Eine gemeinsame Initiative des ETH-Bereichs und Schweizerischer Bundesämter

Transportsysteme
Transport Systems

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Transport Systems: Gliederung

- Overview about Scope of the Database and General Approaches of Transport Modelling in „ecoinvent 2000”
- Example: Air Transportation
- Some first Results
- Some Final Remarks
Transport Systems:

Objective:
Supply a set of highly aggregated environmental inventory data for various transport systems....

To close gaps in life cycle inventories of energy and material systems

→ Focus on fright/goods transportation

→ !!! Careful application in transport LCAs
Transport Systems:

Ecoinvent 2000 Transportation (tkm)

- Air Transport
  - Freight Transport
  - Passenger Transport
- Rail Transport
  - Freight Transport
- Road Transport
  - Freight Transport
  - Passenger Transport
- Water Transport
  - Freight Transport

Functional Unit:

tkm: Unit of Measure of goods transportation, which represents the transport of one tonne of goods by a certain means of transportation over one kilometre.
Transport Systems: Road Transport

Road Transport (tkm)

Freight Transport (CH) (tkm)
- Lorry 16 t (CH) (3.5 -20T)
- Lorry 28 t (CH) (20-28T)
- Lorry 40 t (CH) (>28 t)
- Van (CH) (< 3.5 t)

Freight Transport (EU 15) (tkm)
- Lorry 16 t (RER) (3.5 -16t)
- Lorry 23 t (CH) (> 16 t)

Passenger Transport (CH)(pkm)
- PW CH

Passenger Transport (EU 15) (pkm)
- PW CH

Präsentation: Michael Spielmann
Transport Systems: Rail & Water

Rail Transportation

Freight Transport (CH)

Fright Transport (EU 15)

EU-Diesel/Electricity Mix

Diesel

Electricity

Water Transport

Binnenentschiff

Binnenfrachter

Hochseetankschiff

Hochseefrachter

Freight Transport

EU 15

Water Transport

Binnenfrachter

Hochseefrachter

Binnenentschiff

Hochseetankschiff

Binnenfrachter

Hochseefrachter

Transport Systems: Rail & Water

Präsentation: Michael Spielmann
Transport Systems: Air Transport

Air Transportation

Freight Transport (tkm)
- Intra European (500 km, 1t)
- Intercontinental (6000 km, 25t)
- Average Airtransport (5700km, 23.8t)

Passenger Transport (pkm)
- Intra European (500km, 65p)
- Intercontinental (6000km, 320p)
- Average Airtransport (4356km, 256p)
Transport Systems: Aufbau

Linked Ecoinvent Processes

- Fuels
- Electricity
- Energy
- Materials

Investigated System

- Operation of Vehicle

Infrastructure Processes

- Manufacturing/Maintenance/Disposal of Vehicle Fleet

Direct Environmental Interventions

Cumulative Environmental Interventions
Air Transport

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Air Transport: Übersicht

Air Transportation (tkm)

- Aircraft Operation
  - Fuel Consumption & Airborne emissions (tkm)

- Airport Infrastructure
  - Operation and Maintenance of an Airport (unit*a)
  - Airport Construction (unit)
  - Airport Disposal (unit)

- Aircraft Fleet
  - Material Consumption & Manufacturing (unit)
Air Transport: Operation of Aircrafts

Bestimmung des Kerosinverbrauchs

Ansatz:
Top down approach, based on:
- Kerosin consumption
- Transport performance

Data from BAZL (2002) available for all continents.

Results in kg/tkm
Intraeuropean: 0.453
Intercontinental: 0.288
Average Fright Trans: 0.294

Comparison with other studies

<table>
<thead>
<tr>
<th>Data Source</th>
<th>kg/tkm</th>
<th>Type</th>
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<tbody>
<tr>
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<td>0.185</td>
<td>average</td>
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<tr>
<td>Lufthansa 1997(^2)</td>
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<td>average</td>
</tr>
<tr>
<td>Ifeu(^3)</td>
<td>0.381</td>
<td>short and medium haul</td>
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<tr>
<td>Ifeu(^3)</td>
<td>0.253</td>
<td>long distance</td>
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<tr>
<td>CE(^4)</td>
<td>0.453</td>
<td>short and medium haul</td>
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<td>CE(^4)</td>
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<td>long distance</td>
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<tr>
<td>INFRAS (^5)</td>
<td>0.280</td>
<td>no specification</td>
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</table>
Air Transport: Operation of Aircrafts

Determination of direct emissions

Approach:
Specific emissions (e.g. CO2/tkm) are derived from „Emission Indices“ (EI) and fuel consumption:
Def. EI: Mass of a substance in grams per kilogram of fuel burned.

Types of Emission:
• Airborne Gaseous Emissions
• Particulate Emissions
• Heavy Metal Emissions

Location of emission:
• lower stratosphere + upper troposphere (30% of the cruising)
• low population density (LTO)
• Unspecified (70% of cruising)
Air Transport: Operation of Aircrafts

Bestimmung der direkten Emissionen

Airborne Gaseous Emissions

1. Fuel composition dependent emissions:

Kerosin: \( C_{12}H_{23} \)
- \( CO_2: 3150 \, \text{g/kg} \)
- \( H_2O: 1240 \, \text{g/kg} \)

Sulphur content: international threshold: 0.3 M%
- \( SO_2\)-Emissionen: 6g/kg (ecoinvent: 0.05M%) 

2. Combustion process dependent emissions:

nitrogens (\( NO_x \)); carbon monoxide (CO); Hydrocarbons(HC)

Impact Factors: Type of Aircraft Engine; Actual Operating Conditions; Ambient Conditions.
## Air Transport: Operation of Aircrafts

### Bestimmung der direkten Emissionen

<table>
<thead>
<tr>
<th>Emission</th>
<th>Specific emission (g/kg fuel)</th>
</tr>
</thead>
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<tr>
<td></td>
<td>Lufthansa (2001)</td>
</tr>
<tr>
<td></td>
<td>UNIQUE (2002)</td>
</tr>
<tr>
<td></td>
<td>CE (2002) State of the art aircraft</td>
</tr>
<tr>
<td></td>
<td>CE (2002) Today’s average aircraft</td>
</tr>
<tr>
<td></td>
<td>DLR (2001)</td>
</tr>
<tr>
<td></td>
<td>This project</td>
</tr>
<tr>
<td>CO2</td>
<td>3145</td>
</tr>
<tr>
<td></td>
<td>3170</td>
</tr>
<tr>
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<td>3150</td>
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<td>0.6</td>
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<td>0.6</td>
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<td>12.5</td>
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<td></td>
<td>15</td>
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<td>12</td>
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<tr>
<td></td>
<td>14</td>
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<td></td>
<td>14</td>
</tr>
<tr>
<td>HC</td>
<td>0.49</td>
</tr>
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<td></td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>-</td>
</tr>
<tr>
<td>NMVOC</td>
<td>1.05</td>
</tr>
<tr>
<td>CH4</td>
<td>0.05</td>
</tr>
</tbody>
</table>

1. Lufthansa (2001)
2. UNIQUE (2002)
3. CE (2002)
4. CE (2002) State of the art aircraft
5. CE (2002) Today’s average aircraft
6. DLR (2001)
7. This project

---

**CO2**
- Lufthansa (2001): 3145 g/kg fuel
- UNIQUE (2002): 3170 g/kg fuel
- CE (2002): 3150 g/kg fuel
- DLR (2001): 3150 g/kg fuel
- This project: 3150 g/kg fuel

**CO**
- Lufthansa (2001): 2.5 g/kg fuel
- UNIQUE (2002): 1 g/kg fuel
- CE (2002): - g/kg fuel
- DLR (2001): 3.7 g/kg fuel
- This project: 3.7 g/kg fuel

**SO2**
- Lufthansa (2001): 0.5 g/kg fuel
- UNIQUE (2002): 1 g/kg fuel
- CE (2002): 0.6 g/kg fuel
- DLR (2001): - g/kg fuel
- This project: 1 g/kg fuel

**NOx**
- Lufthansa (2001): 15.2 g/kg fuel
- UNIQUE (2002): 12.5 g/kg fuel
- CE (2002): 15 g/kg fuel
- DLR (2001): 12 g/kg fuel
- This project: 14 g/kg fuel

**HC**
- Lufthansa (2001): 0.49 g/kg fuel
- UNIQUE (2002): 0.5 g/kg fuel
- CE (2002): 1 g/kg fuel
- DLR (2001): 0.3 g/kg fuel
- This project: 1.1 g/kg fuel

**NMVOC**
- Lufthansa (2001): 1.05 g/kg fuel
- UNIQUE (2002): 0.5 g/kg fuel
- CE (2002): 1.1 g/kg fuel
- DLR (2001): - g/kg fuel
- This project: 1.05 g/kg fuel

**CH4**
- Lufthansa (2001): 0.05 g/kg fuel
- UNIQUE (2002): - g/kg fuel
- CE (2002): - g/kg fuel
- DLR (2001): - g/kg fuel
- This project: 0.05 g/kg fuel
Air Transport: Operation of Aircrafts

Bestimmung der direkten Emissionen

NMVOC Split:

<table>
<thead>
<tr>
<th>Unit</th>
<th>Benzene</th>
<th>Formaldehyde</th>
<th>1,3 Butadiene</th>
<th>Ethylene</th>
<th>Total share on VOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTO-average</td>
<td>1.9</td>
<td>15</td>
<td>1.8</td>
<td>17.4</td>
<td>36.1</td>
</tr>
</tbody>
</table>

Particulate Emissions:

Magnitude:  
- old engine: 0.07 - 0.11 g/kg  
- new engines: 0.01 - 0.02g/kg  
- This study: 0.038 g/kg

Size: 10-100 nm (for climb, cruise and decent) → all PM2.5
Air Transport: Operation of Aircrafts

Passenger transport

Reference: pkm
\[\rightarrow\] Calculation: tkm \rightarrow pkm

Transformation factors:
BAZL/BFS (2002): 100 kg (70+30)
Maibach (1999): 190 kg (incl. Sitze etc.)
Dings (2002): 240 kg (including all facilities, Personal)

Spezifischer Energieverbrauch:
Intra European: 0.109 kg/pkm
Intercontinental: 0.069 kg/pkm
Average: 0.082 kg/pkm
Air Transport: Airport Infrastructure

Aircraft Clearing:
- Transport Services for freight & passengers.
- Start of turbines and operation of auxiliary turbines.
- De Icing of aircrafts and runways
- Activities in service garages (VOC-emissions)

Data available from Environmental reports of uniqueairport (2000; 2002).
### Air Transport: Airport Infrastructure

#### Table: Air Transport - Infrastructure Inventory

<table>
<thead>
<tr>
<th>Name</th>
<th>Category</th>
<th>Unit</th>
<th>Operation, maintenance, airport</th>
<th>Uncertainty Type</th>
<th>Standard Deviation 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>operation, maintenance, airport</td>
<td>unit</td>
<td>1.00E+0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BOD5, Biological Oxygen Demand</td>
<td>water kg</td>
<td>6.81E+5</td>
<td>1.00E+0</td>
<td>6.00</td>
<td></td>
</tr>
<tr>
<td>DOC, Dissolved Organic Carbon</td>
<td>water kg</td>
<td>2.02E+5</td>
<td>1.00E+0</td>
<td>6.00</td>
<td></td>
</tr>
<tr>
<td>TOC, Total Organic Carbon</td>
<td>water kg</td>
<td>2.02E+5</td>
<td>1.00E+0</td>
<td>6.00</td>
<td></td>
</tr>
<tr>
<td>COD, Chemical Oxygen Demand</td>
<td>water kg</td>
<td>6.81E+5</td>
<td>1.00E+0</td>
<td>6.00</td>
<td></td>
</tr>
</tbody>
</table>

#### Graph: Air Transport - Infrastructure Inventory

- **Y-axis**: m3/a
- **X-axis**: Year
- **Data**: 1999, 2000, 2001
- **Legend**: Propylen glycol, Ethylen glycol

#### Note:

The data represents the inventory of air transport infrastructure, focusing on specific pollutants and their quantities over the years.
## Air Transport: Airport Infrastructure

### Land Use

**Land type subcategories:**

- **Industrial area, vegetation:** die gesamte nicht versiegelte Fläche
- **Industrial area, built up:** bebaute versiegelte Fläche
- **Traffic area, road network:** Pisten, Aircraft Parking

<table>
<thead>
<tr>
<th>Land Use Type</th>
<th>Unit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupation, industrial area</td>
<td>m²a/unit</td>
<td>8.80E+06</td>
</tr>
<tr>
<td>Occupation, industrial area, built up</td>
<td>m²a/unit</td>
<td>4.00E+05</td>
</tr>
<tr>
<td>Occupation, industrial area, vegetation</td>
<td>m²a/unit</td>
<td>5.50E+06</td>
</tr>
<tr>
<td>Occupation, traffic area, road network</td>
<td>m²a/unit</td>
<td>2.90E+06</td>
</tr>
</tbody>
</table>
Air Transport: Aircraft Fleet

Long Haul Aircraft
Airbus A340-600
Max. zero flight weight: 240t
Typical seating: 380 seats

Medium Haul Aircraft
Airbus A320
Max. zero flight weight: 61t
Typical seating: 150 seats
### Air Transport: Aircraft Fleet

**Material Einsatz:**

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Short/medium haul</th>
<th>Long haul</th>
<th>Average Freight Transport</th>
<th>Average Passenger Transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. zero fuel weight</td>
<td>t</td>
<td>61</td>
<td>240</td>
<td>233.7</td>
<td>181.7</td>
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<tr>
<td>Aluminium</td>
<td>t/unit</td>
<td>54.9</td>
<td>216</td>
<td>210.3</td>
<td>163.5</td>
</tr>
<tr>
<td>Polyethylene, HDPE, granulate,</td>
<td>t/unit</td>
<td>6.1</td>
<td>24</td>
<td>23.7</td>
<td>18.2</td>
</tr>
</tbody>
</table>
Air Transport: Aircraft Fleet

Aircraft manufacturing:
Data for 16 Airbus manufacturing facilities.
Available from Environmental Report.
Processes as follows are included:

- Metalworks
- Surface Treatment
- Component Assembly
- Final Assembly
## Air Transport: Aircraft Fleet

### Environmental Interventions:

<table>
<thead>
<tr>
<th></th>
<th>Seats</th>
<th>Electricity</th>
<th>Natural gas</th>
<th>Heating oil</th>
<th>VOC emissions</th>
<th>total water consumption/discharge</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>number</td>
<td>kWh/unit</td>
<td>MJ/unit</td>
<td>MJ/unit</td>
<td>kg/unit</td>
<td>M3/unit</td>
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<tr>
<td>Short/medium haul</td>
<td>150</td>
<td>1.39E+06</td>
<td>7.11E+06</td>
<td>3.74E+05</td>
<td>6.30E+03</td>
<td>1.61E+03</td>
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<tr>
<td>Long haul</td>
<td>380</td>
<td>3.51E+06</td>
<td>1.80E+07</td>
<td>9.48E+05</td>
<td>3.51E+06</td>
<td>4.07E+03</td>
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<tr>
<td>Average Fright transport</td>
<td>367.58</td>
<td>3.40E+06</td>
<td>1.74E+07</td>
<td>9.17E+05</td>
<td>3.40E+06</td>
<td>3.93E+03</td>
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<tr>
<td>Average Passenger Transport</td>
<td>304.79</td>
<td>2.82E+06</td>
<td>1.44E+07</td>
<td>7.60E+05</td>
<td>2.82E+06</td>
<td>3.26E+03</td>
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</tbody>
</table>
Einschub: Vgl. Vehicle Aircraft vs lorry

Schweizer Zentrum für Ökoinventare
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Air Transport: Bringing it together

Ziel: all modules must be referred to the Functional Unit

Operation- Modul: 1:1

Airport Infrastructure: inverse value of yearly performance and life span

Aircraft Fleet: inverse value of aircraft life time performance
## Air Transport: Zusammenführung

### Nachfrage Flugzeug

<table>
<thead>
<tr>
<th>Reference figure</th>
<th>unit</th>
<th>Freight</th>
<th>Passenger</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Intra Europe</td>
<td>Intercont.</td>
</tr>
<tr>
<td>Kilometric performance</td>
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<td>5.59E+07</td>
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<tr>
<td></td>
<td></td>
<td>5.59E+07</td>
<td>5.59E+07</td>
</tr>
<tr>
<td>Average load</td>
<td>t/vehicle (p/vehicle)</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>65</td>
<td>320</td>
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<tr>
<td>Transport performance</td>
<td>tkm/vehicle (pkm/vehicle)</td>
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<td>1.40E+09</td>
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<tr>
<td></td>
<td></td>
<td>3.63E+09</td>
<td>1.79E+10</td>
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<tr>
<td></td>
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<td>0.940</td>
<td>0.754</td>
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## Air Transport: Bringing it together

<table>
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<th>InfrastructureProcess</th>
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<td>Unit</td>
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<td></td>
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<td></td>
<td></td>
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<tr>
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<td>RER</td>
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<td>tkm</td>
<td>1.00E+0</td>
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<td>own estimation based on uncertainties in the assumed life time performance of aircrafts and the share of freight.</td>
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<td>2.00E+0</td>
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<td>unit</td>
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<td>1.50E+0</td>
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<td>2.58E-12</td>
<td>1</td>
<td>2.00E+0</td>
<td>life span of airports is uncertain</td>
</tr>
</tbody>
</table>
Fazit

A lot have been done to create a comprehensive view on transport activities

but a lot of work is needed to understand the and further aggregate the results