

PROSPECTS OF THE A380 SECOND-HAND MARKET

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Abstract

With the first batch of used A380 entering the market the question arises if there is a second-hand market for this type of aircraft. Aircraft prices – for new and used aircraft – are generally subject to significant discounts and confidentiality, which impedes the development and validation of scientific quantification methods. In this study a fleet-planning-based approach is applied to an exemplary airline to determine the economic viability of introducing a used A380 into an airline fleet. Specifically, a parameter study with varying prices of used A380 is performed. The results indicate that, when compared to a new A380, the discounted used variant can be a reasonable alternative. However, when compared to a younger aircraft type, even a strongly discounted A380 is more cost-efficient only, if not operated for more than a few years. Major cost drivers of the used variant are MRO and fuel cost. Possible operational scenarios for used A380 are pictured and an outlook for further research is given.

1. INTRODUCTION

Since its entry into service in 2007, 335 A380 have been ordered and 233 were delivered as of Q3 2018. In the meantime, five A380 leasing contracts have terminated after a 10-year leasing period. Even though these aircraft have reached only approximately 50% of an average aircraft life expectancy, finding a subsequent operator for three of them did take some time compared to other aircraft types. The remaining two aircraft will be parted out. From 2019 until 2021 14 more used A380 will enter the market [8] due to expiring leasing contracts. The question arises if there is a second-hand market for the A380 from different perspectives:

- From an economic perspective for lessors and operators;
- From an operational point of view in terms of achievable load factors, frequencies and demand;
- From a strategic product management perspective for the manufacturer, in terms of spare parts provision, maintainability and further development of the aircraft program;
- From an overall ecological perspective in terms of sustainable use of raw materials.

Compared to other aircraft types, the question of a second-hand market is particularly challenging for the A380 [3]:

- There's only a limited amount of carriers with the routes, airports and passenger flows to achieve reasonable load factors with a plane of the "very large aircraft" category;
- As a widebody aircraft, that some airlines consider their flagship, most A380s are quite customized, meaning a new operator would have to reconfigure the airplane extensively;

- On long haul routes fuel consumption accounts for the major DOC share which naturally favors newer aircraft as being more fuel efficient;
- If one owner fails to remarket its A380 the visibility of this negative event will be relatively high due to the limited amount of customers and aircraft in service;
- Airport and air space congestion has not yet become such a big issue that airlines would sacrifice frequencies in favor of larger aircraft;
- The orders for new A380s are limited compared to other types, increasing skepticism towards the program;
- The latent chance of an updated A380 ("A380 neo"), regularly requested by a few customers, lessens the attractiveness of the classic version.

On the other hand, there are also more optimistic scenarios [3]:

- The range-payload characteristic of the A380 is relatively strong, enabling it to fly most routes without ETOPS restrictions;
- Fleet commonality, particularly with the Airbus A340 type, is relatively high in regards to maintenance and pilot training;
- Airport and air space congestion may eventually become more relevant;
- At least for the first batch of used A380 entering the market, parting out could be a lucrative option for the first trader of surplus components and engines. The part out value is estimated to be around 80 million USD, mainly for the components and the engines [9].

Independently of the aircraft type the topic of aircraft second-hand markets becomes more important in the future, as reflected by the aircraft manufacturer's order books. Unlike in the previous decade, also smaller and younger airlines have become able to afford new aircraft and do not need to rely on the used variants. This is due

to new financing opportunities, especially from export credit agencies. At some point this will create an oversupply of used aircraft on the market resulting in a decline of the average commercial aircraft's life expectancy of 25 years and the average residual value of 15% [4]. Facing these developments as well as increasing competition in the aviation industry and increasing fuel prices long-term, the need for well-grounded aircraft valuations becomes more important.

Having introduced the used aircraft market situation of the A380, chapter 2 follows with a literature review of publications dealing with aircraft values. In chapter 3 the applied fleet planning model as well as the used input data is described. In the first part of chapter 4 the development of a baseline scenario is delineated. In the second and third part of chapter 4 the results of the parameter study as well as a deeper DOC analysis of a used A380 are described. In chapter 5 the results are discussed and potential operational scenarios for used A380 are drawn. Chapter 6 completes this study with a summary and an outlook.

2. LITERATURE REVIEW

One needs to differentiate between aircraft values which are hypothetical (book) values and used aircraft prices which are actual paid prices for used aircraft. Due to its theoretical nature, chapter 2 refers to aircraft values, whereas in chapters 3, 4 and 5 the term used price will be applied. Some sources cited below use the term residual value which refers to the value of an aircraft at the end of a defined period. In most cases this is not the end of the aircraft's lifetime but the end of the period with its current owner.

Scientific literature regarding aircraft values of commercial aircraft is generally scarce. This applies particularly to quantitative methods to determine aircraft values of used aircraft. Reasons for this are:

- Actual paid prices between buyers and sellers of used aircraft are mostly confidential. This impedes the development and practical validation of potential scientific evaluation methods.
- Compared to other durable goods, such as ground transportation vehicles, the transaction volumes of used aircraft are rather low, whereas the degree of aircraft individualization is rather high. This reduces the availability of potential statistically relevant data bases due to limited data set comparability.
- Used aircraft transactions are characterized by the distinctive presence of information uncertainties, as exemplified by Gilligan (2004) [10] for used business aircraft: complex technical and operational systems, extensive legal and regulatory requirements, limited service and performance warranties, a wide range of different trader and MRO names associated with different quality perceptions as well as varying aircraft original prices. Inevitably, this also puts softer factors into the equation such as trust, perceptions and biases. Especially these softer individual factors reduce the applicability of strictly quantitative evaluation methods.
- As aviation is a highly volatile industry, individual expectations regarding future economic growth

influence aircraft values. In combination with the limited size of market (see above) as well as costly storages and transitions, aircraft values become sensitive to market shifts.

Ehrental (2010) [7] performs a wide range of regression analysis on a data base of commercial aircraft valuations (i.e. not actual prices paid) from 1994 – 2006. The key findings are that aircraft value decreases in age, whereas this effect is stronger for widebodies than for narrowbodies. The aircraft value of narrowbodies increases in US long-term interest rates and decreases in world GDP. Furthermore the aircraft value increases in aircraft orders. Independently from these observations it is noted that aircraft valuation is influenced by behavioral aspects. For instance, aircraft valuations can be manipulated by appraisers if pressured by any of the parties involved into the aircraft transaction (buyer, seller, financier) depending on who is the assigning party. Another aspect is that lessors do not have complete control over how the lessee treats an aircraft which is increasing uncertainty. Eventually, it is mentioned that the increasing international character and vertical disintegration of the aircraft (finance) industry can be a trigger for further research in this field.

Gilligan (2004) [10] finds evidence for the following factors to have a positive influence on the residual value of business jets (i. e. lower depreciation rates): increasing model and brand fleet size, decreasing amount of airworthiness directives, decreasing amount of aircraft operated under a leasing contract and turboprops when compared to jets. Additionally, these effects become stronger with increasing aircraft age.

Mensen (2013) [12] states that aircraft residual values are particularly important for aircraft lessors, especially for shorter leasing periods, as the lessor bears the technological risk of the aircraft. On the one hand, aircraft are attractive leasing objects because they are easily transferrable from one location to another. On the other hand, their residual value strongly depends on the market situation. Newer leasing contract concepts allow lessors to unroll some of the residual value risk to the lessee via "early buy-out", "capped" or "fixed-price" features.

Clark (2017) [6] mentions the following main factors that have an influence on aircraft value: age, production line position, production status, inflation, growth of the economy, prices of new aircraft, interest rates, aircraft economic performance, condition of the aircraft in terms of maintenance as well as flight hours and cycles, commonality, flexibility, fleet rollovers of large carriers and the stability of the manufacturer. Furthermore, the price that the emitting owner paid itself, the leasing rates that were earned or paid, the depreciation policy and tax-related factors can have an influence on the acceptable selling price.

Commercial appraisers, such as *The Aircraft Value Analysis Company* [2], use distinctive methods containing a wide range of variables. In addition to the factors mentioned by Clark (2017), influences such as the amount of operators and lessors, geographical distribution of the operators, amount of stored aircraft, engine type, ETOPS certification, level of customization and the maximum takeoff weight are used to determine aircraft values. In

addition, these appraisals are enriched with subjective judgement.

To summarize this review, it can be stated that aircraft values depend on a significant amount of hard- or even non-quantifiable influences. If they are related to an actual aircraft transaction, valuations are driven by counteracting interests which subjectifies the “right” aircraft value. Methods that take into account many factors may seem sophisticated at first glance. However, it needs to be kept in mind that with an increasing amount of variables – next to the input data quality challenge – the risk of overfitting a model increases. Hence, applying several aircraft valuation methods to one use case seems to be the most promising approach to create a meaningful picture. To extent the scope of available valuation options, we present a methodology to determine and judge aircraft values with an airline fleet planning tool.

3. METHODOLOGY

For this study the fleet planning tool FLOP is applied to an exemplary airline to assess A380 used prices via a parameter study. The approach is to vary the used price of A380 aircraft to quantify the impact on fleet composition as well as cost positions. Unlike the methods described in chapter 2, this can be considered a bottom-up approach as it accounts for various airline-specific criteria such as: the airline fleet and its development over a 10-year planning period, the route network, investment budgets, revenues and costs. Consequently, results need to be considered airline-specific and are not necessarily transferrable to other airlines. In the first part of this chapter the fleet planning model in FLOP is described briefly. In the second part relevant input data is summarized.

3.1. Fleet planning model

Only the parts of the fleet planning model implemented in FLOP are described here that are relevant for this study. Particularly, these are the parameters that differ between a new and a used A380 aircraft:

- Original and used price: discrete value that will be varied between parameter studies;
- Fuel consumption as a function of leg distance and aircraft age;
- MRO cost as a function of leg distance, aircraft age and aircraft type: modeled according to the DOC model of Liebeck (1995) [11][13];
- Maximum aircraft utilization as a function of aircraft age.

FLOP contains a mixed integer programming model that maximizes the airline’s total asset value TAV at the end of a 10-year planning period T . Equations (1) and (2) describe the model on the most aggregated level:

$$(1) \quad \text{maximize } (TAV = c_T^+ - c_T^- + VF)$$

$$(2) \quad c_t^+ - c_t^- = \begin{cases} EC + OPS_t + INV_t + FIN_t & t = 1 \\ c_{t-1}^+ - c_{t-1}^- + OPS_t + INV_t + FIN_t & \forall t \in \{2, \dots, T\} \end{cases}$$

With the following variables:

c_T^+ : cash surplus at the end of

$$t = T (c_T^+ \geq 0, c_T^+ > 0 \leftrightarrow c_T^- = 0)$$

c_T^- : cash deficit at the end of

$$t = T (c_T^- \geq 0, c_T^- > 0 \leftrightarrow c_T^+ = 0)$$

VF : fleet value at the end of $t = T$

EC : Existing cash on hand at $t = 1$

OPS_t : cash from operating activities

INV_t : cash from investing activities

FIN_t : cash from financing activities

Cash from operating activities is directly influenced by the parameter variation. That is, because fuel consumption and MRO cost affect variable cash operating cost (COC). The maximum utilization is modelled as a constraint which limits the revenue potential of an aircraft. Cash from investing activities is influenced by the original price and the used price of the aircraft. Cash from financing activities is indirectly affected via the impact of the variation parameters on profits and losses as well as the resulting earnings and expenses. Further details about the fleet planning model implemented in FLOP can be found in Rosskopf (2013) [13] and Rosskopf (2014) [14].

3.2. Input data

A full service network carrier from the Asia Pacific region that recently replaced parts of its A380 fleet with new A380 was selected as a use case for this study. Since the airline already operates the A380 it can be assumed that the required passenger demands exist in its route network and basic frame conditions (MRO capabilities, trained crews, airport infrastructure) does not need to be considered additionally. Plus, the airline plans to renew its fleet substantially within the next years which makes it a dynamic use case. The examined planning period lasted from 2016 – 2025 (10 years). Tab. 1 contains an overview of key data of the airline network [15].

TAB. 1: Network of the airline in 2016

Network characteristic	Value
Total Flights	85.000
Total ASK	120.000 [pass. km]
Short haul flights (<3.000km) and share of total ASK	33.000 / 14%
Medium haul flights (3.000 – 6.000km)/ share of total ASK	27.000 / 29%
Long haul flights (>6.000km)/ share of total ASK	25.000 / 57%

With regard to Rosskopf (2013) [13], the route network was abstracted via net classes. A net class comprises a set of routes characterized by a certain span of distance flown and passengers transported per flight (for example “2001 – 3000 km, 211 – 300 pax”). For the years 2016 and 2017 historical flight plan data was taken to determine the amount of flights and the capacity in each net class. The capacity is equivalent to the available seat kilometer (ASK) produced by the airline. For the period from 2018 until 2025 growth rates were estimated based on historical flight plan data and announced aircraft orders of the airline for each net class.

Tab. 2 shows an overview of the airline’s fleet as of March 2016 [8]. This fleet was considered as the initial fleet within FLOP and thus the starting base for the fleet development until 2025. The B777-200ER (ER stands for “extended range”) as well as the B777-300ER also include the “non-ER” versions of the airline but were merged for simplicity. As the airline operates different configurations with different amounts of seats of the B777-200 and the A380-800 there are “S” (small) and “L” (large) variants. This differentiation increases the complexity of the model but yields higher accuracy regarding the results. If there were different seat configurations within one net class the average amount of seats was considered. Tab. 2 also shows the span of passenger capacity for each aircraft which results in different net class assignments within FLOP. Regarding the passenger capacity, aircraft can only “compete” within one net class with each other. For instance, an A350-900 can replace an A330-300 but not a B777-200ER-L as the A350-900 and the B777-200ER-L are assigned to different net classes.

TAB. 2: Fleet of the airline in 2016 and assignment to net classes

Aircraft type	Seats	Net class [pax]	In service [owned/leased]
A330-300	285	211 – 300	0 / 28
A350-900	253	211 – 300	1 / 0
A380-800-S	379	301 – 400	5 / 3
A380-800-L	443	411 – 600	5 / 6
B777-200ER-S	264	211 – 300	19 / 0
B777-200ER-L	323	301 – 400	2 / 0
B777-300ER	269	211 – 300	32 / 1

Tab. 3 shows a summary of the aircraft orders of the airline [8] as well as the assumed amounts of seats and net class assignments. The order amounts were modeled as a minimum constraint, meaning FLOP had to buy at least as many aircraft as the airline had already ordered.

TAB. 3: Confirmed aircraft orders of the airline

Aircraft type	Seats	Net class [pax]	On order
A350-900	253	211 – 300	66
A380-800-L	443	401 – 600	5
B787-10	337	301 – 400	48
B777-9	414	401 – 600	20

To account for airline specific cost and revenue effects, the revenue and all parts of the variable COC (ATC fees, crew cost, fuel cost, handling cost, MRO cost, start and landing fees) were calibrated with actual data from the airline’s annual reports for the years 2016 and 2017.

4. DESCRIPTION OF RESULTS

To illustrate the impact on fleet composition and key cost data of a used A380 being available for an airline to purchase, a baseline scenario was calculated first. The development of the baseline scenario is outlined in chapter 4.1. In the baseline scenario no used A380 aircraft were available to purchase for FLOP, whereas in all other scenarios – described in chapter 4.2 – used A380 with varying used prices were available. All scenarios with varied parameters were compared to the baseline scenario. In chapter 4.3 a deeper analysis of fuel and MRO cost as well as their relation to savings resulting from lower purchase prices is performed.

4.1. Baseline scenario

Fig. 1 and 2 depict the fleet of owned and leased aircraft of the airline and their development for the baseline scenario. The following observations can be made:

- Until 2023 FLOP replaces all B777-200ER-S, B777-300ER and leased A330-300 with more fuel efficient A350-900. The total transport capacity within the 211 – 300 pax net class decreases slightly.
- Until 2025 a total of 48 B787-10 is introduced into the fleet, replacing the B777-200ER-L and the A380-800-S. The total transport capacity increases significantly in the 301 – 400 pax net class. This suggests the airline plans to increase the average capacity per flight.
- Until 2022 FLOP replaces all owned and leased A380-800-L with more fuel efficient B777-9. Even though the latest A380-800 joins the fleet in 2020.

To summarize, the entire initial fleet of 2016 is replaced during the planning period except for the one A350-900 that was already in the fleet. The amounts of bought aircraft are largely predetermined by the announced aircraft orders of the airline. New leases are not arranged, existing leasing contracts expire. This can partially be explained by the fact that the acquisitions suffice for the required capacity. Another reason lies in the model logic of FLOP: it maximizes the airline’s total asset value until the end of the planning period (see eq. (1)). The total asset value consists of the cash surplus / deficit and the fleet value. The fleet value is greater if more owned aircraft are in the fleet. Consequently, leasing is more financially attractive if required for temporary capacity peaks. Even though the airline has a significant share of leased aircraft at the beginning of the planning period, a minimum leasing quota could not be deducted from the annual reports and was not applied.

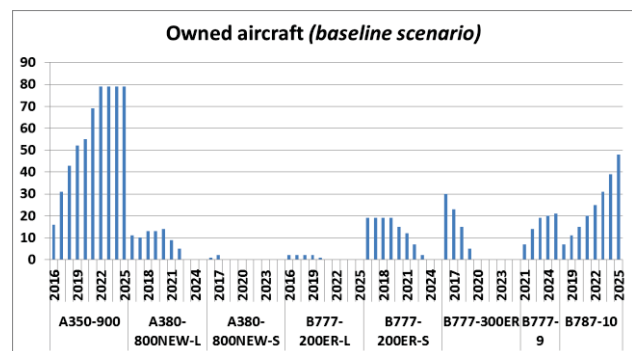


FIG. 1: Owned aircraft (baseline scenario)

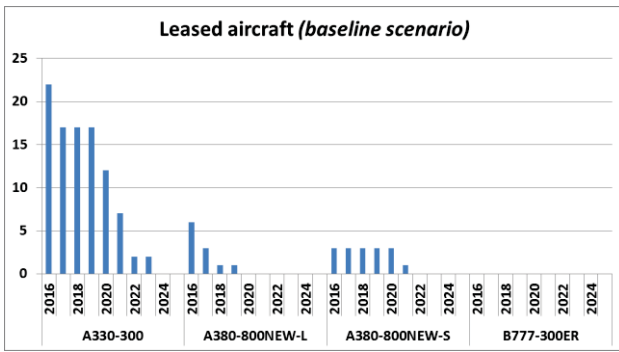


FIG. 2: Leased aircraft (baseline scenario)

4.2. Parameter study

For the parameter study the following assumptions were made:

- A maximum amount of five used A380 is available per year for FLOP to purchase. This is the average amount of used A380 entering the market per year during the next years due to expiring leasing contracts. All other aircraft types are only available in new condition.
- The used A380 is available as the A380-800-L version. Due to expected higher cost of the used variant it seems likely that an operator will opt for a higher seating density.
- A used A380 is 12 years old when being available for purchase. The average duration of the A380 leasing contracts terminating in the next years is 11 years, the additional year accounts for transition times.
- The original price of a new A380 is 289.64 million USD which equals 65% of the 2018 list price of 445.6 million USD [1]. This discount is lower than current media reports suggest [3], however, the airline placed its orders already in 2012 when the demand for the A380 was higher. The used prices are calculated based on the original price (i. e. not on the list price).
- The average fuel consumption of a used A380 is 5% higher than of the new variant. This increase accounts for engine deterioration, higher aerodynamic resistance due to rougher surfaces and an increase in aircraft weight due to modifications and repairs as well as accumulation of dirt and humidity in the aircraft. The value is based on real A380 fuel consumption data and expert knowledge. In reality the fuel consumption of an aircraft also depends on the MRO schedule and MRO quality. Furthermore, engines and airframe are technically independent from each other. Since the average age of the A380 sub-fleet of the airline in 2016 was close to 7 years, the offset for one significantly older aircraft type is a valid simplification to account for above mentioned ageing effects. The fuel consumption of all other aircraft does not change with aircraft age within FLOP.
- An increase in fuel prices according to the standard scenario of the U.S. Energy Information Administration [16] is assumed.

- The maximum utilization declines with 1% per age year for the new and the used A380 as well as all other aircraft types. Consequently, the maximum utilization of a 12-year-old A380 is approximately 12% lower than of the new variant.
- A maximum of 10 aircraft can be sold and a maximum of 30 aircraft can be acquired per year. These amounts are based on historical data of the airline as well as the amounts of officially announced orders.

Tab. 4 summarizes the presumed prices for the calculated scenarios 1 - 4. The used A380 price was varied from 10% - 40% of the original price. In scenario 1 the used price of 40% of the original price is in line with a yearly depreciation rate of 8%-10% for the A380 [3]. Due to the challenging market situation (see chapter 1) for the used A380 a higher used price was not considered.

TAB. 4: Scenarios and considered aircraft prices

Scenario name	Used price A380 [% of original price / absolute value]
Scenario 1	40% / 115.856 million USD
Scenario 2	30% / 86.892 million USD
Scenario 3	20% / 57.928 million USD
Scenario 4	10% / 28.964 million USD

Fig. 3 illustrates the change of owned aircraft in the fleet in absolute values for scenario 1 compared to the baseline scenario. It can be observed that:

- In 2016 FLOP buys all five available used A380 and reduces the number of new A380 purchased by the same amount. In 2020 another used A380 is bought instead of a new one.
- From 2017 until 2023 the total amount of A380 (new and used) is higher by one aircraft to compensate for the lower utilization of the used variant.
- All A380 (new and used) are sold until 2023 and replaced by more fuel efficient B777-9.
- Having more cash on hand due to savings from cheaper A380 acquisitions, one A350-900 is bought in 2018 to replace less fuel efficient B777-200ER-S and B777-300ER earlier. However this additional aircraft is sold again in 2022.
- The fleet development for the B787-10 and B777-9 remain the same.

Compared to the baseline scenario it can be observed in scenario 4 in fig. 4 that:

- From 2016 until 2019 FLOP buys a total of 15 used A380. All new A380 – also the ones that were just bought in the previous year because of fixed orders - are sold until 2019. However, over the years from 2018 until 2022 the capacity of the A380 sub-fleet is increased by 6% to exploit the revenue potential of the used A380.
- Unlike in scenario 1, no additional A350-900 is bought and the sales of B777-200ER-S and B777-300ER are distributed differently among the years 2016 - 2024. Specifically, B777-200ER-S are sold later, whereas B777-300ER are sold earlier. This is due to the constraint limiting the

amount of sold aircraft per year. FLOP needs to handle the increased amount of A380 sales which influences other aircraft type sales as well. From 2017 until 2023 the amount of aircraft sales always reaches its limit of 10 transactions.

- The fleet development for the B787-10 and B777-9 remain the same.

The results of scenarios 2 and 3 are between scenario 1 and 4 and do not yield additional insights. For brevity, they are not further discussed here.

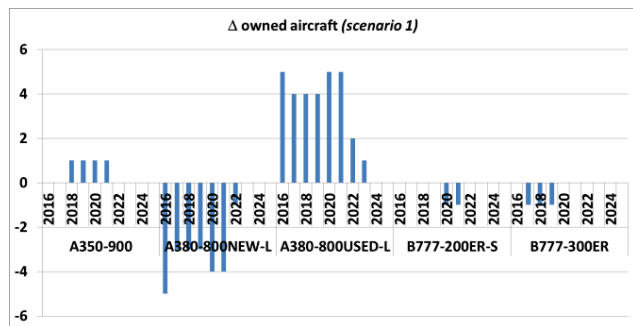


FIG. 3: Deviation of owned aircraft in scenario 1

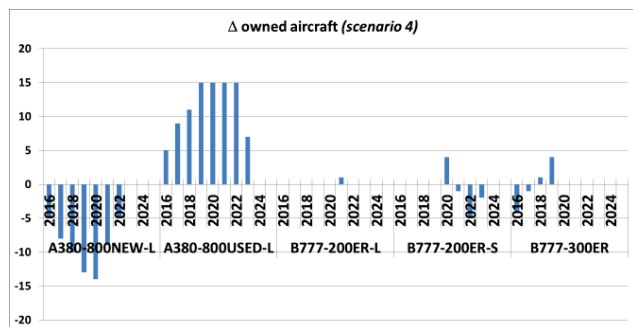


FIG. 4: Deviation of owned aircraft in scenario 4

To illustrate the effect of an increasing amount of used A380 in the fleet on cost fig. 5 depicts the relative change of fuel cost, MRO cost and total capacity of the fleet in scenario 4 compared to the baseline scenario. It can be observed that:

- In 2016 the capacity of the overall airline operations is 4% lower. This is explicable by the earlier sale of B777-300ER (see above) which reduces the overall capacity of the airline.
- Even though the capacity is 4% lower in 2016, the MRO costs are 2% higher. This can be explained by the increased MRO requirements of the older A380 being operated. From 2017 until 2020 MRO increase by up to 13% due to the increasing amount of used A380 in the fleet. After falling back to almost the same level as in the baseline scenario in 2022, MRO costs are practically in line with the baseline scenario for subsequent years. This can be explained by the fact that the fleet development of the A350-900, the B787-10 and the B777-9 remain the same in these years. The used A380 are still in the fleet until 2023 but are not operated. This can again be explained by the limited maximum number of aircraft transactions.

- Fuel cost increase in the same shape as MRO cost, but weaker regarding the relative change (4% at the highest point). Looking at the absolute sum over the entire planning period, the increase in fuel cost is approximately the same as in MRO cost. This is remarkable because fuel costs are 5 times higher than MRO cost when comparing the total values. This indicates a much stronger influence of aircraft age on MRO cost than on fuel consumption in our model.
- All other components of the variable COC – ATC fees, handling fees, airport fees and crew cost – do not depend on the aircraft age but mainly on capacity. Consequently, their relative change is almost in line with the relative change in capacity (for transparency, only capacity is shown in fig. 5).

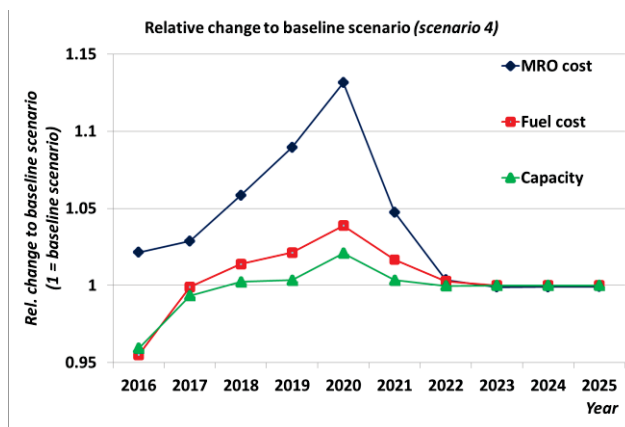


FIG. 5: Relative change of MRO cost, fuel cost and capacity of the entire fleet in scenario 4 compared to baseline scenario

4.3. COC analysis A380

The results in chapter 4.2 demonstrate that FLOP replaces a remarkable amount of new A380 with used A380. The significant discounts compensate the higher variable COC, particularly fuel and MRO cost. However, once the B777-9 – which can be considered as a direct “competitor” of the A380 based on its payload-range-characteristics – is available for purchase, the used A380 aircraft were replaced. To gain a deeper understanding about these effects, the development of the variable COC over time is put in relation to the savings resulting from a low-priced used A380 for an exemplary use case.

For this purpose, the operation of a new A380, a used A380 and a B777-9 were simulated from 2016 until 2025. For comparability, it was assumed the B777-9 is already available in 2016. In the average operation of the airline in 2016 the A380 performed 1.4 flights per day on a distance of 6.500 km. This operation characteristic was used for the simulation, which was performed with FLOP and all other input data and assumptions from chapter 4.2 remaining equal. The following specific calculations were performed for the exemplary use case:

- Determination of the variable COC for each aircraft type per year; a real interest rate of 0% was assumed;

- Determination of the differences in variable COC between the used A380 and the new A380 as well as the used A380 and the B777-9;
- Accumulation of differences in variable COC per year;
- Determination of the price difference between a used A380 (40% of the original price) and a new A380 as well as the price difference between a used A380 (10% of the original price) and a B777-9. The new price of the B777-9 was estimated to 255.48 million USD which equals 60% of the 2018 list price [5]. This discount is slightly higher than for the new A380 since the aircraft program is newer.

The results are depicted in fig. 6. The following can be observed:

- After 10 years the accumulated variable COC of the used A380 are up to 55.74 million USD higher than for the new variant (continuous blue line with filled diamonds). However, this is still lower than the savings (289.64 million USD – 115.86 million USD = 173.78 million USD) if the used A380 was purchased for 40% of its original price instead of a new A380 (dotted blue line with empty diamonds).
- When comparing the used A380 with the B777-9 the accumulated variable COC are up to 312.52 million USD higher after the 10-year period (continuous red line with filled squares). Even if the used A380 was acquired for only 10% of its original price instead of a B777-9, the savings (dotted red line with empty squares / 255.48 million USD – 28.96 million USD = 226.52 million USD) compensate the higher variable COC only until an operation duration of 7 years (year 2022 in the chart). Afterwards the accumulated difference in variable COC of the used A380 exceeds the realized savings due to a cheap A380 acquisition and the B777-9 becomes the more cost-efficient option.

These observations explain the replacement dynamics between the used and new A380 as well as the B777-9. It needs to be stated though, that the analysis in this chapter is solely a cost-related examination. It does not include any revenue- or operation-related considerations.

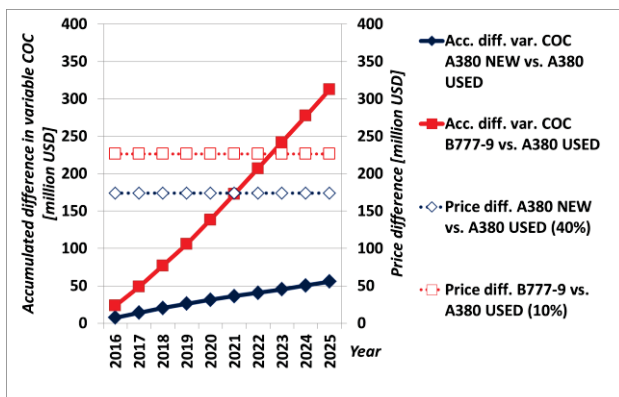


FIG. 6: Accumulated difference in variable COC and price differences between aircraft purchase options

5. DISCUSSION OF RESULTS

The results above show that for the airline considered and with the assumptions made a used A380 can be an economically viable option – even for a price of 40% of its original price – if:

- It is analyzed from a cost perspective and when compared to a new A380. For the airline considered the used A380 is particularly beneficial to bridge the gap until a newer, similar sized aircraft enters the fleet. When compared to the B777-9 the used A380 for 10% of its original price is more cost efficient if not operated longer than 7 years.
- Fuel and MRO prices increase moderately as these are the main cost drivers for the used variant.
- Airport infrastructure as well as maintenance capabilities and trained crews are available and do not need to be considered additionally.
- The lower customer value and potential reduction in airline image due to an older aircraft can be neglected, meaning no significant revenue losses are related to this.
- Taxation and depreciation policies that could favor the acquisition of newer and more expensive aircraft are neglected.

To a certain extent these findings are transferrable to other use cases. Possible scenarios where a used A380 could be an option are:

- An operator does not have the financial resources to acquire more modern aircraft but sees the demand on certain routes to fill an A380.
- A low-priced A380 could be an opportunity to try out new operational concepts with this aircraft type with a relatively low risk. In combination with overhauled engines the impact on MRO cost and fuel consumption might be even lower than presumed in this study.
- Existing (A380-) orders can be cancelled or postponed, so the potential of a used A380 can be exploited for a limited time period. This might seem unattractive for the A380 manufacturer at first glance. Contrariwise, the manufacturer might also be interested in establishing the used aircraft market for the A380 program in order to increase the attractiveness of new variants.
- An airline has the chance to negotiate a “buy-out” option for its expiring A380 leases and utilize the aircraft for a few more years. In this case the aircraft wouldn’t even have to be reconfigured.

Finally, the decision of the exemplary airline to replace old A380 with new A380 shall and cannot be judged in this study. It is unknown if the airline would still buy new A380 or receives them only, because there’s a binding contract of purchase. Moreover, the examinations above show that the profitability of fleet decisions strongly depends on the acquisition prices and financing conditions that could only be estimated and simplified here. Nevertheless, the method in this study yields valuable insights about the fleet developments and cost portions under the assumed

frame conditions. It can be used to validate aircraft value appraisals that are created from a global market perspective, from an individual airline perspective.

6. SUMMARY AND OUTLOOK

In this study the fleet planning tool FLOP was applied to assess the fleet and cost development of a used A380 when available for purchase for an exemplary airline. Used prices were varied from 10% to 40% of the aircraft original price. Already for 40% of the original price a used A380 can be an economically viable option if directly compared to a new A380 despite higher COC. If compared to the next generation aircraft B777-9 a used A380 for 10% of its original price can be economically viable for a duration of 7 years. Main cost drivers for the used A380 variant are fuel and MRO cost, increasing by up to 4% and 13% respectively for the entire fleet. Scenarios for used A380 are possible in the context of limited financial resources to acquire very large aircraft, companies trying out more risky business models, bridging gaps until the delivery of newer aircraft or buy-out options when leasing contracts expire.

As this study focuses mainly on the cost side of used A380, future investigations could address the revenue side for the used very large aircraft market. Specifically, this includes the identification of routes with large passenger demands that are less sensitive to flight frequency as well as to the potentially lower customer value of a used aircraft. The results could then be used to develop concrete new operational concepts. Another research direction could be the deduction of economic performance requirements for an "A380 neo". Having in mind the significant amounts of used A380 entering the market within the next years, it needs to be assessed how much more efficient an "A380 neo" has to be compared to a used A380 to justify its development and production.

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