Air Traffic Growth, Energy and the Environment 2040: Drivers, Challenges and Opportunities for Aviation

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Although there is a general agreement that civil aviation will continue its expansion in all major regions of the world within the next decade, its long-term development is highly uncertain. Aviation stakeholders (especially airlines) build their strategies upon time frames of roughly five to ten years while politics and regulatory authorities define goals for the entire industry that reach far beyond that. This paper presents how the scenario technique can help to interconnect short-term strategies with long-term visions. Three dominant factors determining the future of civil aviation are identified and explored: the increasing scarcity of fossil resources, the change of global climate and the world's growing demand for mobility. The paper addresses intensely discussed issues like the future role of sustainable fuels in aviation by exposing the results of a foresight project performed by the authors together with industry experts and students. Three alternative, comprehensive pictures of the future (scenarios) are described including top-level statements about the world's political and economic situation in 2040 as well as detailed descriptions of how the civil aviation sector will look like. Based on the intended dissimilarity of the three future scenarios, robust strategy options for airlines, manufacturers and airports are eventually portrayed.

Keywords: Future aviation, scenario planning, strategy options

Nomenclature

ATM	Air Traffic Management
BRICS	Brazil, Russia, China, South Africa
CARATS	Collaborative Actions for Renovation of Air Traffic Systems in Japan
FSC	Full-Service Carrier
GDP	Gross Domestic Product
GETS	Global Emissions Trading Scheme
LCC	Low Cost Carrier
N11	Next Eleven Countries: Egypt, Bangladesh, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, Republic of Korea, Turkey, Vietnam
NextGen	Next Generation Air Transportation System (United States)
RAHS	Risk Assessment and Horizon Scanning Web-based Scenario Toolbox
R&D	Research and Development
RPK / RTK	Revenue Passenger Kilometers / Revenue Ton Kilometers
SESAR	Single European Sky ATM Research
SWOT	Analysis of Strengths, Weaknesses, Opportunities, and Threats

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1 Introduction

Looking ahead into the long-term future of the air transport market is both an essential as well as an extremely difficult task for all aviation stakeholders: long-lasting product lifecycles require thoroughly prepared decisions of aircraft manufacturers in order to develop and deliver the right product at the right time; airport planners must predict future air traffic emergence and adequately adapt the airport infrastructure on time; regulative authorities must find ways to foster the economic growth of aviation on the one hand and prevent it from becoming a major threat for the global climate on the other hand. Yet, history has proven that the welfare of the air transport sector strongly depends on the global economic development as well as on the occurrence of major single events such as the September 11th terrorist attacks in 2001 or the nearly pandemic outbreak of SARS in 2002 and 2003 in particular – both of which are impossible to predict.

Major aviation stakeholders publish their market outlook reports on a regular basis (e.g. the Global Market Forecast (Airbus, 2012) or the Current Market Outlook (Boeing, 2012)) to provide their shareholders with detailed information about what they think the future will look like. However, these reports often remain unclear as far as the involved foresight methods are concerned. In addition, the reports literally cover only one picture of the future which makes them appear unrealistic or sometimes even implausible.

In this paper, we demonstrate how the use of selected scenario planning techniques can help to understand the complex interaction schemes between the aviation sector and its environment by producing alternative, consistent pictures of the future (scenarios). We also show how the established scenarios can serve as a basis for a sound and robust corporate strategy development process for aviation stakeholders and identify key drivers for the future of aviation.

At first, we provide a brief overview of the role of modern scenario planning techniques within the strategic decision-making process and then describe how we selected and used those techniques for our specific research purpose. Afterwards, we give a detailed insight into the created scenarios and finally derive robust strategy options for airlines, airports and aircraft manufacturers from these scenarios.

2 Scenario Planning – An Overview

2.1 Future scenarios within the corporate strategy decision-making process

Whenever complex, future-related questions of strategic nature need to be answered, scenario planning techniques provide a helpful bundle of foresight methods and tools to support corporate decision-making processes (see Amer *et al.* (2013) for a detailed review). The key principle of scenario planning is to produce and reflect on multiple, alternative pictures of the future instead of basing the corporate strategy policy on only the one future picture that appears most likely. In this context, it is common to use the term of a “scenario cone” (Pillkahn, 2007, p. 175) to illustrate the output of a scenario study: a broad horizon of alternative futures (Figure 1). Starting with a detailed analysis of the status quo situation, a scenario study is usually aimed at describing several paths that the future may follow. The more distant the future scenario is, the more difficult it becomes to connect the well-known status quo with the

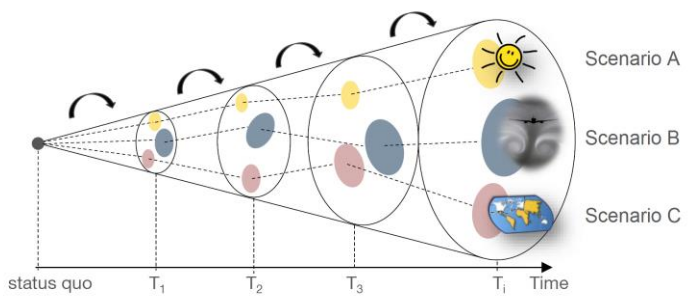

Figure 1. The scenario cone: alternative scenarios on expanding horizons.

scenario: the scenario cone becomes wider as the uncertainty about the future grows.

The development of future scenarios does not have an end in itself but is typically integrated into “a generic approach to a comprehensive foresight project” (Bishop *et al.*, 2007, p. 7). A foresight project as we propose it here consists of the six methodical steps portrayed in Figure 2. Every step premises upon its preceding one and is aimed at eventually finding a reliable support for corporate strategic decision-making. We will provide more details about these methodical steps in section 2.2.

In this context, it is worth mentioning that there are many proposed ways of integrating scenario planning techniques into strategic decision-making processes being discussed in the literature (see O'Brien and Meadows (2013) and Postma and Liebl (2005) for further evidence). However, they all pursue the same ultimate goal: the consideration of multiple alternative futures enhances the “’portfolio of possible strategic initiatives’, leading to action and new experience, that, in turn, leads to (…) new (…) success formulae” (van der Heijden, 2004, p. 158) of strategic decisions, no matter which specific way is chosen in each case.

2.2 Approach to the foresight project

As displayed in Figure 2, we went through six methodical steps during the foresight project presented in this paper. Our initial goal was to identify key drivers and challenges for future aviation and determine robust strategy options for aviation stakeholders to cope with these challenges. As we conducted the project, we were accompanied and supported by a “web-based foresight platform” named “Risk Assessment and Horizon Scanning” (RAHS) – a comprehensive scenario planning toolbox developed by the German Armed Forces and aimed at “strengthening the interdisciplinary and inter-institutional collaboration on foresight activities” (Brockmann, 2012, p. 6).

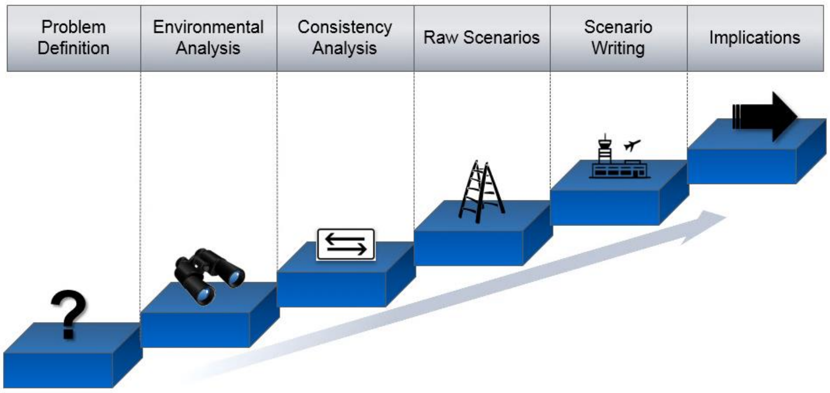

Figure 2. Proposed methodical steps of a strategic decision-making process.

Table 1 provides fundamental information about the framework conditions of the project.

Table 1. Framework conditions of the foresight project.

Project Team:	• 16 students enrolled in engineering and economics courses at the Technical University of Munich • 5 external participants (engineers and economists) from Airbus and Bauhaus Luftfahrt
Project time frame:	April – August 2012
Concept:	Six workshop days with the entire team moderated by the authors of this paper plus additional working time in sub-teams

It is evident that we tried to generate an interdisciplinary project team of engineers and economists to be able to include a large width of relevant expertise into the project.

The six workshop days were organized according to the project group activities scheme of the generic scenario planning workshop model described by Franco *et al.* (2013). This scheme is considered as an “ideal” scenario workshop sequence when working with groups. Table 2 illustrates how each activity phase was assigned to the six methodical steps of the project displayed in Figure 2.

Table 2. Activities scheme of the project, adapted from Franco *et al.* (2013, p. 725).

Methodical Step	Activity Phase Character	Activity Description
Problem Definition	Procedural	Setting the scene.
Environmental Analysis	Procedural	Finding relevant environmental factors. *)
	Discursive	Choosing key environmental factors. *)
Consistency Analysis	Procedural	Determining factor consistencies. *)
Raw Scenarios	Procedural	Calculating raw scenarios. *)
Scenario Writing	Discursive	Choosing scenario ‘themes’.
	Procedural	Generating details of (chosen) scenario themes.
Implications	Procedural	Generating (and evaluating) strategic options.
	Discursive	Choosing ‘candidate’ strategic options for further evaluation.

Note that the activities marked *) in Table 2 were methodically supported by using selected numerical tools of the RAHS platform. Let’s now have a closer look at each project step.

With the overall research purpose in mind to determine major drivers, challenges and opportunities for future aviation, we thoroughly scanned research and position papers of major political institutions, aviation stakeholders and scientists (such as the documents published by the European Union (op. 2011), the Air Transport Action Group (2011) and Vedantham and Oppenheimer (1998)) in the *Problem Definition* phase. On the basis of our findings, we were able to derive three major drivers for future aviation: global climate change, an increasing lack of natural resources (oil, construction materials etc.) and a growing demand for mobility.

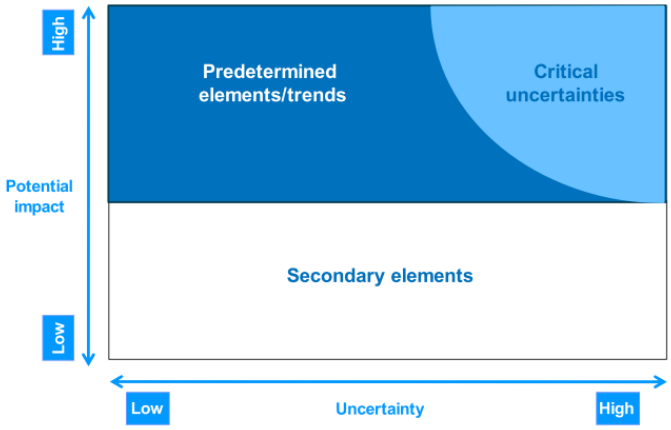

Figure 3. Uncertainty-Impact Diagram.
Source: Wulf et al. (2011, p. 5).

Within the *Environmental Analysis* phase and with the problem statement set, we started looking for environmental factors that have a direct or indirect relationship to the stated problem. For this, we split the considered environment into three parts: the macro-environment containing paramount factors like the world economic situation, political stability or the development of the price for crude oil, the aviation-related meso-environment including factors like the political influence on the aviation sector, the availability of new construction materials or the ecological consciousness of travelers and the problem-specific micro-environment covering factors like the availability of CO_2-neutral and drop-in aviation fuels, the social value and importance of air travel and the occurrence of extreme weather events. We used the STEEPV approach† (with an additional environmental factor area *aviation*) to complete the environmental analysis and structuring task (see Saritas and Nugroho (2012) and Pillkahn (2007) for details). Eventually, we found 45 environmental factors. By mapping the factors on an uncertainty-impact diagram according to their relative impact on the problem as well as according to their relative degree of uncertainty with respect to their future development (see Pillkahn (2007, p. 140) for methodical background information), we subsequently found 12 key environmental factors (Figure 3, *critical uncertainties*), summarized in Table 3.

Table 3. Key Environmental Factors.

Area	Title	Brief Description
Society	Economic and social development of the global middle class	The middle class is the portion of the population which disposes of 75–125% of the median income (per person) in each country. The middle class is the section of the population with a certain status in culture, education, and economic security.
Technology	Availability of drop-in fuels	Drop-in fuels are hydrocarbon-based fuels that are derived from alternative production methods.
Technology	Availability of non-drop-in Solutions	An energy concept is the totality of energy sources, their transport, and their storage as well as their transport into the aircraft and the conversion into thrust. Non drop-in solutions that are not compatible with current, conventional systems require new technical solutions (e.g. new tanks, pumps, propulsion systems).
Technology	Development of alternative propulsion concepts	Alternative propulsion concepts include technological concepts for aircraft propulsion systems that differ in terms of energy supply or functioning principles relative to the propulsion technologies that are currently in operation.
Economics	Development of the global economy	The global economic development can be measured by the global gross domestic product (GDP). The GDP is a measure of the economic performance of a country in a given period.
Economics	Stability of the global economy and of the financial sector	The stability of the global economy is characterized by a constant and moderate growth of the real economy, and a monetary fiscal stability. The stability of the financial sector is determined by a secure supply of capital to the real economy by financial institutions.
Economics	Development of the price for kerosene (Jet-A1)	The price for kerosene is based on supply and demand of crude oil, natural gas, coal, speculations by investors and substitution products (bio-fuels).
Politics	Aviation-related environmental regulations	Environmental factors can be divided into binding self-commitments and legal regulations that will lead to restrictive consequences in case of non-compliance. They define noise and exhaust emissions limits and can be applicable for aircraft manufacturers, operators and passengers.
Politics	Political stability	Political stability is guaranteed by a social and economic equilibrium in a country or in a region. It is very low once the risk of escalating conflicts is very low.

† STEEPV stands for the environmental factor areas *Society, Technology, Economics, Ecology, Politics and Values*

Aviation	Airside airport capacity	Airside airport capacity must be considered relative to the volume of air traffic. It is determined by runway capacity and turnaround time. Each of these can individually become a bottleneck factor for airport capacity.
Aviation	Air Traffic Volume	The global air traffic volume describes the carrying capacity of the entire civil aviation system (airplanes, helicopters, airships, balloons, etc.) per year (passengers, freight and mail) as well as the percentage change over previous years. The transport capacity is measured in RPK and RTK.
Aviation	Relevance of R&D activities for alternative aircraft configurations	The factors describes the readiness of aircraft manufacturers to foster R&D activities for the development of new, alternative aircraft configurations.

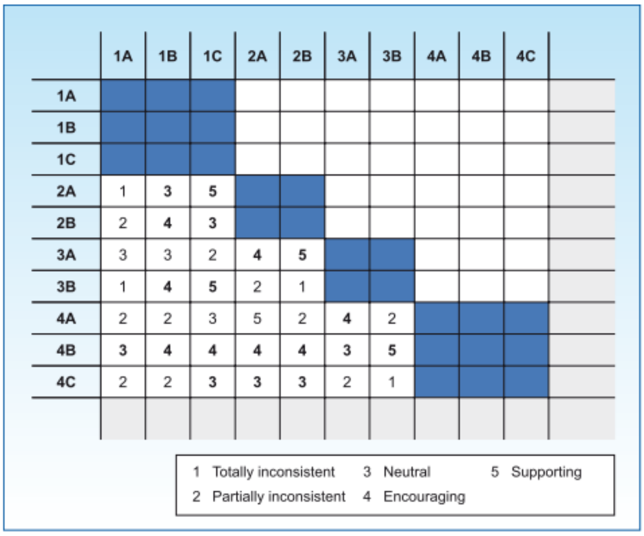

Figure 4. Schematic display of a consistency analysis matrix. *Source: Pillkahn (2007, p. 205).*

In the next step and with the list of key environmental factors at hand, we performed a *consistency analysis* "to check the compatibility of combined variations" of development projections of the key factors (Amer *et al.*, 2013, p. 37), i.e. we quantitatively assessed every existing factor projection pair with respect to their mutual consistency. Figure 4 shows a scheme of the consistency analysis matrix we used.

We then used the RAHS tool to generate *raw scenarios*[‡] with the completed consistency matrix as input and obtained approximately 170 different raw scenarios. Since we had planned to come out with three different scenarios at the end of the scenario generation process, we had to make a selection. In fact, a number of three scenarios is considered as "best" within the literature (Schnaars, 1987, p. 108). RAHS automatically assigned consistency values (i.e. the sum of all consistency assessment values of the corresponding factor projection pairs) to each raw scenario which facilitated the selection process, i.e. we were able to choose very consistent raw scenarios. In addition, we selected scenarios that we considered as having interesting combinations of factor projections and we also intended to widen the scenario cone (Figure 1) with our selection.

The three selected raw scenarios were then assigned each to one of three equally sized sub-teams so that every sub-team could focus on elaborating its own scenario within the *scenario writing* project step. For that, we briefly introduced all sub-teams into the scenario writing methods proposed by Schnaars and Ziamou (2001). In this context, it is worth mentioning that we intentionally did not attach probabilities of occurrence to the three scenarios (cf. Schnaars and Ziamou (2001, p. 30)). Every scenario stands for one specific future situation that is considered as a consistent and imaginable picture of the future in the year of 2040 according to the consistency analysis we conducted. The results of the scenario writing project step, i.e. the storylines of the three scenarios, can be found in section 3.

[‡] We define a *raw scenario* as an unstructured list that contains one projection per considered key environmental factor.

Within the final project step, the *implications* step, we took the elaborated scenarios as the basis for the development of strategy options for various aviation stakeholders. We will provide a more detailed overview of this process step as well as its findings in section 4.

3 The Scenarios in Detail

3.1 The "Bright Horizons" scenario

According to the name of this scenario, crisis regions of the world have stabilized because of political emancipation processes and under the pressure of global organizations. Religious fanaticism has lost its fascination for many people due to higher education standards and less poverty. Furthermore, oil is no longer a reason for conflicts due to the availability of new technologies based on different energy sources. The political stability of the N11 countries pushes their attractiveness for foreign investors and by this means leads to the development of strongly emerging markets. Especially current oil-producing countries enter the renewable energy market. Current industrial and the BRICS countries profit from this fact as a result of a global economic network. GDP growth rates vary in a range of 5-7% for the industrialized and 9% for the BRICS countries, respectively (Figure 5).

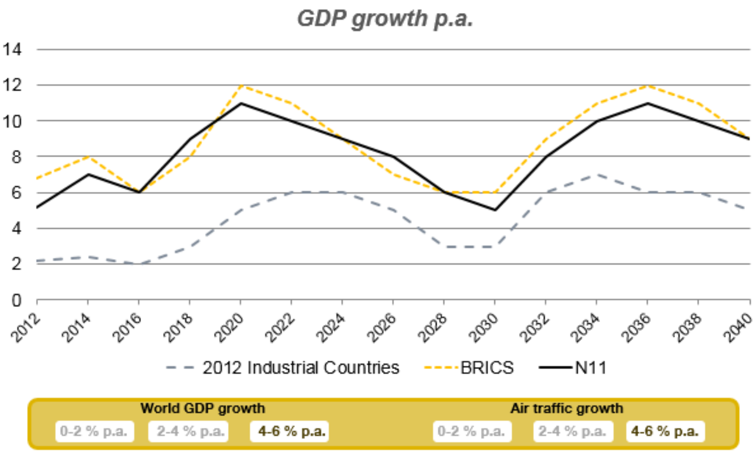

Figure 5. Annual GDP growth rates in [%] of the "Bright Horizons" scenario.

As a result of the political stability and the economic performance, the middle class has grown from 30% in 2012 to 50% of the world population in 2040 and represents the majority of passengers. A strongly growing global economy (Figure 6) causes a sharply increasing and stable air traffic market that is pushed by the growth of the global middle class. In order to satisfy this market, the air traffic volume in 2040 is more than four times higher than in 2012.

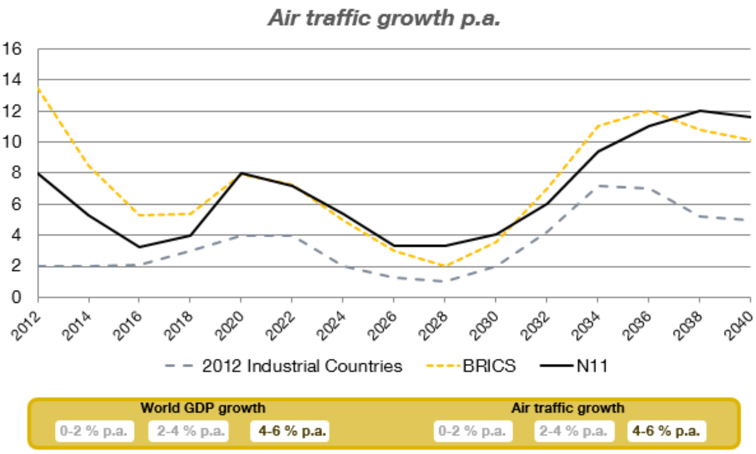

Figure 6. Annual air traffic growth rates in [%] of the "Bright Horizons" scenario.

60% of the global primary energy supply is covered by renewable energy sources. In the new emerging countries (N11), even 75% are based on renewables. Global environmental legislation is permitted by a global institution which has developed from an EU initiative to limit the environmental damage based on global warming. Additionally, a commitment to use the economic force for a sustainable development exists. Governments are committed to this institution. The regulations are restricted to a moderate scope as countries need to reach a consensus. Between 2020 and 2030 the political and economic environment set a beneficial framework for the pre-commercial development of new propulsion systems.

Because of higher demand and limited resources, Jet A-1 prices rise from 117 $/barrel in 2012 to around 630 $/barrel in 2040 which is equal to an annual increase of 6.2%. This accelerates the development of a new propulsion system like fuel cells, high performance batteries and solar energy for aeronautical applications in an international cooperation between industry and research facilities from highly developed countries. These achievements are driven by the increasing price of Jet A-1, the commitment to the environment and the unavailability of drop-in solutions. The use of completely new propulsion systems guarantees independence from oil, i.e. Jet A-1.

Also, a lot of effort is put in the development of new aircraft configurations, for example in order to reach a higher level of integration of the new propulsion systems. Additionally, new air routes are available for airlines. This is possible due to a harmonized Air Traffic Management, formed by a union of programs like SESAR, CARATS and NextGen that leads to simplified and shorter air routes. Airside airport capacity can grow according to the demand (airside volume of traffic increases by a factor of four). Because of the continuously high demand, airlines stay private but become more interlinked. This growth has been possible because of globally improving infrastructural conditions (high investments) and an increasing acceptance of air traffic in the population (fewer emissions).

3.2 The "Rough Air" scenario

In the scenario called "Rough Air", political instabilities still have great influence on the world scenery and cause an inhomogeneous distribution of economic growth of the middle class and of wealth in general which in return leads to new instabilities.

The world financial system is mainly instable and characterized by periodically and geographically differing developments. Different kinds of global economic and environmental challenges (restructuring of the European Union, increasing number of extreme weather events, decreasing oil reserves) are partially causing trouble to the world's financial system. Industrialized countries struggle with decreasing economic growth and saturated markets. The economic growth of emerging countries (BRICS and N11 countries: 4%) is slowing down due to concluded one-time effects (high birth rates) but still contributes to a worldwide moderate GDP growth (Figure 7).

The increasing number of extreme weather events (e.g. storms, floods, etc.) and the sea level rise by 0.5m until 2040 leads to a high environmental consciousness of the global society. This forces governments to implement a global emissions trading system (GETS). Governments subsidize R&D activities of the air transport industry through revenues of the GETS and therefore promote the attractiveness of investments in green technology. Therefore, CO_2 emission can be reduced by 40% until 2040 compared to the year 2000. Governments push for new concepts with environmental regulations to save fuel, but development proceeds in rather small steps.

In the "Rough Air" scenario, drop-in fuels are not available for the aviation sector as they are seen to surge food prices. In general, new environmental regulations (e.g. restrictions on areas of cultivation of feedstock for fuel production) make the production of biofuels unattractive and only marginally profitable. Surcharges like environmentally driven taxes, a further increase of the oil price and profit maximizing activities of big oil companies lead to Jet A-1 prices three times higher than today (around 350 $/barrel by 2040). The increasing environmental consciousness of the public, high ticket prices caused by additional surcharges for Jet A-1, and environmental risks lead to a decline in short distance air travel and an increase of landside feeder traffic.

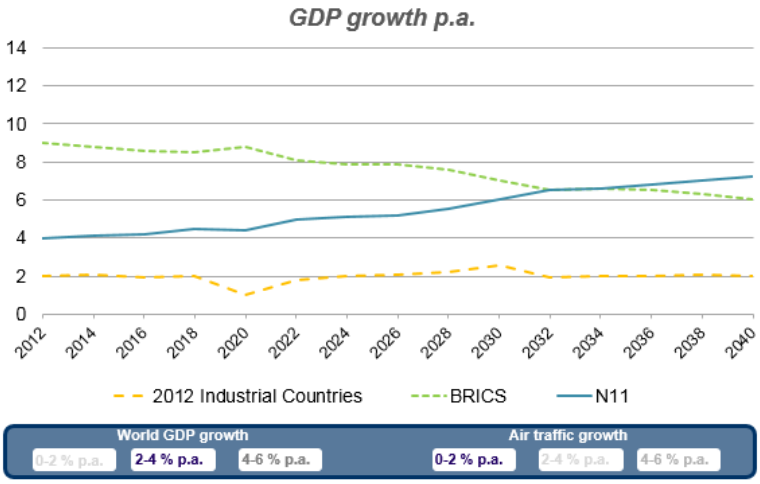

Figure 7. Annual GDP growth rates in [%] of the "Rough Air" scenario.

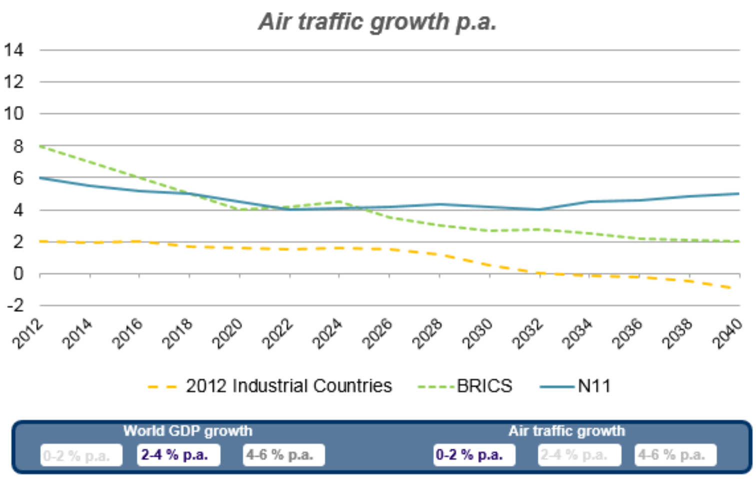

Figure 8. Annual air traffic growth rates in [%] of the "Rough Air" scenario.

Whilst within the industrialized countries air traffic growth stagnates, there is still moderate growth within BRICS and N11 countries (Figure 8). This results in low but robust growth of the world air traffic by 1.5% per year. Due to regional different growth, air traffic management solutions are implemented on a continental level. Their implementation and thus the harmonization of air traffic management (e.g. Single European Sky[§]) contribute to a significant reduction of CO_2 emissions caused by air traffic.

Especially new systems in airport ground traffic management lead to "greener" air traffic by using electric propulsion units for push-back and taxiing and thus reducing CO_2 emissions. Hybrid aircraft like hydrogen and electric hybrid concepts slightly penetrate the market. Battery capacity grows to about 4 kWh/kg because of high R&D activities (the development of high-capacity batteries has an enormous economic relevance). Hence, there is the possibility to partly substitute Jet A-1, as it is only needed for vehicle acceleration.

The increasing number of extreme weather events and related flight cancellations force airlines to cover expensive insurances. Those costs in combination with other cost drivers (e.g. Jet A-1 price) contribute to higher ticket prices. These high fares lead to contrary developments in product characteristics for sophisticated business or wealthy elderly travelers on the one hand and more price-sensitive leisure travelers on the other hand. Thus, airlines especially focus on individually tailored products for sophisticated travelers in order to earn profit.

The business model of the traditional Low Cost Carrier (LCC) disappears more and more in saturated markets like Europe and North America due to stagnant growth, rising operating costs and strong competition. Additionally, following the trend of environmental awareness and the willingness of short distance travelers to use landside traffic, many established carriers rethink their business structures and concepts and transform into "Lifestyle companies" with a large variety of additional services (unbundling of fares for business

[§] Single European Sky (SES) is a European ATM initiative.

models). Flying becomes more individualized and connected (additional intermodal services) enabling airlines to generate new means of income.

3.3 The “Decoupled Powers” Scenario

Europe’s economic crisis in 2011 onwards effects global development well into the decade. The short term recession in Europe and North America (GDP growth -1%) also causes a drop in GDP growth in the emerging countries including BRICS and N11 from 5% to 2% (Figure 9). After the global financial crisis has intensified, a global agreement to return to a connected system of real and financial economy is reached. Speculative actions are largely banned. The financial sector understands itself once again as an enabler of the real economy. From 2016 onwards, the world economy grows more slowly but also more sustainably. The global GDP growth reverts to a low level of 2% annually.

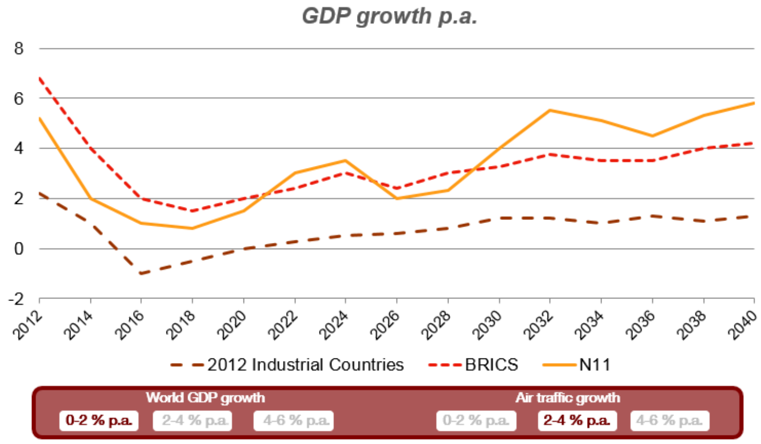

Figure 9. Annual GDP growth rates in [%] of the “Decoupled Powers” scenario.

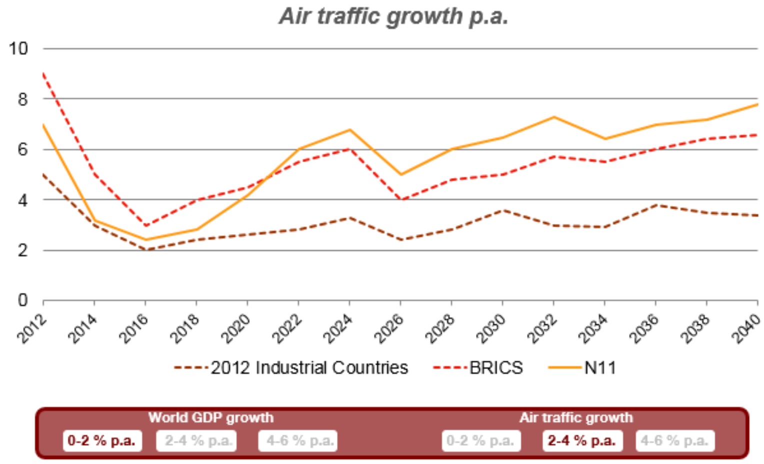

Figure 10. Annual air traffic growth rates in [%] of the “Decoupled Powers” scenario.

In the long term, emerging countries seek more economic independence and decouple from the dragging western markets. To this end, they also form a stronger internal economic network from 2025 onwards. Around 2040, the global GDP growth stabilizes on the level of 2.5%. Europe and North America have an annual growth of 1-2% whereas BRICS countries show annual growth rates of 3% to 4%. The N11 countries and their successors show much higher growth rates of around 6%, however the increased living standards, more powerful labor unions and a stronger demand for freedom and leisure are also contributing to lower growth rates.

Oil price is only increasing moderately due to the availability of renewable energies and thus a reduced demand for fossil fuels. Most types of transportation like cars and ships are using a mixture of energy sources and oil is becoming less important. Expansion of renewable energies is supported by governmental grants. Air traffic grows moderately (RPK, 3.3% p.a.) despite a weak economy due to affordable ticket prices and a growing global middle class (Figure 10). Increasing globalization also increases total RPK through longer flight distances and new markets. Acceptance of flying remains largely the same as environmental considerations have only a limited impact on flying habits. On the other hand, flying is seen as daily business with no renewed fascination.

Air transport capacity (airports, air traffic management) can keep up with increasing traffic through increasing efficiency and adopting new standards. In the United States and the European Union, structural expansions are rare while elsewhere infrastructure is strengthened massively. No great technology changes in aviation are necessary. Conventional aircraft configurations with similar, more efficient engines and retrofits are preferred over costly new developments. Airplanes use a mix of Jet A-1 and bio-fuel (up to 30%).

4 Strategy Implications for Aviation Stakeholders

4.1 Approach to Strategy Development

The linkage between corporate strategic decision-making and scenario planning is appropriately described by Verity (2003, p. 195): "Strategy is largely formulated for the future and is concerned with the world outside the organization at least as much as with what is going on within its boundaries. Scenario techniques are one of the few tools strategists have to help them formulate their ideas about both." It becomes evident that strategy development within an organization has to comprise both the consideration of exterior boundary conditions (that are set by the future scenarios in our case) and an analysis of the internal (company-specific) situation.

In the foresight project presented here, we followed the suggestion of O'Brien *et al.* (2007) to use "the SWOT [Strengths, Weaknesses, Opportunities, and Threats] tool as a framework for organizing an assessment of future opportunities and threats that emerge from an analysis of the future external environment (using scenario planning) with an assessment of the strengths and weaknesses of current resources and competencies" (O'Brien and Meadows, 2013, p. 644). In fact, SWOT is the most frequently applied tool for the methodic support of strategy development in organizations (Gunn and Williams, 2007, p. 207). Figure 11 illustrates the scheme of how we used SWOT in our case. Note that we combined the SWOT method with the TOWS analysis proposed by Weihrich (1982) for the development of strategy options.

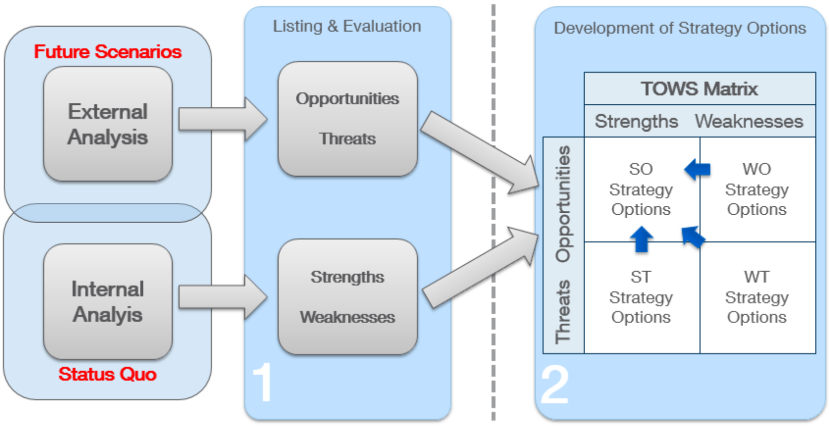

Figure 11. SWOT/TOWS scheme applied in the foresight project. *Following Weihrich (1982).*

Within the *Implications* step of our project (Table 2), we did the following: at first, we split up the entire project team into four sub-teams and assigned one of the following major types of aviation stakeholders to each of these teams: the full-service carrier (FSC), the low-cost carrier (LCC), the hub airport and the aircraft manufacturer. We then asked every team to put itself in the place of the assigned stakeholder and intuitively create an unstructured list of internal strengths and weaknesses with regard to the status quo situation (i.e. 2012) of the respective stakeholder (Figure 11, *Internal Analysis*) who are under the influence of the three major drivers we identified: global climate change, an increasing lack of natural resources and a growing demand for mobility (see section 2.2). We also made the teams derive stakeholder-specific opportunities and threats from each of the three elaborated future scenarios and put them into three different lists (Figure 11, *External Analysis*). We subsequently made them arrange their lists according to what they thought their more and less important findings were (Figure 11, *Listing and Evaluation*).

The actual strategy development process began in phase 2 (Figure 11, *Development of Strategy Options*) when we made each team work on the three scenario-specific TOWS matrices: for each scenario, they put the top opportunities and threats into the two side boxes of the TOWS matrix while the top stakeholder-specific strengths and weaknesses stayed the same in every matrix. By completing the four remaining central boxes of the TOWS matrices (Figure 11, boxes marked *SO*, *WO*, *ST*, and *WT*), the teams finally elaborated strategy options with the ultimate goal to find ways for the respective stakeholder to turn external threats into opportunities and internal weaknesses into strengths. Strategy options that seemed promising for more than one scenario (i.e. strategy options appearing in more than one of the three TOWS matrices) were then developed further (see section 4.2).

4.2 Strategy Options

As described in section 4.1, we focused on the development of strategy options for a generic full-service carrier, a generic low-cost carrier, a hub airport and a major aircraft manufacturer. In this section, we summarize the stakeholder-specific strategy options that proved applicable in all of the three scenarios (see section 3). Table 4 shows the developed TOWS matrix for the full-service carrier.

Table 4. TOWS matrix for a generic FSC.

	Strengths: • **Strong airline alliance network** • **Customer confidence**	**Weaknesses:** • **Expensive and complex business concept** • **High dependency on energy costs**
Opportunities: • **New, attractive market areas in emerging countries opening up**	SO • Maintain high customer service standard • Exploit new markets	WO • Focus on emerging markets • Introduce simplified ticket pricing philosophy
Threats: • **Increasing market penetration of competitors from emerging countries** • **Changing customer needs (trend towards individualization)**	ST • Strengthen the airline alliance (i.e. more airlines, larger route network) • Consolidate the alliance-wide business concept and customer handling	WT • Foster strategic cooperation with companies of the entire mobility chain (bus, train) • Optimize passenger handling processes

The TOWS matrix for the FSC together with the proposed strategy options reveal that the consolidation process of the airline industry will continue. Only strong airlines and alliances with a clear focus on the actual needs of their customers will be able to survive. High and volatile energy costs paired with a trend towards the individualization of customer needs will require a new level of cooperation between the ground- and air-based means of transport in order to optimize the door-to-door transport chain.

The low-cost carrier faces a similar situation, cf. Table 5. The strong dependency on energy costs together with an increasing price sensitivity of passengers puts the LCC under enormous pressure. The urbanization trend is another challenge since ground-based means of transport will cover an increasing amount of short distance travel routes in and around metropolitan areas. The LCC should therefore consider to become a part of an intermodal transportation system and connect rural areas with big cities. Evaluating penetration strategies to enter the long-haul market is a further option.

Table 6 presents the TOWS matrix for a hub airport. At first glance, with its monopolistic position (at regional level), the hub airport appears to be standing at a relatively stable position. But an increasing environmental consciousness of the society will require improved forms of communication between the airport and the local population that is directly concerned by airport noise and emissions. This will especially become important once it comes to the planning and realization of infrastructural expansion projects (runways, terminal buildings etc.).

Table 5. TOWS matrix for a generic LCC.

	Strengths: • **Experience in operational cost reduction measures** • **Clearly focused business concept**	**Weaknesses:** • **High dependency on energy costs** • **No or few long-haul routes offered**
Opportunities: • **New, attractive market areas in emerging countries opening up** • **Increasing price sensitivity of customers**	SO • Exploit new markets on regional level	WO • Focus on emerging markets • Analyze possibilities to offer more long-haul routes
Threats: • **Increasing market penetration of competitors from emerging countries** • **Urbanization**	ST • Focus on ticket pricing • Focus on niche markets at regional level	WT • Foster strategic cooperation with companies of the entire transport chain (bus, train) • Analyze possibilities to offer more long-haul routes

Table 6. TOWS matrix for a hub airport.

	Strengths: • **Non-aviation revenue stabilizes earnings** • **Monopolistic market position at regional level**	**Weaknesses:** • **Infrastructural adaptation or expansion plans difficult to realize** • **Dependent mostly on one strong airline alliance**
Opportunities: • **Urbanization** • **Changing customer needs (trend towards individualization)**	SO • Increase the variety of non-aviation offers (food, shopping etc.)	WO • Optimize city connections
Threats: • **New market areas in emerging countries opening up** • **Increasing environmental consciousness of the population**	ST • Offer expertise in airport planning for growing airports in emerging markets • Improve the dialogue towards the local population	WT • Foster strategic cooperation with other aviation and non-aviation companies of the entire transport chain • Improve the dialogue towards the local population

The major aircraft manufacturer benefits from his established market position and his profound expertise to develop, build and deliver airplanes to the market (cf. Table 7). However, the rise of competitors from emerging countries (particularly in the narrow-body segment) should make the aircraft manufacturer increasingly invest into R&D activities and foster corporate creativity to ensure his position as a technological leader. The emergence of new markets can be an attractive chance to build new production plants and to become less dependent on politics.

Table 7. TOWS matrix for an aircraft manufacturer.

	Strengths: • **Well-established market position** • **Profound expertise in aircraft design**	**Weaknesses:** • **Increasing product complexity** • **Company policy strongly influenced by politics**
Opportunities: • **New, attractive market areas in emerging countries opening up** • **Air traffic volume highly likely to grow**	SO • Foster creativity in product design and R&D activities	WO • Build production plants in new markets
Threats: • **Rising competitors in the narrow-body segment** • **Unstable financial sector**	ST • Consider penetration into new markets of the transport/mobility business	WT • Build production plants in new markets • Strengthen strategic cooperation with suppliers • Increase equity ratio

5 Conclusion

In the preceding sections, we have demonstrated how we used selected scenario planning techniques to support robust corporate strategy decision-making in the aviation industry.

With an interdisciplinary team composed of 21 members (both university students and experienced industry professionals), we went through six workshop days and elaborated three alternative future scenarios of the year of 2040 that contain statements both at a macro- and an aviation-specific level.

The scenario-based approach we have presented here proved to be an adequate method to support the understanding of complex interactions schemes between an aviation stakeholder and its environment and to assist creative and pragmatic thinking when making strategic decisions. In addition, the diversity of the three scenarios helped to extract robust strategy options.

The three scenarios of 2040, although intentionally designed to differ one from another, show some interesting similarities that are relevant for the aviation industry. The scenarios are all driven by the global climate change, an increasing lack of natural resources and a growing demand for mobility.

Other factors also play important roles: the urbanization and individualization trends will strongly affect future airline and airport business concepts. The increasing environmental consciousness of the society will play an important role in airport expansion. The emergence of new markets will pose both threats and chances to established companies of the aviation sector. And rising and volatile energy costs will require new technological steps to become less dependent from non-renewable resources.

The introduction of a truly seamless intermodal transport chain covering all travel segments from door to door will play a key role in the future success of the aviation sector. Here, the various players will need to learn to cooperate at a much more intense level than today. In this context, airlines will be required to focus stronger on serving long-haul routes since the ground-based means of transport will be able to operate more efficiently on short distances.

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