SCENARIO BASED AIRCRAFT DESIGN EVALUATION

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Abstract

It is becoming more and more difficult to work out future strategies for the aerospace industry characterized by long product development cycles in a very complex environment with considerable uncertainties about the development of relevant factors. The application of scenario planning in the aircraft design process can help on the one hand to get a useful set of requirements and on the other hand to evaluate design concepts in different scenarios and markets.

This paper will focus mainly on the scenario based aircraft design evaluation. Today's standard direct operating cost (DOC) methods can no longer be the one and only means to determine the competitiveness of a new project. Instead, the manufacturer has to prove, that a new aircraft concept reflects the transportation needs of the coming decades. Therefore, the importance of added value factors, i.e. factors other than economics or commonality, in an aircraft design evaluation process is increasing.

These factors and their future development can be considered in a scenario process. A method will be shown, how the design parameters and their relative significance in different scenarios are connected in a valuation approach.

1 Introduction

As aircraft manufacturers in the last decades have perfected their product strategies, the aircraft market in the segment of more than 100 seats has changed dramatically: whereas in the past several manufacturers offered quite different aircraft, today exist only two competitors which share the market almost equally and whose products hardly show significant differences technically as well as economically.

At least the next decades will be characterized more by an incremental evolution of aircraft design and operation than by revolutionary innovations and performance leaps. The sizing, stretching and shrinking of existing configurations will result in reduced production costs, low noise aircraft with cleaner, quieter engines, compliance with new regulations made with regard to societal demands and finally an increase in return on investment for both aircraft manufacturer and airline. As this trend will continue for the relatively mature conventional aircraft configurations, an aircraft designer already today has to foresee, which design characteristics finally still can achieve decisive competition advantages on the different future markets.

In this paper, the today's evaluation criteria will be explained and it will be shown, how scenario methods can help to create the decision base for a more robust design. A tool will be presented which is designed to implement the integration of scenario results in an aircraft evaluation process. The results of an evaluation example show, how this approach can be helpful already in the early phases of an aircraft design.

2 Design evaluation

The acquisition of an aircraft usually follows a detailed evaluation of the models which fit the requirements of the customer. In order to pass this selection procedure, the aircraft manufacturer has to evaluate his design critically against the requirements as well as against competing aircraft already in the concept phase. He should know the characteristics of the competitors exactly when starting an entirely new design. Consequently, he must be able to prove that his design can meet the future selection criteria and requirements of potential customers and that it has beyond that operational advantages compared to its competitors.

The evaluation of competing products usually turns on economical factors as seat mile costs versus range or technical factors as fuel burn and field performance. But as today, however, the differences between new designs and in production aircraft are so small, other criteria have to be considered as well, to win the fierce competition for an airlines purchase decision.

2.1 Design requirements

In general, the aircraft manufacturer runs an early market survey to identify air transport demands and operational issues concerning environment, air traffic control (ATC), regulations and airports. Based on this survey, a product idea will establish and an intensified analysis in the market segment will be run to determine a first set of requirements.

This initial design definition usually consists of seating capacity and importance of cargo, range and operating cost levels. Secondary issues in the set of requirements are performance and comfort standards, the number of engines, technology levels, infrastructure needs and commonality demands. Later in the pre-launch period, specific requirements of key airlines can be included in the set of requirements. The conceptual design leads to a geometric definition, an engine evaluation and special features.

Some ‘unquantifiables’ for the success of this new product during the feasibility phase are for example the image of a manufacturer, different future comfort standards, the development potential of the product and product support capability.

2.2 Classic evaluation criteria

The conceptual design as an approach to fulfill the given requirements is evaluated against its competitors. In the past, this aircraft evaluation was made almost exclusively from an economic point of view with DOC comparisons.

For the DOC calculation different methods exist, which correspond to the particular needs of aircraft manufacturers and operators. In the core however, all DOC methods consider the costs from acquisition and ownership, maintenance and operation. Result is a cost specification per standard mission (trip cost), per flight mile (aircraft mile cost) or per passenger mile (aircraft seat mile).

Typical technical factors considered in the evaluation of civil passenger aircraft are e.g. fuel burn, payload-range characteristics, the number of seats in a standard cabin layout, weights, freight volumes and flight performances. In contrast to the DOC calculation, the evaluation of these technical data gives not a single reference value, but a multiplicity of comparisons, which vary in their relative significance depending upon region and customer.

The increasing similarity in the economical and technical characteristics of new products consequently leads to similar DOC structures and performances for competing aircraft. Therefore, these criteria alone can no longer give a clear basis for an evaluation. Besides, the long-term advantages for the operator, which result from commonality or the application of new technologies, are not taken into consideration by DOC methods.

2.3 Added values

The current trend in aircraft evaluation is the additional consideration of commonality effects and ‘added values’, as they are specified by Dasa Airbus [1]. These are capability characteristics, which result in an economic advantage for an airline, but are not directly related to the DOC. Such factors are for example cabin comfort aspects, operational flexibility, compatibility with the infrastructure or environmental viability. The economical surplus value for the operator manifests in an increase in utilization, load factor and customer acceptance, lower costs for crew, maintenance and transition, smaller crew load and environmental fees, a higher residual value and better product support.

In contrast to the purely economic and technical evaluation criteria, in the field of added values sometimes significant differences can be found between competing products. In addition, the relative importance of these factors may change dramatically in the future as operation responds to new market needs. Cabin comfort may serve as an example: in the last years, airlines put their efforts on increasing load factors to thus fully utilizing their capacity. As a result, passengers have become much more conscious of crowded flights and accordingly of relative comfort across different airplanes. Being criticized of shortcomings in this area, airlines will have to renew their focus on passenger comfort, at least for high-paying business customers.

Already today, the relative significance of added value factors depends strongly for every region and every airline. With regard to its future development, a high degree of uncertainty can be seen.

3 Scenario methods in aircraft design

How the factors which characterize today's air transport industry will merge to create the world of tomorrow is impossible to predict with any certainty. The examination of future developments is subject to the important principle that the future cannot be known. Answers to questions concerning future developments can be given in the form of hypotheses or assumptions only.

The uncertainty of future developments with regard to economical, technological and political factors is increasing all the more, the more we look into the future. In such a situation – coming to a decision a long time ahead with sometimes considerable uncertainties about the development of relevant factors – scenario methods offer a pragmatic way to limit the uncertainties, and to work them up methodically, in order to derive recommendations for action which are comprehensible, plausible and systematic [2].

For this, a complex analysis is needed to structure the task and the relevant influencing factors precisely, and this is the goal of scenario processes: complex problems are seized systematically, the mutual influences and networks are analyzed and finally the consequences are reflected. The results are a staging of alternative future worlds, a description of the events leading to these worlds and a definition of the driving forces in these systems. It is necessary to get an idea of the environment to expect which is plausible enough to use it as a base for cost-intensive strategic decisions like the go ahead for a new aircraft concept. Scenarios help to think in alternatives and thereby to think 'in store'.

3.1 Scenario levels

There are essentially three different levels of scenario implementation in aircraft design, see Figure 1:

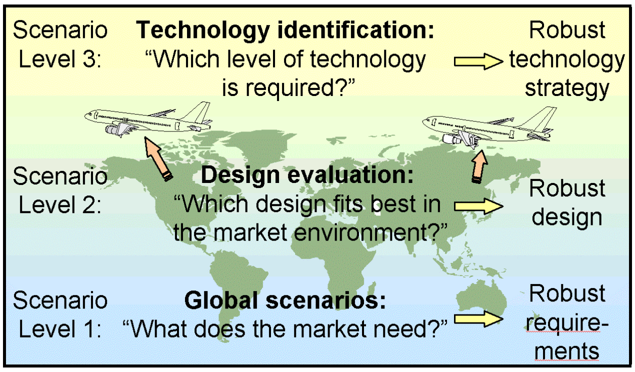

Figure 1: Scenario levels in aircraft design

The first level regards in a 'top down' approach different scenarios in different markets and gives as a result the requirements as an input for the design process. This definition of the markets needs does not differ from the traditional approach described in chapter 2.1, but as different alternatives in the future development are considered, the result may be a more robust set of requirements.

The second level evaluates the resulting design concepts ‘bottom up’ in various future markets. The alternative design concepts fit more ore less in the possible environments of key markets and therefore the most promising concept has to be identified in this step. As the concept hast to consist not only in a prognosticated environment of a key market, but in addition in its alternative developments, the robustness of the design will be improved.

Political regulations – very often environmentally motivated – and operational fees from airports and ATC can stimulate the introduction of new technologies, giving economical advantages. Therefore, in the third scenario level, appropriate technologies for an inclusion in the new or modified design concepts are selected and, as resources usually are limited, market-driven research priorities are defined. A good technology choice has the potential to succeed in a variety of potential future markets, whose priorities are resolved in the first two scenario levels. The robust aircraft design concepts are subsequently analysed in order to identify core technologies across a range of products [3].

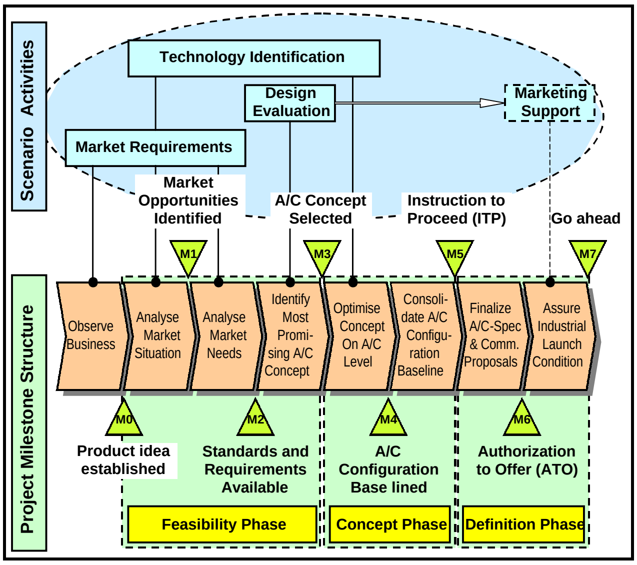

Figure 2: Scenario activities and ACE milestone structure

These basic considerations can be assigned to the milestone structure as it is defined in the Airbus Concurrent Engineering (ACE) project [4], see Figure 2.

Before M0, the business in general is observed to identify market opportunities and to initiate a new project. A refined market analysis follows between M0 and M1, including a first feedback from the customer. At this stage, not only the airlines’ needs have to be analysed, but also the development of the infrastructural, economical and political situation. In different degrees of refinement, this process corresponds to the outlined scenario level 1.

Scenario level 2 will take place between M2 and M3, where the results of a preliminary design process are evaluated in order to identify at this early stage the most promising aircraft concept. This concept will then be sized in trade-off studies in the following optimisation process.

Technology requirements, as they can be derived in scenario level 3, are identified mainly in the feasibility and early concept phase. Technologies will be introduced to a certain level, which allows a market-orientated definition of a competitive new product and guarantees a return on investment for the manufacturer as well as for the airline. Unexpected costs and risks have to be evaluated carefully and the technology readiness level has to be assured. A decision on service readiness for new technologies has to be taken at latest in the definition phase and at this point, the level of advanced technology for the project has to be frozen.

An additional use of scenario results can be seen after the authorization to offer (M6): as product success is tied closely to the marketing strategy, the evaluation results have to be communicated to the marketing organization, where arguments from different scenarios are used to respond to particular customers’ needs.

3.2 Scenario based evaluation

Varying results of an aircraft evaluation are much more related to the market environment in which a particular airline will operate than to any inherent economic differences of competing designs. And it is exactly this airline environment, which is worked up methodically in a scenario process.

In different market environments the relative significance of the various evaluation factors will change in the view of an aircraft operator. A scenario based design evaluation therefore has to connect market drivers with design parameters by the means of adapting the relative criteria significance to the alternative future worlds. Like for most valuation approaches, design data and criteria definitions first have to be set, but instead of reckoning them up in a fixed scheme, the criteria weighting will change for every scenario. Result is a set of evaluations, which show strong and weak points of a design concept in different future worlds. A deeper analysis of the evaluation results will show across a range of markets, which design characteristics to keep and which to improve.

This scenario based aircraft evaluation process can complement the standard comparisons. In addition, with inclusion of the third scenario level, a recommendation for the long term orientation of technology research programmes can be given. This leads to a competitive new generation aircraft design with improvements for example in ground and flight operations, mission flexibility, noise and emission characteristics and economics.

4 Evaluation tool

In this chapter, an evaluation tool is described, which is derived from approaches of Dasa Airbus to quantify added values [1] and from DLR to rank aircraft alternatives [5]. Though DOC have a major significance in this evaluation method, additional factors are considered as well to a high degree and may change the evaluation result compared to a pure DOC calculation.

As the tool is intended to serve in the early stages of aircraft design, only factors are considered which are related to the manufacturer and his product while those are ignored which are related to a specific airline and its operation. This refers for example to those passenger comfort aspects which are only affected by an airline's cabin interior design and not by the aircrafts geometrical cabin characteristics. Commonality – though being a decisive criterion – is another aspect which is almost not considered in this evaluation approach, as it reflects more an airline's fleet mix than the savings potential of a specific design.

The valuation routine will be explained in the following and an example will demonstrate method and results.

4.1 Description

The design parameters are identified which are related to the market drivers and which can be used in a scenario context. The relative significance of these parameters will change for different regions and airlines in every scenario.

In general, the evaluation factors can be classed in three groups:

- Performance characteristics like payload capability, airport compatibility and flight performances for take-off, climb, cruise and landing.
- Economics and added values other than performance, covering all DOC components, aircraft related passenger comfort, freight flexibility and the manufacturer's image and strategy.
- Environmental characteristics, i.e. noise, emissions and disposal costs, which are of no further interest today, but might be in some future scenarios.

Most of these factors are subdivided more precisely, like for example cruise performance, consisting of cruise speed, max speed, max certified altitude and max range.

In view of the evaluation process, all factors can be divided in three categories: monetary factors, expressed as money unit per trip, technical factors, given in physical and/or measurable units and finally subjective factors, which cannot be seized with a measurable value, but with a subjective 'mark' for example on a scale from 0 to 10.

The aim of the tool is to combine all evaluation factors to a single reference value, which can be compared to other designs. In this tool, an 'equivalent value per flight' is calculated, and could be measured on an abstract scale. In our case, the unit [$/trip] has been chosen, which is very familiar to every user, but which should not be confounded with an absolute economical value.

The valuation routine needs a set of input data, which are stored in a data base and specified briefly in the following.

4.1.1 Aircraft data

The general aircraft data cover designation, manufacturer and cell price. For engine installation, general data are recorded as well as technical data, e.g. pressure and bypass ratio, thrust and specific fuel consumption, which are needed for the determination of DOC. Basic technical data, number of passengers in a standard layout, max take-off weight and operating weight empty are used in the cost calculation and, in addition in the calculation of flight performances. Flight performances consider payload-range characteristics, typical cruise or max airspeeds and altitudes, take-off and landing distances and minimum landing speed.

The section for cabin data covers cabin dimensions, a subjective value for cabin flexibility and comfort data like over-head bin volume and interior noise. For cargo transportation, cargo volumes and/or types and number of containers are entered. Only subjective values are taken for the manufacturer’s image, his product support organization, a possible family concept for the new design and its development potential in general. Environmental factors finally cover noise values for take-off, sideline and approach, a quantification of emissions and – taking account of possible future developments – disposal costs.

Some evaluation factors correspond directly to the input data, others have to be calculated from the given data. For a reasonable comparison of competing designs, the use of consistent aircraft data sets is of particular importance at this point.

4.1.2 General factors and scaling functions

A second set of data includes all non-aircraft related factors necessary for the DOC calculation like salaries, fuel price, interest rate etc. In addition, data are stored to determine the revenue potential of a new design. These are for example weights of passenger and luggage and fares for different range categories.

To combine all factors with different dimensions to a single value in the end, they have to be normalized at first. A scale from -1 to 1 is employed here, which has to be defined individually for each criterion. The higher the normalized value is, the more the criterion will be considered in the evaluation.

To define the scaling function, a minimum and a maximum value are proposed for a specific criterion. Values above or under these limits will result in a 1 or -1 respectively. Cabin height may serve as an example, see Figure 3: If this measure is 6,5ft or less, no passenger will feel comfortable at all. An increasing height will be perceived as more and more comfortable up to a height of 8,5ft in this example. But more cabin height than this will no longer improve the perception of comfort, as a standard passenger will never reach that high.

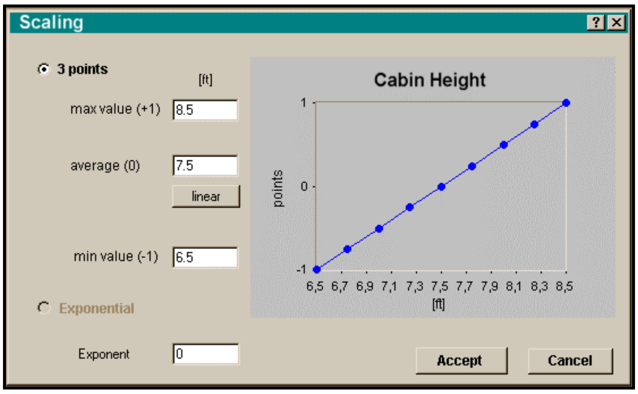

Figure 3: Scaling Example

As shown in Figure 3 on the left side, scaling functions can be composed linearly with two gradients out of three points, defining min, average and max value. Some criteria like speed and range can be scaled alternatively with exponential functions. Already this example shows, that it is a complicated task to determine a meaningful value range for all aspects considering performances, comfort and environment. And moreover, the scaling function for a particular criterion may change in a scenario differing from the today’s trends.

The marks for subjective factors are transformed numerically from a 0 to 10 scale to a -1 to 1 scale, and from a 0 to 5 scale to a 0 to 1 scale respectively.

4.1.3 Relative criteria weights

Not all design features considered in this method have the same significance in an evaluation. DOC for example today and still tomorrow will weigh much higher than airport compatibility. Moreover, the relative importance of evaluation criteria varies for every airline and every region. Therefore, a third set of data contains the scenario dependent criteria weights.

All factors considered in the valuation routine can be adapted to the relative significance as given by a scenario, summing up to 100%. Table 1 gives an example, where the first level of refinement with performance, economics/added values and environment can be seen as well as a second level, specifying these three basic elements. A further, more detailed subdivision is done for most factors, as explained already above.

The today's weight structure can be obtained by market surveys and in direct airline contact, but as the weighting procedure has a significant influence on the evaluation result, these values have to be determined carefully. For any scenario, the changes in air transport environment have to be translated in a new weight structure, reflecting the needs of the new market situation.

4.1.4 Valuation process

Having prepared all necessary input data, the valuation routine can be run (Figure 4). A comparison, saved as a fourth data set, consists of up to three chosen aircraft designs, a set of scaling functions, a set of relative weighting and a study range.

In a first step, DOC are calculated for the given study range with a conventional DOC method. The revenue potential (RVP) as a second monetary criterion is determined as a function of passenger and freight capacity, fares and payload-range characteristics. The difference of revenues and operating costs can be read as a 'real value per trip' [$/trip].

Technical and subjective evaluation factors are scaled in a second step as explained above and multiplied each with their relative weight. The scaled and weighted factors can be added and transformed to an 'equivalent value per trip' [$/trip].

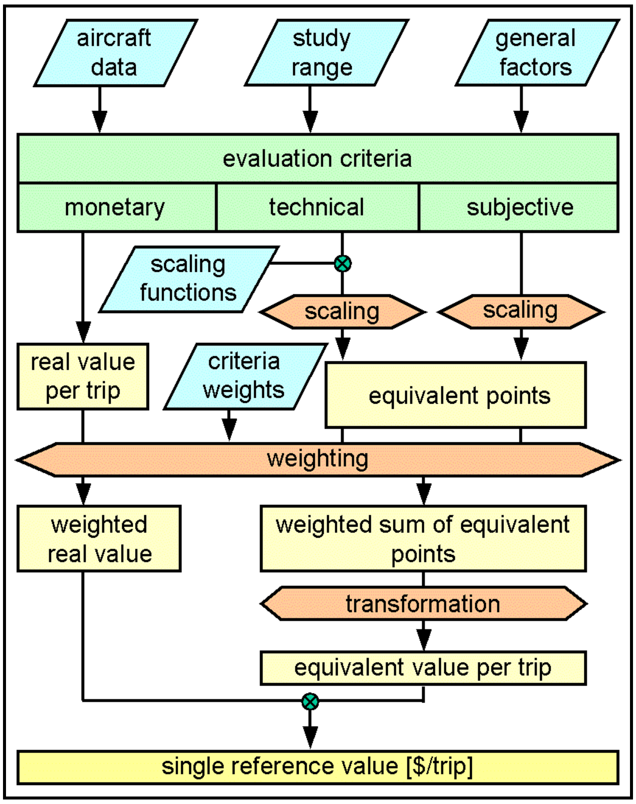

Figure 4: Valuation process

A single reference value, the aim of the evaluation, can finally be obtained by adding this 'equivalent value per trip' to the weighted 'real value per trip'.

4.1.5 Results

This single reference value is not the only result obtained from the enormous amount of input data. A series of results is given numerically and graphically: the reference value is given for the compared aircraft as an absolute and a specific value per revenue passenger mile (RPM). In addition, the equivalent values for the three factor groups performance, economics/added values and environment are shown. In order to compare the results to other evaluation methods, DOC and RVP are given with their absolute, non-weighted value as well.

The equivalent value per trip or per RPM for every evaluation factor as explained in chapter 4.1 can be edited graphically, comparing the competing products. In this way, specific advantages and disadvantages of a design in a certain scenario can be identified easily.

As the tool description is very abstract to a certain point, an evaluation example may help to understand, how aircraft data and scenario results are composed to a scenario based aircraft evaluation.

4.2 Example

In 1999 we held an air transport scenario course with students and experts of Dasa Airbus entitled 'Flight Unlimited 2015 – how to avoid operational limitations for large civil jet aircraft' [6]. It was the goal of this scenario process to clarify what should be done by the actors in the air transport system in order to avoid future operational limitations. In the field of air transport for example environmental factors like noise, emissions, energy consumption, land use, safety and the economic impact of air transport were examined. The risk of operational limitations on airports for example can already be reduced in the concept phase of an aircraft design as dimensions, weights, pavement loads, turn-around times, wake vortex staggering or approach procedures can be influencing factors. An analysis of the interactions of these factors gave a range of possible scenarios from which a set of four consistent futures had been chosen.

4.2.1 'Trend'

A trend scenario was developed which is characterized by air traffic being a consumer good, supported by world-wide economic stability and a continuous desire for mobility. Air traffic growth is moderate with 2-4% p.a. for passenger transportation and 3-6% for cargo.

The acceptance of air traffic in general is fairly good, as aircraft are perceived as modern and safe. Nevertheless, public acceptance varies by region and the ecological impact of aviation is the main source of criticism. Especially on short and medium haul routes, the attractiveness of alternative transport means remains.

Though airport and ATC fees increase, airline yields increase, as operating costs, and especially fuel prices in this scenario remain constant. In addition, alliances prove to operate economically.

Airport and ATC infrastructure follow demand with a considerable delay and turn out to be the weak link in the air transport industry.

As a consequence of the limited availability of funds, the development potential of new technologies in air transport is not fully exploited. Alternative energy supply is not yet viable.

4.2.2 'Peace, Love & Congestion'

A different picture is drawn in 'Peace, Love & Congestion' (PLC): world-wide political and economical stability is the base for a strong economical growth with an increasing desire for mobility. This leads to a strong growth in air traffic with growth rates of 5-6% p.a. for passengers and up to 10% for cargo.

In the economically sound industry, funds for financing new aircraft technologies are available and the development potential of new technologies starts to be exploited. Even alternative energy sources will be used limitedly.

But due to the strong traffic growth and the limited land availability for airports, their capacity reaches its limits on the airside as well as on the land-side. Together with the increasing turn-around time for ground handling, this leads to a collapse of airport infrastructure.

4.2.3 'Home Sweet Home'

A pessimistic view of the future of air transport is given in the scenario 'Home Sweet Home' (HSH): transport policies and regulations are orientated regionally and mobility is decreasing. A difference in passenger traffic with growth rates less than 2% p.a. and freight activity with more than 6% can be seen.

Air transport lost its public acceptance, as it is no longer attractive for traveling while cargo business is growing with a continuously moderate economic growth. But as a result of the decreasing mobility, alternative transport means have the same acceptance problems.

Due to operational restrictions and an increasing turn-around time, airport capacity reaches its limits. New technologies in air transport are not exploited for the same reasons than in the trend scenario.

4.2.4 'Air TraffiXXL'

In contrast to HSH, 'Air TraffiXXL' (XXL) shows a very optimistic view of the future with regard to public acceptance: with an increasing desire for mobility, acceptance is ensured and moreover, the image of air transport is positive. Passengers even accept the high ticket prices. Air traffic grows strongly with more than 4% p.a. for passenger transportation and more than 6% for cargo respectively.

In spite of increasing fuel prices, airlines operate with profits and therefore, funds for exploiting technological development potential are available in the air transport industry.

Only infrastructure capacity is double-edged: due to the strong growth in passenger and freight volume, airport landside capacity reaches its limits while the technologically advanced ATC infrastructure can cope with air traffic demand.

4.2.5 Relative criteria weights

The four different worlds described above entail a different relative significance of the evaluation criteria as explained in chapter 4.1.3. Flight performance for example will be an important factor in any scenario, which is characterized by a restricted airside capacity of airport infra-structure.

	Trend	PLC	HSH	XXL
Performance	**16,0%**	**21,5%**	**17,6%**	**18,8%**
Payload	6,0%	7,1%	5,4%	7,1%
Cruise	4,0%	5,2%	5,0%	4,9%
Landing, take-off	2,0%	2,6%	2,5%	2,0%
Climb	2,0%	3,3%	2,6%	2,0%
Compatibility	2,0%	3,3%	2,1%	2,8%
Econ./added values	**74,0%**	**66,0%**	**70,9%**	**71,5%**
DOC/RVP	43,0%	36,1%	39,0%	36,7%
Comfort	14,0%	11,5%	15,1%	14,3%
Freight flexibility	6,0%	7,1%	6,7%	7,6%
Manufacturer	11,0%	11,3%	10,1%	12,9%
Environment	**10,0%**	**12,5%**	**11,5%**	**9,7%**
Noise	6,0%	6,5%	6,3%	5,7%
Emissions	4,0%	6,0%	5,2%	4,0%
Disposal	0%	0%	0%	0%

Table 1: Scenario dependent relative criteria weights

Table 1 shows the result of a transforma-tion of the four scenario characteristics in percentages reflecting changes in the evaluation criteria's relative importance. The weighting schemes in this example correspond to typical European scheduled operations and are just given to illustrate the evaluation principles.

4.2.4 Evaluation results

Two different short range 120-seater designs – a reference aircraft and a competing new design, both shrink derivatives – will be evaluated in this example with the different sets of criteria weights given in Table 1. Some of the results with significance for design parameters will be shown in the following.

The scaling functions first have been adapted to short range operations and a study range of 800 nm has been set. For each scenario, a calculation has been run with the given criteria weights. Table 2 shows the scenario dependent scores for the new design as a result of the scaling and weighting procedure:

	Trend	PLC	HSH	XXL
Reference value	**24900**	**24334**	**23781**	**24038**
Performance	**3899**	**5024**	**3890**	**4695**
Payload	2346	2776	2112	2776
Cruise	152	169	169	217
Landing, take-off	691	896	867	691
Climb	-41	-68	-54	-41
Compatibility	751	1250	796	1051
Econ./added values	**17493**	**15026**	**15918**	**15952**
DOC	-3055	-2565	-2771	-2608
RVP	16815	14117	15251	14352
Comfort	1094	1039	1241	1319
Freight flexibility	-1115	-1319	-1244	-1413
Manufacturer	3754	3754	3441	4302
Environment	**3508**	**4284**	**3973**	**3390**
Noise	2346	2542	2464	2229
Emissions	1161	1742	1510	1160
Disposal	0	0	0	0

Table 2: Scenario dependent evaluation results [$/trip]

An analysis of the results will focus at first on the trend, where weak characteristics in the design will result in low values for a specific criterion. But in addition, the performance of the design in alternative future developments can be analysed in order to cover deviations from the trend. Climb performance for example may seem sufficient for the requirements in the trend scenario, but the results in scenarios with infrastructural problems at the airport's airside indicate, that an improvement of the design's climb rate should be taken into consideration.

As the design is evaluated against a competitor, the next interest will focus on a comparison, which is given graphically for all evaluation criteria. In Figure 5, the overall results for the trend scenario are given as an example.

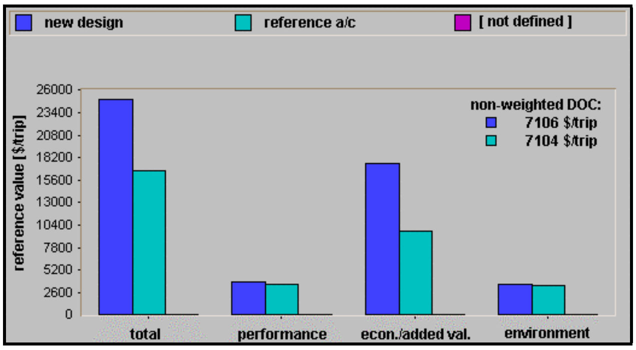

Figure 5: Evaluation results for new design and reference

The new design can compete against the older generation aircraft, offering above all more comfort, while the pure DOC are almost equal with about 7100 $/trip, due to the higher acquisition cost. But the gaps in performance and environmental characteristics may be too small in this example and have to be analysed more deeply, for the trend scenario as well as for the alternative future developments.

5 Conclusions

One problem in the method shown above is the determination of the relative significance of all evaluation criteria for a given trend as well as for alternative scenarios. But as the 'delta' in the results for different aircraft is compared, the tendencies in the evaluation are always reflected correctly. By this means, the design criteria can be identified, which set up the success of a new design.

In general, a major problem of scenario processes is the translation of 'soft' scenario results in 'hard' facts needed in an engineer's environment. The usefulness of this translation depends to a high degree on the skills of the scenario team and cannot be calculated, but has always to be the result of a straightforward discussion. This is one of the characteristics of scenario processes in general.

As a consequence of integrating product strategy, customer requirements and research & development in a series of scenario processes as proposed in this paper, the probability increases to have the 'right' product at the end. A meaningful factor for the success of this new product is timing and accordingly the process of accurately accessing changes in airline fleet strategy and needs.

An understanding of real market requirements and opportunities is absolutely necessary before starting a new project, especially with regard to the uncertainties in future developments. As this phase of analysis and planning should take up to two years for a successful project, the time required for a series of scenario processes should be available and will lead to a deeper understanding of the market needs. Scenario planning is an appropriate method to evaluate the long-term viability of current design studies or technology investments in the early design phases.

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