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Christoph Winter
Uniwersytet Ekonomiczny we Wrocławiu

A WAY TO IMPROVE PROFITABILITY OF REVOLUTIONARY CIVIL AIRCRAFT PROJECTS

Summary

Revolutionary new civil aircraft projects often struggle to amortize the investments made. The starting point is: reduction of risk of costs overruns (difference between actual and planned cost) and consequently aligned further variables of investment calculation would increase profitability of a project if it is implemented at all. That means, if project volume could be predicted more precisely, project´s appraisal could either assume more realistic parameters, like with aircraft pricing or reconsider the project with regard to technical content or market conditions. This questions the efficiency of presently applied planning and investment calculation methods to yield a realistic business case of a "revolutionary" new aircraft.

The paper verifies the problem by comparing list price changes of revolutionary aircraft projects (Airbus A380, Airbus A350 and Boeing B787) over time with those of legacy aircraft projects in search for anomalies correlated with significant cost overruns.

As a second step, this paper proposes an approach to overcome above deficiencies combining a dedicated parametric estimate model (CER) to determine project volume for future aircraft projects with a verified parameter setting in investment calculation of those projects.

The model uses the degree of new technologies applied (Technical Complexity, TC) and the number of countries, suppliers and final assemblies (Organizational Complexity, OC) as independent variables in order to reflect the revolutionary character of the projects analyzed. As a result, the approach meets the requirements of application in practice and is likely, when applied, to improve investment decision making.

Key words: investment efficiency evaluation, cost overruns, risk, parametric estimate, very large scale projects, aircraft

JEL Codes: F23, G12, G32, L62, L93, O32

List of Acronyms:

CAPEX	Capital Expenditure
CER	Cost Estimate Relationship
CFC	Carbon Fibre Composite
CPI	Consumer Price Index
DOC	Direct Operating Cost
ER	Extended Range

IRR	Internal Rate of Return
neo	New Engine Option
NPV	Net Present Value
OC	Organizational Complexity
R&D	Research & Development
TC	Technical Complexity

Introduction

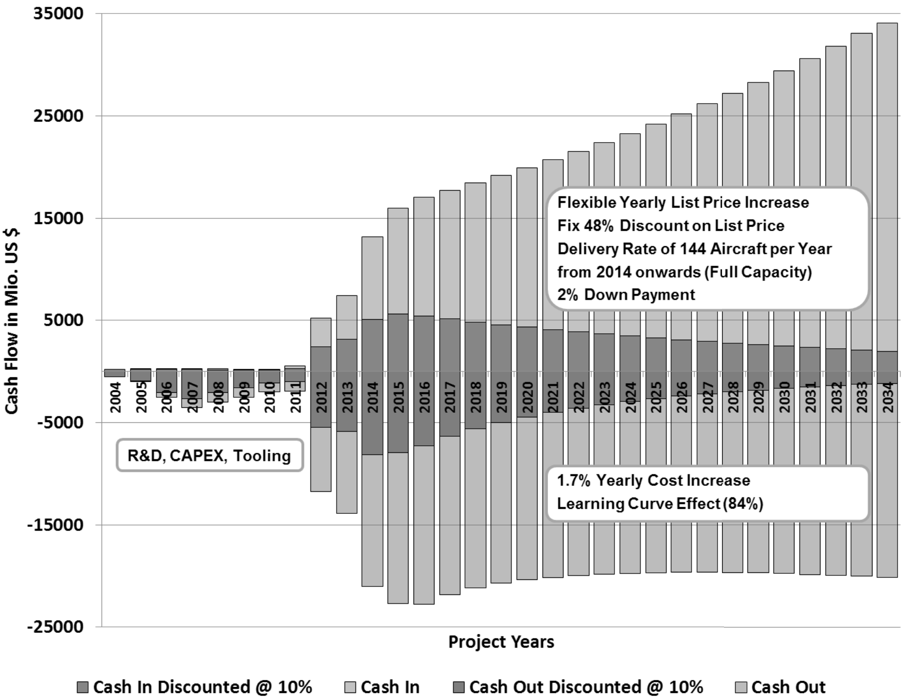
From 2000 until 2016, some new civil aircraft projects which entered revolutionary new technical terrain (total size, A380 (*Creating a Titan* 2005), structure made mainly of CFC, A350 (*Taking the lead…* 2006) and B787 (*About the 787…* 2013)) became not only notorious for cost overruns but also caused severe doubts if they would ever amortize the investments made. The reasons were mainly traced to experienced cost overruns generated during development and following production preparation until Initial Delivery. Apart from being a financial burden to the aircraft manufacturers, their investors and financiers (private or public) are also affected. Since a successful aircraft industry is still of interest to relevant nations (Harrison 2011), reliable figures of new aircraft projects are of public interest especially when public loans are granted (Reinhardt 1973, pp. 821–838). As such, projects are the result of an investment decision. The question was if an inaccurate estimate of the development effort (this includes all effort until Initial Delivery) could be actually the cause for the struggling business case. If yes, what would be a solution to improve estimate of development effort and how could this improve the project business case? As a consequence, presented research served to verify the cause and effect combination of estimated development effort and a negative business case of the aircraft project as well as to develop and verify a dedicated solution model.

The scientific problem behind was approached by analyzing the investment calculation of a civil aircraft project, its parameters and their degree of uncertainty. There are some specifics associated with the production and selling of civil aircraft. There is a long, open production period and thus a long selling period with an unknown total number of aircraft produced. In addition, the time between ordering and delivery is often years. In consequence, there is a significant uncertainty with regard to total production volume (numbers), production rate per year as well as total revenues, revenues per year and total cost as well as cost per year. That is why, per default, it is difficult to set up a reliable business case. At the same time, investment costs are very high and the economic success can be vital to an aircraft manufacturer.

In order to get a detailed understanding of the relevant variables of an investment calculation of civil aircraft projects, a typical cash flow profile of an aircraft program was generated which is shown in Figure 1.

Theory

Figure 1. Generic Aircraft Project Cash Flow Using Key Data of Boeing 787



Source: Author's calculations based on Internet articles on B787.

It is basically generic but in order to achieve a realistic magnitude of cash flow, Boeing´s B787-8 Dreamliner program key data was used for most of the parameters. The Dreamliner program was launched in 2004 with initial delivery seen in 2011 (*Boeing 787…* 2014) and an assumed production until 2034 according to 2015 Boeing Market Forecast (Tinseth 2015). For this generic example no technical upgrades were assumed. After a ramp up period (actual B787 deliveries between 2011 and 2015 according to Boeing), a constant delivery rate of 144 aircraft (12 per month) (Trimble 2015; Tinseth 2011) was assumed which was covered by the market forecast, too. Further, it was assumed that delivery rate equals production rate – thus no inventory would be built up. With regard to aircraft prices, the list prices according to Boeing were used until 2016, for deliveries beyond, the average yearly price increase between 2011 and 2015 (price increase for 2016) for a B787-8 aircraft (4%) was extrapolated until final delivery. Other variants (B787-9 and B787-10) were not included.

As usually high discounts are granted to aircraft customers, an orientation for B787 aircraft discounts of 48% (Fontevecchia 2013) was assumed for all aircrafts sold, not considering the usual changes in discounts over an aircraft′s production life span.

Furthermore, in order to limit complexity, it was assumed that customers pay for their aircraft the price of the year of delivery including discount. Finally, a 2% (Ausick 2015) of the actual price paid per aircraft was added to Cash In as down payment due when the order is being placed. With regard to Cash Out, during the early years of the program, main expenses are owed to Research & Development (R&D), Capital Expenditure (CAPEX) and tooling investment. Boeing spent approx. $16bn on these items until 2010 (Gates 2011). This volume was distributed generically over the years 2004-2010, assuming a steep ramp-up at the beginning and a flat dipping over the following years, as with reducing development effort, production investment increases. Assuming that it would not change the key results of the analysis, a discounting of the yearly development effort had not been done. Since initial aircrafts require much more effort to be manufactured and thus cause the greatest cost to manufacture per unit, $310mn was assumed as a rough estimate of the cost of each delivery in 2011 (Irastorza 2011).

The production of all following aircrafts sees improvements and productivity increases which lead to cost reductions. This learning curve effect was considered with a learner of 84% which Boeing could achieve with the B777. Since cost also change over time, this was considered by escalating the cost of 2011 by the average US CPI from 2011-2015 (*Consumer Price Index…* 2016) (1.7%) on a yearly basis until 2034. In addition to the actual cash flow of each year (light colors) which allows to calculate the Payback Period of the project, the Discounted Cash Flow was added (dark colors) starting from 2005 (first year discounted) in order to evaluate the program from an investment perspective using Net Present Value (NPV) and Internal Rate of Return (IRR).

For the applied discount rate, it was referred to Airbus′ target of 10% (Nietfeld 2013) which matches with Cost of Equity in 2013 for Boeing (9.11%) and Airbus (7.44%) as well as Cost of Capital in 2013 of Boeing (7.22%) and Airbus (7.00%) (Dutta-Roy 2014).

Figure 1 indicates clearly that an aircraft program faces high expenditures during its early years due to investments in R&D, CAPEX and Tooling while there are only small down payments on the income side. Even after deliveries have started, it takes several years until learning effects have reduced cost that much that they equal aircraft prices (break-even) and allow for a positive Cash Flow with succeeding deliveries. In Figure 1 break-even is reached in 2021. When it comes to evaluating the profitability of the program and thus if the project would meet the expectations of investors, a simple comparison of total Cash In ($514,272mn) versus total Cash Out ($-470,875mn) yielded a surplus and the investment seemed to be profitable although its amortization would have only be reached after 27 years!

Since financial resources invested also come with a price (time value of money), profitability of the program had to be recalculated with discounted Cash Flow.

Discounted Cash In ($82,958mn) plus Discounted Cash Out ($-99,586mn) yielded a negative NPV; thus the generic program was not profitable at the given discount rate and only yielded an IRR of 3%. The reason is shown in Figure 1. The high expenses during the early years of the program and the higher cost of the early aircraft produced contribute much more to NPV than the higher revenues in later years. That means that the variables influencing the early years of an aircraft program have a higher impact on cash flow profile compared to the variables influencing the later years.

When an investment decision is to be made whether to start a certain aircraft program or not, values for the above mentioned variables have to be assumed. The uncertainty of the variables along with their potential impact constitutes the risk of the investment appraisal. Therefore, the risk elements had to be evaluated in order to estimate their influence and how difficult it is to make predictions and thus to identify the residual risk. The consequences of these risk elements is that repayment would be shifted significantly to the right, worst case, it would be beyond aircraft end of sales. Then, the project would never see any profits.

R&D, CAPEX and Tooling

As capital investment and tooling investment is mainly a matter of planning, uncertainty with regard to cost rests mainly with uncertain development effort (technical and organizational problems) depending on the complexity of the planned aircraft project. It has to be distinguished between evolutionary updates of successful legacy aircraft (e.g. A320neo (*The neo…* 2016) with a **n**ew **e**ngine **o**ption or B737 Max (*Boeing Introduces…* 2011) and revolutionary new aircraft projects featuring e.g. significant different new cruising speed (Boeing Sonic Cruiser (Norris 2003)), new passenger capacity (A380) or new manufacturing technologies (A350, B787). The technical as well as market risk is naturally smaller with evolutionary projects compared to revolutionary projects. In addition, the development effort and thus cost of revolutionary concepts is significantly higher although this is relative as initially revolutionary concepts become evolutionary improvements with later aircraft models (Fehrm 2015). As shown in Figure 1, development cost have a significant influence on profitability of an aircraft project since high Cash Out during the early years contribute significantly to NPV.

Consequently, a precise estimate of development cost is very important because in case of negative NPV (and unchanged Discount Rate) either the project would be abandoned or it would be postponed until the boundary conditions allow a profitable business case. Alternatively, it would allow to adjust other parameters (e.g. list price, discounts) in order to improve investment calculation variables.

Cost Increase

Uncertainty with regard to production cost results from possible changes in cost of e.g. material, labor, tools as well as changes in e.g. regulations, taxes or exchange rates. Since aircrafts are traded in US $, producing or sourcing outside the US increases risk of aircraft manufacturers due to changing exchange rates. Since the application of escalation formulas in aircraft procurement contracts (considering e.g. aerospace materiel and labor costs as well as US Dollar/Euro exchange rate (*Airbus erhöht…* 2011)) and foreign currency hedging reduces risk of those cost increases, the relevance of this parameter for an aircraft investment decision was regarded as rather small.

Learning Curve Effect

The Learning Curve Effect describes the increase in productivity with growing experience and production improvement over the number of units produced. Therefore, it is essential to learn fast in order to reduce production cost. A small learner (e.g. 0.9) and high initial production cost increase Cash Out. However, as clearly indicated in Figure 1, the impact on NPV is still limited as improvements are soon reduced to marginal level, especially with high production rates. In addition, the value added provided by Airbus or Boeing has decreased over the years. For example, for Airbus it came down from originally 40% to 20% with the A350 (Hegmann 2013). As a consequence, the aircraft manufacturers have a limited direct control over production cost but also a limited risk with regard to cost overruns providing dedicated contract agreements.

List Price

Aircraft list prices released by Boeing or Airbus are average prices as there are many options to customize the planes (*Airbus List…* 2005; Leighton 2010). Apart from that, the determination of aircraft list prices is mainly influenced by development and production cost, the list prices of comparable aircraft of competitors or own company and the pricing policy but they have no relevance to market forces or the competition (*Airbus "Discounting"…* 2007). The list prices, in principle, are calculated by taking the estimated production cost and adding a share of the development cost based on the assumed minimum number of aircraft to be sold (Ordrich 2015). The resulting list prices should be within the range of comparable aircraft of competitors or of own product family as otherwise customers would prefer alternative options. Consequently, stretching development cost recovery over more units to be sold leaves room for discounts. This again stresses the importance of high numbers of aircraft to be sold as well as an accurate forecast of development cost. The pricing policy of an aircraft manufacturer definitely influences initial list prices (Ostrower 2011).

An indication for the impact of pricing policy on later deliveries would be a deviation in price adjustment compared to other aircraft of the same manufacturer because the increase in list prices is largely independent from market pressures. Price adjustments (rises) are more a function of specific formulas and indices relating to aircraft manufacturing (*Boeing erhöht…* 2009). Most aircraft purchases are subject to escalation such that the base price on signing of the contract will be subject to inflation or escalation at the time of delivery. Consequently, a long delivery schedule may see a significant increase over the original purchase price, particularly if escalation exceeds normal inflation. A change in basic specification of the aircraft may also lead to rises in list prices. Equipment that was originally considered an option may be included as standard. In addition, the purchase price could also include pilot training, product support or spares provisioning (*Airbus List…* 2003). Although hardly any customer is paying list prices, they constitute a starting point for price negotiations.

Discount on List Price

Discounts on list price had to be approached from two sides, aircraft manufacturers and customers, as it is the result of negotiations between both parties. Aircraft manufacturers can identify some potential for discount by remodeling their redemption scheme or promote productivity increase thus bringing down production cost earlier than originally planned. In addition, engines, which are included in list prices, are usually sold at high discounts, too, and count e.g. for some 20-30 percent off the list price of a twin-engined wide body aircraft. These discounts could be passed on to customer as well.

The pricing policy for discounts is influenced by many factors which can be grouped around three main areas: market development (e.g. economic prosperity, changes in oil price, competitors, changes in customer preferences, environmental laws etc.), technical progress (e.g. aging of aircraft, fuel consumption, comfort features, noise level etc.), and of course purchase elements like volume, customer history etc. Apart from the last one, each factor is linked to a significant risk for changes.

Discounts are also influenced by the pricing policy chosen to market new aircraft. Often high discounts (up to 50-60%) are granted to launch customer. For example, with the B787, Boeing originally planned with a very optimistic project budget that allowed for a very aggressive pricing strategy when the aircraft entered the market. In consequence, the historic pricing discounts put pressure on program's profitability because the actually required project budget turned out to be significantly higher. That means that project assumptions heavily influence pricing policy and thus revenues.

On the customer side, there are mainly two parties, airlines and aircraft investors which value an aircraft from a different perspective. "An airline refers to an aircraft's profit-generating potential where the value of the asset is justified based on the expected present value of the operating profits that the aircraft is expected to generate over its life. Analysis of the aircraft's Direct Operating Cost (DOC) per available seat mile, maintenance costs, dispatch reliability, and mission flexibility are also weighed in the decision framework. Fleet commonality will also play a significant factor given the substantial cost savings in training and spares inventories that can be achieved by operating a common fleet of aircraft. In contrast, aircraft investors base their investment decisions on the expected present value of the lease income and the capital gains from the sale of the aircraft" (Ackert 2012).

Consequently, both customer parties also refer to market development and technical progress to support their negotiation position. They are supported by professional rating agencies providing calculations of "real prices" referring to the individual market situation of a certain aircraft type (Forsberg 2016) and thus its real value from a customer´s perspective which is addressed by the aircraft manufactures as well (*Airbus erhöht…* 2014). Still, aircraft financial evaluation is a complex issue (Gibson, Morrell 2004).

As those analyses rather refer to the performance and economic benefit of an aircraft, development effort is not considered. In total, discounts have increased since late 80ies and grew with increasing list prices as the latter use an escalation formula that do not take into account elements like e.g. leaner manufacturing, the reduction or elimination of the amortization of development costs, or market forces. In 2005, discounts ranged from 25-50% with single aisle aircraft around 30% and twin aisle aircraft around 40%, only to reach 20-60% and an average of 45% in 2012 (Michaels 2012). Consequently they have a high impact on Cash In and thus on profitability of an aircraft project.

Down Payment

When a customer places an order the contract includes an agreement on Pre-delivery Payments which will be paid by the buyer to the seller for each aircraft. Pre-delivery Payments are non-refundable. The payment schemes are contracted individually but the following example of Boeing may serve as an orientation. Assuming an order is for further out than 18-24 months, Boeing collects a down payment at ~2% of the purchase price.

Then approximately 18-24 months prior to delivery, the customer begins making additional payments to Boeing, with roughly 40% of the purchase price in total due prior to delivery. The customer pays the remaining ~60% balance at the time of delivery.

In order to avoid high Pre-delivery Payments, customers pursue the following strategy. They contract the smallest thus cheapest aircraft of a family with the option to upgrade their order to the bigger version they actually want (Arvai 2013). Although the agreements on Pre-delivery Payments are flexible, the amounts are small and predictable within a tolerance thus do not have a significant impact on Cash Flow.

Delivery Rate per Year

The total delivery volume and the yearly delivery rate of an aircraft have a major influence on the investment decision. The higher both, the earlier amortization of the development effort can be achieved. In order to achieve high production volumes and thus rates, new aircraft are usually drafted as a family concept. The targeted range of passenger capacity will be defined and the initial model of the new family covers the lower end of the passenger capacity. By extending the fuselage, the middle and higher capacities will be then covered by later versions (e.g. A320, A350, B787 family).

The family concept has two main advantages. First, it allows for providing tailored solutions to airlines with a range of similar aircraft thus improve efficiency. Second, the later produced larger derivatives are cheaper in development and production, more mature and more economic. The latter is a result of a maximum use of the design potential with the largest derivative as no further growth potential is required. In addition, with a moderate modernization (e.g. new engines), sales period could be extended thus allowing to recover some more investment. Consequently, high cost overruns with successful aircraft are less severe than the same with less successful aircraft. That is why a detailed market analysis and outlook is of paramount importance.

Airbus and Boeing both are working on their own market analysis and publish the result annually (*Current Market…* 2015; *Flying by Numbers…* 2015). It contains a long-term forecast of passenger and cargo traffic and the estimate of the number and size of airplanes needed to fit the forecast. The forecast is used to shape product strategy and guide long-term business planning as well as to inform airlines, suppliers, and the financial community of trends both companies see in the industry. Despite the comprehensive data base used, there is still room for different interpretation. The discussion around the hub concept (with feeder aircraft) versus point-to-point connections when the A380 was launched (2000) may serve as an example (Esty, Ghemawat 2002).

Market forecasts heavily influence the investment decision. Should an aircraft project be started now or later or never? For example, Boeing´s Sonic Cruiser (2001) was not meeting market preferences. Therefore, the project had to be abandoned (not enough initial orders). Orders with A380 are fewer than expected thus confirming the risk which is still associated with market forecasts (Carson 2016).

Scientific Problem

The review of the parameters had revealed that the ones with the greatest influence on investment calculation are R&D, CAPEX and Tooling (= development effort), Discount on List Price as well as the Delivery Rate per Year/ Total Production Volume. Out of this, the parameter R&D, CAPEX and Tooling was regarded the most uncertain because, especially for revolutionary projects, it is much less predictable than a market forecast or discounts as deviations of more than 100% are possible. Consequently, the scientific problem was to verify and confirm that wrong assumptions regarding the development effort make revolutionary aircraft projects struggle. A model had to be found to estimate the development effort and the feasibility had to be proven of improving the business case (NPV, IRR, Amortization) by improving the estimate of the development effort and consequently change pricing policy.

Proposed Solution

In order to verify the problem, the list price changes of revolutionary aircraft projects over time had to be analyzed and searched for anomalies compared to legacy aircraft projects which should mainly follow general cost increases. If those anomalies would have appeared in timely correlation with significant cost overruns, it would have confirmed the problem and pointed already to the direction of the solution. Since list prices are the reference for final prices after negotiation, which were not available, they were regarded as a valid indicator for the latter. In order to solve the problem, the effort required for R&D, CAPEX and Tooling up to initial delivery had to be estimated. This should be done with a parametric cost estimate model considering the revolutionary aspects of the new aircraft project.

The model of choice provided a Cost Estimate Relationship (CER) for the targeted effort depending on technical aspects (Technical Complexity, TC) as well as organizational parameters like number of suppliers, number of countries/aircraft manufacturers or number of final assemblies forming Organizational Complexity (OC). In detail, the Technical Complexity consisted of two dimensions. The first dimension was the level of new technologies introduced to the new aircraft, and second, the new aircraft was not treated as one unit but divided in 5 individual technical areas which were Airframe and Manufacturing, Flight and Flight Control Systems, Avionics, Propulsion, Interior/Armament/Payload. This allowed for a more detailed description of a new aircraft. Finally, it was assumed that if predicted development effort would be significantly higher than planned, it could be largely compensated by avoiding aggressive aircraft list prices and reducing discounts on them. As the main two aircraft manufacturers Airbus & Boeing are facing the same problems, they might compete less by granting high discounts. This would result in higher Cash In and earlier redemption of investment. Without this approach, aircraft manufacturers would only be able to respond to delays and cost overruns which would be less effective as to be already able to take appropriate actions at time of investment decision.

Methods

Methods – Verification of theoretical problem

The sample projects chosen to verify the problem were the Airbus A350 (all new CFC aircraft) and A380 (largest passenger aircraft) as well as the Boeing B787 (all new CFC aircraft) representing the revolutionary projects. For the legacy projects Airbus A320, A321 and A330 as well as Boeing B737, B767 and B777 were selected. The data had been retrieved from internet sources, mainly the company sites of Airbus and Boeing and covers a period from 1999/2000 to 2016. The change of list price of the revolutionary project over the years was compared with the same for the legacy projects. The anomalies were then checked for correlation with significant project cost overruns.

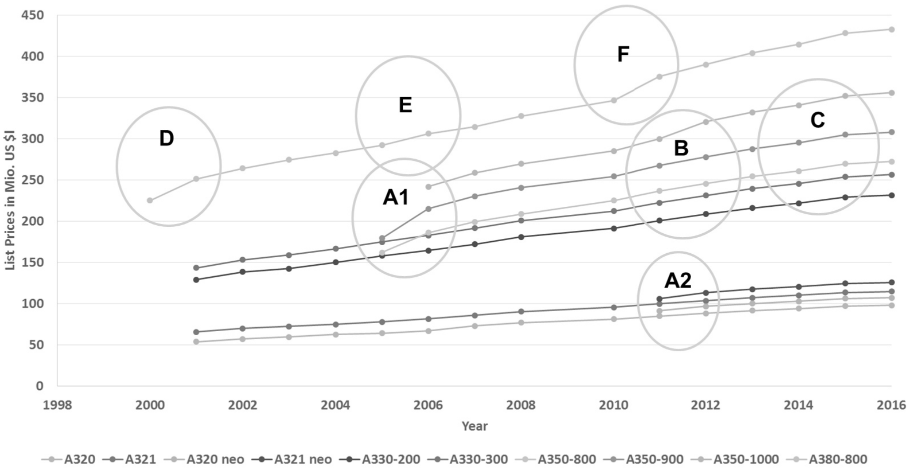
Methods – Verification of proposed solution

At first, the parametric estimate formula was applied to A350, A380 and B787, and the estimated development effort was calculated. As all projects were part of the aircraft projects used to determine the CER, the required values for the parameters were already available. There results were compared with the originally planned project budgets. The verification of the proposed solution was then done using the introduced generic aircraft project Cash Flow model as it includes original prices and key parameters of Boeing´s B787. For that, the generic aircraft Cash Flow model was calculated for the originally planned, actual and estimated development cost (pro rata adjustment for the years 2004-2010) with varying aircraft price discounts. For an additional calculation, the B787-8 list price of 2016 was calculated back to 2004 applying average price increases of legacy aircraft thus eliminating extraordinary price increases.

Results

Results – Summary of Empirical Results I

Figure 2. List Prices of Selected Airbus Aircraft



Source: Author's calculations based on Airbus Company information as well as on internet press articles.

In Figure 2, the list prices for the revolutionary aircraft A350 and A380 as well as the legacy aircraft A320, A321 and A330 are depicted from 2000 until 2016.

Area A: It is obvious that Airbus granted a big discount for initial orders of the A350-800 and -900 but not for the -1000 (Area A1). The evolutionary updates of the legacy aircraft A320 (A320neo) and A321 (A321neo), which were mainly equipped with new engines, had been introduced to the market with significantly smaller discounts (Area A2).

Area B: The A350s were significantly higher priced than the correspondent legacy aircraft of similar passenger capacity which are A350-800/A330-200 and A350-900/A330-300. In addition, the difference in list prices increases until 2012. Especially the A350-1000 shows a 7% price increase in 2012. This happened when cost overruns burdened the project between 2010 and 2013.

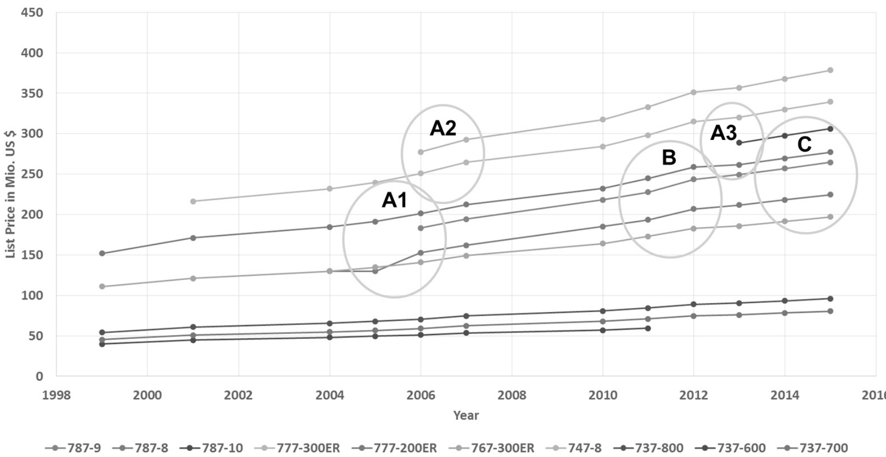
Area C: From 2012 to 2016 all aircraft list prices had been increased at the same percentage.

Area D: Initial A380 customers were also granted significant discounts.

Area E/F: The A380 project encountered cost overruns which could be assigned to the development phase from 2006 to 2010. During this period, a significant increase in list prices could be observed in 2005/2006 (4.9%, Area E) and 2010/2011 (8.4%, Area F).

The increase according to Airbus escalation formula was only approx. 4.2% in 2006 and approx. 3.9% (2011). Airbus referred to the outstanding and profitable performance of the A380 when explaining the price hike.

Figure 3. List Prices of Selected Boeing Aircraft



Source: like in Figure 1.

In Figure 3, the list prices for the revolutionary aircraft B787 as well as the legacy aircraft B737, B747, B767 and B777 are depicted from 1999 until 2015 (list prices for 2016 were identical).

Area A: It is obvious that Boeing marketed the B787-800 very aggressively in 2004 and 2005 as the list price was increased by 17.5% in 2006 (Area A1). This was much more than the price increase after introduction of the B747-8 (5.5%, Area A2). The variants B787-900 (Area A1) and -1000 (Area A3) did not show any additional discounts on initial sales.

Area B: As with the A350-800, the B787-800 was priced above its legacy counterpart, the B767-300ER (ER = Extended Range) and the difference in list price increased until 2013 with only one exception in 2011. At the same time, the difference in list price between the B787-900 and the higher priced legacy aircraft B777-200ER had been reduced.

B787 project encountered major cost overruns in development between 2006 and 2010 and was only improving slowly after initial delivery.

Area C: In 2014 and 2015 all aircraft list prices had been increased at the same rate.

Results – Summary of Empirical Results II

With the CER, the total project volume V_{to} until Initial Delivery for the relevant projects (A350, A380 and B787) was calculated with the equation:

$V_{to} = V_{tc} + V_{oc} = 0.03023\ X_{tc}^{0.89989} + 3.92986 + 0.00578\ X_{oc}$ in constant 2010 bn €.

Where V_{tc} represents the project volume related to TC and consequently V_{oc} represents the project volume related to OC. The variable X_{tc} represents TC and is calculated as the product of ratings for 5 different aircraft areas (Airframe and Manufacturing, Flight and Flight Control Systems, Avionics, Propulsion, Interior/Armament/Payload), according to the level of new technologies introduced. The ratings distinguish 5 different levels with 1 being the level of lowest introduction of new technologies. The variable X_{oc} represents OC and is calculated as the product of the number of aircraft manufacturers, countries and suppliers involved in an aircraft project and the degree of de-centralized production (number of final assemblies).

The equation is valid for a minimum range of project volume from 6 to 15bn in constant 2010 € (7.95 to 19.9 bn US $). Together with the originally planned project volume, the actual project volume and all values converted into 2010 US $ (average Dollar/Euro 2010 exchange rate 1.325695$/€ (*Historischer…* 2014)), the results are shown in Table 1.

Table 1. Originally planned, Estimated and Actual Revolutionary Project Volumes

Project	TC X_{tc}	OC X_{oc}	Originally planned Project Volume in constant 2010 bn $	Estimated Project Volume in constant 2010 bn $	Actual Project Volume in constant 2010 bn $
A350	360	254	14.32	15.16	15.96
A380	432	526	16.29	18.67	22.43
B787	540	784	06.91	22.74	15.38

Source: Author's calculations based on internet press articles as well as CER.

The introduced generic aircraft project Cash Flow model yielded the following results for different sets of input parameters (development cost rounded).

Table 2. Total Discounted Cash Flow, IRR as well as Payback Period for different Price and Discount settings

Total Discounted Cash in mn €/Discount Rate	Generic Aircraft ModelActual Development Cost, 16 bn US $	Generic Aircraft ModelOriginally Planned Development Cost, 7 bn US $	Generic Aircraft ModelActual Development Cost, 16 bn US $Prices Adjusted	Generic Aircraft ModelEstimated Development Cost, 23 bn US $	Generic Aircraft ModelActual Development Cost, 16 bn US $	Generic Aircraft ModelEstimated Development Cost, 23 bn US $
Discount	48%	48%	48%	48%	37%	36%
Cash In/10%	82 953	82 953	83 122	82 953	100 501	105 287
Cash Out/10%	-99 586	-93 203	-99 586	-104 551	-99 586	-104 551
IRR	3%	5%	3%	2%	10%	10%
Payback Period in Years	27	26	27	28	21	20

Source: like in Table 1.

Discussion

It could be shown that revolutionary aircraft projects were often marketed initially with high discounts compared to evolutionary aircraft, not so later variants. Although it happens often with new aircraft projects, it is not deemed necessary as there are other arguments to promote a new aircraft, like e.g. low operational costs or a big leap forward in comfort and inflight entertainment. In addition, high initial discounts may establish the reference for later prices and thus impede effective price hikes. Then, it became obvious that revolutionary aircraft projects experienced greater price increases over time than their counterparts among the legacy aircraft with similar passenger capacity. In consequence, the difference in list prices was growing. Since this had happened during periods of significant cost overruns, it can be considered as evidence that the aircraft manufacturers had underestimated aircraft development cost and tried to recover the additional cost as much as possible by increasing aircraft prices. This confirmed the problem identified.

Table 1 shows the originally planned project volumes, the estimated project volumes and the actual project volumes until Initial Delivery for three revolutionary aircraft projects. The A350 encountered a moderate cost overrun with an estimated value close to the actual one. With the A380, the estimated value is above the originally planned but significantly below the actual one.

That means, the cost overruns are high in relation to the Technical as well as Organizational Complexity of the aircraft. In contrast, the complexity of the B787 would allow for a much higher cost overrun. Actually, its actual project volume was about the same as the one of the comparable A350. The greater cost overruns mainly resulted from a very optimistic originally planned project volume. In summary, all estimated values indicated correctly that the to-be-expected actual values are higher than the originally planned project volumes. This confirmed the approach to improve the forecast of expected development costs.

Table 2 shows different investment calculation indicators (Discounted Cash Flow, IRR, Payback Period) of the generic aircraft project model for different parameter settings. Column 2 shows the project model with the initial parameters. With a discount rate of 10%, NPV was clearly negative and an IRR of 3% would have not met investors´ expectations let alone a Payback Period of 27 years. Column 3 indicates that even if the project would not face cost overruns until initial delivery, NPV would not be positive under the given requirements. Still IRR had almost doubled compared to Column 2 which confirmed the great influence of expenses during the investment phase. Column 4 shows the result of the original generic aircraft project model applying adjusted prices thus eliminating above average list price increases. The improvement was marginal. It proved that corrective (price) actions have hardly any influence on business case. Column 5 shows the results with the estimated development cost. Although significantly higher than the actual development cost, IRR was only one percentage point smaller and Payback Period only one year longer (28 years).

That meant, applying the estimated development cost would have clearly indicated the problem of this investment. Column 6 & 7 show the maximum discounts the aircraft manufacturer would be allowed to grant if NPV should be at the threshold to being positive which equals an IRR of 10%. With 37% and 36% the values were very close for the actual and the estimated development effort.

It confirmed that reducing the discount is an appropriate lever to meet the investment criteria. In addition, it confirmed also the suitability of the CER to determine figures for appropriate actions. If the discounts would appear too challenging for the aircraft manufacturers there would be still the option to reduce Technical and/or Organizational Complexity and with it development cost.

This confirmed that a better forecast for aircraft project development cost allows for a better investment decision as the calculation of NPV/IRR yields a guidance for discounts on list prices or for other (minor) influencing parameters.

Conclusions

The underlying phenomenon of this research was the questionable amortization of revolutionary civil aircraft projects after experiencing significant cost overruns during development and following production preparation until Initial Delivery.

After a thorough analysis of a generic civil aircraft project Cash Flow profile over a typical life span, it could be concluded that development effort is indeed the parameter with significant impact and the greatest uncertainty factor when it comes to civil aircraft investment calculation.

By comparing the list prices of three revolutionary aircraft projects with legacy aircraft projects it could be confirmed that inaccurate estimations of development effort during investment decision had been the main source of the problem.

It could be proven that with a better estimate of development effort through applying a parametric CER and a subsequent correction in pricing policy (reduced discounts) it is possible to achieve a satisfying investment calculation/business case.

It is left to the aircraft manufacturers to consider if reduced discounts can be enforced under market conditions but then still there is the chance to reflect on a reduction of Technical or Organizational Complexity of the planned aircraft, to review the real added value of new technologies to the potential customers or to wait until market conditions are more in favor of the planned project.

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Sposób na poprawę opłacalności rewolucyjnych projektów samolotów dla lotnictwa cywilnego

Streszczenie

Projekty produkcji nowych samolotów przeznaczonych dla lotnictwa cywilnego wykorzystujące „rewolucyjne" technologie mają często problemy z odzyskaniem poniesionych kosztów inwestycji. Punktem wyjścia jest stwierdzenie zmniejszenia ryzyka wystąpienia różnicy między rzeczywistym i planowanym kosztem projektu i odpowiednie dopasowanie dalszych parametrów oceny opłacalności inwestycji powinno zwiększyć opłacalność inwestycji, zakładając, iż w ogóle dojdzie do jej realizacji. Oznacza to, że jeżeli rozmiary projektu byłyby określone bardziej precyzyjnie, w ocenie projektu można by przyjąć bardziej realistyczne parametry, takie jak ceny samolotów, lub rozważyć założenia techniczne czy przyszłe warunki rynkowe. Stawia to pod znakiem zapytania skuteczność obecnie stosowanych metod planowania i oceny projektów dla uzyskania realistycznych szacunków opłacalności projektów produkcji „rewolucyjnych" nowych samolotów.

W artykule przeprowadzono weryfikację tego problemu w drodze porównania zmian cen (w czasie) samolotów z „projektów rewolucyjnych" (Airbus A380, Airbus A350, Boeing 787) ze zmianami cen samolotów wytwarzanych w oparciu o wypróbowane technologie. Celem analizy było wykrycie anomalii i ich korelacji ze znacznymi przekroczeniami kosztów. Wnioski pozwoliły na zaproponowanie nowego podejścia dla wyeliminowania obserwowanych braków. Podejście to łączy opracowany model oceny parametrycznej (CER) dla określenia rozmiarów projektu ze zweryfikowanym otoczeniem parametrycznym dla liczenia opłacalności inwestycji w takie projekty. Model wykorzystuje jako zmienne niezależne: stopień zastosowania nowych technologii (złożoność technologiczna) oraz liczbę krajów, dostawców i ostatecznych miejsc montażu (złożoność organizacyjna). Zmienne te stanowią o „rewolucyjnym charakterze" analizowanych projektów. W konsekwencji podejście to powinno znaleźć zastosowanie praktyczne dla trafniejszego podejmowania decyzji inwestycyjnych.

Słowa kluczowe: rachunek efektywności inwestycji, ryzyko, przekroczenie planowanych kosztów, szacunki parametryczne, zarządzanie wielkimi projektami, produkcja samolotów.

Kody JEL: F23, G12, G32, L62, L93, O32

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Afiliacja:
Dipl.-Ing., Dipl. Wirtsch.-Ing. Christoph Winter
Airbus Defense and Space GmbH
Uniwersytet Ekonomiczny we Wrocławiu
Europejski Program Studiów Doktoranckich
w dziedzinie Ekonomii, Zarządzania i Finansów
ul. Komandorska 118/120, bud. A
53-345 Wrocław
tel.: 71 36 80 801
e-mail: ChristophWinter1@gmx.de