Searidge, the leading supplier of remote and digital tower systems.

Table 7: ANSP business model typology: main characteristics

Non-commercial models			Commercial models		
Traditional ANSPs	Basic ANSPs	Collaborating ANSPs	Transitional ANSPs	Innovators	Large professionals
indep. entity	gov. dept. or common airport-ANS entity	indep. entity	indep. entity	indep. entity	indep. entity
public	public	public	public	public	public or private
non-commercial	non-commercial	non-commercial	commercial	commercial	commercial
national	national	national	international	international	international
no collaboration	alliances	JVs and alliances	low collaboration	JVs and alliances	JVs and alliances
en-route focus	low unit costs	terminal focus	low innovation low efficiency	very innovative efficient	
MET in-house civil only	MET outsourced civil only	mixed	MET in-house mixed	insourcers	outsourcers

Source: own composition

The level of collaboration and terminal efficiency varies within the group, and the same is true for capital intensity and en-route efficiency. However, the scores on the capital intensity and en-route efficiency factor tend to be above average.

4.7 The case of Greece

It seems that HCAA does not fit well in any of the previously mentioned categories as it is the only ANSP that has extreme (high or low) scores on all of the five factors. These extreme scores are likely due to HCAA's extreme value for the labour to capital ratio in 2016. As shown in Table 8, the ACE benchmarking reports disclose a large drop in the book value of fixed assets from 2014 to 2015. This might be the consequence of a revaluation of book values of government assets linked to the Greek debt crisis and Greece's new agreement with the International Monetary Fund (IMF). In that sense, it cannot be said with certainty that HCAA has a unique business model, despite that it scores very low on corporatisation, high on collaboration and terminal efficiency, capital intensity and en-route efficiency, as well as on the level of outsourcing and very low on mixed alliance participation.

Table 8: Evolution of the labour ratio of HCAA

Year	FTEs	Assets	PPI	Labour ratio
2009	1 870	137 723	99.70	1.35
2010	1 870	179 994	100.50	1.04
2011	1 786	167 194	100.70	1.08
2012	1 786	130 469	101.00	1.38
2013	1 725	105 455	101.10	1.65
2014	1 660	103 644	100.60	1.61
2015	1 658	7 009	100.00	23.66
2016	1 633	7 284	100.10	22.44

Source: own composition based on data from the ACE benchmarking reports

5 Linking business models with ATM/CNS profit

Business model choices inevitably have consequences for the overall performance of the ANSP. In order to quantify this link, the different business model factors identified in Section 3 are regressed on the 2016 air traffic management (ATM)/CNS profits. The ATM/CNS profits are calculated from the 2016 ACE benchmarking report as the difference between gate-to-gate ATM/CNS revenues and gate-to-gate ATM/CNS costs. Profits from commercial activities and subsidiaries are not included in the data. The ordinary least squares (OLS) estimations are shown in Table 9. As discussed in Section 2.4, profitability is just one of the criteria which can be used to assess ANSP business model performance, as ANSPs usually also have other objectives than only profit maximisation.

Table 9: Dependence of ATM/CNS profits on business model characteristics (OLS)

	Model 1	Model 2	Model 3
(Intercept)	23472.78***	−59998.90	7023.32
	(6039.62)	(56426.95)	(6631.16)
corporatisation	7656.25**	6746.22*	7306.67***
	(2481.34)	(2846.13)	(1946.90)
collaboration	2510.20	1664.13	
	(3347.85)	(3354.52)	
capital intensity	1875.16	1281.11	
	(4172.17)	(4325.01)	
outsourcing	18893.28***	11201.25*	12107.18**
	(4583.39)	(4842.89)	(3939.48)
mixed alliance vs comm. focus	1211.10	3987.36	
	(6078.42)	(5262.68)	
airspace		0.05**	0.05**
		(0.01)	(0.01)
complexity		1667.57	
		(2587.41)	
variability		43990.99	
		(40802.42)	
R^2	0.53	0.69	0.66
Adj. R^2	0.46	0.60	0.63
Num. obs.	36	36	36
RMSE	35322.62	30179.82	29300.43
RESET test p.val.	0.8433	0.0196	0.1687
Goldfeld-Quandt test p.val.	0.8611	0.6190	0.9226
Breusch-Pagan test p.val.	0.1150	0.0793	0.0736
Kolmogorov-Smirnov test p.val.	0.0893	0.4291	0.5485

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Source: own composition

All three estimated models apply with the heteroscedasticity and normality assumptions of the error term required in OLS estimation, as the null hypothesises of the Goldfeld-Quandt test, Breusch-Pagan test and Kolmogorov-Smirnov test cannot be rejected at the 95% significance level. The models suggest a significant positive relation between the ATM/CNS profit and the levels of corporatisation and outsourcing. The other business model components do not show significant impacts, which might be due to the fact that there is less variability in the corresponding independent variable which reduces the standard errors of the estimated regression coefficients[9]. Since the first five dependent variables here stem from a factor analysis, the more down one goes in Table 9 (or the more to the right in Table 2), the lower the variance of the factor scores (the eigenvalues in Table 2) and hence the higher the standard errors of the coefficients.

The findings from the regression analysis are logical. ANSPs with a higher level of corporatisation tend to have a higher probability to be partly privately owned, to have an international scope, to have a commercial service offer and to participate more in joint-ventures which often also have a commercial focus. It is reasonable to assume that those ANSPs put more attention to profit maximisation. Also the impact of outsourcing on profit seems to make logical sense.

Table 10: p-values for pairwise comparison of ATM/CNS profit per sq. km airspace by business model

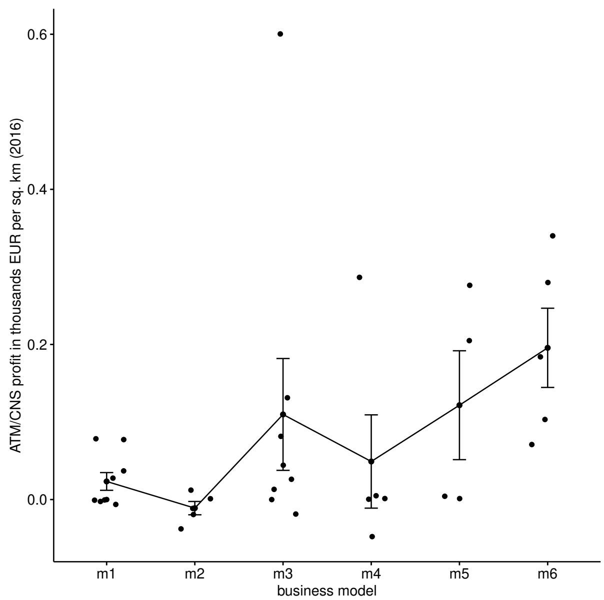
	(m1) traditional ANSPs	(m2) basic ANSPs	(m3) collaborating ANSPs	(m4) transitional ANSPs	(m5) innovators
basic ANSPs (m2)	0.24				
collaborating ANSPs (m3)	0.46	0.15			
transitional ANSPs (m4)	0.90	0.64	0.53		
innovators (m5)	0.28	0.24	0.87	0.64	
large professionals (m6)	0.06	0.06	0.24	0.24	0.56

Source: own composition
p-values according to Benjamini and Hochberg (1995) correction for multiple comparisons
$p < 0.10$ clear sign. difference; $p < 0.30$ difference, but less significant; $p > 0.50$ no difference

When looking at the different business models themselves, it seems from Figure 3 that the collaborating ANSPs (model 3) and the large professionals (model 6) are able to generate higher ATM/CNS profits per square kilometre airspace than the other models. A Kruskal-Wallis rank sum test indeed suggests a significant difference in means between

[9]This is a mathematical fact rather than a finding specific to this study.

Figure 3: ATM/CNS profit per sq. km airspace by business model (2016)



Source: own composition

the six models ($\chi^2_5 = 13.321$, p-value= 0.0206)[10]. For the pairwise comparisons between the models, a Wilcoxon rank sum test is performed. The p-values, adapted for multiple comparisons via the Benjamini and Hochberg (1995) correction are shown in Table 10. The results of the tests suggest that the large professionals indeed realise a significantly larger profit per square kilometre of airspace in comparison with the traditional and basic ANSPs. Given that this is the group of ANSPs with the highest levels of corporatisation and outsourcing this is a logical outcome. The difference in ATM/CNS profit between the collaborating ANSPs and the other groups does not seem to be highly significant. The higher average ATM/CNS profit of the collaborating ANSPs compared with the two other non-commercial models might be due to their high participation in mixed alliances.

[10]Normality assumptions needed for a parametric one-way analysis of variance are not fulfilled, hence a non-parametric test is conducted.

6 Implications for future business models

The results suggest that ANSPs can increase their revenues from ATM/CNS by increasing their level of corporatisation and outsourcing. There is hence an expected evolution towards the large professionals which can be achieved in several ways. Firstly, ANSPs can be brought closer to the fully privatised side of the spectrum by reducing constraints inherent to government organisations. This includes more flexible access to human and financial resources and replacing politically appointed board members with industry stakeholders. While the increased flexibility enables ANSPs to invest in technology and further operational automation, Adler et al. (2020) show that including stakeholders in the board of directors or as shareholders has a positive impact on the efficiency of service provision. Involving local stakeholders furthermore helps the ANSP to anchor its business locally, creating a possible competitive advantage when the liberalisation of the ANS market continues.

Secondly, ANSPs can increase revenues by reorganising their in-house offered support services. In case the ANSP can create a competitive advantage for a certain support service it should consider turning it into a revenue centre (increasing the level of corporatisation), while other support services are better to be outsourced. This makes the ANSPs less dependent on revenues from the heavily regulated core-services. As remote tower technology, space-based technologies and unmanned traffic management (UTM) systems are driving innovation in the ANS sector, experience with these technologies could further increase an ANSP's competitive advantage in a liberalised market. Especially because UTM has to be offered in an open market according to European legislation.

7 Conclusions

This paper proposes a business model typology based on a factor analysis of mixed data sourced from the 2016 ACE benchmarking report, ANSP websites and annual reports. It bridges a gap in the literature by analysing the European ANS industry in a business model framework. Five main ANSP business model components are identified: level of corporatisation, level of collaboration and terminal efficiency, capital intensity and en-route efficiency, level of outsourcing and focus on mixed alliance participation vs a commercial service offer. The identified models and components are afterwards linked to ATM/CNS profits.

The results of the factor analysis suggest that there is no single *European ANSP business model*, but that multiple models exist. Based on similarities in factor scores, six different models are proposed. Of the three models with a lower level of corporatisation, a distinction can be made between the traditional ANSPs which limit their operations to basic ANS provision and take advantage of lower wages; the basic ANSPs which operate as government department or common airport-ANS entity and focus on unit cost reduction; and the collaborating ANSPs which innovate and collaborate in alliances centred on unit cost reduction. The other three models have a high level of corporatisation as these ANSPs have a commercial service offer and often also an international scope. The transitional ANSPs are insourcers and neither very collaborative nor very innovative. They distinguish themselves via a combination of a small commercial service offer and their international en-route ANS activities. The innovators to the contrary emphasise both technological as business model innovation via their high participation rate in Horizon 2020 projects, alliances and joint ventures. The last group, the large professionals, have the highest level of corporatisation as these are large ANSPs with a commercial service offer. Some of them have private ownership and also provide ANS internationally, demonstrating a shift to multinational, multiproduct global ANS companies as observed by Tomová (2017). The large professionals are outsourcers and take a leading role in all kinds of alliances and joint ventures.

Most of the analysed ANSPs operating outside the EU or in newer EU Member States are classified within the traditional or basic ANSPs. This might suggest that the SES initiative is contributing to the evolution towards more commercial and corporatised business models. The revealed models reflect the structural changes within the ANS industry in Europe, mainly within the EU member countries.

This study furthermore suggests that a higher level of corporatisation and outsourcing positively contributes to ATM/CNS profits, which makes it likely that ANSPs will move closer to the large professionals over time. This can be achieved by increasing stakeholder involvement, increasing flexibility of human and financial resources and reorganising the currently in-house support services offer.

While the current study relies on cross-sectional data gathered between 2016 and 2019, it would be interesting to extend it to a panel data approach in future research. Such a method would enable researchers to assess the evolution of the factor scores and business models when market liberalisation continues.

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A Appendix

Table 11: Factor scores of the European national ANSPs by country

	Country	ANSP	Corporatisation	Collaboration	Capital intensity	Outsourcing	Mixed alliances vs commercial focus
AL	Albania	Albcontrol	-1.61	-1.60	0.64	-1.19	0.51
AM	Armenia	ARMATS	-1.72	-3.11	0.85	0.19	0.30
AT	Austria	Austro Control	3.35	1.34	-0.91	-2.04	0.63
BE	Belgium	Skeyes	3.35	-1.57	-5.20	-1.80	0.12
BG	Bulgaria	BULATSA	-2.03	-1.26	0.98	-0.18	-0.43
CH	Switzerland	Skyguide	4.50	-3.22	-1.36	2.45	0.50
CY	Cyprus	DCAC Cyprus	-3.13	0.27	0.65	1.29	-0.88
CZ	Czech Republic	ANS CR	1.43	-1.26	0.53	-1.15	-1.40
DE	Germany	DFS	4.66	1.14	0.23	0.32	-0.48
DK	Denmark	Naviair	3.21	2.90	1.64	-1.12	-0.48
EE	Estonia	EANS	1.21	1.30	2.23	-0.50	-2.02
ES	Spain	ENAIRE	2.27	-0.38	0.30	0.85	-0.24
FI	Finland	ANS Finland	-1.18	0.89	-0.20	-0.74	-0.63
FR	France	DSNA	-1.75	0.40	-0.81	1.86	0.55
GE	Georgia	Sakaeronavigatsia	-1.64	-3.81	1.09	-0.63	0.72
GR	Greece	HCAA	-4.43	3.26	-3.71	2.84	-3.82
HR	Croatia	Croatia Control	-0.46	1.13	-0.24	-1.59	2.24
HU	Hungary	HungaroControl	2.18	-0.52	-0.33	-1.89	-0.78
IE	Ireland	IAA	-0.45	2.83	2.04	-0.05	1.96
IT	Italy	ENAV	3.84	-2.14	0.94	3.43	0.12
LT	Lithuania	Oro navigacija	-1.19	1.98	0.42	-0.42	2.82
LV	Latvia	LGS	-1.38	0.35	1.68	-0.52	0.55
MD	Moldova	MoldATSA	-1.93	-2.52	0.72	-0.87	-0.50
MK	Macedonia	M-NAV	-2.27	0.48	-1.47	-0.45	-0.66
MT	Malta	MATS	-2.16	-0.66	0.79	-0.00	0.88
NL	Netherlands	LVNL	-0.95	0.97	-5.18	0.28	2.69
NO	Norway	Avinor	-2.01	2.69	1.05	-0.03	0.30
PL	Poland	PANSA	-2.01	1.57	0.95	1.40	0.50
PT	Portugal	NAV Portugal	-1.67	1.39	-0.31	1.24	0.57
RO	Romania	ROMATSA	-2.18	-1.25	-0.49	-0.17	-0.59
RS	Serbia	SMATSA	1.52	-1.66	0.20	-1.98	-2.26
SE	Sweden	LFV	3.51	4.32	0.27	-1.71	-1.00
SI	Slovenia	Slovenia Control	-1.51	-1.07	-0.67	-0.23	0.51
SK	Slovakia	LPS	1.52	-1.29	-0.46	-1.01	-0.55
TR	Turkey	DHMI	-2.90	0.05	1.34	0.47	-0.19
UA	Ukraine	UkSATSE	-2.00	-2.42	0.51	-0.10	-0.28
UK	United Kingdom	NATS	6.00	0.50	1.29	3.77	0.69

Source: own composition