8

Case Study IV
End Use:
Transport

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1

World Transport Energy Use in 2017 (Mtoe, IEA, 2019)

World

Million tonnes of oil equivalent

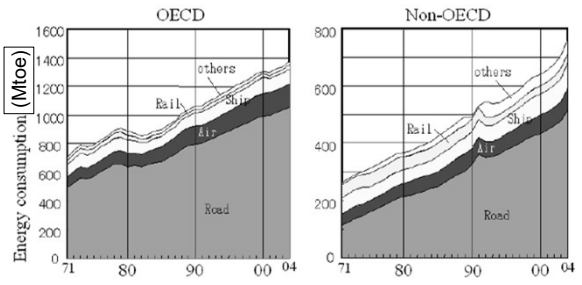
SUPPLY AND CONSUMPTION	Coal & peat	Crude oil	Oil products	Gas	Nuclear	Hydro	Geotherm. solar etc.	Combust. renew. & waste	Electricity	Heat	Total
TRANSPORT	0.06	0.00	2558.61	104.71	-	-	-	83.69	51.27	-	2808.16
World aviation bunkers	-	-	195.37	-	-	-	-	-	-	-	195.37
Domestic aviation	-	-	128.04	-	-	-	-	-	-	-	128.04
Road	-	-	1960.37	43.81	-	-	-	82.73	4.55	-	2091.46
Rail	0.05	-	28.84	-	-	-	-	0.50	22.12	-	51.52
Pipeline transport	-	-	0.25	60.62	-	-	-	-	2.89	-	63.75
World marine bunkers	-	-	216.87	0.06	-	-	-	0.22	-	-	217.15
Domestic navigation	0.00	-	54.48	0.07	-	-	-	0.14	-	-	54.69
Non-specified	0.01	0.00	4.29	0.15	-	-	-	0.00	1.71	-	6.17

	final energy	service
	Mtoe	10e12 pass-/ton-km
People	~1600	32
Goods	~1200	46

Rough equivalence:
1 passenger = 1.5 tons!

2

Transport Energy Use Trends (in Mtoe)

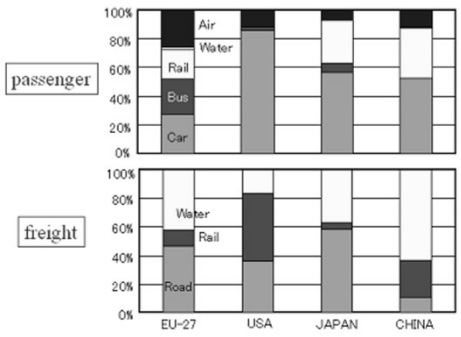


Source: GEA KM9 (2012) based on IEA

3

Modal Share in Transport Output

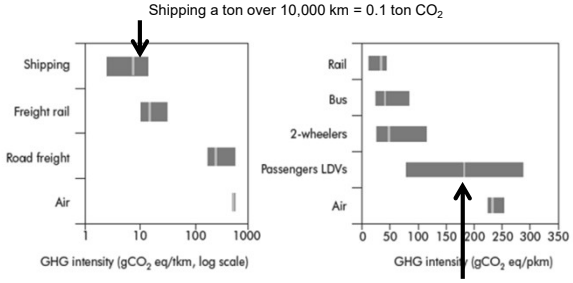
(Source: GEA KM9 2012)



4

GHG Intensity of Different Transport Modes: What do the numbers mean?

Shipping a ton over 10,000 km = 0.1 ton CO_2



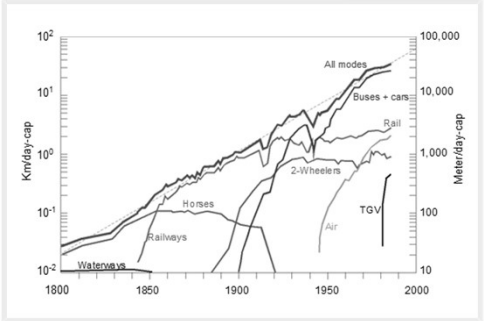
US average: 25,700 pass-km/capita
@ 170 g CO_2/pass-km = 4.3 tons CO_2

Private car travel in US is equivalent of importing 43 tons of goods from China for each person, so if you worry about your C-footprint worry about driving to the shopping mall rather than about CO2 from shipping imports from Chi

5

France - Growth in Motorized Mobility

(pass-km per day per capita)



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6

Mobility Drivers

Amplifiers:

- Interconnectedness
- Income
- Technology (speed)

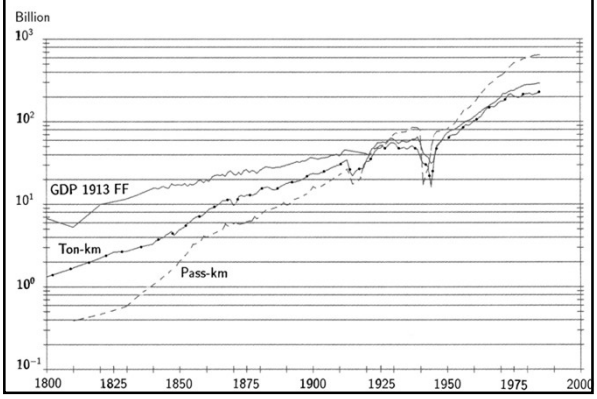
Constraints

- Time
- Money
- Space (congestion)

Mediator: Lifestyles & Policy

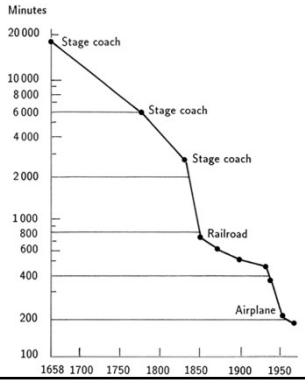
7

FRANCE: 1913 FF GNP AND TRANSPORT TON- AND PASS-KM

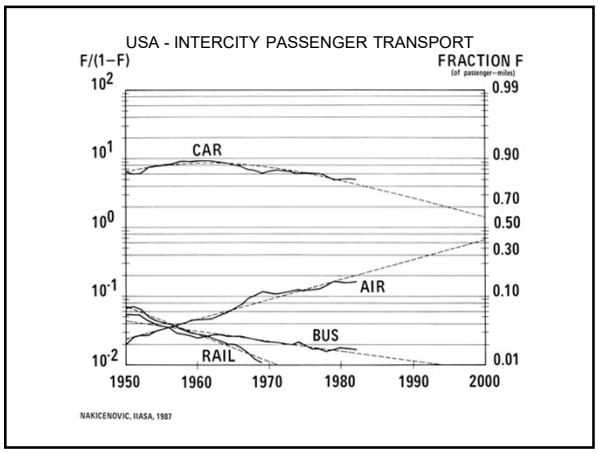


8

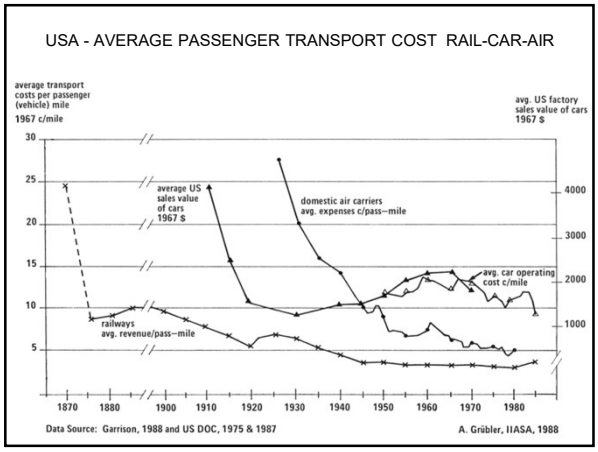
London – Edinburgh Travel Time



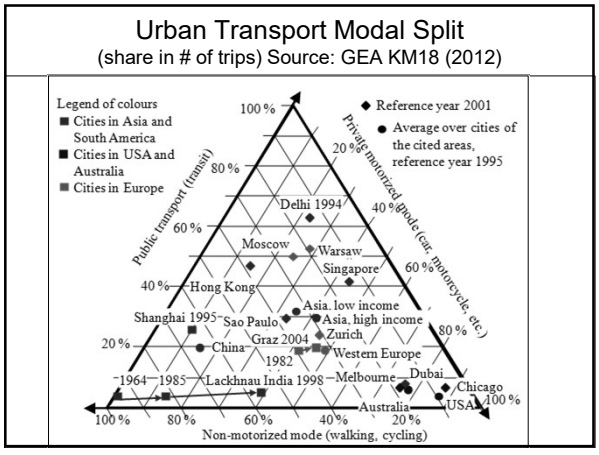
9


USA - INTERCITY PASSENGER TRANSPORT
F/(1−F)
FRACTION F
(of passenger−miles)
CAR
AIR
BUS
RAIL
NAKICENOVIC, IIASA, 1987

10

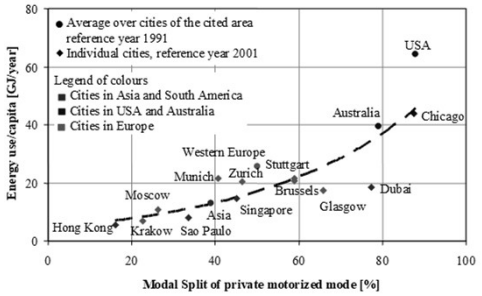

USA - AVERAGE PASSENGER TRANSPORT COST RAIL-CAR-AIR
average transport costs per passenger (vehicle) mile 1967 c/mile
avg. US factory sales value of cars 1967 $
average US sales value of cars 1967 $
domestic air carriers avg. expenses c/pass−mile
avg. car operating cost c/mile
railways avg. revenue/pass−mile
Data Source: Garrison, 1988 and US DOC, 1975 & 1987
A. Grübler, IIASA, 1988

11


Urban Transport Modal Split
(share in # of trips) Source: GEA KM18 (2012)
Legend of colours
Cities in Asia and South America
Cities in USA and Australia
Cities in Europe
Reference year 2001
Average over cities of the cited areas, reference year 1995
Public transport (transit)
Private motorized mode (car, motorcycle, etc.)
Non-motorized mode (walking, cycling)
Delhi 1994
Moscow
Warsaw
Singapore
Hong Kong
Asia, low income
Asia, high income
Shanghai 1995
Sao Paulo
Zurich
Graz 2004
China
1982
Western Europe
1964
1985
Lackhnau India 1998
Melbourne
Dubai
Chicago
USA
Australia

12

Transport Energy Use vs. Modal Split



Source: GEA KM18 2012

13

Y. Zahavi's Transport Demand Model

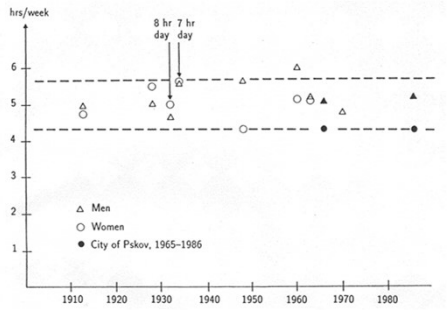
(controversial theory but sound empirics)

- Maximization of travel range ("contact/exchange surfaces" or "encounter potentials" = miles traveled)
- Subject to:
  -- travel time budget (~1 hr/day)
  -- income (~15% of family income)
  constraints

14

Weekly Travel Time Budgets in the USSR

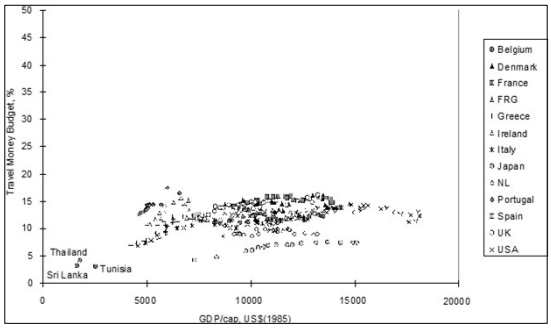
(Variation across 12 countries: 0.65-1.48 hrs/day/person; Szalai, 1972)



15

Travel Money Budgets (% of Income)

Source: Schafer & Victor, 2000, Trnsp.Res.A. 34(3):171-205



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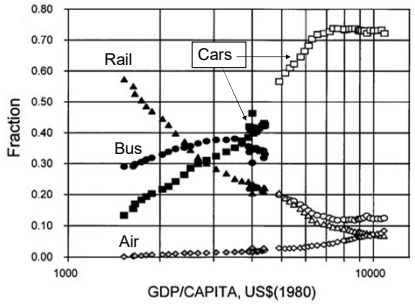
16

Western and Eastern Europe Passenger Modal Split

Based on Schafer & Victor, SciAmer. October 1997:56-59



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17

Individual Mobility by Country and Purpose (US), 1990 Data

*Trip purpose**	*10^9 pass-km*	*Percent*
Work (commute)	1,190	17.7%
Family & HH	2,981	44.5%
Leisure#	2,484	37.0%
"go for a ride"	55	0.8%
TOTAL US	6,710	100.0%
Total mobility in:		
China	607	
Ex-USSR	1,770	
France	704	
Norway	47	

* Based on NTPS, 1992. # vacation, seeing friends, other social and recreational activities.

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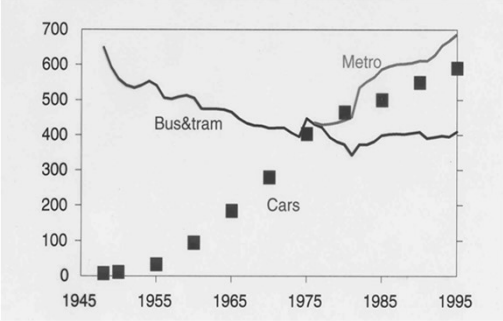
18

Transport Choices and Technology

- Importance of logistical **chains**
- Subjective weighting of travel time (waiting time = 3x travel time)
- Policy leverage: "back end" (parking fees/restrictions) **over** "front end" (subsidized public transport)
- Infrastructures: "orgware" (schedules, reliability, hassle) **and** "hardware" (speed, cleanliness, security) more important than costs

19

Vienna Public Transport Trips per Year (cumulative) and Car Ownership per Capita



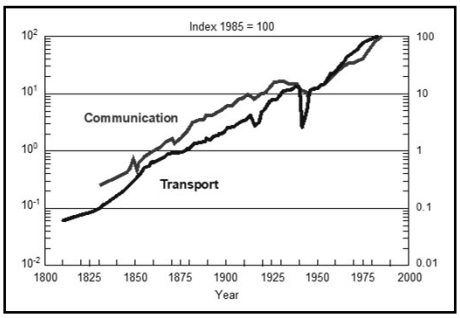
20

Transport & Environment

- Travel & Communication: Complements rather than substitutes
- Unabated demand growth
- Path dependency (prices matter after all)
- Gender differences weakening
- Technology improvements "taken back" by behavioral change (load factors, SUVs)

21

France – Transport & Communication Volume (Index 1985=100)



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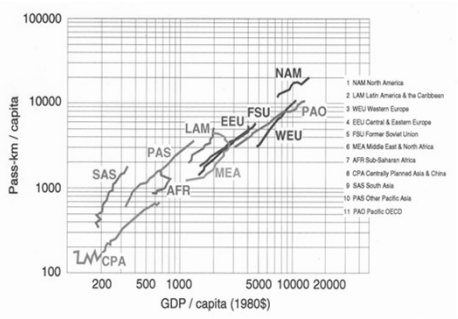
22

Motorized Mobility vs GDP/capita

Based on Schafer & Victor, SciAmer. October 1997:56-59



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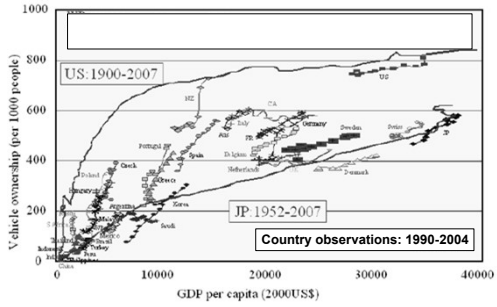
23

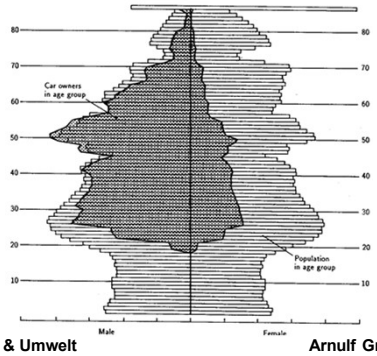
Path Dependent Vehicle Ownership Trends



Source: GEA KM9 (2012) based on IPCC AR4 (2007)

24

Germany: Car Ownership by Gender and Age Cohorts
Source: Buttner&Grubler, 1995.



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25

"Take-back" Effects

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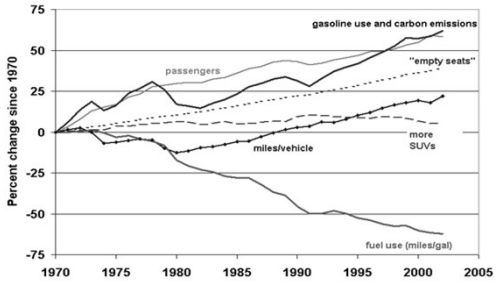
26

Percent Change since 1970 in US Automobile CO_2 Emissions and Driving Forces



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27

User Behavior More Powerful than Technological Efficiency: Example Energy End Use in Transport

50 miles/gal	15 miles/gal	8 miles/gal
1 Yalie in Zipcar	Soccer mom + 3 kids	Driver + 20 school children

Distance traveled (all examples) : 100 km

1.5	1.25	0.50

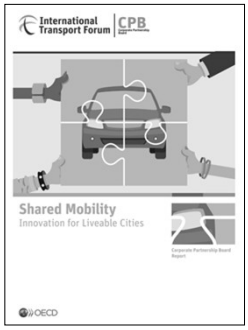
Energy use: MJ per passenger-km traveled

28

US Poster From WW II

29

The "Sharing Economy": Mobility Case Studies



Reductions (%) in shared mobility scenario compared to status quo

	vehicle fleet	con-gestion	mobility costs	CO2 emissions	
Auckland	-95%	-49%	-43%	-54%	
Dublin	-98%	-43%	-50%	> -31%	*
Helsinki	-96%	-37%	-43%	> -34%	*
Lisbon	-97%	-30%	-50%	-62%	

* IC vehicle fleets, no electrification

30

Disruptive Change

Source: Carbontracker, 2018

31

Summary 8
(End-use: Transport)

- **Most important changes with industrial revolution: time and money budgets**
- **Time: life expectancy increases, working time decreases**
- **Money: increasing personal income (2%/Jahr), stability (housing) and structural shifts (communication) in expenditures**
- **Translation of above into increased mobility**
- **Zahavi's transport model: maximize mobility under time (1 hr/day) and money constraints (15% of disposable income)**
- **Importance of technology and infrastructure in influencing space-time-money triangle of mobility**
- **Increasing environmental importance of HOW technologies are used**

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32