Medium Haul Fleet Segmentation
Airbus A320neo & A321neo Weight Variant Selection

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Abstract

In competitive businesses as commercial aviation, every amount is worth saving. Bearing in mind this cost reduction paradigm, the present paper reveals a novel aircraft Weight Variant (WV) selection method, aiming to obtain an optimized fleet composition with an associated lightweight cost. The implemented method makes use of three different aircraft Zero-Fuel Weight and Trip Fuel values to create polynomial relations. After polynomial relations are computed for every route and time period considered, the coefficients as well as the WV specifications become inputs of the designed model. The model reveals the total payload available and, if any, the operational limitations. Afterwards, the available maximum passenger number and cargo is computed for every WV. The method aims to mitigate an airline direct costs through the navigation and landing fees reduction as well as the aircraft ownership cost, once the optimum WV is selected. The optimized selection would implicate sub-fleets of different WVs, but since airlines do care about fleet commonality an intermediate decision is more likely to happen, simplifying the fleet management and aircraft spares. Before TAP′s privatization in 2015, the aircraft weight variant selection was simply over dimensioned in order to guarantee the operational feasibility of every aircraft on every route at any time period. The present method is therefore capable of reducing the associated direct costs without compromising the operational feasibility and thus assuring a competitive market position.

Keywords: Fleet planning, Aircraft definition, Weight Variant selection, Operational costs reduction

1. Introduction

The global network provided by civil aviation airlines combined with the social media advertisements causes curiosity and interest in other places, leading people to fly between cities. These factors also encourage people to see themselves as global citizens, to meet and understand each other and in last instance it is one of the most powerful forces.

Since the nineteen-eighties decade the connectivity between cities has doubled, driven by the aviation business, and continues to grow due to the increasing use of aircraft (AC) transportation by people from either mature or emerging world economies [1]. According to Airbus *"It was another good year for aviation in 2017, with traffic growth measured in Revenue Passenger Kilometers (RPK) up 7.5% year on year, and capacity, Available Seat Kilometers (ASK) up 6.5%. As in 2016, this additional capacity was added carefully indicated by the fact that an already record global load factor improved further by almost a percentage point."* [1]. Thus, reinforcing the previous mentioned statement.

In order to satisfy this stupendous demand, aircraft manufacturers strive to produce in large scale new aircraft models, capable of performing greater ranges and accommodate even more passengers. Considering the present market demand, as the latest generation aircraft are delivered either to fleet growth or to fleet replacement, the fleet productivity based on the ASKs per aircraft has continued to grow faster on the single-aisle (SA) fleet than the wide-body (WB) fleet. This is due to an overall increase in operations, increase in aircraft size and longer routes being operated.

Knowing these previous facts, the civil aviation industry is developing additional forms of business model. The low-cost carriers have evolved with ultra-low cost and long-haul low-cost variants growing the number of available seats. Airbus even ensures that these new business models have helped to stimulate extra traffic growth on the relatively mature transatlantic market [1]. The full-service and legacy airlines are also replacing their fleets with these new SA aircraft. TAP for instance, is replacing the A320ceo (Current Engine Option) family aircraft by the new A320neo (New Engine Option) family, looking to segment further, but this time with more efficient, comfortable and interac-

tive cabins, increasing the focus on brand differentiation and auxiliary revenues.

This SA aircraft growth implicitly shows the overlap between aircraft segments created by its evolution in terms of range, available seats and available WV options. Therefore, considering the new Airbus aircraft segmentation for the particular case of TAP, the present dissertation will focus on the operational and economical impact of the optimal narrow-body (NB) fleet segmentation through the right selection of the A320neo and A321neo WV, within the current network.

1.1. Problem Description and Objectives

Before TAP′s privatization, the company used to adopt a relatively conservative attitude regarding the aircraft WV selection within the available WV options on the *System Configuration Guide* (SCG) [2]. This procedure was mainly established as a way to assure that any aircraft belonging to TAP′s narrow body (NB) fleet was capable to perform every route operated by TAP without any constraint and, therefore, reducing the tail assignment process complexity. Although this decision led to a simple and unique A320 fleet, it implies higher direct and indirect costs for the company itself. Starting with the direct costs, the selection of higher WVs can increase up to 1,5 million euros the purchase cost of the aircraft and this selection decision has a perpetual indirect cost, as long as the aircraft operates, caused by navigation and landing fees, which are mathematically indexed to the aircraft Maximum Take-Off Weight (MTOW).

Therefore, the present work provides a qualitative tool able to compute the optimum WV fleet segmentation, based on TAP′s current route network, for the next twenty five A320neo aircraft committed with Airbus on the company purchase agreement.

Considering that neo aircraft generation is capable of better fuel consumption than the previous one [3], specially on cruise flight phase, the study goes even further reassigning those new aircraft to the biggest block-hour routes within medium-haul network, improving the company′s fuel performance.

The amount of fuel cost saved with this new fleet assignment, and the associated CO_2 emissions reduction are also included on the present work, translating into quantitative data the importance of greenhouse gases reduction to an airline and reminding TAP′s social responsibility commitment.

2. Weight Variant Selection

All concepts, models and algorithms that were used throughout this work are explained on the present section. Regarding the results computation, it was required an implementation of a computational code written in SQL language, on the *QlikView 11 software*, making use of the developed methodology afterward presented.

2.1. Design Weights

On the very beginning of an aircraft model development, just after the conceptual design phase, design weights are established in order to ensure the aircraft compliance with respect to the predefined aircraft mission (e.g. civil, commercial, military). Some of the most important design weights are included on the WV package and will be used throughout the entire work: MTOW, Maximum Zero-Fuel Weight (MZFW), Maximum Landing Weight (MLW) and Maximum Fuel Capacity (MFC).

Proper weights and balance control are vital to an efficient and safe aircraft operation, therefore the maximum allowable weights for an aircraft are determined by the manufacturer through design considerations. The manufacturer provides the aircraft empty weight value and its center of gravity location to the aircraft operator at the time the certified aircraft leaves the factory. These weight limits are based on the aircraft maximum structural capability, which is established during aircraft design and certification phases culminating on the Manufacturers Empty Weight (MEW), that ultimately defines the aircrafts flight envelope.

Given that each airline operator has their own items onboard, whose weight may vary from airline to airline, and thus the resultant Operating Empty Weight (OEW) differs from airline to airline within each aircraft model, the OEW is therefore computed for each aircraft model as follows:

$$\begin{aligned} OEW = MEW + Standard\,Items \\ +Operator\,Items \end{aligned} \tag{1}$$

In commercial aviation, every aircraft purchase is beforehand evaluated in terms of these design weights constraints in order to analyse flight envelops, operational feasibility and potential commercial profit. The design weights constraints are related to different flight stages: taxi-in, take-off, climb, cruise, descent, loiter, landing and finally taxi-out.

Regarding the aircraft and passengers′ weight, the MZFW is the design weight that limits the Zero-Fuel Weight (ZFW) itself, in other words, the most an aircraft may weight when loaded with passengers (pax) and cargo, without any usable fuel or oil onboard.

$$ZFW = OEW + Max\,Payload \tag{2}$$

Adding to the previous mentioned ZFW the oil and fuel weight needed to operate and we get the Take-Off Weight (TOW), which is confined by the MTOW. This is, the design weight constraint for

the feasibility of the take-off, however, two different scenarios may exist when the TOW is the only weight concern: either the pax and cargo load exceed the aircraft MTOW or due to airport limitations the TOW is limited by the runway (TOW_{rwy}).

The TOW_{rwy} limitation is the maximum weight that a specific aircraft can safely lift of from a runway where some identified disadvantageous conditions may exist, such as: severe meteorological conditions, Take-Off Run Available (TORA), enroute obstacles or even potential engine failure. On the final flight phase landing - the aircraft must be light enough to comply with its structural limits when touching down, which is defined by the MLW stated on the aircraft design weight itself. This means that the initial fuel carried on board should not overcome the trip fuel plus alternate fuel, in order to guarantee that the Landing Weight (LW) is lower than the MLW at touch-down time.

2.2. Polynomial Method

Based on the estimated performance values given by the manufacturer, regarding the trip fuel consumption and the ZFW in three different Load Factor (LF) scenarios: max pax, 85% LF and 70% LF; it was observed that within these three different points a polynomial approximation could be made, in order to get a mathematical relation between the trip fuel consumption and the ZFW.

Using those three different points, corresponding to three distinct payload scenarios (max pax, 85% LF and 70% LF), it is possible to compute a polynomial equation:

$$Trip\,Fuel\,[kg] = A.ZFW^2 + B.ZFW + C \quad (3)$$

After the complete computation of coefficients A, B and C for every route on every quarter of the year, including annual average, considering that every quarter of the year and every operated route have their own coefficient values due to own characteristics such as, temperature or pressure; it is possible to identify and compute any operational restriction associated with weight limitations (i.e., MTOW, MZFW, TOW_{rwy}, MLW or MFC), through the implementation of these coefficients on the equation system presented on the next subsection.

2.3. Weight Constraints

Focusing on the main goal of this present work: selecting the optimum WV for the A320neo family sub-fleet; it is known that the only constraints, regarding the payload and thus the ZFW value [see equation (10)], are the design weights. These constraints can be described on the following equations and afterwards decomposed in several variables based on the previous calculated coefficients. The ZFW limitations are:

$$\begin{cases} TOW \leq MTOW \\ ZFW \leq MZFW \\ TOW \leq TOW_{\text{rwy}} \\ LW \leq MLW \\ LoadedFuel \leq MFC \times \rho \end{cases} \quad (4)$$

Which are equivalent as:

$$\begin{cases} ZFW + Trip\,Fuel + Reserves \leq MTOW \\ ZFW \leq MZFW \\ ZFW + Trip\,Fuel + Reserves \leq TOW_{\text{rwy}} \\ ZFW + Reserves \leq MLW \\ Trip\,Fuel + Reserves + Ground\,Fuel \\ -Taxi_{\text{in}} \leq MFC \times \rho \end{cases} \quad (5)$$

Where:

$$\begin{cases} Additional\,Fuel = 300\,kg \\ Trip\,Fuel = A.ZFW^2 + B.ZFW + C \\ Reserves = Contingency\,Fuel \\ +Diversion\,Fuel + Additional\,Fuel \\ Contingency\,Fuel = 3\% \times Trip\,Fuel \end{cases} \quad (6)$$

Once these five equations are separately solved for each route and time period five distinct ZFW values are obtained, however, the unique ZFW result for each route and time period must be:

$$Max\,ZFW\,[kg] = Min \begin{cases} ZFW_1 \\ ZFW_2 \\ ZFW_3 \\ ZFW_4 \\ ZFW_5 \end{cases} \quad (7)$$

In order to guarantee reliable results of maximum ZFW, through the quadratic approximation, all the three coefficients are necessary (i.e. A, B and C). Otherwise, the approximation would become either linear or constant:

$$Trip\,Fuel = \begin{cases} = B.ZFW + C;\ if:\ A = 0 \\ = C;\ if:\ A = B = 0 \end{cases} \quad (8)$$

Consequently, the implementation of conditional statements on the developed *QlikView script*, were necessary to ensure accurate values of maximum available ZFW for each route and time period. The following conditional propositions were thus stated:

$$ZFW = \begin{cases} Eq.(7);\ if:\ A,\ B,\ C \neq 0 \\ Null;\ if:\ A = B = 0 \end{cases} \quad (9)$$

Knowing the ZFW and the aircraft OEW, the maximum available payload to carry on board is easily computed:

$$Max\,Payload\,[kg] = ZFW - OEW \tag{10}$$

Since TAP′s main business is pax transportation, the following equation shows the pax number computation. However, if this value overcomes the total aircraft available seats, the remaining value of available payload is assigned to cargo transportation. The corresponding load factors for the same routes and periods are also trivially calculated:

$$\#Pax = min\,(\frac{Max\,Payload}{Avg\,Pax\,Weight};\,\#seats) \tag{11}$$

$$Cargo\,[kg] = Max\,Payload - Total\,Pax\,Weight \tag{12}$$

$$LF\,[\%] = \frac{\#Pax}{\#seats} \times 100 \tag{13}$$

Summarizing the methodology, it makes use ZFW and Trip fuel values for three distinct load factor scenarios to obtain several quadratic coefficients for each route and time period. Once the coefficients are computed the available maximum ZFW is calculated through five limitation equations [see eq.(9)]. Thereafter, the maximum available payload, namely, pax number and cargo on board, are trivially computed for each WV in every route and year quarter.

2.4. **Selection Criteria**

As the objective of the present work is determining the optimum medium-haul fleet composition according to the selected WV, including all WV specifications on the present methodology was therefore required. To do so, the corresponding design weights of each WV (i.e., MTOW, MLW, MZFW) are inputs of the previous ZFW limitation equations and consequently each WV can lead to distinct limitations, within the same routes and time periods.

In order to achieve those quantitative limitations, in terms of maximum available payload and design weight constraint, respectively, an average pax weight value had to be primary settled down.

Starting from each WV MZFW value and knowing TAP′s OEW for both aircraft (A320neo and A321neo), the maximum available payload is then calculated through equation (2). After that, dividing the maximum available payload per an average pax weight we get the maximum pax number that can be carried on board.

So, considering this approach, a conservative average pax weight of 100kg was selected and considered on further computations within this chapter, based on bibliography [4].

Since every aircraft model has its own weight variant specification, the following table summarizes every design weight considered in a preliminary study for the medium-haul fleet segmentation, which are also the inputs of the above mentioned "ZFW limitation equations".

Aircraft	WV	MTOW	MLW	MZFW
A320neo	050	73,5	66,3	62,8
	051	73,5	67,4	64,3
	052	77	66,3	62,8
	053	77	67,4	64,3
	054	79	66,3	62,8
	055	79	67,4	64,3
	056	70	66,3	62,8
	057	70	67,4	64,3
A321neo	050	89	77,3	73,3
	051	89	79,2	75,6
	052	93,5	77,3	73,3
	053	93,5	79,2	75,6
	070	80	71,5	67

Table 1: WV specifications in tonne [t]

This Tab.1 comes from the *System Configuration Guide* [2], and enables some preliminary WV exclusions.

A320neo preliminary WV exclusion:

Every WV containing a MZFW value equal to 62,8 tonnes (t) - i.e., WV050, WV052, WV054 and WV056 - are primary excluded from the analysis otherwise their selection would represent a huge initial limitation in terms of maximum available pax number and cargo.

The WV057 is also primary excluded from the study due to its low value of MTOW (equal to 70 tonnes). Observing the values of required TOW on every time period for every route studied, an A320neo with WV057 selected would not be able to perform 89% of total legs during every year quarter, within TAP route network, and therefore is excluded from the analysis.

A321neo preliminary WV exclusion:

Since the OEW for this aircraft model on TAP's future fleet is equal to 52122 kg, the following calculation shows the inefficiency of the WV050, WV052 and WV070 (both with MZFW=73300kg) to operate within high standards, which is, on full pax occupation. Considering equation (10) applied to an A321neo ACF model with an average pax weight of 100kg the maximum available payload would be 21178kg, which represents a load factor of 95,8%. This value represents a huge initial payload limitation and therefore these WVs are excluded.

Since TAP′s main business is passenger and cargo air transportation, respectively, the chosen principal criteria to analyse route feasibility is of course the maximum load factor available, in respect to pax number, for each WV under analysis. Hereupon, the sequence of selection criteria for each aircraft fleet segmentation study is as follow:

1. Only feasible routes (i.e., with minimum 70% LF capability) are eligible for analysis;
2. If different WV have the same LF capability for the same considered routes, the lowest WV is then selected on those routes;
3. Within the same routes, if maximum LF available is less than 85% for every WV, the lowest WV is selected;
4. For routes with available LF greater than 85%, a comparison between maximum available LF and real LF, obtained through airline flight records, should be made route by route;

3. Results

3.1. Quadratic Coefficients

The quadratic coefficients used by the developed *Qlikview application* to get the proposed performance load factor results, through the ZFW limitations equations, are related to every year quarter plus annual average for every considered route.

Unfortunately, due to preliminary overlapped ZFW and Trip Fuel values within LF=70%, 80% or 100%, some coefficients can be null and therefore the correspondent routes cannot be analysed, as previous mentioned on chapter 2.3.

For computation effect, only routes with null quadratic coefficients during the entire year are excluded from the study, since these coefficients are required for the correct running of the *QlikView tool*. Those excluded routes are shown on the table below:

Routes:	VXE-LIS	DME-FNC	PDL-YYZ
A320neo	Null	N/A	N/A
A321neo ACF	Null	Null	Null
A321neo non-ACF	Null	Null	Null

Table 2: Null coefficients

Although these routes are excluded, the load factor result from the complementary legs (e.g. LIS-VXE, FNC-DME, YYZ-PDL) may be simply indicatives of hypothetical values.

3.2. Available Payload

In order to properly select the optimum WV, a series of parameters were chosen to display route-by-route every aircraft WV′s feasibility. Since the developed *QlikView tool* forecasts every route limitation (i.e. MTOW, MZFW, MLW and TOW_{rwy}) and the consequent maximum ZFW value, it uses equation (10) to compute the available payload and then, in accordance with the average pax weight chosen by the application user, is displayed the maximum available pax and cargo on board as well as the associated load factor, for each route, period and weight variant, as it can be seen on the following figure 1:

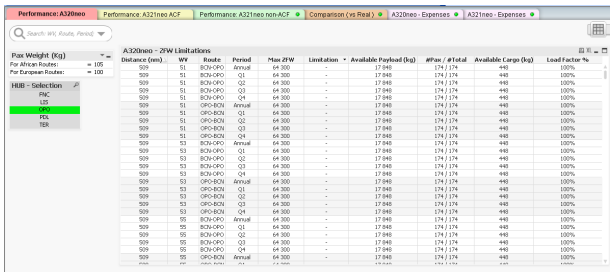


Figure 1: Payload results

3.3. Feasibility Analysis

The *QlikView tool* displays several performance-related parameters as we have seen before on fig.1, however, the key-factor to decide which WV to be selected is going to be the LF result (i.e. max pax per total aircraft seats), since passenger transportation is the main TAP′s operation focus. Having that in mind, a route-by-route LF analyses was performed considering an average pax weight of:

- 100kg on European routes;
- 105kg on African routes;

The LF results are classified according to the following rules:

- $LF \leq 90\%$ - red background
- $90\% < LF < 95\%$ - yellow background
- $95\% \leq LF < 100\%$ - green background
- $LF = 100\%$ - green background & bold

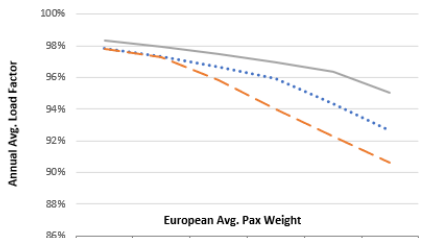
Regarding the A320neo WV051 route feasibility analyses and despite its lightweight costs associated the overall load factor results revealed that only 170 out of 223 routes - i.e. 76% of total route network - would be feasible to operate with LF greater than 85%, which means that WV051 is not a viable financial option due to the huge revenue decrease that it would create. At this point in time, only WV053 and WV055 are worth analysing and therefore the following algorithm was route-by-route fulfilled in order to select the optimum WV:

$$\begin{cases} LF_{WV053} = LF_{WV055}, & WV053 \\ LF_{WV053} \leq 85\% \,\&\, LF_{WV055} \leq 85\%, & WV053 \\ LF_{WV053} \leq 85\% \,\&\, LF_{WV055} \geq 85\%, & WV055 \end{cases} \tag{14}$$

3.4. **Sensitivity Test**

In order to qualify the WV selection decision robustness, a sensitivity test was performed manipulating the average pax weight through a controlled user experience on the *QlikView application*.

The following charts summarizes the expected annual average LF when applying average pax weight increments. The considered average pax weight range is [100kg; 110kg] for European routes and the average pax weight regarding African routes is assumed to be 5kg heavier, however, fig.2 includes both values on the entire route network. The average pax weight is incremented by consecutive 2kg steps.



	100	102	104	106	108	110
A321neo non-ACF WV051	98,3%	97,9%	97,5%	96,9%	96,4%	95,1%
A321neo ACF WV051	98%	97%	97%	96%	94%	93%
A320neo WV053	98%	97%	96%	94%	92%	91%

Figure 2: Sensitivity results

These sensitivity tests regarding A320neo WV053 and A321neo ACF & non-ACF WV051 shown remarkable figures:

- Even though the initial avg. pax weight conservatism (heavier pax than from reference [4]) the initial LF results are still feasible regarding the WV selection criteria;
- After an unrealistic 10kg average pax weight increment, the entire route network can still be operated with a $LF \geq 90\%$.
- With this extremely conservative average pax weight results is proven that the proposed WV′s have still some safe buffer.

3.5. **Cost Reduction**

The novel WV selection method compared with the older TAP′s WV selection method, has revealed significant figures regarding financial cost reductions, associated with a downgrade regarding the new A321neo coming out of factory between 2020 and 2025 when compared with the current TAP′s A321ceo fleet.

This section shows the major cost reductions achieved, sometimes considering for the effect an hypothetical overall route operation equal to 2018′s one. The achieved results concerns immediate costs as aircraft acquisition and perpetual costs such as navigation fees, landing fees and ownership costs. Due to confidentiality issues, the following results are shown in terms of delta between weight variants related to the higher one, for both aircraft models A320neo and A321neo.

Landing Fees:

There are many charges to be paid by airlines due to airport services. Those airport services are charged through various fees related to: landing/take-off, parking, aircraft shelter, passenger service (per boarding count), equipment, safety and even with reduced mobility passenger services.

To compute the accumulated annual landing fees for the present case study, an average landing fee from all Portuguese airports [5] was computed and used for every airport landing charge according with the aircraft MTOW value.

Although this method may not include the accurate value of each airport, it is still a reliable way to obtain the desired results, since TAP′s main hub is Lisbon and $44,5\%$ of its total operations goes through Lisbon, roughly half of the landing fees are paid in Portugal. Also, these results only represent deltas instead of particular values.

Aircraft	WV	MTOW [tonne]	Landing Fees [euro/AC]
A320neo	055	79	-
	053	77	-28.178,00
	051	73,5	-74.295,75
A321neo	053	89	-
	051	89	-63.400,50

Table 3: Annual Landing Fees Cost Reduction

As expected, the WV selection has a relevant impact on TAP expenses regarding landing fees, thus, Tab.3 shows the annual cost reduction values per aircraft in terms of delta, between the higher WV and others, for the A320neo and A321neo aircraft.

Navigation Fees:

Air service navigation providers recover the cost for facilities and services provided to airspace users through route charges. Therefore, on an international flight the total amount paid by an airline is the sum of every navigation fee charged on each overflown flight information region (FIR), i.e. each FIR has its own unit rate that multiplied by the correspondent flown distance (from the FIR entry point until the exit point in kilometres) and multiplied again by the aircraft weight factor, gives the navigation fee charged by each air service navigation provider [6]:

$$Navigation\,Fee = Distance\,Factor \times Weight\,Factor \times Unit\,Rate \tag{15}$$

$$\Leftrightarrow Navigation\,Fee\,[eur] = \frac{Distance\,[km]}{100} \times \sqrt{\frac{MTOW\,[t]}{50}} \times Unit\,Rate\,[eur] \tag{16}$$

In order to compute the previous equation (16) for every operated route considering different WV′s, the same flights operated by TAP during 2018 were considered and the unit rate used through the computation is an Eurocontrol countries′ average [7] in euro currency, which is 50 euro rounded up. Although the most accurate approach would have been the computation of navigation fees with every unit rate from each FIR for every considered route, the present one gives a reasonable perspective since the desired values represent a delta between navigation fees when flying aircraft with different WVs.

Aircraft	WV	MTOW [tonne]	Navigation Fees [euro/AC]
A320neo	055	79	-
	053	77	-25.898,75
	051	73,5	-72.044,46
A321neo	053	89	-
	051	89	-47.979,48

Table 4: Annual Navigation Fees Cost Reduction

As it can be seen at Tab.4 the WV selection has indirect costs associated with navigation fess, since the MTOW represents in this case a navigation fee input, as shown on the previous equation (16).

Ownership Costs:

Nowadays, it is difficult to find an airline owning an entire purchased fleet without leased aircraft, due to different reasons, but mainly because of the lack of financial liquidity or even strategic reasons. Aircraft operational lease contracts usually covers a 12-year period, which allow airlines to adopt short-term strategic decisions in order to fit into more updated market constraints.

As result of this floating demand, lessors (owners of aircraft) adjust their rents according to market conditions and translates the operator aircraft specifications (designated as lessee) into increased ownership costs (e.g. rent values). Since the WV selection comes from a manufacturer chargeable specification change notice (SCN). Thes costs are presented on table 5 as a delta:

In order to translate the SCN charge into a monthly ownership cost increase, a correlative factor of monthly rent increase per extra lessors investment was established as 1,1%. In other words, this factor means that lessors usually charge (through a monthly rent increase) 1.100Eur/month more per each 100.000Eur they invest in operator customized items, such as the WV. The previous correlative factor is not a random choice since it came from TAP managers experience, who got it throughout many years on aviation business.

Aircraft	WV	MTOW [tonne]	SCN Cost [euro/AC]
A320neo	055	79	-
	053	77	[redacted]
	051	73,5	[redacted]
A321neo	053	89	-
	051	89	[redacted]

Table 5: WV SCN Cost

Aircraft	WV	MTOW [tonne]	Ownership Cost [euro/AC]
A320neo	055	79	-
	053	77	[redacted]
	051	73,5	[redacted]
A321neo	053	89	-
	051	89	[redacted]

Table 6: Annual Ownership Cost Reduction

Bearing in mind the 1,1% factor, WV selection implies different WV SCN cost and so the ownership cost per aircraft, as shown on table 6.

4. Conclusions

The feasibility analysis performed on the A320neo WV053 has proven that the suggested WV053 is capable to comply with the predefined feasibility criteria in almost every route within the case study. Besides, the missing routes where A320neo WV053 does not met the feasibility requirements are currently not operated by TAP, therefore no route belonging to TAP route network is affected. In the future, if TAP decides to open some new routes which require increased designed weights a specific study shall be performed for those routes. Several factors shall be included on that study, namely the passengers′ demand which will affect directly the payload and as result the rate of annual flights that would require increased WV. If this rate is minor, it would not justify the additional investment as well as the loss of the A320 neo fleet commonality.

The major share of TAP′s medium-haul fleet is composed by Airbus A320 aircraft, and the new A320neo version is now becoming a key player

within that major share. In a few years, the A320neo will represent more than 50% of the total TAP's medium haul fleet. Following the recommendation presented on the this study in regards to the WV selection (In the end of 2019, TAP will already have 7 A320neo with that specification) and taking into consideration that "Cabin wise" all A320neo have exactly the same configuration, therefore, the result will represent an advantage for TAP′s operations control center, because all of its A320neo aircraft will be able to cover the entire medium-haul route network, simplifying the process to surpass any operational irregularity.

On top of that, sensitivity analysis results regarding average pax weight are also acceptable for the A320neo, which allows TAP to generate additional revenue either from passengers extra luggage or by selling cargo capacity, while keeping the same WV. Regarding the A321neo aircraft with "European" configuration, during the course of 2019 TAP will reach 9 of these aircraft model (6 A321neo non-ACF and 3 A321neo ACF). As it was previously highlighted, and in order to avoid splitting even more the medium-haul fleet, TAP will most likely consider the A321neo ACF and A321neo non-ACF aircraft as single aircraft model for route assignment purposes.

These 9 airplanes already contain the WV053 and, as it was demonstrated on this study, it is more than sufficient to cover all those routes already operated by TAP that might require the highest WV053. This specific analysis was very conservative, both in terms of required payload (average pax weight, number of seats blocked for business seat triples and for crew rest) and required block time (total annual utilization was considered). Besides that, a satisfactory feasibility result was also achieved, since only PDL-EWR and YYZ-PDL routes did not comply with the imposed feasibility criteria even selecting the WV051 for the A321neo non-ACF. Although these routes are not currently operated by TAP, and despite the non-compliant feasibility result, it would still be possible to operate PDL-EWR and YYZ-PDL at least with 85% LF and 82% LF, respectively, with the A321neo non-ACF.

Besides, this study proves that the WV051 should be selected for the incoming A321neo ACF (10 aircraft to be delivered between 2020 and 2025), because the routes requiring the WV053 are already covered by the current A321neo WV053 fleet, the selection of 10 aircraft A321neo with WV051 instead of WV053 will represent a total annual saving of 2,4M euro, roughly, from 2025 afterwards (see tab. 7). This value already demonstrates a great achievement, but it will probably be underestimated since TAP is currently considering adding some further aircraft from the lessors′ market (on top of those 10 airplanes) during that period.

Cost Reduction	[euro/AC]
Landing Fees	-63.400,50
Navigation Fess	-47.979,48
Ownership Cost	-128.199,99
Total:	-239.579,97
Total per fleet (10 AC):	-2.395.799,70
Total during lease (12 years):	-28.749.596,40

Table 7: A321neo ACF WV051 cost reduction

Last but not least, this dissertation also provides a great support for the required fleet renewal in terms of WV selection. TAP will probably replace several ceo aircraft by neo aircraft during the incoming years and these achieved results show that keeping the current network, TAP should select WV053 and WV051 for the A320neo and A321neo ACF, respectively. If TAP decides to launch new routes requiring increased design weights, a specific route-by-route analysis shall be performed. However, it is important to highlight that the current A321neo fleet already provides some buffer for that requirement.

The present study will support TAP′s final decision regarding the WV selection for A320neo and A321neo ACF fleets, to be delivered between 2020 and 2025, that should be announced in July 2019.

5. Future Work

Although the proposed work objectives were achieved, many other features may still be included on the developed Qlikview tool in order to enhance it and support airline decisions on several topics. The performance algorithm already included on the QlikView tool was developed in such way that allows quick updates, therefore, implementing additional programming code lines would enable more sensitivity analyses, for instance based on Equivalent Still Air Distance (ESAD) variation, runway conditions and other factors that directly impacts the OEW (e.g. loaded water or available catering items). As previous explained, aircraft definition and configuration process is also made of several SCNs, and not exclusively the WV one. Therefore, other charged SCNs can also be evaluated in order to compute cost/benefit ratios. The tool can be primary updated to support other selections that may require performance analysis, such as: engines suppliers and maximum thrust rates, avionics (e.g. SATCOM), as well as cabin and cargo characteristics depending on the commercial and operational requirement for each route. Selecting those systems based on routes requirements, and not for the entire medium haul fleet, would definitely decrease the air-

lines ownership costs of those airplanes. Although the implemented *QlikView tool* is now set to quantify route feasibility and cost reduction related to the current available WV options for the A320neo and A321neo aircraft, it can also be applied on different aircraft (e.g. A220, A330 or A350) as well as in different route network profiles, since the polynomial relation (see eq.3) developed for the Trip Fuel computation was successfully tested.

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