Cities & transport systems
MIT 11.165/477, 11.286J

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Materials for today

- David JC MacKay. Sustainable Energy - Without the Hot Air. UIT Cambridge Ltd., 1 edition, February 2009. Chapters 5, C.
- Daniel A Mazmanian. Los Angeles Clean Air Saga Spanning Three Epochs, Chapter 4. In Michael E Kraft and Daniel A Mazmanian, editors, Toward Sustainable Communities: Transition and Transformations in Environmental Policy. MIT Press, Cambridge, Mass, 2nd ed edition, 2009.
- Mimi Sheller. Racialized Mobility Transitions in Philadelphia: Connecting Urban Sustainability and Transport Justice. City & Society, 27(1): 7091, 2015. ISSN 1548-744X. doi: 10.1111/ciso.12049. URL.
- Aiofe O'Leary. Chapter 16: aviation. In Michael B. Gerrard and John C. Dernbach, editors, Legal Pathways to Deep Decarbonization in the United States, pages 424443. Environmental Law Institute, 1 edition edition, March 2019.
- Stefan Gössling and Andreas Humpe. The global scale, distribution and growth of aviation: Implications for climate change. Global Environmental Change, 65:102194, November 2020. ISSN 0959-3780. doi. URL.
- OPTIONAL: Patrick Bigger, Johanna Bozuwa, Mijin Cha, Daniel Aldana Cohen, Billy Fleming, Yonah Freemark, Batul Hassan, Mark Paul, and Thea Riofrancos. Inflation Reduction Act: The Good, The Bad, The Ugly. Technical report, Climate and Community Project, 2022. URL.

Policy analysis

Economic framing of policy analysis: cost-benefit analysis

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Two main concerns:

1. efficiency: with are the highest priority items?

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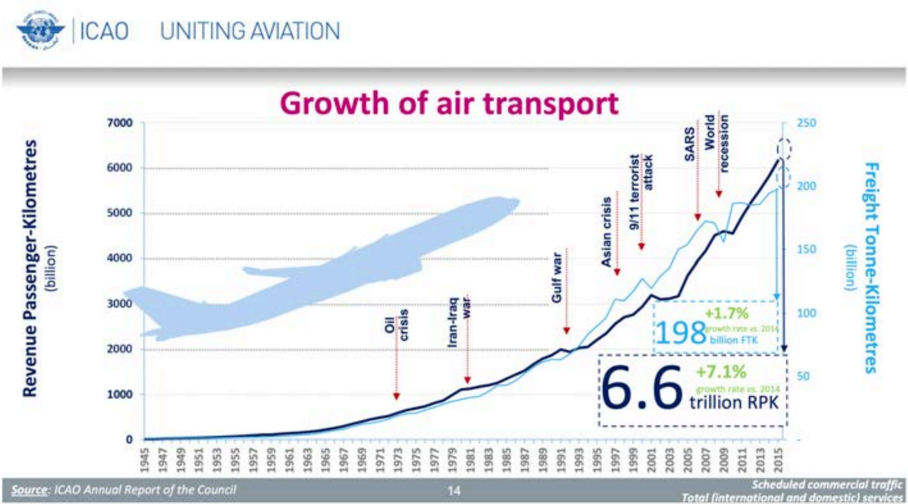
- implementation: who, how, where?
- growth, speed
- geography: does this work the same in all places?

Policy analysis

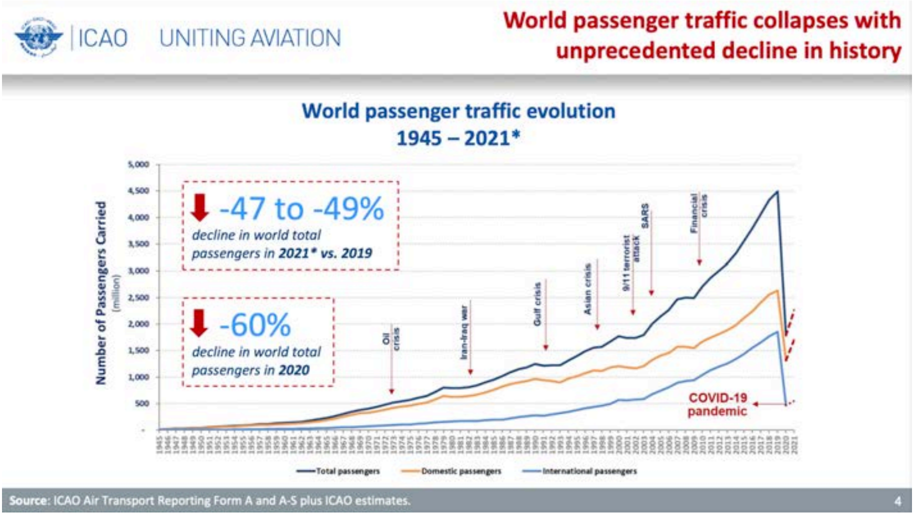
Three case studies:

- global aviation
- walking, bicycling, and transit in Philadelphia
- Los Angeles' efforts towards clean air (leading to CARB)

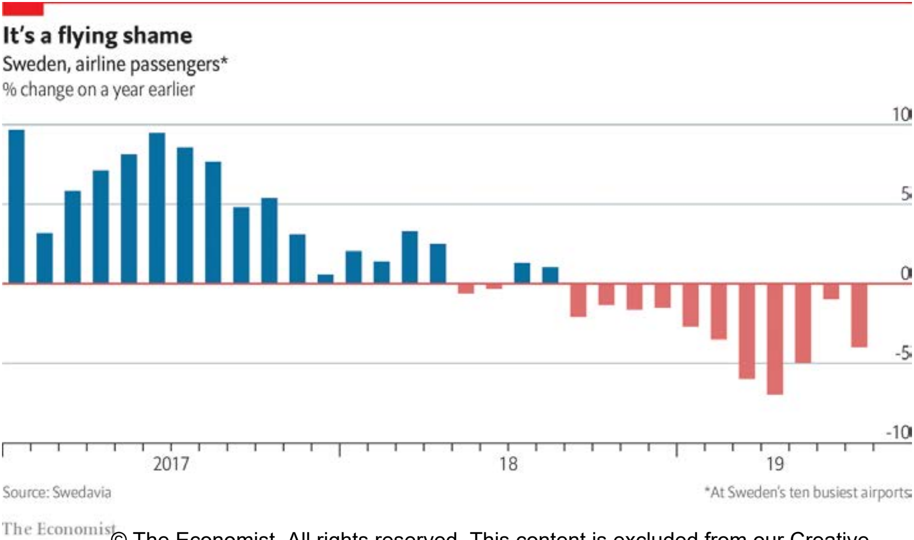
ICAO, 2017


ICAO UNITING AVIATION
Growth of air transport
Revenue Passenger-Kilometres (billion)
Freight Tonne-Kilometres (billion)
7000
6000
5000
4000
3000
2000
1000
0
250
200
150
100
50
Oil crisis
Iran-Iraq war
Gulf war
Asian crisis
9/11 terrorist attack
SARS
World recession
198 +1.7% growth rate vs. 2014 billion FTK
6.6 +7.1% growth rate vs. 2014 trillion RPK
1945 1947 1949 1951 1953 1955 1957 1959 1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Source: ICAO Annual Report of the Council
14
Scheduled commercial traffic
Total (international and domestic) services

ICAO, 2021

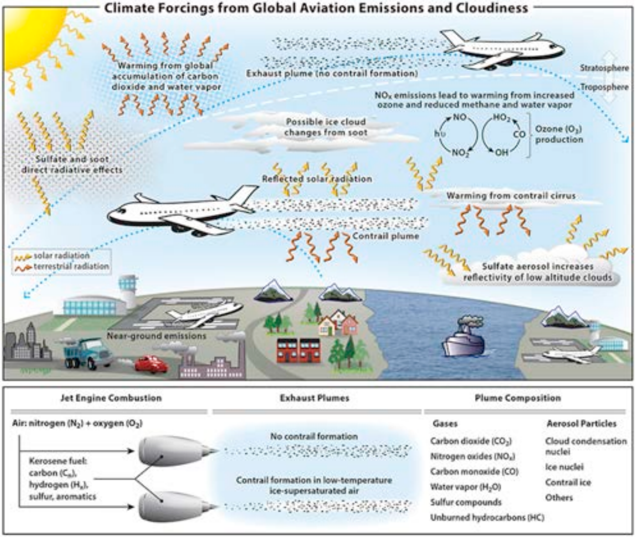

ICAO UNITING AVIATION
World passenger traffic collapses with unprecedented decline in history
World passenger traffic evolution 1945 – 2021*
-47 to -49% decline in world total passengers in 2021* vs. 2019
-60% decline in world total passengers in 2020
Number of Passengers Carried (million)
Oil crisis
Iran-Iraq war
Gulf crisis
Asian crisis
9/11 terrorist attack
SARS
Financial crisis
COVID-19 pandemic
Total passengers
Domestic passengers
International passengers
Source: ICAO Air Transport Reporting Form A and A-S plus ICAO estimates.
4

Economist: "flygskam"



Lee et al 2021 paper

Graphic courtesy of Elsevier, Inc., https://www.sciencedirect.com.



Aviation is 3.5% of radiative forcing (oft-quoted 2%; large non-CO2 effect)

Gössling and Humpe 2020 paper

Table 1
Theoretical maximum share of flying population.

	Population 2018 (million)*	Passengers 2018 (million)*	Passengers per capita of the population	Flying population (%)	Maximum flying population (million)
Low income	705	23	0.03	1.63	11
Lower middle	3,023	454	0.15	7.51	227
Upper middle	2,656	1,313	0.49	24.72	657
High income	1,210	2,442	2.02	100.00	1,210
Total	7,594	4,233			2,105

*Source: World Bank (2020b).
The "theoretical maximum" assumes that each individual participates in exactly one trip per year.

Table 2
Share of flying population adjusted for non-flying share of population, 2018.

	Population (million)*	Passengers(million)*	Passengers per capita of the population	Flying population (%)	Flying population (million)
Low income	705	23	0.03	0.7	4.9
Lower middle	3,023	454	0.15	3	90.7
Upper middle	2,656	1,313	0.49	10	265.6
High income	1,210	2,442	2.02	40	484.0
Total	7,594	4,233			845.2

Source: own calculations, based on World Bank (2020b)*. Flying population: The share/number of the population/people in each income group that flies at least once per year.

Gössling and Humpe 2020 paper

Distributions in Table 1 do not consider that there is a significant share of the population in every country that does not fly, while some air travelers participate in one, two, or multiple trips. For example, data for the USA suggests that 53% of the adult population do not fly (Airlines for America, 2018). In Germany, 65% of the population do not fly (IFD Allensbach, 2019), while this share is 66% in Taiwan (Tourism Bureau Taiwan, 2019). In the UK, the non-flying share of the population 16 years or older is 59% (DEFRA, 2009). These national surveys indicate that in high income countries, between 53% and 65% of the population will not fly in a given year. The share of non-fliers is likely larger in low-income, lower-middle and upper-middle income countries. For a

Gössling and Humpe 2020 paper

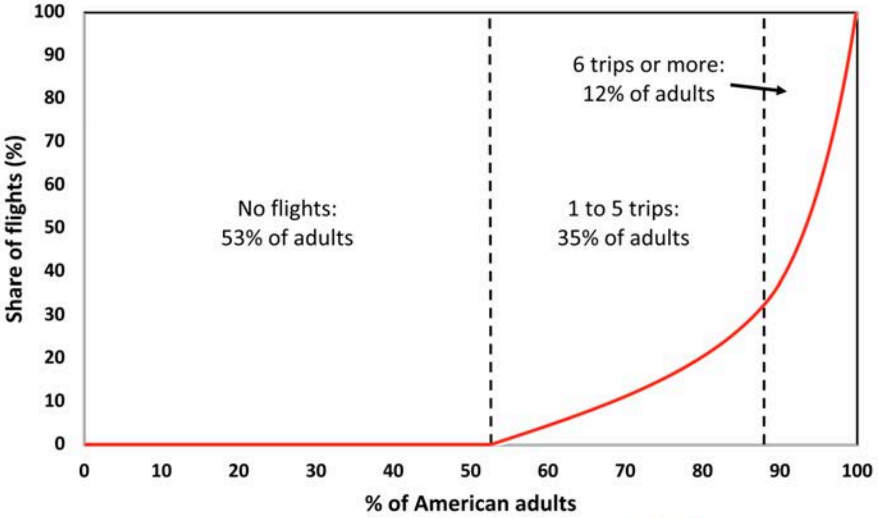


Fig. 6. Air transport demand distribution in the USA. Source: based on ICCT (2019).

Gössling and Humpe 2020 paper

Table 4
Total and per capita emissions from commercial air passenger transport.

Region	CO_2 global (Mt, 2018)	CO_2 global (Mt, 2050)	CO_2 per capita (kg, 2018)	CO_2 per capita (kg, 2050)
Africa	14	53	11	21
Asia-Pacific	241	956	57	196
CIS	19	41	78	160
Europe	169	363	250	546
Latin America	44	158	69	207
Middle-East	47	182	278	683
North America	190	366	521	860
Rest of world	19	51	n.a.	n.a.
Average/ Total	743	2,169		

Source: own calculations based on Airbus (2019), Boeing (2019), ICCT (2019), UN DESA (2020). Emission factors: 0.035 l fuel per RPK burns to 0.087 kg CO_2 per RPK in 2018.

Mackay figure 20.23 – vertical axis in kWh / p-100 km!

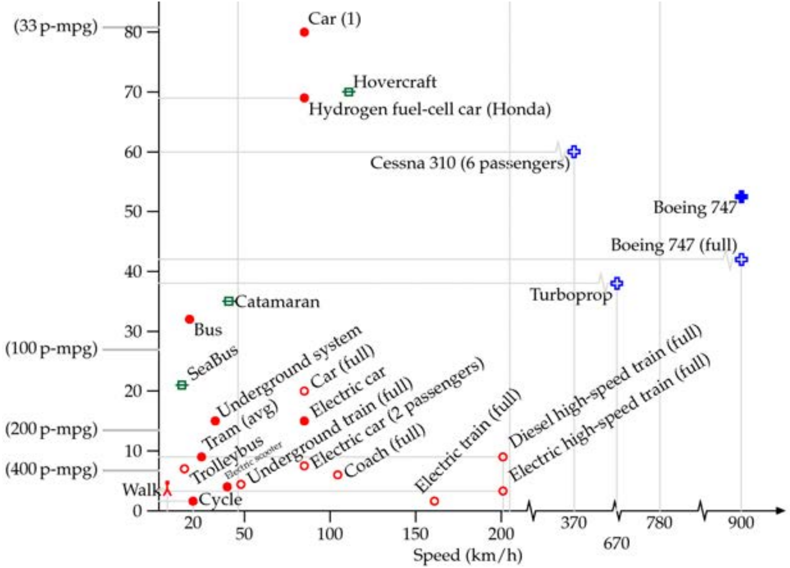


Figure courtesy of David MacKay.

Homework problem: time-distance

Key assumptions: turboprop, 670 km/h; high-speed train, 200 km/h

From the train's perspective:

$$670 \left(\frac{\text{km}}{\text{hours}}\right)(x-3)\ (\text{hours}) \quad = \quad 200(x)\left(\frac{\text{km}}{\text{hours}}\right)(\text{hours})$$

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670\left(\frac{\text{km}}{\text{hours}}\right)(x-3)\ (\text{hours}) &= 200(x)\left(\frac{\text{km}}{\text{hours}}\right)(\text{hours}) \\
670x - 2010 &= 200x \\
470x &= 2010 \\
x &= 4.27 \text{ hours by train} \\
\therefore 200x &= 855 \text{ kilometers}
\end{aligned}
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From the plane's perspective:

$$\begin{aligned} 670x &= 200(x+3) \\ 470x &= 600 \\ x &= 1.27 \text{ hours by plane} \\ \therefore 670x &= 855 \text{ kilometers} \end{aligned}$$

Homework problem: energy-speed

Key assumptions:

- turboprop, 38 kWH/p-100 km, 670 km/h
- high-speed train, 4 kWH/p-100 km, 200 km/h

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For a turboprop:

$$38 \, \frac{\text{kWH}}{\text{p-100 km}} \times 856 \text{ km} \;\; = \;\; 325.3 \, \frac{\text{kWH}}{\text{p}}$$

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Or see quickly that it is a ∼10X (9.5X) difference (key numbers: $\approx 38, 4$).

Mackay on planes, Appendix C

Can planes be improved?

If engine efficiency can be boosted only a tiny bit by technological progress, and if the shape of the plane has already been essentially perfected, then there is little that can be done about the dimensionless quantity. The transport efficiency is close to its physical limit. The aerodynamics community say that the shape of planes could be improved a little by a switch to blended-wing bodies, and that the drag coefficient could be reduced a

little by laminar flow control, a technology that reduces the growth of turbulence over a wing by sucking a little air through small perforations in the surface (Braslow, 1999). Adding laminar flow control to existing planes would deliver a 15% improvement in drag coefficient, and the change of shape to blended-wing bodies is predicted to improve the drag coefficient by about 18% (Green, 2006). And equation (C.26) says that the transport cost is proportional to the square root of the drag coefficient, so improvements of c_d by 15% or 18% would improve transport cost by 7.5% and 9% respectively.

Text courtesy of David MacKay.

CNN travel

DESTINATIONS FOOD & DRINK NEWS STAY VIDEO

Long-awaited Celera 500L 'bullet' plane is finally revealed

Maureen O'Hare, CNN • Updated 28th August 2020

18-25* miles per gallon compared to 2-3 miles for a comparable (small) jet.

Factor in the new Celera 500L!

Private jet, 2-3 mpg:

$$\frac{10\mathrm{kWH}}{\mathrm{l}} \times \frac{\mathrm{gal}}{2.5\ \mathrm{miles}} \times \frac{\mathrm{l}}{0.26\ \mathrm{gal}} \times \frac{\mathrm{mile}}{1.6\ \mathrm{km}} \times \frac{100}{100} = \frac{961\ \mathrm{kWH}}{100\ \mathrm{km}}$$

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Internal combustion engine SUV, 22 mpg:

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All carry about six people, so divide by six to get kWH/p-km.

Homework problem: energy

How do our various modes compare?

$$\text{Private jet} \quad 961\ [\frac{\text{kWH}}{6\ \text{p.-100 km}}] \times 856\ \text{km} = 1371.0\ \frac{\text{kWH}}{\text{p}}$$

$$\text{Turboprop} \quad 38\ \frac{\text{kWH}}{\text{p-100 km}} \times 856\ \text{km} = 325.3\ \frac{\text{kWH}}{\text{p}}$$

$$\text{Celera 500L or SUV} \quad 109\ [\frac{\text{kWH}}{6\ \text{p.-100 km}}] \times 856\ \text{km} = 155.5\ \frac{\text{kWH}}{\text{p}}$$

$$\text{High-speed train} \quad 4\ \frac{\text{kWH}}{\text{p-100 km}} \times 856\ \text{km} = 34.2\ \frac{\text{kWH}}{\text{p}}$$

O'Leary, "Aviation" chapter

History of policy actions on aviation

- 1997 Kyoto Protocol: all countries reduce by 5% from 1990-2012
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- 2012 European Union introduces Emissions Trading Scheme (ETS)
- 2011 US Congress passes the EU-ETS Prohibition Act of 2011
- 2016 EPA endangerment finding (under the Clean Air Act)
- 2016 ICAO develops CORSIA, a carbon cap and offsetting scheme from 2020
- 2017 ICAO adopts a CO2 standard for aircraft
- 2017 EU decides this only applies to intra-EU flights

O'Leary, "Aviation" chapter

Options

1. improve vehicle efficiency
2. biofuel use
3. operational measures
4. demand reduction

US policy options

1. carbon tax including aviation emissions
2. increase taxes on aviation specifically
3. introduce an emissions standard
4. require or encourage use of biofuels
5. reduce emissions at airports
6. voluntary emissions reductions measures
7. enable or encourage less flying
8. individuals purchase high-quality offsets
9. reduce freight emissions

Is aviation a moral or individual issue?

A: Red herring, canard, waste of time

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1. FF companies sell products to consumers . . . e.g., us
2. rich countries consume much more than poor ones
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Sheller 2015 paper

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Analogous questions:

- how do we think about lower-emitting transportation technologies?
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Consider the following transportation transitions, who and how can these be accessed?

- cars (ICE to EVs)
- e-bikes

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- cars (ICE to EVs)
- e-bikes
- subways and light rail
- walking
- buses

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- how do we think about lower-emitting transportation technologies?
- what we would have to do to make them equitable, fair, just?

Consider the following transportation transitions, who and how can these be accessed?

- cars (ICE to EVs)
- e-bikes
- subways and light rail
- walking
- buses
- land use and living patterns?

Mazmanian chapter

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- what changes do we have to start making now?

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The saga of making long-term changes in the auto system, land use, regional governance:

- what changes do we have to start making now?
- how do we sustain those changes and efforts?

Tuesday 9/27 class

We'll talk about how to achieve justice / fairness / equity in different urban modes of transport. It may help to think about the various readings from previous classes.

For all of the modes on the previous slide, you should be able to argue for:

- the existing status quo or trajectory of the system we have OR

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>
> F. Scott Fitzgerald, 1936?