Emission reduction potential across the long-haul network

A. Paul, M. Engelmann, L. Koops, D. Steinweg, F. Troeltsch, J. van Wensveen, M. Hornung, Bauhaus Luftfahrt Team

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The Long-haul Air Traffic Market

~10% of global air transport passengers (2016)

~35% of global air transport CO$_2$ emissions (2016)

Source: OAG 2016, Eurocontrol Base of Aircraft Data (BADA)
Goal of Bauhaus Luftfahrt Group Design Project 2019

The design of a
- long-haul traffic concept
- fulfilling emission reduction goals
- by incorporating measures to enhance both operational (on the air transport system level) and technical efficiency (on the aircraft level),
- keeping in mind passenger comfort and requirements.
Holistic Approach for Long-haul Network Emission Reduction

- Business model innovation
- Energy supply scenario
- Aircraft and cabin design
Re-thinking the Long-haul Network Structure

- Aircraft Sharing:
  Implementation of ShAirline business model
- Continuous connecting banks to reduce on-ground time
- Novel on-board services

Business model innovation

- Energy supply scenario with liquid hydrogen
- Realizing benefits from scalable and cost-efficient production

Energy supply scenario

Aircraft and cabin design

- Facilitating the integration of new energy sources
- Increasing passenger comfort
- Integration of new technologies
Emission reduction potential across the long-haul air traffic network

- **Business model innovation**
- **Energy supply scenario**
- **Aircraft and cabin design**
Inefficiencies on Long-haul Network

Distribution of passengers across direct and indirect flights

<table>
<thead>
<tr>
<th>Direct (38%)</th>
<th>Indirect (62%)</th>
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<tbody>
<tr>
<td>Indirect available (97%)</td>
<td>Direct available (37%)</td>
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<tr>
<td>Indirect cheaper (72%)</td>
<td>Direct cheaper (26%)</td>
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</tbody>
</table>

Majority of today’s long-haul passengers travel on indirect connections.

Source: Sabre 2017
Inefficiencies on Long-haul Network

On average ~25% of unutilized on-ground time per long-haul flight
(after maintenance and turnaround)

Source: FlightRadar 24
Aircraft sharing as enabler for a more efficient network structure

Fleet reduction potential: ~ 13 – 27%

Source: OAG 2012
**Business Model Innovation**

- **Passenger journey**
  - Passengers define trip characteristics: arrival and destination location, time, amenities

- **Seat exchange platform**
  - Flexible seat allocation per flight and route, combining multiple providers

- **Aircraft fleet composition**
  - Aircraft fleet is scheduled according to demand on route level and rotates globally

- **Extra services**
  - Stakeholders such as hotels, cafés, restaurants, entertainment and amenities can provide extra services on board

**Implementation of seat exchange platform**

- Abandoning airline-aircraft ownership concept
- Renting out physical aircraft space to multiple providers “by the hour”
- Enabling flexible passenger assignment on route level
- Meeting fluctuations in demand
Seat Exchange Platform

Passenger journey
- 2-deck seating options with increased seat pitch
- Added value during flight due to family and dwell areas

Seat exchange platform
- Lower entry barrier for new providers due to removal of airline lock-in effect
- Process optimization due to integrated data platform

Aircraft fleet composition
- Customizable white label air transport (OEM)
- Potential for more efficient standardization
- Optimization of MRO cycles and economies of scale

Extra services
- Lower deck containers providing additional passenger amenities
- Adjustment to flight duration and time of day
Business model innovation

Energy supply scenario

Aircraft and cabin design
LH₂ vs. (Alternative) Fuels

- Conventional jet fuel
- BtL - Biomass to Liquid
- HtL - Hydrothermal Liquefaction
- StL - Sun to Liquid
- HEFA / jatropha
- HEFA / eucalyptus
- HEFA / UCO
- HEFA / camellia
- HEFA / microalgae
- BtL / eucalyptus
- BtL / poplar
- BtL / forestry residues
- LH₂
- PtL

Source: Results from EU FP7 Project CORE-JetFuel, continuously updated according to BHL renewable fuel literature database.
Emission reduction potential across the long-haul air traffic network

- Business model innovation
- Energy supply scenario
- Aircraft and cabin design
The Aircraft Platform

Existing Long Range Model

- High cruise Mach number \( \Rightarrow \) Reduction of block times
- High overall vehicular efficiency

ShAirline Long Range Model

- Design cruise Mach number \( \sim 0.7 \)
- Increased seat pitch + comfort/dwell areas
- LH\(_2\) tanks (front & rear)
- Lower deck \( \Rightarrow \) service elements

Flight Mach number \( \downarrow \)
- LH\(_2\) as fuel

Increased passenger comfort
- More direct flights
- Enable onboard service models
Emission reduction potential across the long-haul air traffic network

Resulting Aircraft: 3-View & Key Performance Data

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<th>C004</th>
<th>Conv. Ma 0.82 AC</th>
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<tbody>
<tr>
<td>MTOW</td>
<td>196 t</td>
<td>264 t</td>
</tr>
<tr>
<td>Wingspan</td>
<td>81 m</td>
<td>67 m</td>
</tr>
<tr>
<td>Wing Loading</td>
<td>588 kg/m²</td>
<td>713 kg/m²</td>
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<tr>
<td>Fuel Mass Design Mission</td>
<td>18.6 t</td>
<td>72.5 t</td>
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<tr>
<td>OEW</td>
<td>128 t</td>
<td>138 t</td>
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<tr>
<td>Total Installed Tank Volume</td>
<td>371 m³</td>
<td>128 m³</td>
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Source: Troeltsch (2019)
**Aircraft Cabin Design**

- **Different areas for passengers**
  - Meeting and working areas
  - Upper deck: 6 abreast with 2 aisles, 64” seat pitch
  - Main deck: 12 abreast with 3 aisles, max. 1 person to pass, 36” seat pitch (+16%*)
  - Cargo Deck: swappable containers, height 2.40m, accessible via staircase

- **Integration of various service elements**
  - Hotels, restaurants, dwell areas
  - Engagement of multiple service providers in renting out space

*compared to a Lufthansa A380*
Passenger Journey

East-West-bound traffic (2016)
- Repr. Cluster: 28% of flights on this market
- 12:12h – 15:59h [weighted mean times]

North-South-bound traffic
- Repr. Cluster: 44% of flights on this market
- 21:43h – 06:48h [weighted mean times]

East-West-bound traffic (ShAirline)
- Repr. Cluster: 26% of flights on this market
- 12:04h – 17:35h [weighted mean times]

North-South-bound traffic (ShAirline)
- Repr. Cluster: 42% of flights on this market
- 21:49h – 08:30h [weighted mean times]

Source: OAG 2016
Holistic Approach for Long-haul Network Emission Reduction

1. Business model innovation
2. Energy supply scenario
3. Aircraft and cabin design
Initial Emission Reduction Potential

ENERGY SUPPLY SCENARIO
1. LH₂: Reduced cost vs Alternative Fuels
2. Facilitation of synergies between different sectors
3. Scalable, cost-efficient production

BUSINESS MODEL INNOVATION
1. Continuous connecting banks
2. Seat exchange platform
3. On-board services

AIRCRAFT AND CABIN DESIGN
1. Speed vs SFC
2. Passenger comfort vs Speed
3. Synergies LH₂ – Cabin

Global fleet: CO₂ emissions (in Mt) for 2050 and 2100*

*Entry into service: 2040+
## Team at Bauhaus Luftfahrt
(in alphabetical order)

<table>
<thead>
<tr>
<th>V. Batteiger</th>
<th>M. Höser</th>
<th>M. Nickl</th>
<th>A. Seitz</th>
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<tr>
<td>K.-D. Büchter</td>
<td>M. Hornung</td>
<td>A. Paul</td>
<td>M. Shamiyeh</td>
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<tr>
<td>D. Empl</td>
<td>J. Kaiser</td>
<td>C. Penke</td>
<td>A. Sizmann</td>
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<tr>
<td>M. Engelmann</td>
<td>H. Kellermann</td>
<td>F. Peter</td>
<td>D. Steinweg</td>
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<tr>
<td>C. Falter</td>
<td>H. Kuhn</td>
<td>K. Plötner</td>
<td>A. Straubinger</td>
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<tr>
<td>A. Habermann</td>
<td>U. Kluge</td>
<td>B. Portner</td>
<td>F. Troeltsch</td>
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<td>A. Habersetzer</td>
<td>L. Koops</td>
<td>A. Roth</td>
<td>M. Urban</td>
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<td>A. Heußner</td>
<td>J. Michelmann</td>
<td>A. Scholz</td>
<td>J. van Wensveen</td>
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<td>P. Vratny</td>
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Contact Details

Dr. Annika Paul
Lead Operations
annika.paul@bauhaus-luftfahrt.net
References

- Eurocontrol, Base of Aircraft Data (BADA).
- Sabre (2017), Sabre Data & Analytics Market Intelligence.