Fleet Level Direct Operating Cost Assessment of Advanced All New Mid-Range Transport Aircraft

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Abstract

Aircraft concepts and technologies can be assessed in various ways, targeting several key performance indicators. They can be assessed on mission level, fleet level or global air transport level. In this paper a fleet level direct operating cost (DOC) assessment of an advanced all new mid-range aircraft is performed. In a first step, range dependent DOC and seat mile cost (SMC) characteristics are provided for various aircraft. The new mid-range aircraft concept is then integrated into a fleet composition and compared to a baseline fleet scenario with the respective fleet level direct operating cost.

Keywords: Technology Assessment, Overall Aircraft Design, Fleet Level Assessment, Mid-range aircraft, AVACON Research Baseline

1. Introduction

Modern aircraft and aircraft technologies are increasingly developed and analyzed using multidisciplinary and integrative methods. Model based system engineering (MBSE) methods play an important role for holistic assessment of configurations and technologies. The focus of the paper lies on a fleet level direct operating cost (DOC) assessment of the technologies that are integrated with MBSE means and a respective mindset into conceptual design of an advanced mid-range aircraft. In the two project ATLAs (DLR-internal project) and AVACON (German funded LuFo V.3 project) the tasks of integrating technologies into an all new midrange aircraft were very similar. Although the technologies assessed in each project are unalike the integration and assessment are comparable.

2. Overall Aircraft Models and Performance

The models of the different disciplines from various partners and institutions were integrated into an integration framework. The workflow used in ATLAs is described in [1] and shown in Figure 1.

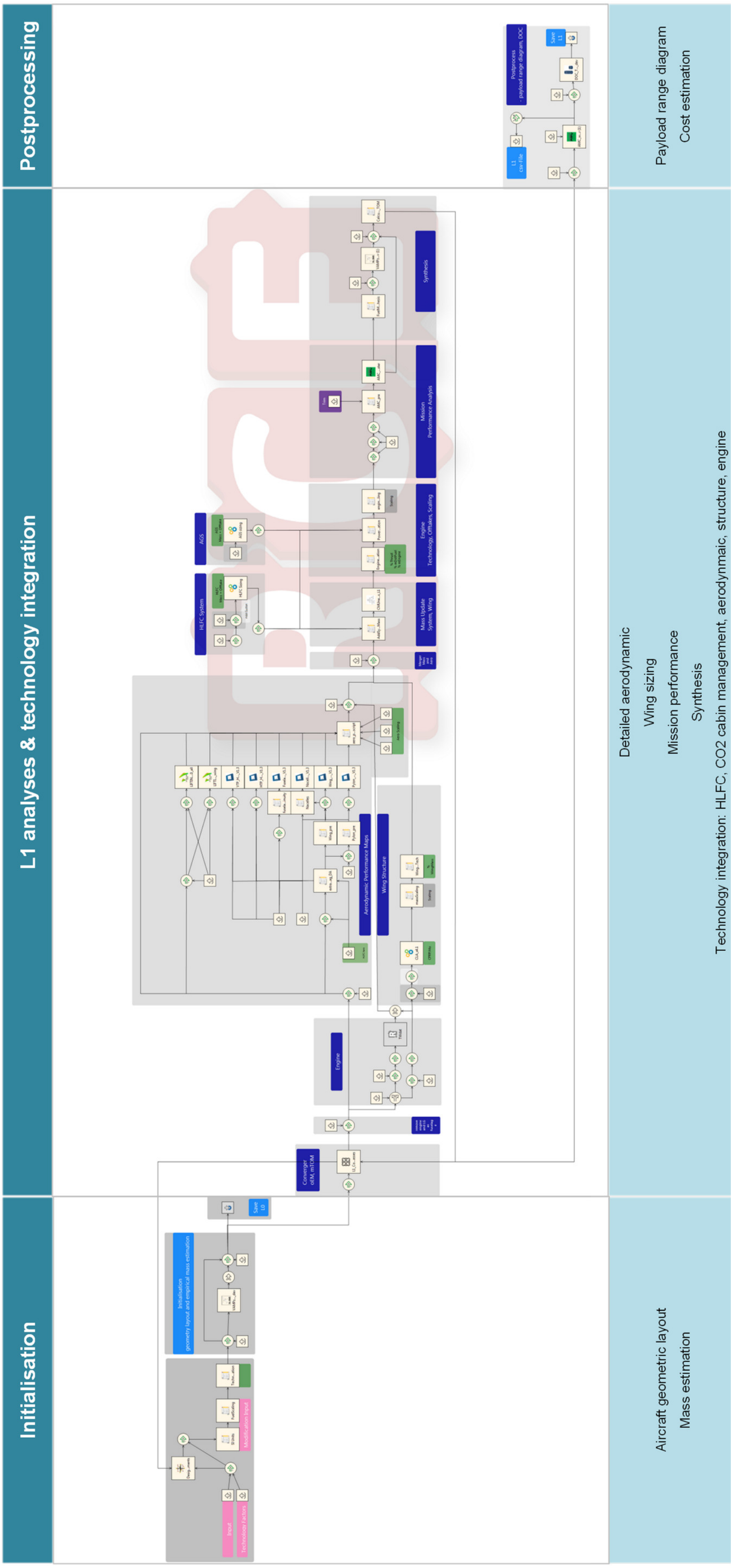

Figure 1 – Design and integration workflow.

The reference future mid-range aircraft taken into consideration is the AVACON research baseline (ARB2028) described in [2] and [3]. The top-level aircraft requirements (TLARs) for the ARB2028 are compared to the B767-300 ones and listed in Table 1.

TLARs	Unit	Boeing 767-300	ARB2028
Design Range	nm	4000	4600
PAX (2-class Layout)	-	261	252
Mass per PAX	kg	99.23	100
Standard payload	kg	25900	25200
Max. payload	kg	40900	30000
Cruise Mach number	-	0.80	0.83
Take-Off field length (SL, ISA)	m	2600	< 2000
Approach speed	kt	≤ 141 (Cat. C)	≤ 141 (Cat. C)
Span limit	m	≤ 52 (4D)	≤ 52 (4D)

Table 1 – TLARs of the ARB2028 and the B767-300

The following expected conventional technology enhancements are already integrated into the research baseline:

- UHBR Engine (BPR~16)
- High aspect ratio CRFP wing (AR~12.3, -5% weight factor compared to today's CFRP technology
- Flat cross section with 7-abreast cabin layout and LD3-45 standard-container capability

These assumptions lead to the payload range characteristics and the trajectory of the design mission shown in Figure 2.

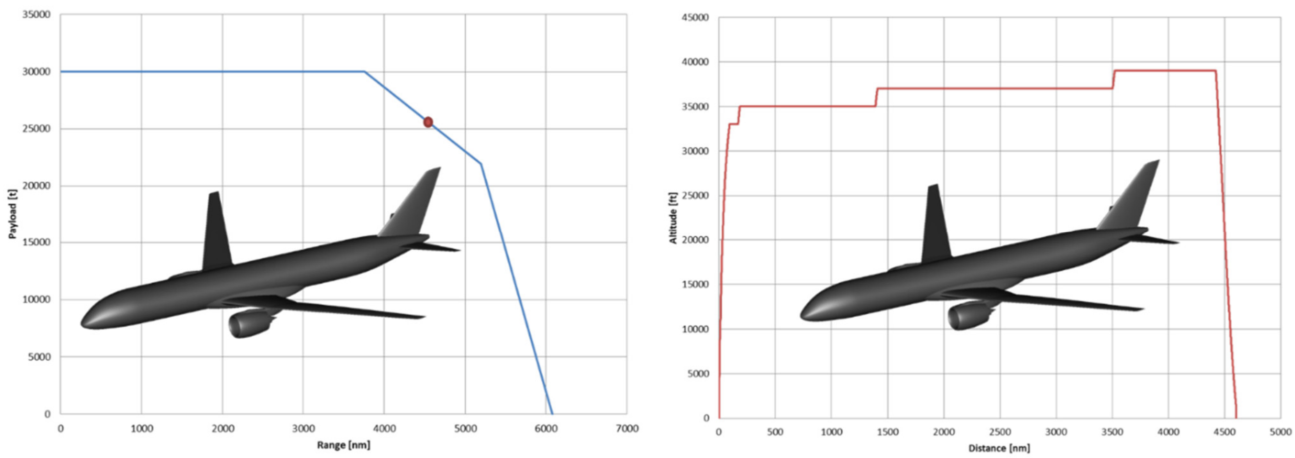

Figure 2 – Payload-range diagram and design mission trajectory of the modelled ARB2028 baseline aircraft

The other members of the current and future fleet scenarios are described by a set of aircraft that are consistently modelled in the same conceptual collaborative aircraft design environment described in [1]. The relevant aircraft additionally modelled are: A321ceo-like, A321-neo-like (D185-321-2015), B757-200-like (D185-752), B757-300-like (D250-753), B767-300-like (D250-763-1980), A330-800-like (D250-333), and A330-900-like. Each aircraft was modelled in a DLR interpretation of the variants with fair and comparable set of assumptions across all programs. The off-design characteristics are assessed afterwards with a coherent performance (cp. Figure 3) and direct operating cost model (cp. Figure 4).

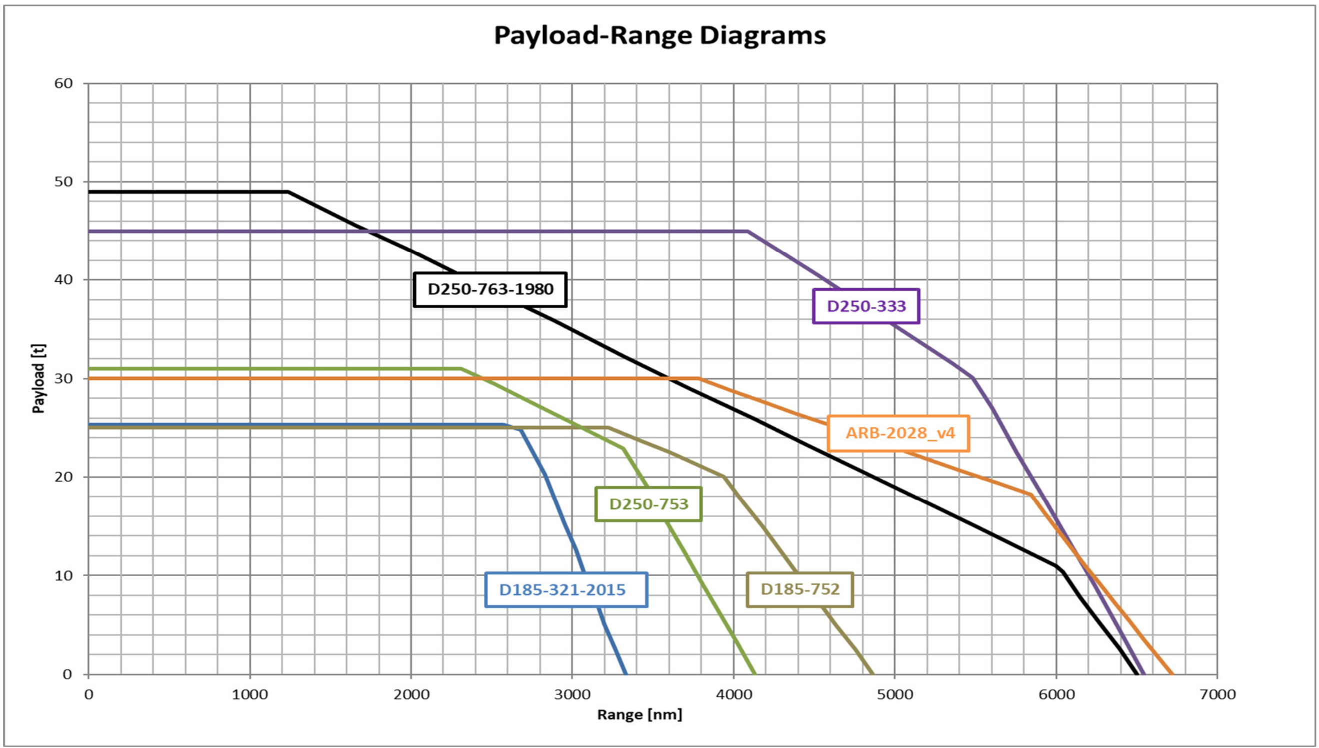

Figure 3 – Payload-range characteristics of assumed members of current and future fleet

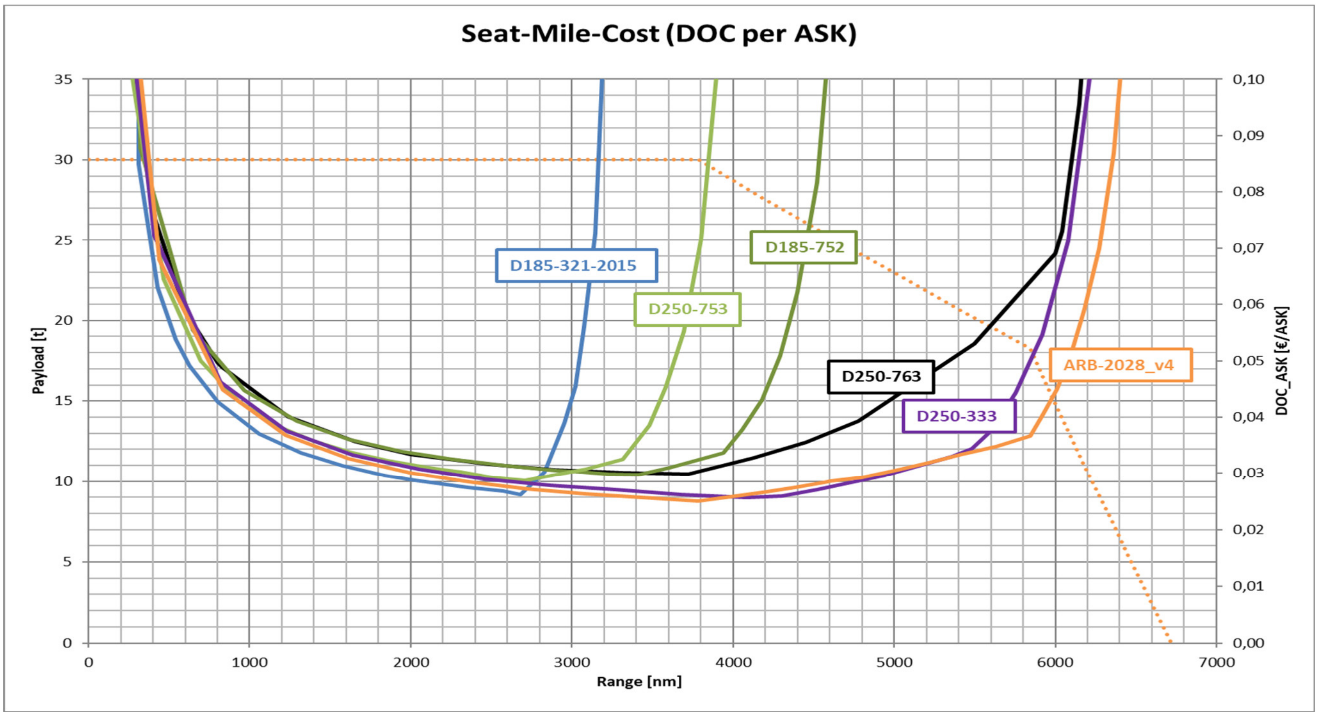

Figure 4 – Seat mile cost of assumed members of current and future fleet

On the mission level cost assessment one can observe that the advanced all new mid-range aircraft has the potential to combine both, the range flexibility of today's wide-body aircraft with nearly the economics of today's single aisle aircraft. At 2000nm the seat-mile-cost of the ARB2028 are about 4,5% higher than a today's A321NEO-like aircraft while the energy consumption per available seat-kilometer is about 3,5% lower. A further cost reduction potential of the ARB2028 could come from shorter turn-around times due to the additional aisle in the cabin. In the current study this potential is not taken into consideration.

The direct operating costs assessment for each aircraft is mainly based on a simplified cost model described in [4]. New technologies and configuration will have an impact on both components of the DOC, the cash operating cost (COC) of an aircraft as well as its prize related capital cost. A typical split of the COC for a fuel prize scenario of about 0.65EUR/kg is shown in Figure 5 for two different payload-range capabilities of the ARB2028.

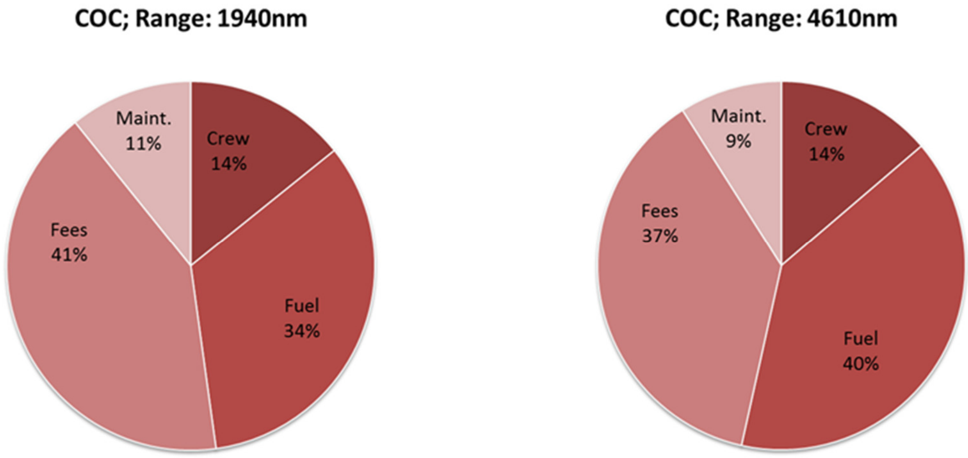

Figure 5 – COC split for two different payload-range capabilities of the ARB2028

The aircraft with the lowest COC per mission will be assigned into the assumed future fleet.

3. Reference fleet and fleet level assessment

In this study the economic and operational viability of the AVACON Research Baseline 2028 (ARB2028) aircraft was further validated by assessing not only the direct operating cost (DOC) but also the fleet composition and fleet assignment when introducing this aircraft into an existing fleet for a specific route network. The resulting fleet scenario serves as a reference for further technology assessment studies.

In the first step, the aircraft types that are bordering the ARB2028 in terms of payload and range that are available on the market were identified. That way, its closest competitors were identified (Figure 6). Due to the assumed entry into service (EIS) in 2028, newer aircraft types such as the A321neo and A330-900neo were also considered. It is clearly visible that the ARB2028 fits well into the middle of the market gap between current single- and twin-aisle aircraft. As the ARB2028 performs ecologically and economically well (see Figure 4) over a broad range of flight distances, this illustrates that it can potentially gain market shares from the single- and twin-aisle segment.

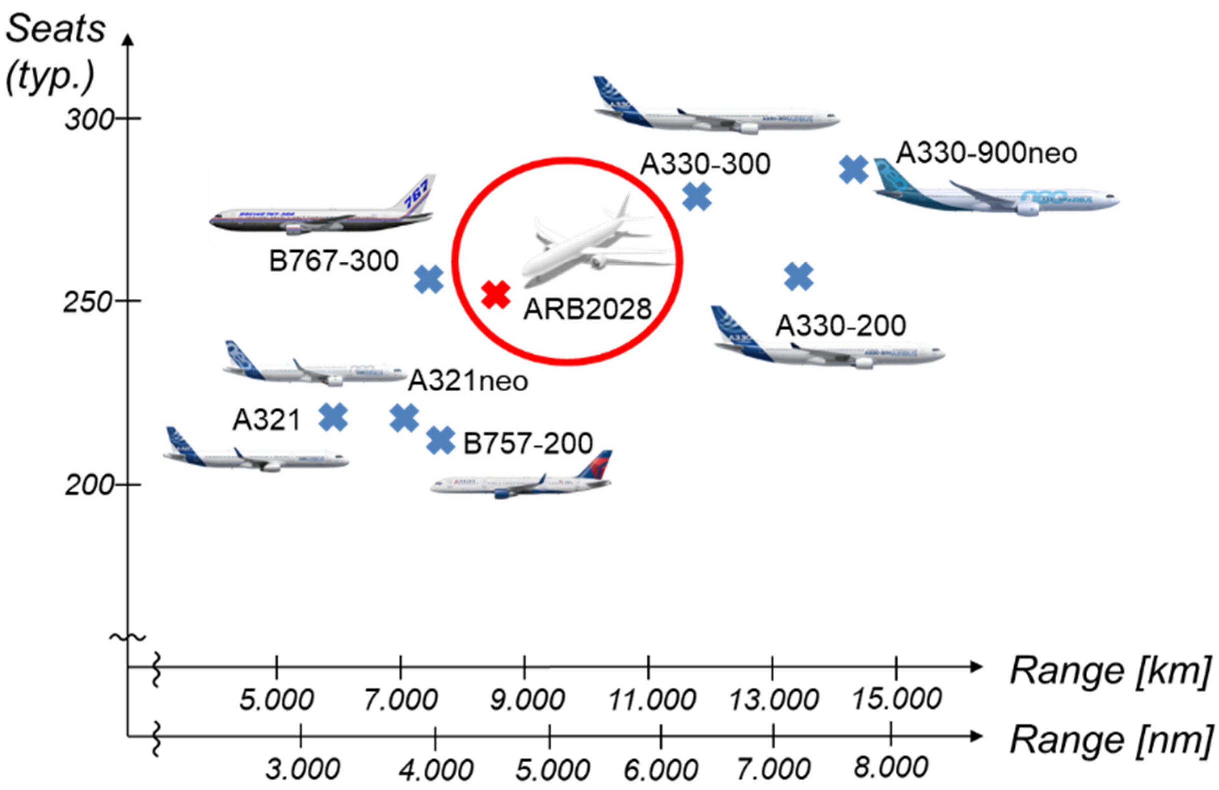

Figure 6 - Payload & range positioning of ARB2028 and its closest competitors

Based on a comprehensive worldwide fleet analysis from [5] it was explored that Delta Airlines operates substantial numbers of all relevant aircraft types as depicted on Figure 7. The average fleet age is relatively high, particularly of the B757- and B767-family. These aircraft types are the most similar to the ARB2028 and produce the majority of available seat miles in the route network. This indicates that a comprehensive fleet rollover could be due within the next years in order to remain competitive. Furthermore, the route network is relatively large and diverse. Therein, each aircraft type (see bottom of Figure 7) is assigned to a specific range of mission lengths from [6]. The A321 operates mainly on short routes, the B757-family covers the short- as well as the medium-haul segment and the A330 as well as the B767 are deployed on the long ranges. Consequently, the selected sub-fleet and the airline network represent a suitable and interesting use case to assess potential replacement dynamics when introducing the ARB2028 into a fleet.

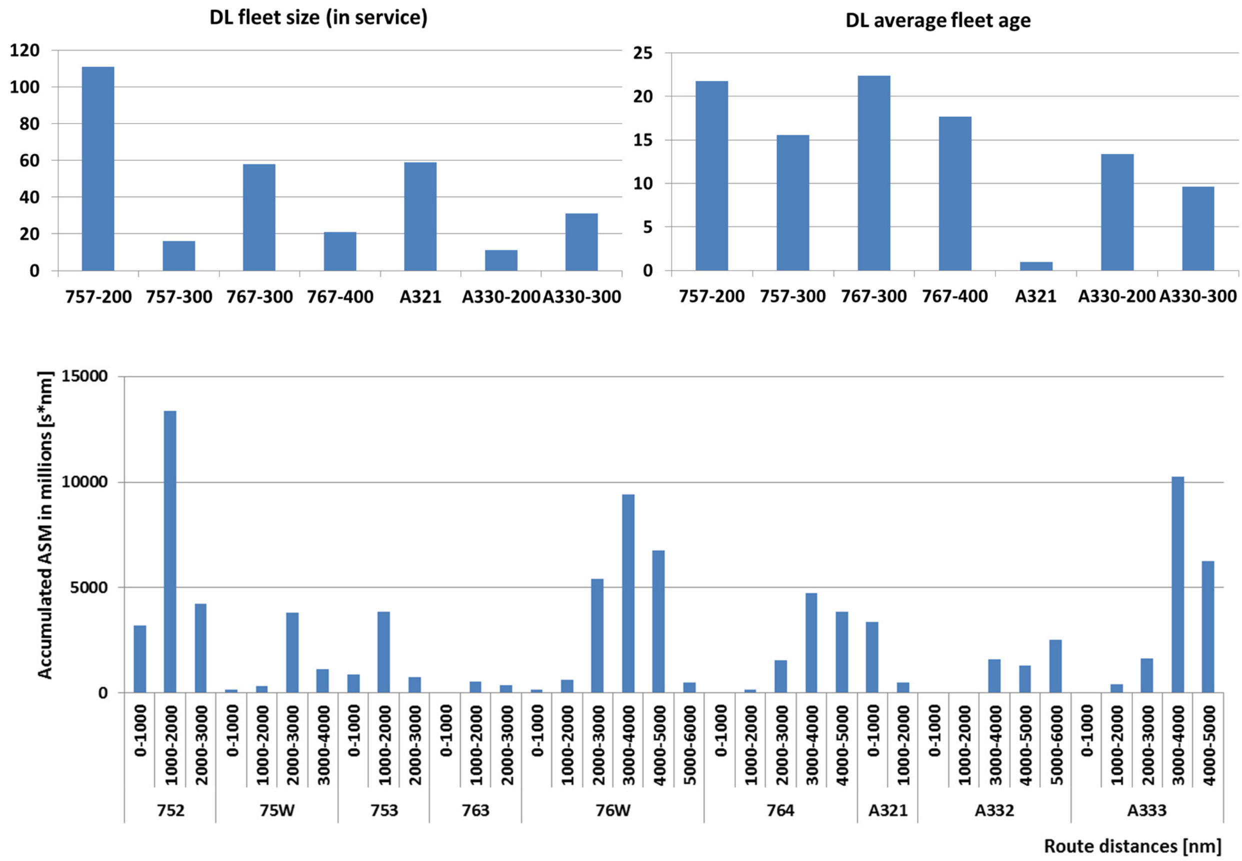

Figure 7 – Top: fleet structure and age; Bottom: fleet assignment of relevant aircraft types in exemplary airline (Status 2017)

To operationalize this goal, replacement rationales were formulated. These reflect according to what logic an airline would introduce the ARB2028. Figure 8 depicts which aircraft types in the airline fleet are replaced. Actual 321neo aircraft orders of the airline were considered as well. In addition, different cabin layouts were assumed for the ARB2028, depending on which aircraft type is replaced. For example, the ARB2028 replacing the B757-300s features a denser seating configuration than the one replacing the B767-300 as the latter is mainly operated on long-haul routes with a notable share of premium seating. The A330-300 is not replaced since it is mainly deployed on routes outside the payload-range capabilities of the ARB2028.

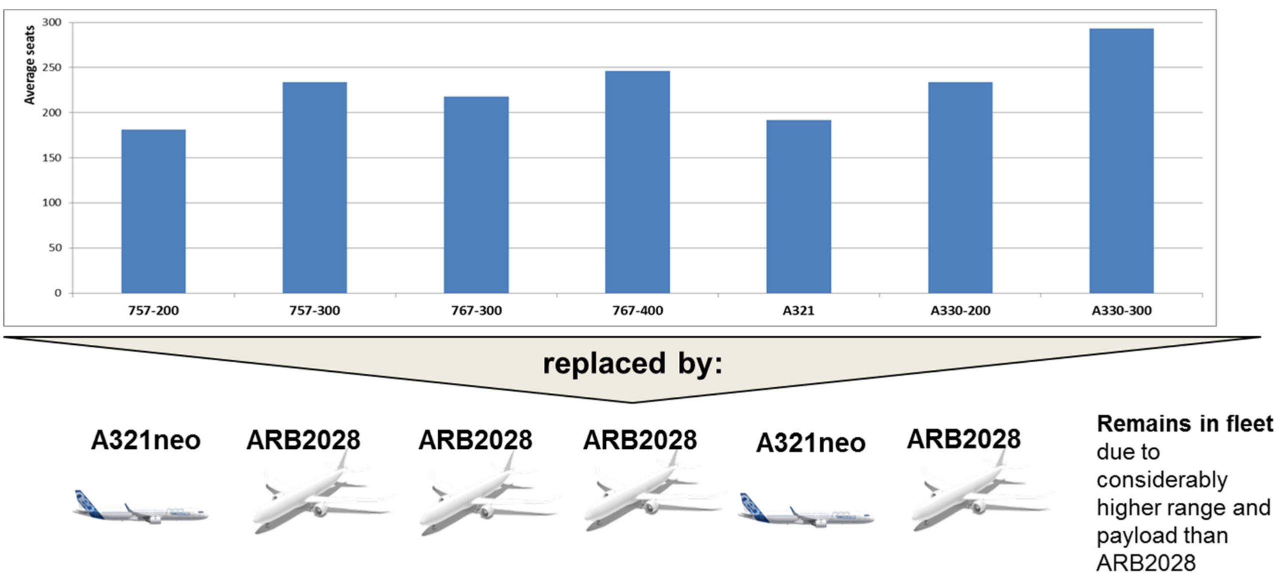

Figure 8 – Aircraft replacement strategy of the reference fleet

The local altitude depending aggregated fuel consumption of the replaced sub-fleet is visualized in

Figure 9. It gives an indication of the network dependent fuel cost distribution, which is the main target of DOC reduction.

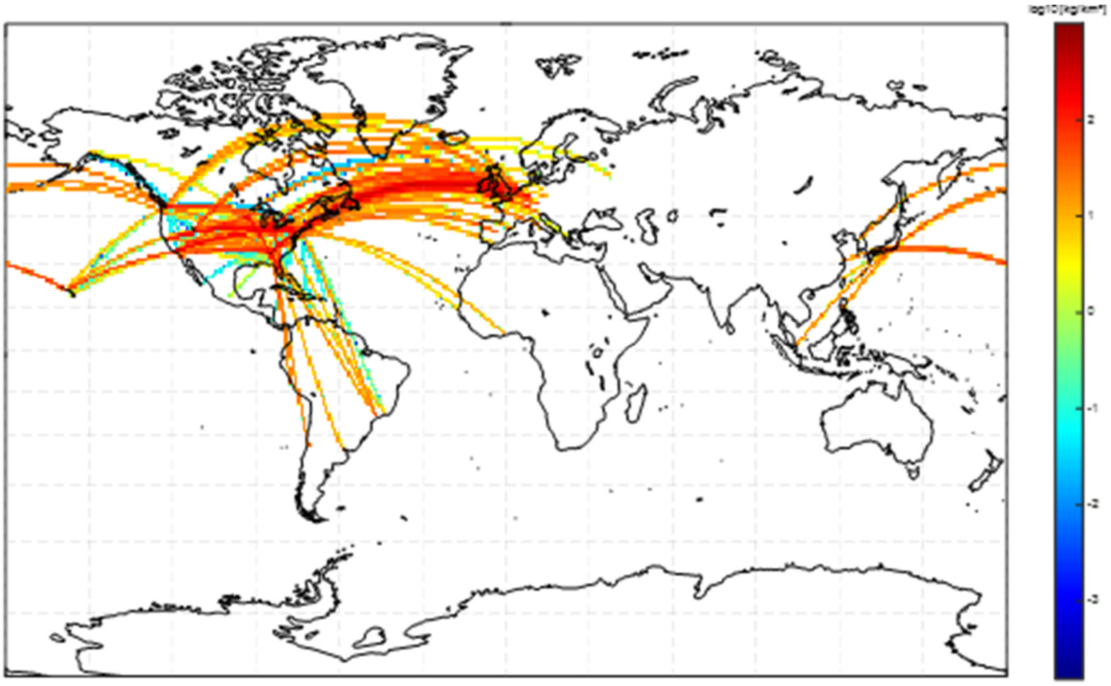

Figure 9 – Visualization of fuel consumption of the replaced sub-fleet network

Figure 10 shows the fleet composition as well as the fleet assignment after the introduction of the ARB2028. The number of different aircraft types decreased from nine to five. The small share of remaining B767 results from a few longer routes that cannot be served by the ARB2028. In practice, an airline would presumably phase-out this type completely to profit from higher fleet commonality. Each aircraft was replaced 1:1, assuming the same aircraft utilizations. A potential increase of the possible aircraft utilization due to technical advancements would reduce the number of required aircraft to perform the same flight schedule which would have a positive impact on capital cost. The right side of Figure 10 illustrates the wide range of distances the ARB2028 is operated on. The large share of flights close to the design range of the ARB2028 (4.600nm) underlines the fit of this aircraft to the exemplary network.

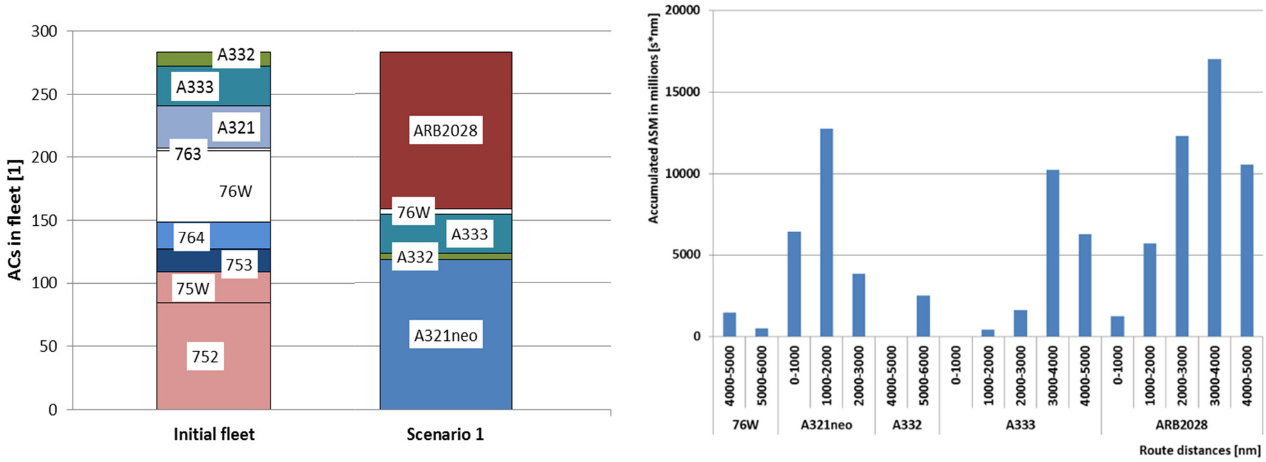

Figure 10 – Left: fleet composition before and after introduction of the ARB2028; Right: Fleet assignment after the ARB2028 introduction

Even though the number of aircraft in the fleet remains constant, the accumulated DOCs of the considered sub-fleet are approximately 12% lower than initially (Figure 11). These numbers were individually calculated based on the DOC model described above. Savings result mainly from the increased fuel efficiency of the ARB2028. The indicated absolute values represent a lower bound as a comparatively low fuel price of 0.25€/kg was assumed for a conservative approach.

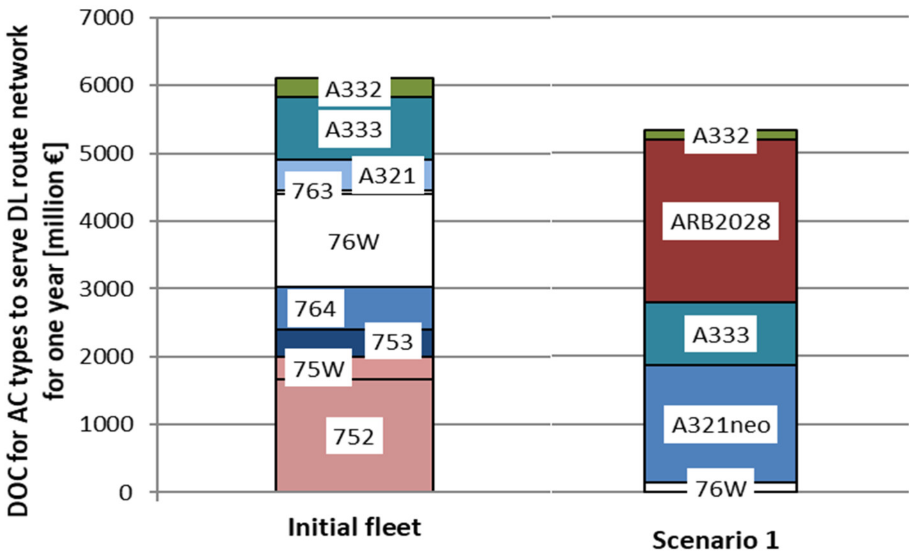

Figure 11 – Yearly accumulated DOCs for the assessed sub-fleet

4. Conclusion

It was demonstrated that the designed ARB2028 covers a broad range of operational profiles. Hence, it is particularly beneficial for diverse airline networks if the number of aircraft types shall be minimized. The presented assessment approach can be applied to other airlines as well as expanded to market regions e.g. to determine market potentials.

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6. Copyright Statement

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