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DESIGN AND ECO-EFFICIENCY ASSESSMENT OF A PEOPLE MOVER AIRCRAFT IN COMPARISON TO STATE-OF-THE-ART NARROW BODY AIRCRAFT

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Abstract

The focus of the is paper is the question whether a People Mover aircraft can make its contribution towards the climate targets by replacing highly efficient narrow body aircraft where preliminary results indicate a significant disadvantage in terms of CO2 emissions per passenger seat. Therefore, the concept will be assessed on its economic performance and on its climate impact contribution.

Keywords: Overall Aircraft Design, People Mover, Cost Assessment, openAD

1. Introduction and Motivation

The People Mover aircraft is a known concept that is designed to carry a large number of passengers on short range routes optimized for short haul operations. In the past, the aircraft design was focused on economics but with respect to the European green deal, future aircraft designs have to reduce their ecological footprint to be sustainable viable. The question that arises is weather such a People Mover concept can make its contribution towards the climate targets by replacing highly efficient narrow body aircraft where preliminary results indicate a significant disadvantage in terms of CO_2 emissions. Therefore, the concept is assessed primarily on its climate impact contribution and secondarily on its economic performance. In this paper the People Mover concept will be derived from the Airbus A350 and compared to a redesign of the Airbus A321neo (both depicted in Figure 1) for a projected technology scenario in 2035 to identify the CO_2 emission and direct operating cost (DOC) saving potential per passenger seat at a comparable technology level. The Airbus A350-1000 will be redesigned with respect to the revised top-level aircraft requirements derived from the DLR 2050 market forecast and anticipated airport constraints [5].

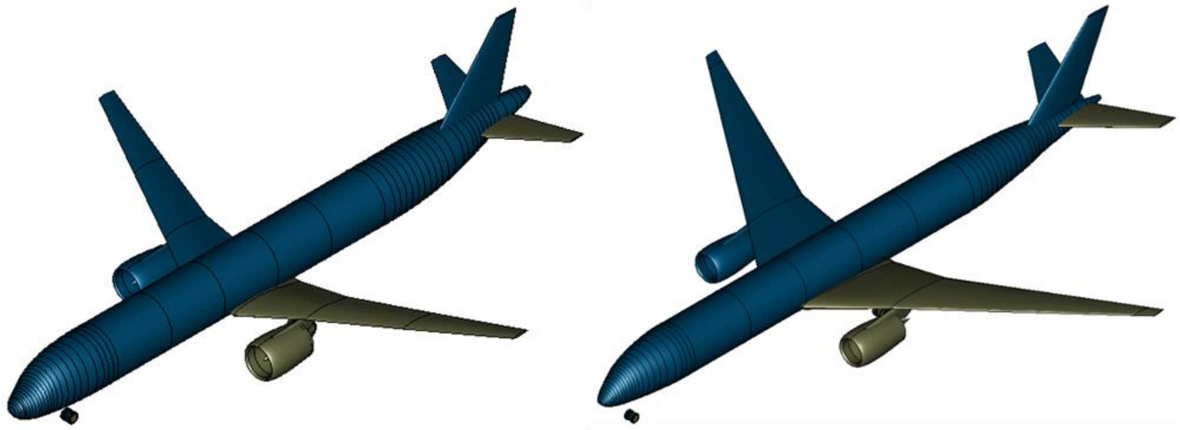


Figure 1 - A321neo and A350 similar aircraft designed utilizing the overall aircraft design environment developed at the DLR-Institute of System Architectures in Aeronautics. [9]

Present-day research, as well as the market forecast released by Boeing and Airbus, highlight a steadily increasing air traffic demand and hence the demand for various new aircraft within the next 30 years [1] [2]. The COVID-19 pandemic is expected to have a short-term negative effect while the long-term air traffic growth will return to pre-crises trends by mid-decade [2]. Particularly Airbus illustrates high demand for aircraft in the category from 175 to 210 seats. In comparison the manufacturers backlog underlines this estimation where the aircraft sales of the Airbus A321neo are surpassing the outstanding orders of smaller versions of the A320 family aircraft [3]. Compared to the forecast of the aircraft manufacturers, studies carried out by DLR indicate an even greater demand for aircraft in the 211-300 seat capacity and above [5]. Figure 2 depicts the passenger aircraft demand until 2050 based on the prediction model described by Gelhausen et al. [4]. The substantial increase in the higher seat categories and the overall tendency towards higher capacity aircraft compared to the manufacturers' forecast is based on capacity constraints of the prospective airport infrastructure.

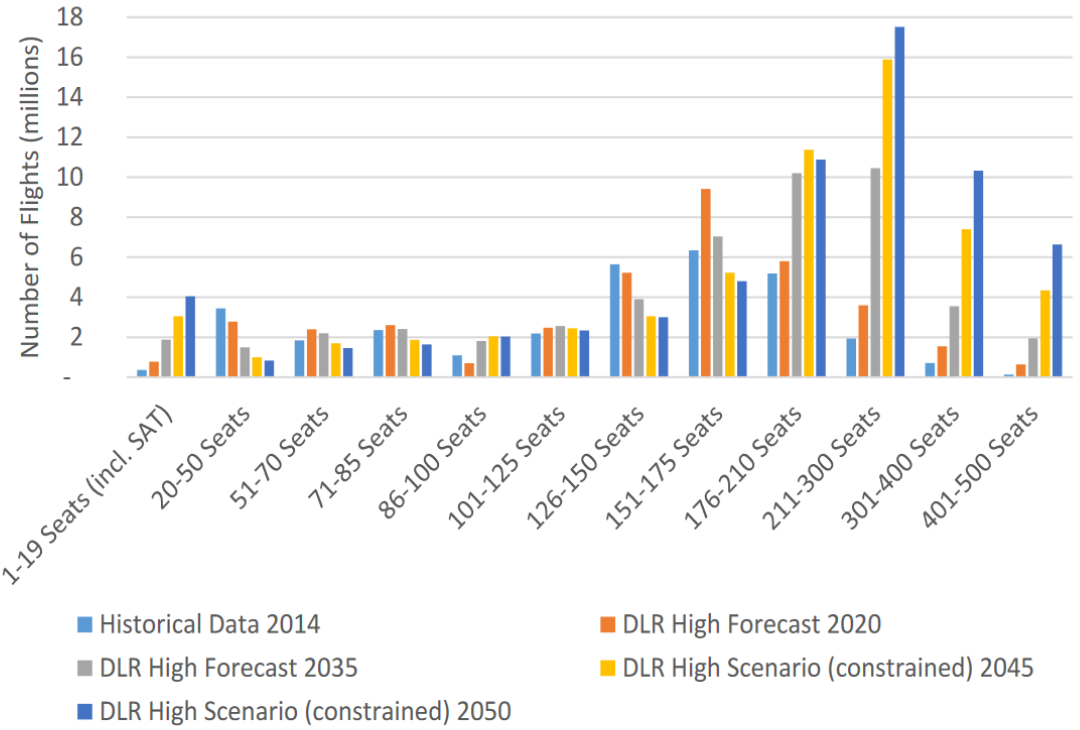
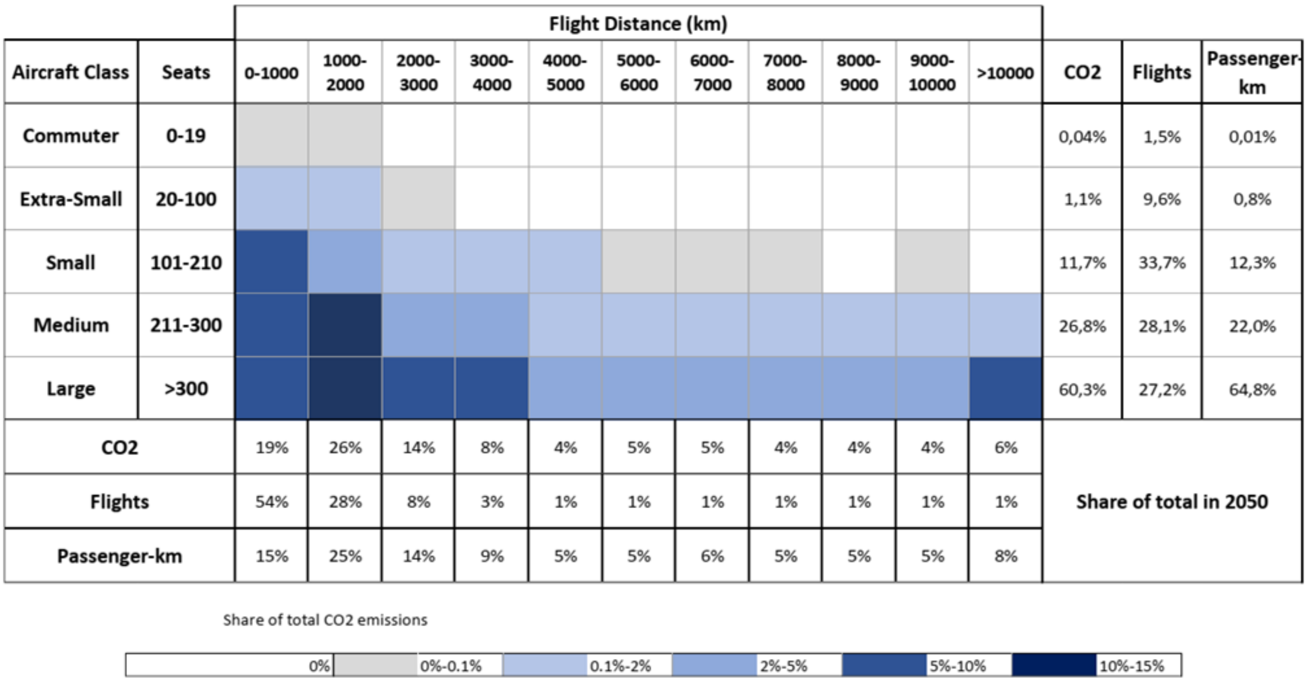


Figure 2 - Fleet evolution in terms of number of flights by seat class up to 2050. [5]

As highlighted by Airbus, the 211-300 seats category can mostly be covered by the stretched versions of the single aisle aircraft family like Airbus A320 and Boeing 737 where the A321neo can accommodate up to 244 passangers. The Boeing 757-300 marked the peak capacity of single aisle aircraft to date, accomodating up to 295 passenger in a high density single class layout [5]. For higher capacities, the narrow body design is not suitable for further stretching due to high turnaround times at the airport and the structural feasability due to slenderness ratio of the fuselage.

Besides the shift towards larger capacity aircraft also the majority of flights (roughly 80%) is anticipated to concentrate on shorter routes as depicted in Figure 3. Thus for larger aircraft of more then 300 seats, a majority of flights is estimated to take place under the range of 4000km. In order to satisfy the air traffic demand and to serve the operational missions in 2050 the People Mover, a wide body aircraft designed for shorter ranges will be focus of this paper. To identify the potential of such a concept, the highest possible seat count based on the A350-1000 reference aircraft will be evaluated.



		Flight Distance (km)													
Aircraft Class	Seats	0-1000	1000-2000	2000-3000	3000-4000	4000-5000	5000-6000	6000-7000	7000-8000	8000-9000	9000-10000	>10000	CO2	Flights	Passenger-km
Commuter	0-19												0,04%	1,5%	0,01%
Extra-Small	20-100												1,1%	9,6%	0,8%
Small	101-210												11,7%	33,7%	12,3%
Medium	211-300												26,8%	28,1%	22,0%
Large	>300												60,3%	27,2%	64,8%
CO2		19%	26%	14%	8%	4%	5%	5%	4%	4%	4%	6%	Share of total in 2050		
Flights		54%	28%	8%	3%	1%	1%	1%	1%	1%	1%	1%			
Passenger-km		15%	25%	14%	9%	5%	5%	6%	5%	5%	5%	8%			

Share of total CO2 emissions

0% | 0%-0.1% | 0.1%-2% | 2%-5% | 5%-10% | 10%-15%

Figure 3 – Aircraft emission by size and distance, DLR forecast 2050. [5]

2. Methodology and Assumptions

Reference point for the design study is the Airbus A350-1000 aircraft in 369 passengers dual-class configuration described by Airbus [6] referred to as D369 in this paper. The D369 represents the DLR interpretation based on the publicly available data. To compare the People Mover design to the state-of-the-art narrow body in terms of efficiency, the Airbus A350 platform was chosen. Together with the Boeing 787, it is the most advanced wide-body aircraft on the market while offering a higher seat capacity than the Boeing 787 competitor. The Boeing 777X was not considered since it has not been certified to this date.

For the short-range concept of the People Mover, a single-class cabin layout needs to be introduced which achieves a comparable comfort standard to state-of-the-art single-aisle short-range configurations. To this end, an outside-in cabin design is performed for the A350 platform using a knowledge-based approach described in [12] and [17]. The results are then compared to a single-aisle design.

The baseline dual-class layout with 54 seats in business class and 315 seats in economy class is displayed in Figure 4. It is based on an existing layout of the A350 [6]. Four exits, two of type A and type B respectively, are necessary to provide the required evacuation capacity. The seat pitch in business class is 60in whereas in economy class it is 32in.

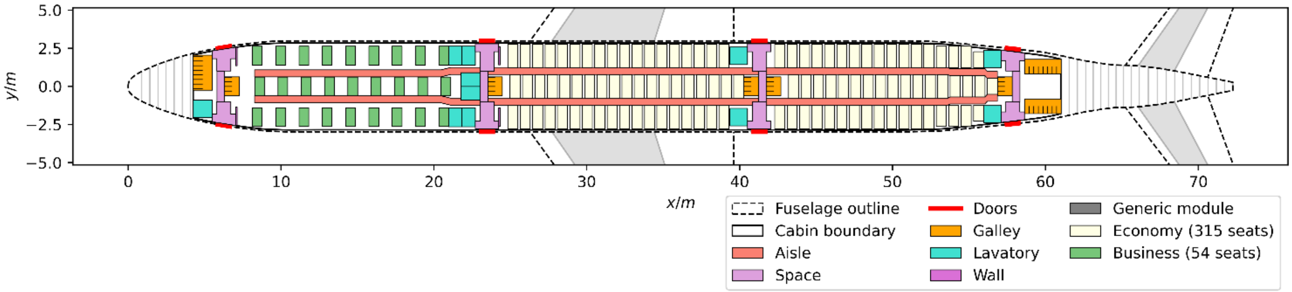


Figure 4 - Dual-class seat layout of the D369 reference configuration after [6]

The seat layout for the People Mover is given in Figure 5. The seat pitch is reduced to 28in, which allows for an increase in the number of passengers to 590. For the further nomenclature this configuration will be referred to as D590. To provide sufficient exit capacity for emergency evacuation, all four existing exits must be certified as type A+ exits with a capacity of 120 passengers for each pair [10]. Furthermore, an additional type A exit is required, which is implemented as an over wing exit. A similar solution can be found in the Boeing 777-300.

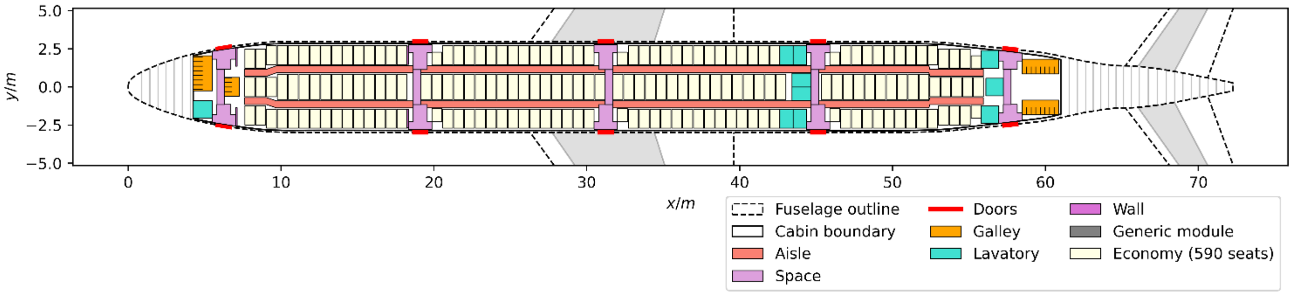


Figure 5 - Proposed single-class seat layout for the 590-passenger configuration

The D239 configuration, which represents the DLR interpretation of the A321neo in high-density layout proposed by Airbus [13], is used as single-aisle reference. It is shown in Figure 6. The first five rows are installed at a seat pitch of 30in, whereas the remainder of the seats are placed with a 28in pitch like in the D590 cabin. Due to the high number of passengers, this layout requires two type C+ exits, with a capacity of 65 passengers, a dual type III over wing exit and a further type I exit behind the wing.

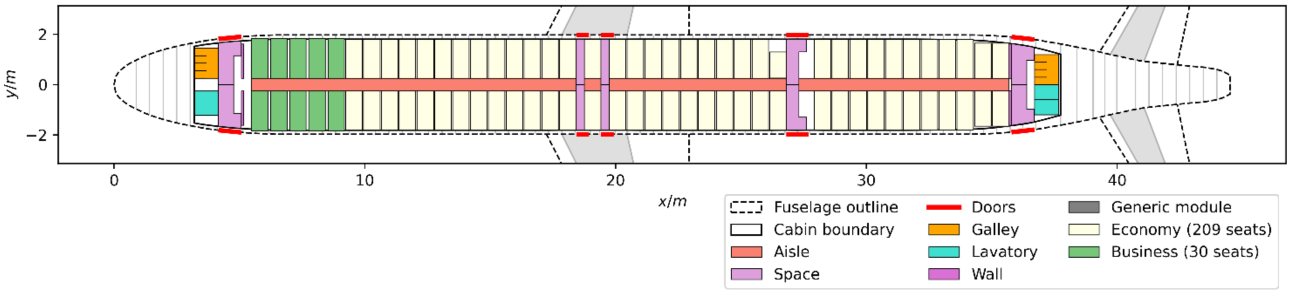


Figure 6 - Cabin A321neo 239 PAX, based on sketch by Airbus as found in [13]

The relevant metrics for the cabin comfort assessment are collected in Table 1 for the three designs. Visibly, the level of comfort is reduced significantly for the People Mover compared to the A350 baseline layout. Aside from the decreased seat pitch, the number of PAX per trolley is increased by over 150%. Similarly, the number of passengers per lavatory is increased by 75%. On the other hand, the D590 still outperforms the D239 cabin, providing both a lower trolley and lavatory utilization.

Table 1 - Comparison of cabin metrics

		D239	**D369**	**D590**
Number of PAX	[-]	239	369	590
Seat pitch (Economy)	[in]	28	32	28
Seat pitch (Business)	[in]	30	60	n/a
Number of trolleys	[-]	8	43	27
Number of lavatories	[-]	3	11	10
PAX / trolley	[-]	29.88	8.58	21.85
PAX / lavatory	[-]	79.67	33.55	59.00
Exits	[-]	2xC+, 2xIII, 1xI	2xA, 2xB	4xA+, 1xA
Exit capacity	[-]	240	370	590

Once the market and size of the People Mover design are fixed, the top-level aircraft requirements of the wide body aircraft have to be adjusted for high frequency short range operation and the associated airport infrastructure. As discussed, the D590 will be designed for a range of 4000km and 590 passengers in single class layout with a maximum payload of 60t. The reduction of the maximum payload compared to the D369, is made since the capability to carry additional cargo is less relevant for short haul operations compared to long haul flights. Thus, the D590 will be optimized for passenger transport only. The flight Mach number and maximum operating altitude are adapted to the characteristics of the A321 to integrate into the established short-range operation and airspace restrictions.

The People Mover aircraft is foreseen to operate mainly on slot restricted airports. Therefore, a seamless integration into today's operations is necessary in terms of separations and noise restrictions during approach which results in a reduced approach speed. The limit is adapted to a maximum of 140 kts to fit the ICAO aircraft approach category C with an approach speed between 121 and 140 knots [14]. Otherwise, compared to the Category D of the A350-1000, a higher separation and noise emissions would have a negative effect on the airport operations at higher flight cycles on shorter routes. Also, the maximum take of field length has to be reduced due to the available airport infrastructure for the advised market. An extension of the runway length on certain airports for the foreseeable future is not considered for the study. Figure 7 depicts the runway length distribution of origin-destination pairs for the anticipated market in 2050. While a shorter take off capability has a negative effect on the efficiency of the design, a higher requirement would limit the operable market share. As a tradeoff, a runway length is selected where around 90% of the market can be serviced.

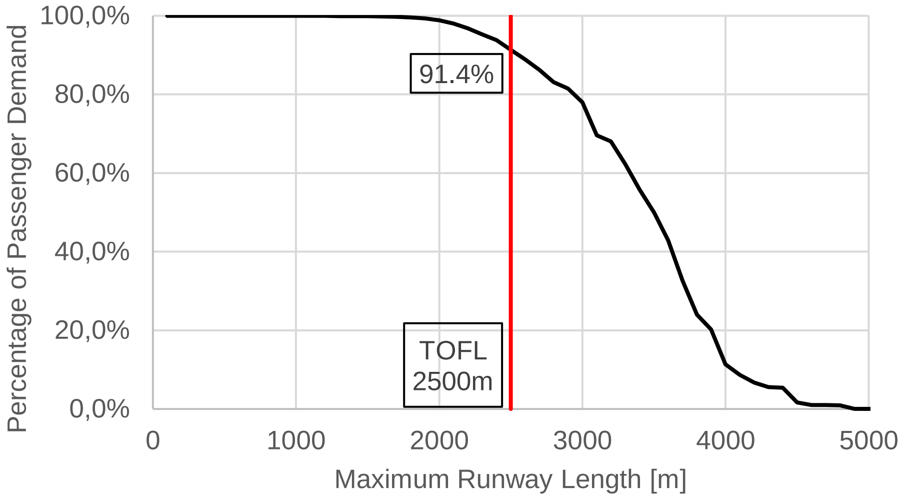


Figure 7 – Runway length distribution for the foreseen market and passenger demand

For airport compatibility, also the outer main gear wheel span, overall length of the aircraft as well as the wing span have to be considered. Especially the wing span categorized by EASA [15] limits the operational capability at the destination airports. According to Bradley et al. [16] the areas impacted by the wing span are:

- runway – runway separation
- runway – object separation
- runway – taxiway separation
- taxiway – taxiway separation
- taxiway – object separation
- aircraft parking position
- de-icing facilities
- engine run-up pad
- aircraft hangars

Since insufficient information about the airport limitations is available for the foreseen market, a worldwide airport traffic statistic is utilized. According to [16] only 23% of airports worldwide are suitable for the operation of a wingspan category D (52m up to 65m) or higher based on the aircraft that actually serve the airports, whilst 58.5% are restricted up to category C (36m). Since a criterion cannot be derived from the market forecast, two designs for 65 meters and 52 meters wing span and a corresponding outer main gear wheel span limit of 15m and 9m will be presented to emphasize the sensitivity on the requirement.

Table 2 summarizes the TLARs for the D590 People Mover together with the TLARs for the D239 and D369 derived from the airport and maintenance planning manuals [14] [6].

Table 2 - TLARs of the D239, D369 and D590

		D239	D369	D590
Design Range	[nm]	2500	7420	2160
Design PAX	[-]	239	369	590
Mass per PAX	[kg]	95	95	95
Design Payload	[kg]	22705	45600	56050
Max. Payload	[kg]	25000	67000	60000
Cruise Mach number	[-]	0.78	0.85	0.78
Max. operating altitude	[ft]	40000	43000	40000
TOFL (ISA +0K SL)	[m]	2200	2900	2500
Rate of Climb @ TOC	[ft/min]	>300	>300	>300
Approach Speed (CAS)	[kt]	136	147	140
Wing span limit	[m]	36	65	65/52
Outer Main Gear Wheel Span	[m]	9	15	15/9
Alternate Distance	[nm]	200	200	200
Holding Time	[min]	30	30	30
Contingency	[-]	3%	3%	3%

The study aims to compare the People Mover design to the state-of-the-art single aisle aircraft. The A321 was originally designed during the 1980s with an engine upgrade in 2015, while the Airbus A350 was designed around 2010 introducing the application of carbon fiber-reinforced polymers (CFRP) for wing and fuselage manufacturing. Thus, the state of technology is not suitable for a fair comparison. Therefore, a redesign for an estimated technology scenario in 2035 will be derived for both designs featuring a similar technology level. Table 3 and Table 4 elaborate the main assumptions for technology factors applied to both designs. The assumptions made are derived from various projects and are applied on overall aircraft design level.

Table 3 – Technology assumption of the D239 redesign for a 2035 scenario

Engine Performance	8%	With respect to PW1000, Bypass 15.5, improved thermal efficiency
Fuselage Mass	-5%	Compared to D239. New Al-alloys as well as new manufacturing and assembly methods, but also new requirements and certification
Wing Structural Mass	-15%	Compared to D239. New materials (CFRP)
Empennage Mass	-3%	Compared to D239. Advanced manufacturing and assembly methods and improved material characteristics
System Mass	ISO	Potential mass reductions are mitigated by new requirements and certification rules as well as additional modularity and increased complexity
Furnishing	ISO	
Operator Items	ISO	

Table 4 – Technology assumption for the D590 design for a 2035 scenario derived from the D369

Engine Performance	11%	With respect to Trent XWB, Geared Turbofan, Bypass 15.5, improved thermal efficiency
Fuselage Mass	-5%	Compared to D369. Advanced manufacturing and assembly methods and improved material characteristics
Wing Structural Mass	-5%	
Empennage Mass	-3%	
System Mass	ISO	Potential mass reductions are mitigated by new requirements and certification rules as well as additional modularity and increased complexity
Furnishing	ISO	
Operator Items	ISO	

Besides the assessment of the climate impact that is derived based on the redesigns discussed, also the DOC is to be elaborated to evaluate the People Mover concept. Therefore, the DOC-model introduced by Thorbeck [18] is applied in this study. It offers a simplified approach that is applicable at overall aircraft level while taking the relevant parameters into account to the extent necessary. The yearly DOC will be calculated and referred to as cost per available seat kilometer (ASK).

In total, the DOC consists of capital, crew, fuel, fees and maintenance cost. To calculate the capital cost, an interest rate of 5%, a depreciation period of 12 years, a residual value factor of 15% and an insurance rate of 0.5% are applied. The price of the aircraft is derived from the aircraft delivery price by taking the recurring and non-recurring costs as well as a profit margin of 20% into account. The adaptations made to the DOC model are described by Hoelzen et al. [19]. It is assumed, that 4000 aircraft of the D239+ are produced while for the D590 scenarios only 1000 are manufactured. This considers, that the People Mover is less flexible at its utilization due to the high passenger demand needed whereas the D239+ can serve additional routes of lower demand due to its smaller seating capacity.

For crew cost, a yearly salary of 85,000 USD for each flight attendant and 175,000 USD for each flight crew member are assumed. The number of flight attendants is estimated by a ratio of one flight attendant per 50 passenger, two pilots per flight and 5 crews in total are considered per aircraft.

The fees are divided into landing, air traffic control (ATC) and ground handling interests. For the range dependent ATC fees, a price factor of 0.65 is assumed for a global utilization of the aircraft as well as a handling fee of 0.1 €/kg and a landing fee of 0.01 €/kg.

As for the maintenance cost prediction, a cost burden of 2 and a labor rate of 50€/h are applied.

The fuel cost and the associated price of Jet-A1 are subject to strong fluctuations and thus hard to predict due to external factors. Therefore, an average fuel price of 0.57 €/kg based on Jet A1 fuel price developments from 2015-2019 is selected [20] to exclude the impact of the COVID-19 pandemic in the years after.

To calculate the yearly flight cycles, a potential yearly operation time of 8760h and an average downtime of 2750 hours are assumed in regard to maintenance, technical and operational reserves as well as night curfews for all designs. The average block time is estimated by 1,65h whereas the deviation from the DOC-method is related to the definition of the block time. In the mission definition utilized for this study, the taxi-in and taxi-out times are included and have therefore to be excluded from the average block time.

3. Aircraft Design and Trade Off Results

For the first design phase, the A350 and A321neo have to be designed using the DLR design environment described by Wöhler et al. [9] based on the publicly available data in [6] and [13]. The nomenclature D369 and D239 is used to refer to the DLR interpretation of an A350-1000 and A321neo similar aircraft. The model for the D239 is designed and calibrated for the maximum take-off mass of 93.5t and the corresponding maximum zero fuel mass of 75.6t similar to weight variant WV052 while the D369 is designed for a maximum take-off mass of 316t and a respective maximum zero fuel mass of 223t according to weight variant WV002. Figure 8 depicts the payload-range diagrams derived for the D239 and D369 compared to the A21neo and Airbus A350-1000 to illustrate the calibration of the reference aircraft.

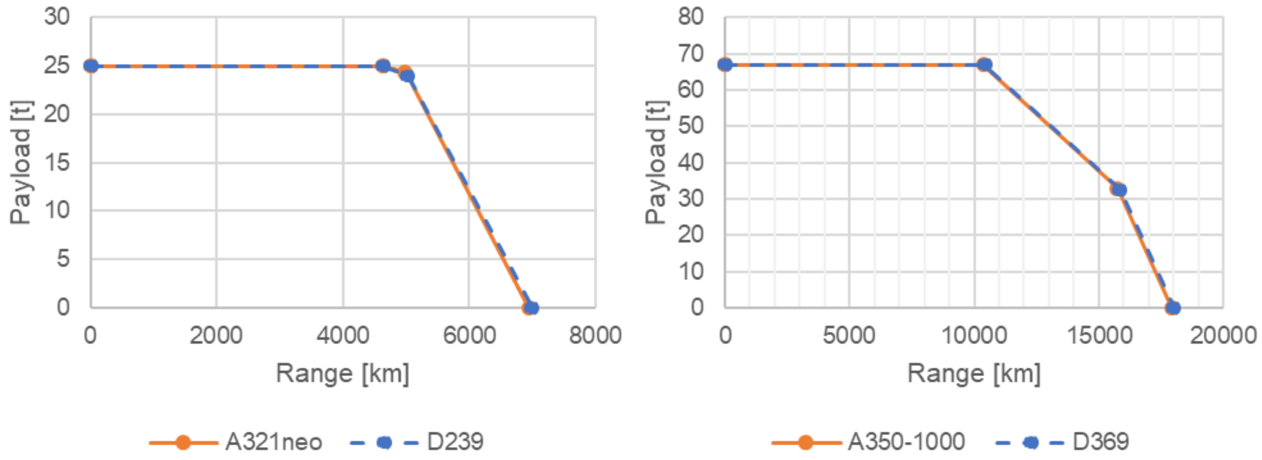


Figure 8 - Comparison of the payload range diagrams of the Airbus A350-1000 and A321neo according to [6] and [13] and the D239 and D369

For the design of the D590 the following design assumptions are made:

The fuselage geometry is kept constant for consistency with the A350. The furnishing, operator items as well as the environmental control system (ECS) and auxiliary power unit are adapted to accommodate 590 passengers on short range operation. Hence, less galleys are integrated and less catering is needed. The crew rest compartment is redundant as well as the inflight entertainment system and the business class seats for high density short haul operation. Liquids such as unusable fuel, oil and water together with the emergency equipment are adjusted to the new tank size and higher seat count. In total, the mass of operator items decreases by around 10% while the furnishing mass increases slightly despite one less lavatory. For provision of the ECS and galleys, the bleed offtakes and power offtakes of the engines have to be increased and are scaled by the number of passengers. The wing area is resized with respect to take off and landing performance and for fuel capacity while fixing the wing span to the box limit of 65m and 52m for the trade study. Adaptations to the planform designs are made with regard to the lower flight Mach number and altitude for profiles, relative chord thickness, wing sweep and taper ratio. As a result of the A350 calibration, a comparatively low maximum landing coefficient of 2.25 is identified. This leads to the conclusion, that the wing area was mainly driven by the need for tank volume among other factors and not by low speed performance. Hence, for the D590, the high lift system is adapted to achieve a higher maximum landing coefficient by integrating a single slotted fowler system leading to a reduced wing area and higher aspect ratio.

The overall changes to the aircraft design compared to the D369 necessitate a redesign of the engines. A new thermodynamic model is set up to incorporate the thrust requirements for take-off, end of field, top of climb and mid cruise condition. The engine is modeled as a geared turbofan with a bypass of 15.5. Based on this architecture, the engine performance deck, geometry and masses are derived and utilized in the design of the D590.

The empennage is resized according to the revised wing keeping the volume coefficient constant. Conclusively, the new set of TLARs and the technology factors are applied. Accompanied by the design of the D590, the specified technology factors for the D239 are applied and the D239+ for 2035 is derived using a comparable approach. Wing, empennage and engine are resized with a span limit of 36m.

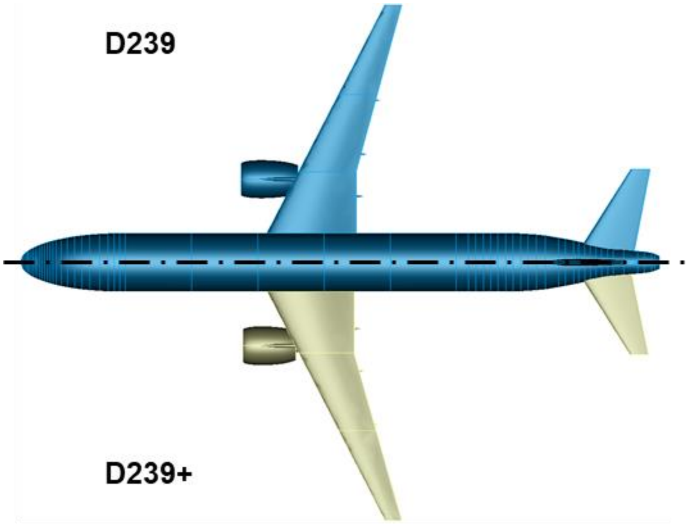


Figure 9 - Comparison of the D239 and D239+ in top view

Figure 9 visualizes the minimal impact of the D239+ redesign compared to the geometry of the D239. Noticeably, the radius of the engine is higher while the nacelle is shorter due to the higher bypass ratio and smaller core size of the engine. At the same time, the wing size is reduced, resulting in a higher aspect ratio at constant span. Overall, the block fuel efficiency is improved by almost 10% on the comparative mission of 800nm, mainly driven by the introduction of CFRP on the wing and the next generation geared turbofan. The 800nm mission is chosen for evaluation as it represents a typical use case of the Airbus A321 in the short-range segment.

In Figure 10 the top views of the D590 at 65m and 52m are compared to the D369, where the change in wing, empennage and engine geometry can be perceived. Particularly, the wing planform adjustment in terms of sweep angle, wing area and aspect ratio plus its impact on the horizontal stabilizer is recognizable. The main design drivers are the lower flight Mach number, the revised high lift system and the drastically reduced design range that leads to a difference in maximum take-off mass of 225.5t (65m) and 232.5t compared to the 316t of the D369. The key characteristics of the D239+ and both D590 span variants are summarized in Table 5.

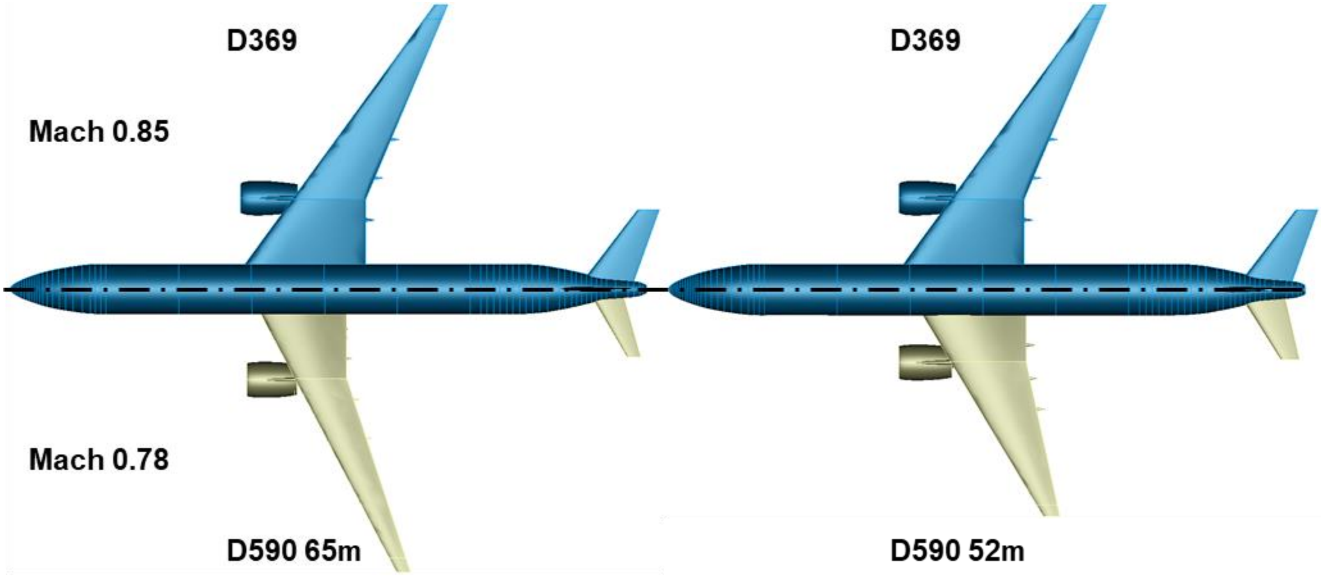


Figure 10 – Comparison of the top views of the D590 designs and the D369

Table 5 - Key characteristics of the D239+ and the D350

		D239+	D590 65m	*Diff. to D239+*	D590 52m	*Diff. to D239+*	*Diff. to D590 65m*
Key Sizing Parameters							
Wing loading (MTOM)	[kg/m2]	715,9	669,2	*-6,5%*	643,1	*-10,2%*	*-3,9%*
Thrust loading (MTOM)	[-]	0,313	0,275	*-12,1%*	0,317	*+1,3%*	*+15,3%*
Masses							
MTOM	[kg]	89050	225450	*+153,2%*	230800	*+159,2%*	*+2,4%*
MLM	[kg]	76250	201800	*+164,7%*	202050	*+165,0%*	*+0,1%*
MZFM	[kg]	73050	198800	*+172,1%*	198450	*+171,7%*	*-0,2%*
OEM	[kg]	48050	138800	*+188,9%*	138450	*+188,1%*	*-0,3%*
Geometry							
Wing Span	[m]	35,8	64,75	*+80,9%*	51,8	*+44,7%*	*-20,0%*
Wing Aspect Ratio	[-]	10,3	12,5	*+21,4%*	7,5	*-27,2%*	*-40,0%*
Wing MAC	[m]	4,16	6,42	*+54,3%*	8,29	*+99,3%*	*+29,1%*
Wing Ref. Area	[m2]	124,4	336,7	*+170,7%*	358,9	*+188,5%*	*+6,6%*
Propulsion (one engine)							
Equivalent static thrust (Sea-level/ISA)	[kN]	136,8	304,5	*+122,6%*	358,5	*+162,1%*	*+17,7%*
Thrust top of climb Req.	[kN]	27,2	57,5	*+111,4%*	68,9	*+153,3%*	*+19,8%*
Thrust mid cruise Req.	[kN]	23,4	49,2	*+110,3%*	58,7	*+150,9%*	*+19,3%*
TSFC mid cruise (800nm)	[kg/s/kN]	0,0137	0,0135	*-1,5%*	0,0136	*-0,7%*	*+0,7%*
Aerodynamics							
C_L cruise (800nm)	[-]	0,581	0,585	*+0,7%*	0,531	*-8,6%*	*-9,2%*
L/D cruise aver. (800nm)	[-]	17,23	21,26	*+23,4%*	18,04	*+4,7%*	*-15,1%*
C_L max TO	[-]	2,43	2,28	*-6,2%*	1,9	*-21,8%*	*-16,7%*
C_L max LDG	[-]	3,03	2,8	*-7,6%*	2,63	*-13,2%*	*-6,1%*
Performance							
Block Fuel (800nm)	[kg]	4567	10156	*+122,4%*	11917	*+160,9%*	*+17,3%*

In Table 6 the CO_2 emissions and DOC for the D590 are summarized and compared to those of the D239+ on an evaluation range of 800nm.

Table 6 - Comparison of the CO2 emission and DOC of D239+ and D590 on 800nm per PAX

		D239+	**D590 65m**	*Diff. to D239+*	**D590 52m**	*Diff. to D239+*
Emissions						
CO_2 (800nm, Mach 0,78)	[kg]	**14431,7**	**32093,0**	*+122,4%*	**37657,7**	*+160,9%*
CO_2 per PAX	[kg]	**60,4**	**54,4**	*-9,9%*	**63,8**	*+5,6%*
Charges						
DOC	[USDct/ASK]	**4,44**	**4,3**	*-3,2%*	**4,5**	*+1,4%*

Compared to the D239+, the D590 with a span limit of 62m achieves a reduction in CO_2 per PAX of 10% mainly driven by a superior aerodynamic efficiency in cruise. While the lift over drag ratio (L/D) is 23% higher due to a higher aspect ratio of the wing among other factors, the benefit is partly cancelled out by an adverse effect of the 17% greater operating empty mass per passenger. The advantage in thrust-specific fuel consumption (TSFC) is the result of a higher total propulsion efficiency due to the considerably larger engine size and indicates a comparable engine technology level.

The second design of the D590 is significantly penalized by the 52m span restriction, which leads to higher CO_2 emissions per PAX of almost 6% in comparison to the D239+. The increased fuel consumption per PAX compared to the 65m span variant is mainly driven by the adverse aerodynamics of the decreased aspect ratio and the negative effect on the maximum lift coefficient in landing configuration resulting in an increased wing area. The operating empty mass and thus the structural efficiency is similar to the 65m span variant, while the lift over drag ratio is 15% inferior. Whereas the lift over drag ratio is still 5% superior to the D239+, the operating empty mass per PAX is 17% inferior. A similar situation can be identified in terms of DOC. Whereas the D590 with a span of 65m has an advantage towards the D239+ of 3,2%, the 52m span variant is at a slight disadvantage of 1,4%. Figure 11, Figure 12 and Figure 13 depict the DOC split for the designs considered. The difference of the number of cycles per anno of all designs result from a difference in climb performance and cruise altitude and thus flight time for the 800nm mission.

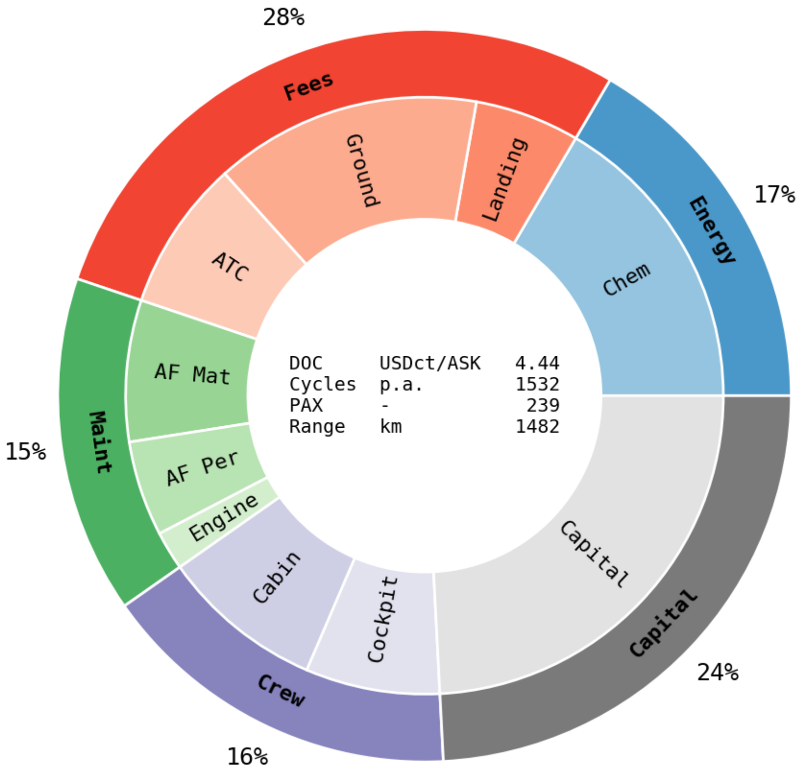


Figure 11 - DOC split of D239+ on 800nm

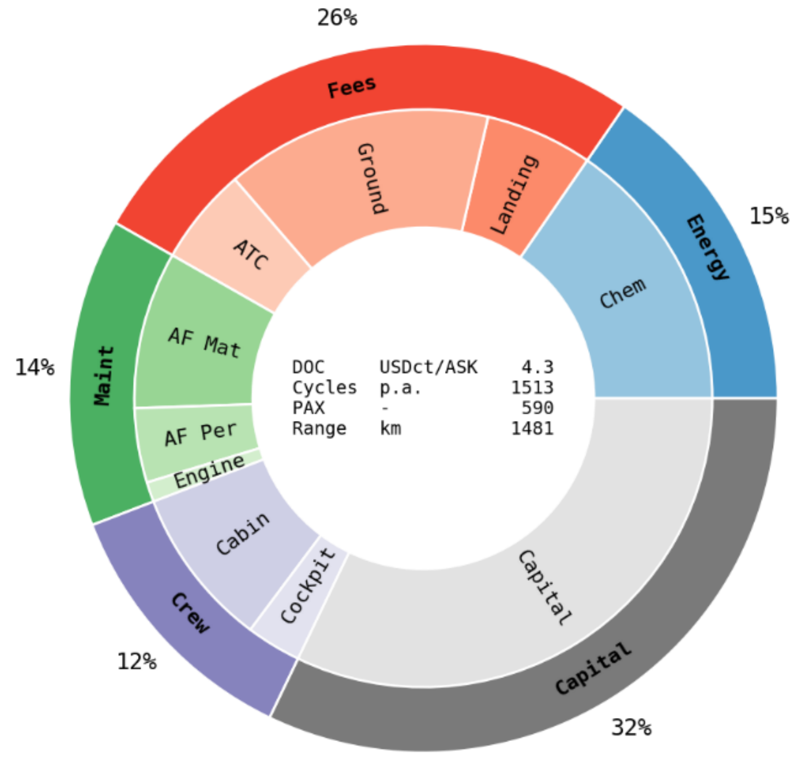


Figure 12 - DOC split of D590 with 65m span on 800nm

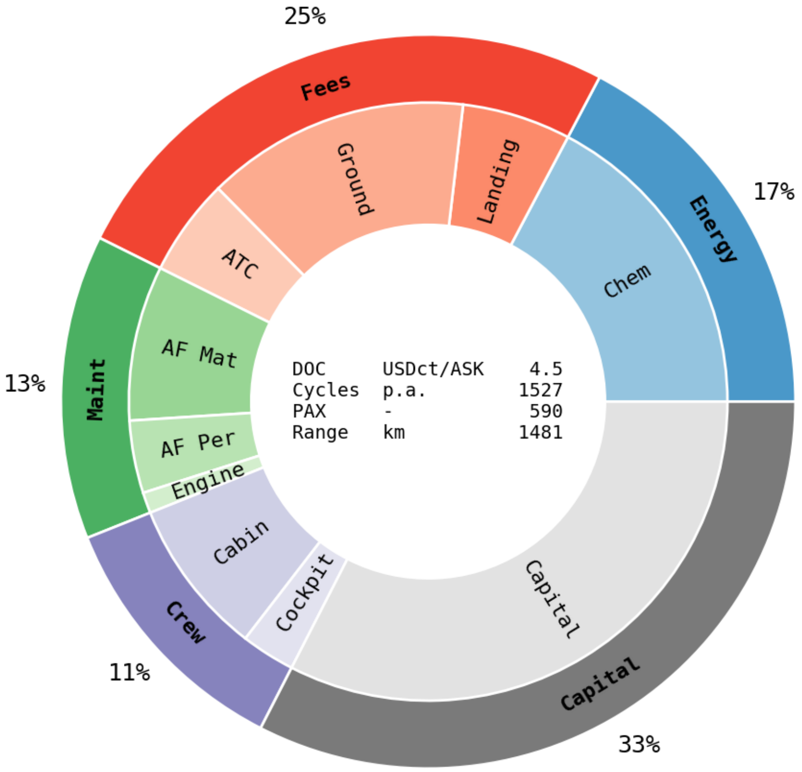


Figure 13 - DOC split of D590 with 52m span on 800nm

Noticeable are the considerable larger rates of ATC fees and cockpit crew salaries per ASK of the D239+ compared to the D590 variants. The ATC fees are mostly driven by the range, while the number of pilots per aircraft is constant and therefore independent of the number of PAX. This distinctive advantage of the People Mover concept is almost compensated by the higher capital cost as depicted by the comparison of the DOC split in absolute values in Figure 14. The greater capital costs are a result of the higher operating empty mass of the aircraft and the lower number of aircraft estimated to be manufactured. Thereby the development, flight testing and production-related costs are allocated to fewer aircraft and are therefore higher for each individual aircraft. The inferior ASK of the D590 with a span of 52m compared to the D590 with a span of 65m and the D239+ can directly traced back to the higher fuel consumption.

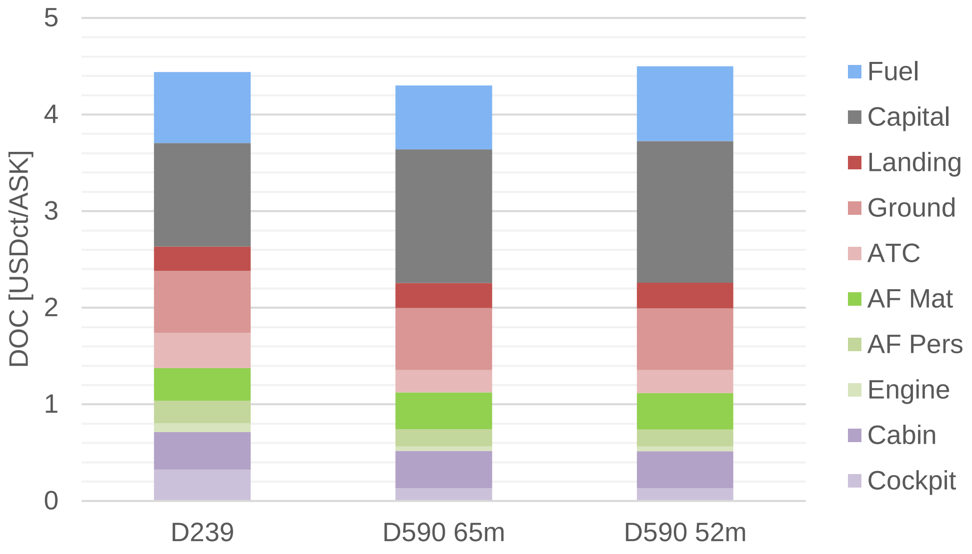


Figure 14- Comparison of the DOC split between D239+, D590 with 65m span and D590 with 52m span

4. Conclusion

In this paper, the design of a People Mover aircraft is presented, based on the DLR market forecast for 2050 under capacity constraints of the prospective airport infrastructure. The People Mover aircraft was derived from the Airbus A350-100 reference aircraft to carry 590 passengers on a range of 4000km for an anticipated technology scenario in 2035. For comparison, a redesign of the Airbus A321neo was conducted for a comparable technology scenario to achieve a consistent evaluation of the People Mover concept. The assumptions made for the adaptions of the TLARS, selection of technology factors, assessment of the DOC and the rationales for the aircraft design decisions are introduced and discussed. Subsequently, the economic performance and climate impact assessment was carried out and presented.

The findings point out the advantage of the People Mover concept compared to the smaller single aisle aircraft, indicating a CO_2 emission reduction of 10% and DOC per PAX improvement of 3% for a wing span of 65m. For the airport-restricted scenario where the wing span was limited to 52m, the People Mover design is inferior to the narrow body design with regards to both evaluation criteria. The CO_2 emissions are 6 % higher and the DOC are slightly worse by 1%. In this scenario, the People Mover aircraft could solve the increased passenger demand limited by the airport slot constraints but only at a higher cost of CO_2 emissions and direct operating cost.

This indicates, that the viability of the People Mover concept is strongly linked to the available infrastructure and the question, whether a sufficient share of airports can be served. Thereby, only 41,5% airports worldwide can be operated by aircraft with a wing span of 52m or higher. Correspondingly, 58,5% of today’s airports cannot be served and would even require a wing span limited to 36m and less. Not considered in this study is the integration of folding wing tips as introduced by Boeing on the 777X. This technology would allow to exceed the span constraint by folding the outer parts of the wing at the given span limit after landing to operate at certain airports and thus improve the efficiency of the concept. However, if a wing span constraint of 36m would be necessary to serve a significant number of airports, the People Mover concept would become even less efficient since the folding length of the wing is limited and cannot reach up to 52m. Concurrently, folding wing tips can also be introduced on the single aisle aircraft to further improve efficiency of those.

The People Mover design in this study is based on the Airbus A350 and aims to serve the upper boundary of the foreseen market. With a fuselage length of 72,3m compared to the length of 44,5 of the Airbus A321neo the airport compatibility in terms of fuselage length and the consequence thereof are neglected. To further study the feasibility of the People Mover concept, it is necessary to investigate the prospective airport infrastructure in detail to derive the corresponding wing span limitation and further constraints.

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6. Copyright Statement

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