AIRCRAFT DESIGN AND SYSTEMS GROUP (AERO)

Direct Operating Costs, Fuel Consumption, and Cabin Layout of the Airbus A321LR

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Abstract

Purpose – Assessment of the Direct Operating Costs (DOC) and fuel consumption of the Airbus A321LR using typical use-cases and comparison with those from similar aircraft. Investigation of the flexibility of the cabin layout using examples from different airlines. Calculation of Ecolabels based on different cabin configurations.

Methodology – All aircraft-related data is retrieved from the Original Equipment Manufacturers’ (OEM) manuals. The DOC assessment uses the Association of European Airlines (AEA) and the TU Berlin method. The fuel consumption is assessed with a tool based on the Breguet Range equation, using successive iterations. The Ecolabel considers resource depletion, global warming, local air quality, and noise pollution, weighted and combined into one overall rating. A cabin study contrast layouts from Airbus with those from operators and also considering ergonomics.

Findings – The A321LR offers improvements in flight range compared to A321CEO and A321NEO. It can operate medium range very efficiently with only minor payload reduction. Very low-density layouts of a few airlines are purely their marketing preferences. Costs per seat and Ecolabel rating vary significantly between low-density and high-density cabin configurations. Predictions for the A321XLR are also very favorable.

Research Limitations – DOC results are not unique numbers but depend on the DOC method applied. Some of the characteristics for the XLR can so far only be estimated, since its entry into service is scheduled for 2023 and, as such, after the submission of this thesis.

Practical Implications – Good reasons for operating the A321LR are elaborated. The Ecolabel allows passengers and operators to openly discuss the ecological implications of different cabin layouts.

Originality – This seems to be the first scientific report that extensively investigates economic and ecologic aspects when operating the A321LR with different cabin layouts.
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Direct Operating Costs, Fuel Consumption, and Cabin Layout of the Airbus A321LR

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Introduction
General Considerations

Facts

- The A321LR was launched in 2018, as an extended-range variant of A321neo and it offers two engine variants: CFM LEAP-1A or PW-1100G

- Actual operators: TAP Air Portugal, JetBlue, Air Astana, Air Transat, Aer Lingus, ...

- Technology: up to 3 Additional Center Tanks (ACTs) → more fuel → fly longer. An extra-long range (XLR) variant is scheduled for 2023

Questions/Presumptions

- Structural weight limits with ACTs installation → reduced maximum payload → fewer passengers:
  - e.g., JetBlue’s A321LR cabin fits 138 seats while most A321neo fit 180-220 passengers!
  → reflects in the cost per seating passenger
  → much higher ticket prices

What does Airbus/ airlines say?

“… with a range of up to 4,000 NM (7,400 km), the A321LR is the unrivalled long-range route opener, featuring true transatlantic capability and premium wide-body comfort in a single-aisle aircraft cabin.” (Airbus 2019a)

“It [A321LR] delivers 30% fuel savings and nearly 50% reduction in noise footprint compared to previous-generation competitor aircraft.” (Airbus 2019a)

What speaks for the LR?

- Crescent popularity of long-range missions operated with single-aisle aircraft: lower financial risk, strategical decision – e.g., COVID-19 (less demand) and Airbus A380 (expensive, more seats)

- Pilots and cabin crew do not need additional training due to commonality along the A320 family (world’s best selling single-aisle aircraft family)
Introduction

Which Missions are Being Flown?

Scheduled long-haul flights operated by A321LR aircraft – winter season 2021/22 (edited from Pearson 2021a)

<table>
<thead>
<tr>
<th>Airline</th>
<th>From</th>
<th>To</th>
<th>Distance (miles)</th>
<th>Distance (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAP</td>
<td>Belém</td>
<td>Lisbon</td>
<td>3,726</td>
<td>6,000</td>
</tr>
<tr>
<td>Air Transat</td>
<td>Faro</td>
<td>Toronto</td>
<td>3,693</td>
<td>5,940</td>
</tr>
<tr>
<td>SAS</td>
<td>Boston</td>
<td>Copenhagen</td>
<td>3,671</td>
<td>5,910</td>
</tr>
<tr>
<td>TAP</td>
<td>Lisbon</td>
<td>Recife</td>
<td>3,628</td>
<td>5,840</td>
</tr>
<tr>
<td>TAP</td>
<td>Lisbon</td>
<td>Washington Dulles</td>
<td>3,592</td>
<td>5,780</td>
</tr>
<tr>
<td>Air Transat</td>
<td>London Gatwick</td>
<td>Toronto</td>
<td>3,576</td>
<td>5,750</td>
</tr>
<tr>
<td>Air Transat/TAP</td>
<td>Lisbon</td>
<td>Toronto</td>
<td>3,576</td>
<td>5,750</td>
</tr>
<tr>
<td>Air Transat</td>
<td>Malaga</td>
<td>Montreal</td>
<td>3,554</td>
<td>5,720</td>
</tr>
<tr>
<td>Air Transat</td>
<td>Porto</td>
<td>Toronto</td>
<td>3,515</td>
<td>5,660</td>
</tr>
<tr>
<td>TAP</td>
<td>Lisbon</td>
<td>Natal</td>
<td>3,496</td>
<td>5,630</td>
</tr>
<tr>
<td>TAP</td>
<td>Fortalezaa</td>
<td>Lisbon</td>
<td>3,478</td>
<td>5,600</td>
</tr>
<tr>
<td>JetBlue</td>
<td>London Gatwick</td>
<td>New York JFK</td>
<td>3,47</td>
<td>5,580</td>
</tr>
<tr>
<td>JetBlue</td>
<td>London Heathrow</td>
<td>New York JFK</td>
<td>3,451</td>
<td>5,550</td>
</tr>
<tr>
<td>Air Transat</td>
<td>Montreal</td>
<td>Paris CDG</td>
<td>3,442</td>
<td>5,540</td>
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<tr>
<td>Air Transat</td>
<td>Manchester</td>
<td>Toronto</td>
<td>3,434</td>
<td>5,530</td>
</tr>
<tr>
<td>Aer Lingus</td>
<td>Dublin</td>
<td>Washington Dulles</td>
<td>3,404</td>
<td>5,480</td>
</tr>
<tr>
<td>TAP</td>
<td>Lisbon</td>
<td>Newark</td>
<td>3,384</td>
<td>5,450</td>
</tr>
<tr>
<td>TAP</td>
<td>Lisbon</td>
<td>New York JFK</td>
<td>3,366</td>
<td>5,420</td>
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<tr>
<td>Aer Lingus</td>
<td>Manchester</td>
<td>New York JFK</td>
<td>3,341</td>
<td>5,380</td>
</tr>
<tr>
<td>Air Transat</td>
<td>Glasgow</td>
<td>Toronto</td>
<td>3,293</td>
<td>5,300</td>
</tr>
</tbody>
</table>

Top ten A321 routes between Europe and North America in 2021, according to number of flights (Pearson 2021b)
Introduction

Aircraft and Missions Considered

- **Mission 1 (M1)** coincides with the range at maximum payload of the A321LR – 5.600 km
- **Mission 2 (M2)** is equidistant to the ranges of M1 and M2 – 6.500 km
- **Mission 3 (M3)** coincides with the range at maximum fuel weight of the A321LR – 7.400 km

<table>
<thead>
<tr>
<th>AIRCRAFT</th>
<th>MTOW [kg]</th>
<th>MZFW [kg]</th>
<th>OEW [kg]</th>
<th>MFW [kg]</th>
<th>Max. Payload [kg]</th>
<th>Range(B) [km]</th>
<th>Range(C) [km]</th>
<th>Range(D) [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A321ceo</td>
<td>89.000</td>
<td>71.500</td>
<td>48.436</td>
<td>18.600</td>
<td>23.571</td>
<td>3.704</td>
<td>4.198</td>
<td>5.865</td>
</tr>
<tr>
<td>A321neo</td>
<td>93.500</td>
<td>75.600</td>
<td>50.774</td>
<td>18.440</td>
<td>25.000</td>
<td>4.630</td>
<td>4.990</td>
<td>6.960</td>
</tr>
<tr>
<td>A321LR</td>
<td>97.000</td>
<td>75.600</td>
<td>52.060</td>
<td>25.790</td>
<td>23.540</td>
<td>5.600</td>
<td>7.400</td>
<td>9.400</td>
</tr>
<tr>
<td>A321XLR</td>
<td>101.000</td>
<td>74.374*</td>
<td>52.660*</td>
<td>31.016*</td>
<td>22.314*</td>
<td>6.750*</td>
<td>8.700</td>
<td>11.800*</td>
</tr>
<tr>
<td>A330-900 neo</td>
<td>242.000</td>
<td>181.000</td>
<td>135.640</td>
<td>109.186</td>
<td>45.360</td>
<td>7.700</td>
<td>8.900</td>
<td>17.287</td>
</tr>
</tbody>
</table>

MTOW: Maximum Take-Off Weight
MZFW: Maximum Zero Fuel Weight
OEW: Operating Empty Weight
MFW: Maximum Fuel Weight

(Airbus 2020 and 2021c)

The passenger mass considered = 97,0 kg (pax + luggage)
Fuel Consumption of the Airbus A321LR
Fuel Consumption of the Airbus A321LR

The Breguet Range and Aircraft Weight

\[ B = \frac{R}{\ln \left( \frac{m_1}{m_2} \right)} \]

Mission Fuel Mass:

\[ m_{fuel} = m_2 \left( e^B - 1 \right) \]

<table>
<thead>
<tr>
<th>Range (at Point)</th>
<th>Take-off weight ((m_1))</th>
<th>Landing weight ((m_2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>B (range max. payload)</td>
<td>MTOW</td>
<td>MZFW</td>
</tr>
<tr>
<td>C (design range)</td>
<td>MTOW</td>
<td>MTOW-MFW</td>
</tr>
<tr>
<td>D (ferry range)</td>
<td>OEW+MFW</td>
<td>OEW</td>
</tr>
</tbody>
</table>

MTOW: Maximum Take-Off Weight  
MZFW: Maximum Zero Fuel Weight  
OEW: Operating Empty Weight  
MFW: Maximum Fuel Weight
Fuel Consumption of the Airbus A321LR

Fuel Consumption – kg/100km/PAX

- ↑ passengers transported, ↓ fuel consumption distributed for each passenger
- 6.7-1.3 kg/100km/pax from lowest to highest cabin density (Δ=81%). For each add. 10 pax Δ=-11.6%
- Fuel consumption at take-off is relatively high. With increasing range, there is better distribution/compensation. E.g., 300-1.000 km Δ=-51%
- decreasing trend is maintained until the range at MPL – ~5.600 km. For farther ranges, sensible fuel consumption only possible with reduced maximum capacity (less than 240 pax)

Note: from the moment the slope of the curve is inverted, the range is not supported anymore with the corresponding number of pax → passenger reduction must take place – the fuel is distributed to an (ever) decreasing number of passengers
Fuel Consumption of the Airbus A321LR

Fuel Consumption – kg/100km/PAX

Fuel consumption per range and passenger over flown distance: Comparison for a standard cabin density

(generated with Scholz 2021a)
Fuel Consumption of the Airbus A321LR

Fuel Consumption – kg/100km/PAX

Fuel consumption per range and passenger over flown distance: Comparison for a low-density cabin

(generated with Scholz 2021a)
Fuel Consumption of the Airbus A321LR

Fuel Consumption – kg/100km/PAX

Fuel consumption per range and passenger over flown distance: Comparison for a high-density density

(generated with Scholz 2021a)
Fuel Consumption of the Airbus A321LR

Fuel Consumption – kg/100km/PAX

Fuel consumption per range and passenger over flown distance:
Engine comparison, standard density cabin

Comparison of the fuel consumption A321ceo and the A321LR – 200 pax

(generated with Scholz 2021a)
Direct Operating Costs of the Airbus A321LR
Direct Operating Costs of the Airbus A321LR

General Composition of the DOC

\[ C_{DOC} = C_{DEP} + C_{INT} + C_{INS} + C_F + C_M + C_C + C_{FEE} \]

Development of the kerosene price from 1980 to 2021 (EIA 2021)

Relative aircraft utilization; edited from Scholz (2015)

→ The longer the flight time the fewer the maximum allowed flight-trips (per day, month or year)
### General values for DOC computation of the A321LR with/without cargo – AEA method, M1: 160 pax; Scholz 2021b

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>A321LR - M1</th>
<th>w/cargo</th>
<th>no cargo</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of PAX</td>
<td>160</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range (Mission)</td>
<td>5.600 km</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MTOW</td>
<td>97.000 kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MZFW</td>
<td>75.600 kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OEW</td>
<td>52.060 kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max Payload (Point B)</td>
<td>23.540 kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breguet Factor B(B)</td>
<td>- 22.467 km</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landing Weight (B)</td>
<td>- 67.580 kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass Payload (Mission)</td>
<td>23.540 kg 15.520 kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass Pax (Mission)</td>
<td>15.520 kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass Cargo (Mission)</td>
<td>8.020 kg 0 kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass Fuel (Mission)</td>
<td>21.400 kg 19.130 kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flight Speed</td>
<td>850 km/h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flight Time</td>
<td>6.6 h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SLST</td>
<td>145 kN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engine Weight</td>
<td>3.000 kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nr. cabin crew</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cockpit crew hourly rate</td>
<td>246.5 US$/h</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Cabin crew hourly rate</td>
<td>81 US$/h</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Block Time</td>
<td>1.83 h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### General values for DOC computation of the A321LR with/without cargo – TUB method, M1: 160 pax

- **Number of engines** $n_e$:
- **Airframe mass** $m_{AF}$: 46060 kg
- **Payload mass** $m_{PL}$: 23540 kg
- **Baggage mass** $m_{Baggage}$: 3520 kg
- **Cargo mass** $m_{Cargo}$: 8020 kg
- **Passenger mass** $m_{pax}$: 12000 kg
- **Fuel mass** $m_f$: 21400 kg

**AEA**: Association of European Airlines

**TUB**: Technical University of Berlin
Direct Operating Costs of the Airbus A321LR

Breguet Factor Calculated from the Payload-Range Diagram?

Extended Payload-Range diagram; based on Young (2017)

1. \[ B = \frac{R}{\ln \left( \frac{m_1}{m_2} \right)} = \frac{R}{\ln \left( \frac{OEW + PL + MFW}{LW} \right)} = \frac{6500 \text{ km}}{\ln \left( \frac{52060 + 20795 + 23595}{52060 + 20795} \right) \text{ kg}} = 23.168 \text{ km} \]

or

2. \[ m_{fuel} = m_2 \left( e^B - 1 \right) \iff \frac{R}{B} = \ln \left( \frac{m_{fuel}}{m_2} + 1 \right) \iff B = \frac{R}{\ln \left( \frac{m_{fuel}}{m_2} + 1 \right)} = \frac{6500 \text{ km}}{\ln \left( \frac{23595}{72855 + 1} \right) \text{ kg}} = 23.168 \text{ km} \]
DOC distribution for the A321LR in M1, M2, and M3: low-density cabin configuration, without additional cargo – TUB Method

DOC distribution for the A321LR in M1, M2, and M3: low-density cabin configuration, without additional cargo – AEA Method
DOC Comparison between Aircraft

- Different accounting for the nr. of flight trip contributes to distinguished variations along the missions and methods.
Seat-Kilometer Cost Comparison between Aircraft

- SKC comparison: standard density cabin: TUB Method
- SKC comparison: high-density cabin: TUB Method
- SKC comparison: low-density cabin: TUB Method
- SKC comparison: low-density cabin: AEA Method

![Graphs showing SKC comparison for different aircraft and cabin densities using TUB and AEA methods.](image-url)
Ecolabel

Applied to the Airbus A321LR
Ecolabel Applied to the Airbus A321LR

General Considerations and Limitations

Flyer explaining the Ecolabel to the general public or passengers (Hurtecat 2021)

Exemplary layout of the Ecolabel (Hurtecat 2021)
## Ecolabel Applied to the Airbus A321LR

### General Considerations and Limitations

![Pie chart 1](image1)

Ecolabel: exemplary distribution of the impact categories – weighted (Hurtecant 2021)

![Pie chart 2](image2)

Ecolabel: exemplary distribution of the impact categories – unweighted (Hurtecant 2021)

### Comparison of $E_{NOx}$ between the EEA emission calculator and the Ecolabel

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>EEA Emission Calculator</th>
<th>Ecolabel</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Engine</td>
<td>$E_{NOx}$ [kg/kg]</td>
<td>Engine</td>
</tr>
<tr>
<td>A321</td>
<td>Not specified</td>
<td>0.0171</td>
<td>CFM56-5B1/2P</td>
</tr>
</tbody>
</table>
### Ecolabel Applied to the Airbus A321LR

#### Ecolabels: A321LR

**Ecolabel for the Airbus A321LR: Airbus standard configuration**
- 202 passengers in Y/C

**Ecolabel for the Airbus A321LR: Air Transat**
- 187 passengers in Y/C
- 12 passengers in B/C

**Ecolabel for the Airbus A321LR: TAP Air Portugal**
- 113 passengers in Y/C
- 42 passengers in premium Y/C
- 16 passengers in B/C

* Y/C: Economy Class; B/C: Business Class; F/C: First Class

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**Travel Class Fuel Consumption (kg/km/seat)**
- Economy: 0.0189 kg/km/seat
- Premium Economy: N/A
- Business: N/A

**CO2 Equivalent Emissions (kg/km/seat)**
- Economy: 0.283 kg/km/seat
- Premium Economy: N/A
- Business: N/A

**Fuel Consumption (kg/km/seat)**
- Economy: 0.0192 kg/km/seat
- Premium Economy: N/A
- Business: N/A

**Local Noise Level (EPNdB/EPNdB)**
- Economy: 0.913 EPNdB
- Premium Economy: N/A
- Business: N/A

**Local Air Pollution (NOx/Thrust) [g/kN]**
- Economy: 42.1 [g/kN]
- Premium Economy: N/A
- Business: N/A

**OVERALL RATING (0-10; 10 is best)**
- Airbus standard config.: 7.69
- Air Transat: 7.71
- TAP Air Portugal: 7.39

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* Generated with Hurtecant (2021)*

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* Ecolabels: A321LR
- 187 passengers in Y/C
- 12 passengers in B/C

---

* Y/C: Economy Class; B/C: Business Class; F/C: First Class

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* Ecolabel for the Airbus A321LR: TAP Air Portugal
- 113 passengers in Y/C
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* Presentation of the Bachelor Thesis
  Hamburg, 2022-02-17

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* Aircraft Design and Systems Group (AERO)
Ecolabels: A321LR, A321ceo, and A321neo

Ecolabel for the Airbus A321LR:
JetBlue
- 90 passengers in Y/C
- 24 passengers in premium Y/C
- 22 passengers in B/C
- 2 passengers in F/C

Ecolabel for the A321ceo: Airbus std. configuration
- 220 passengers in Y/C

Ecolabel for the A321neo: Airbus std. configuration
- 202 passengers in Y/C

* Y/C: Economy Class; B/C: Business Class; F/C: First Class

generated with Hurtecant (2021)
Cabin Layout of the Airbus A321LR
Cabin Layout of the A321LR: The Role of the Seat Pitch

Seat pitch 31” (Honig 2018)

- Uncomfortable/ unnatural knee angle
- Limited legroom and body freedom
+ More seat rows
→ Low-cost airlines /economy class

Seat pitch 34” (Honig 2018)

+ More comfortable
- Less seat rows
→ Legacy airlines /Starting from B/C

Table 6.1

<table>
<thead>
<tr>
<th>Percentile</th>
<th>5% American female</th>
<th>95% American Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backrest</td>
<td>estimated at 3.14” (80 mm)</td>
<td></td>
</tr>
<tr>
<td>BKL</td>
<td>21.3” (542.1 mm)</td>
<td>26.3” (667.4 mm)</td>
</tr>
<tr>
<td>Seat pitch</td>
<td>29” 737 mm 34” 864 mm</td>
<td>29” 737 mm 34” 864 mm</td>
</tr>
<tr>
<td>Legroom</td>
<td>25.9” 657 mm 30.9” 784 mm</td>
<td>25.9” 657 mm 30.9” 784 mm</td>
</tr>
<tr>
<td>Clearance</td>
<td>4.51” 114.5 mm 9.51” 241.5 mm</td>
<td>4.57” 116.2 mm</td>
</tr>
</tbody>
</table>

Clearance (at knee height) = Legroom - BKL

Conditioned by:
- Demography (body height, weight) – e.g., population of the USA vs. Japan
- Gender
- Market strategy – low-cost vs. legacy airlines

Table 6.1  Legroom for considered percentiles at a 29” and 34” seat pitch (SeatMaestro 2021a and Ergocenter NCSU 2006)

(Edited from Gosende 2017)
Cabin Layout of the Airbus A321LR

Exemplary Seats (Classes)

JetBlue Mint Studio – business class (JetBlue 2021b)  
JetBlue coach seats – economy class (JetBlue 2021b)
## Cabin Layout of the Airbus A321LR

### Assessment of A321LR Operators – Seat Pitch / Width

#### Table 6.2  Cabin configurations for different airlines (measurements in inch)

<table>
<thead>
<tr>
<th>Airline</th>
<th>Total PAX</th>
<th>Economy Class</th>
<th>Premium Economy Class</th>
<th>Business Class</th>
<th>First Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Seat Pitch</td>
<td>Seat Width</td>
<td>PAX</td>
<td>Seat Pitch</td>
</tr>
<tr>
<td>Airbus std.</td>
<td>202</td>
<td>32</td>
<td>18</td>
<td>202</td>
<td>0</td>
</tr>
<tr>
<td>Air Transat</td>
<td>199</td>
<td>31</td>
<td>18</td>
<td>187</td>
<td>0</td>
</tr>
<tr>
<td>Aer Lingus</td>
<td>184</td>
<td>31</td>
<td>18</td>
<td>168</td>
<td>0</td>
</tr>
<tr>
<td>TAP Portugal</td>
<td>171</td>
<td>31</td>
<td>17,7</td>
<td>113</td>
<td>32</td>
</tr>
<tr>
<td>Air Astana</td>
<td>166</td>
<td>30</td>
<td>20,5</td>
<td>150</td>
<td>0</td>
</tr>
<tr>
<td>JetBlue</td>
<td>138</td>
<td>33</td>
<td>17,8</td>
<td>90</td>
<td>37</td>
</tr>
</tbody>
</table>

(Airbus 2020; SeatGuru 2021a, 2021d, 2021b; Air Astana 2021 and JetBlue 2021b)
Summary and Conclusions
Summary

„Ideal“ Fuel Consumption for Specific Airlines

Overall fuel consumption evaluation regarding the cabin configurations of the A321LR by different airlines

<table>
<thead>
<tr>
<th>Airline</th>
<th>Cabin Config. (PAX)</th>
<th>Recommended Max. Range (RMR)</th>
<th>Fuel Consumption at RMR (kg/100km/Pax)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airbus Std.*</td>
<td>202</td>
<td>6800 km</td>
<td>1.57</td>
</tr>
<tr>
<td>Air Transat</td>
<td>199</td>
<td>6800 km</td>
<td>1.60</td>
</tr>
<tr>
<td>Aer Lingus</td>
<td>184</td>
<td>7400 km</td>
<td>1.76</td>
</tr>
<tr>
<td>TAP Air Portugal</td>
<td>171</td>
<td>7450 km</td>
<td>1.83</td>
</tr>
<tr>
<td>Air Astana</td>
<td>166</td>
<td>7550 km</td>
<td>1.90</td>
</tr>
<tr>
<td>JetBlue</td>
<td>138</td>
<td>7600 km</td>
<td>2.01</td>
</tr>
</tbody>
</table>
Overview of the DOCs and SKC for the A321LR – Chart, TUB Method

Yearly DOCs and SKCs of the A321LR with the TUB Method: all missions and cabin configurations; a: with cargo; b: without cargo
Summary

DOC Observations

In terms of the ratio DOC/flexibility (without cargo), it seems reasonable to operate the LR with a cabin configuration of around 190 pax since there is only an insignificant difference between the DOCs (and SKCs) of the contemplated missions → airlines have the most flexibility while choosing routes and with minimal DOC difference:

- 35,00 M US$/yr with 713 flight cycles à 5,600 km;
- 35,17 M US$/yr with 673 flight cycles à 6,500 km;
- 35,12 M US$/yr with 570 flight cycles à 7,400 km.

**Reason:** effects of flight cycles and flight distance (inversely proportional) neutralize each other in this particular case: $C_{FEES}$ vs. $C_{FUEL}$, respectively

→ Most profitable option depends on ticket prices, i.e., medium-haul versus long-haul, and multiply it by the number of flight cycles.
Final Conclusions

1. Deeper insight into the Airbus A321LR: better understanding of operational aspects

2. Theoretical DOC methods will deliver different costs than those from airlines. The assessment allowed to rank operating costs and clarify the relationship between flight cycles, flight time, and total costs.

3. Better understanding the implementation of the ACTs (to the A321neo) in order to fly larger ranges → The accommodation of ACTs does not have significant impact on the maximum possible payload in the LR for the given missions. Geometrical/cabin limitations already limit the number of seating passengers in the neo (despite higher MPL)

4. The neo engines (A321neo, LR, XLR) have showed clear advantage towards the ceo (emissions and fuel consumption) – 20 years gap between both engines

5. An update from the neo to the LR is not justifiable if only (very) low-density cabin configurations are employed. In all other cases the LR is the best choice.

6. The XLR can accommodate 20,3% more fuel, due to a +4,3% MTOW and -5,2% MPL but is only sensible after a range of 7.400 km compared to the LR

7. A higher density cabin is ecologically always the best choice. Advantage for low-cost carriers!

8. The seat pitch and market strategy dictate the cabin layout and influence the passenger comfort. This happens in contradiction to the ecological best choice
Infographic and possible routes for the Airbus A321LR (Lothar 2021)
Direct Operating Costs, Fuel Consumption, and Cabin Layout of the Airbus A321LR

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