8

Case Study IV

End Use:

Transport

Arnulf Grübler

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

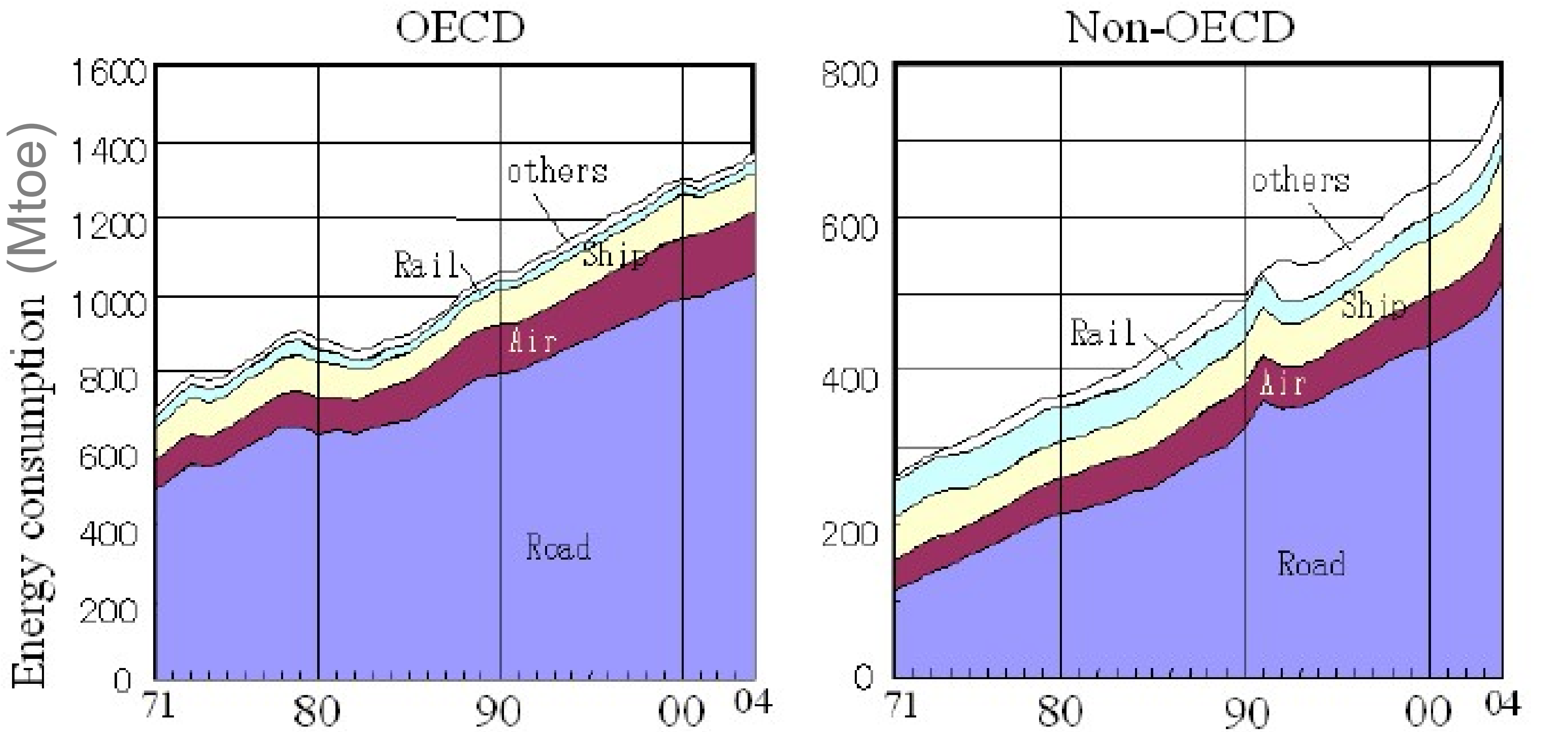
World

SUPPLY AND CONSUMPTION	Coal & peat	Crude oil	Oil products	Gas	Nuclear	Hydro	Geotherm. solar etc.	Combust. renew. & waste	Electricity	Heat	Total
	Million tonnes of oil equivalent										
TRANSPORT	0.06	0.00	2688.61	104.71	-	-	-	83.68	31.27	-	2808.16
World aviation bunkers	-	-	195.37	-	-	-	-	-	-	-	195.37
Domestic aviation	-	-	128.04	-	-	-	-	-	-	-	128.04
Road	-	-	1960.37	43.81	-	-	-	82.73	4.55	-	2091.45
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!

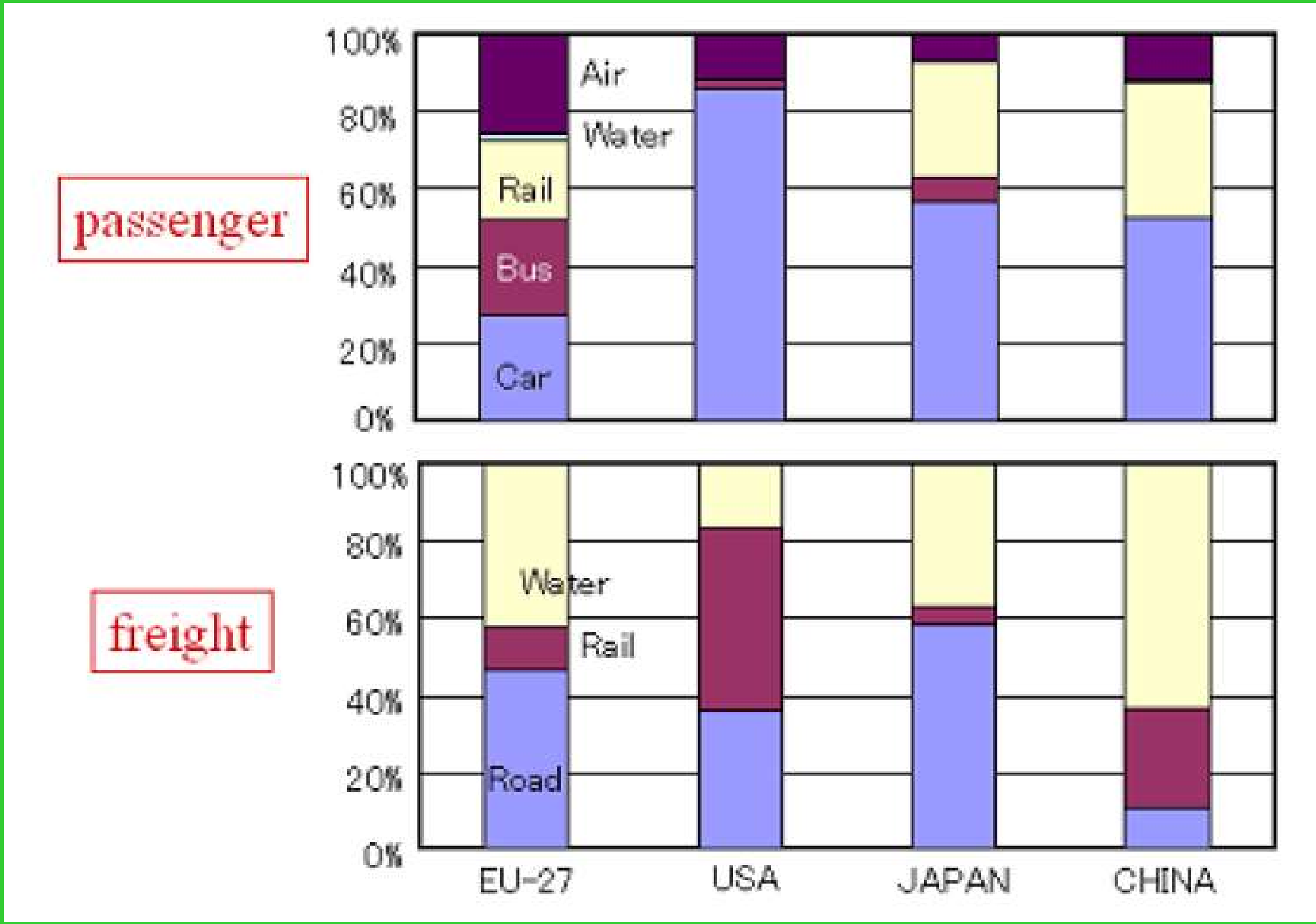
Transport Energy Use Trends (in Mtoe)



Source: GEA KM9 (2012) based on IEA

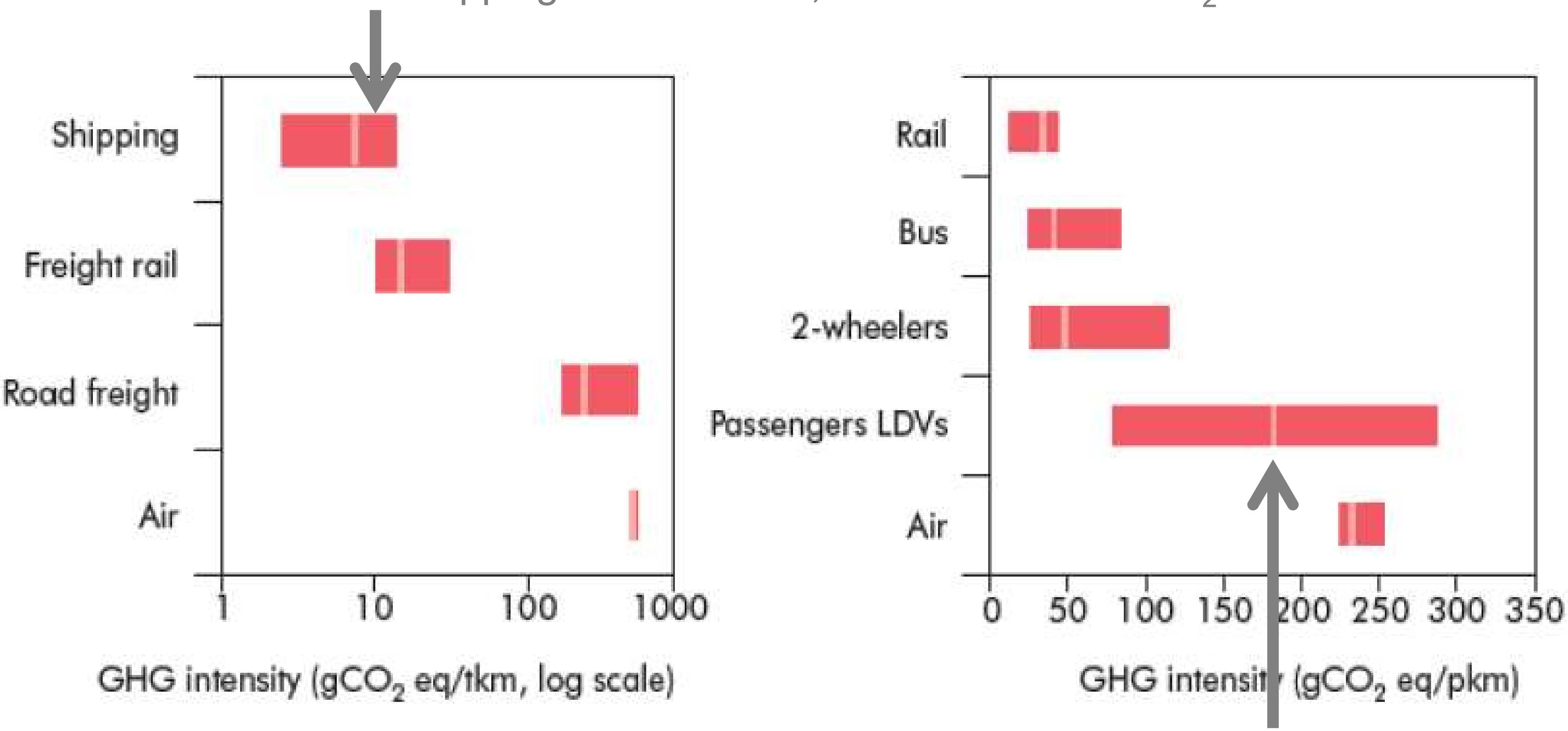
Modal Share in Transport Output

(Source: GEA KM9 2012)



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

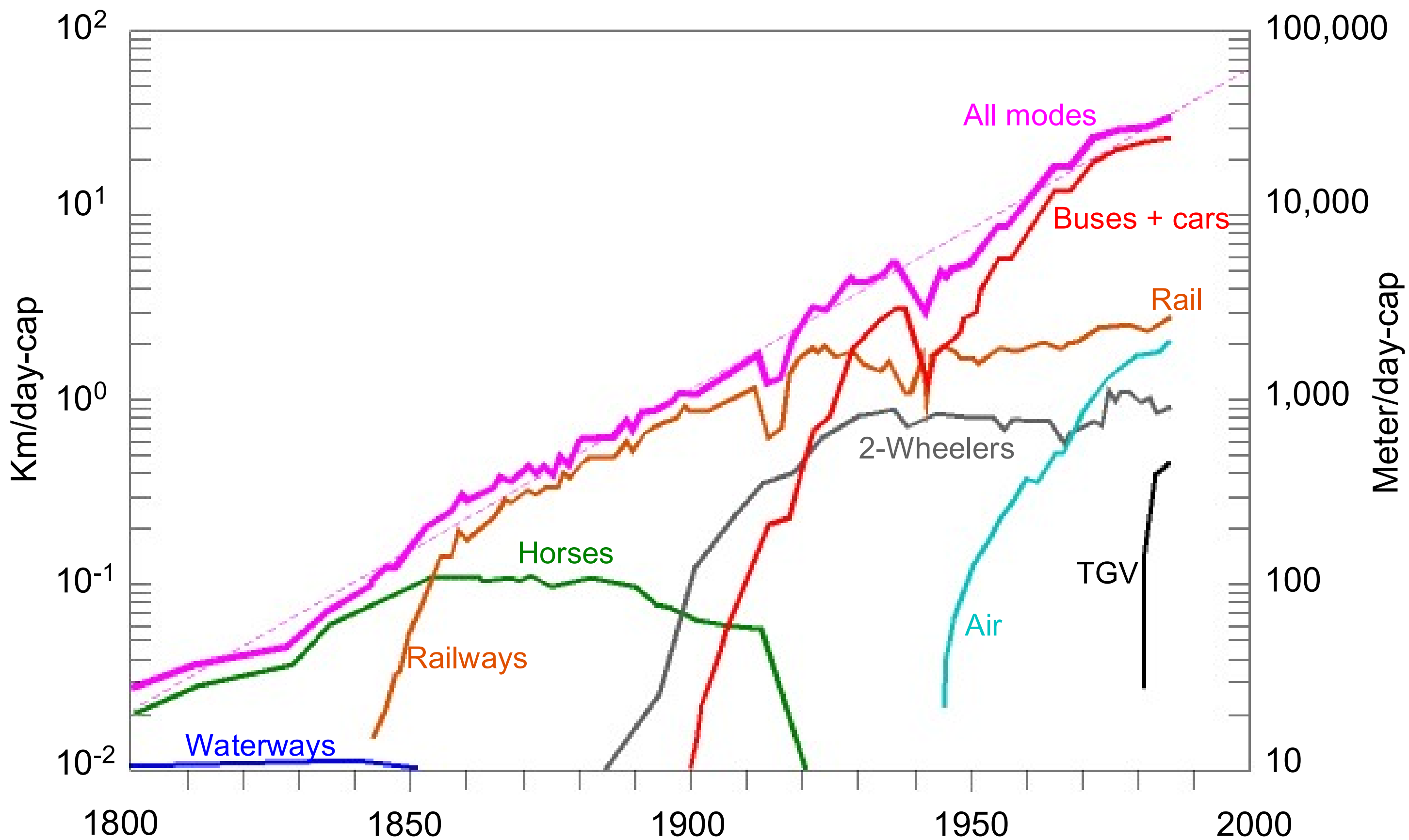
Shipping a ton over 10,000 km = 0.1 ton CO_2



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 Chin

France - Growth in Motorized Mobility
(pass-km per day per capita)



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Mobility Drivers

Amplifiers:

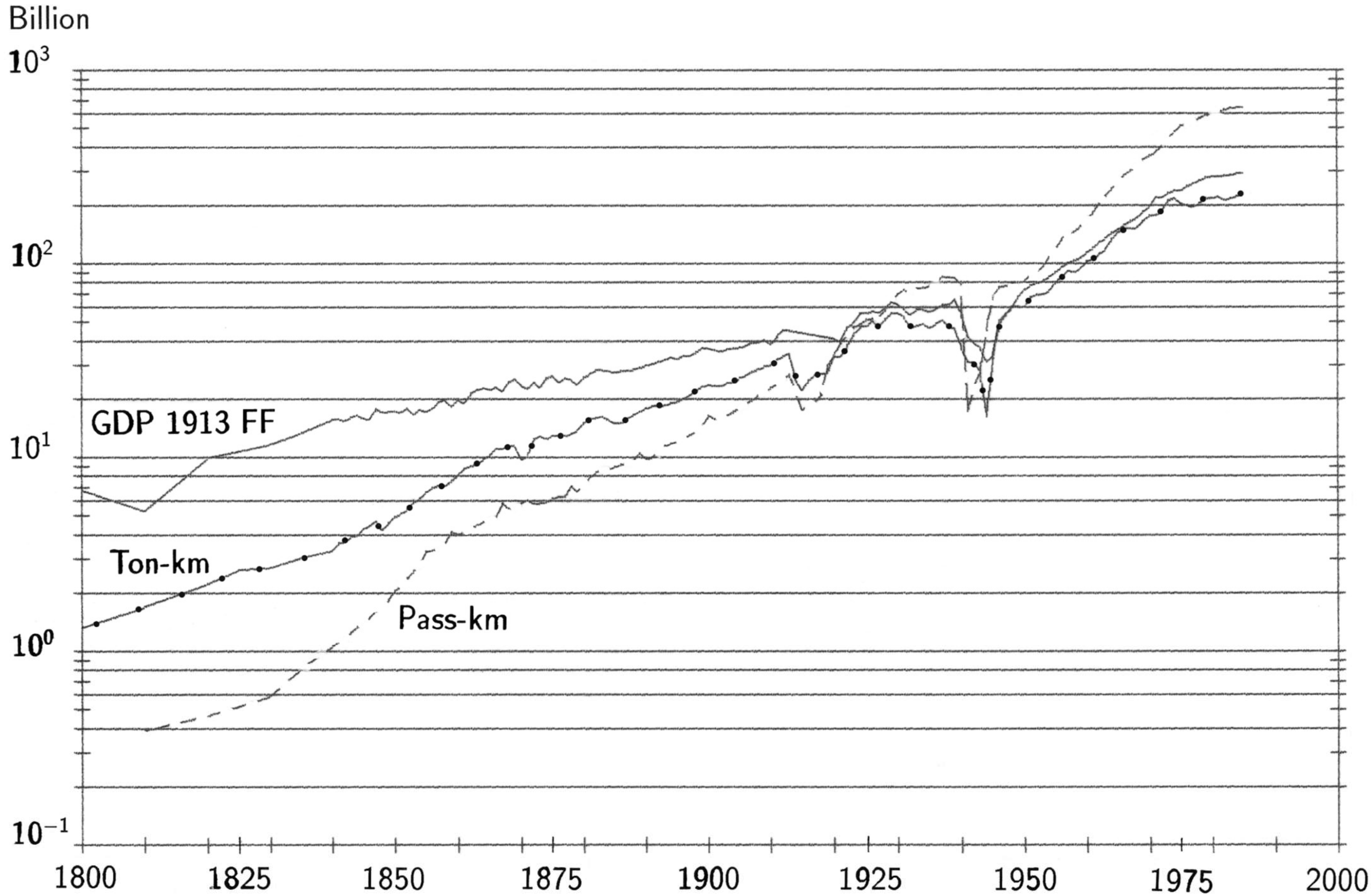
- Interconnectedness
- Income
- Technology (speed)

Constraints

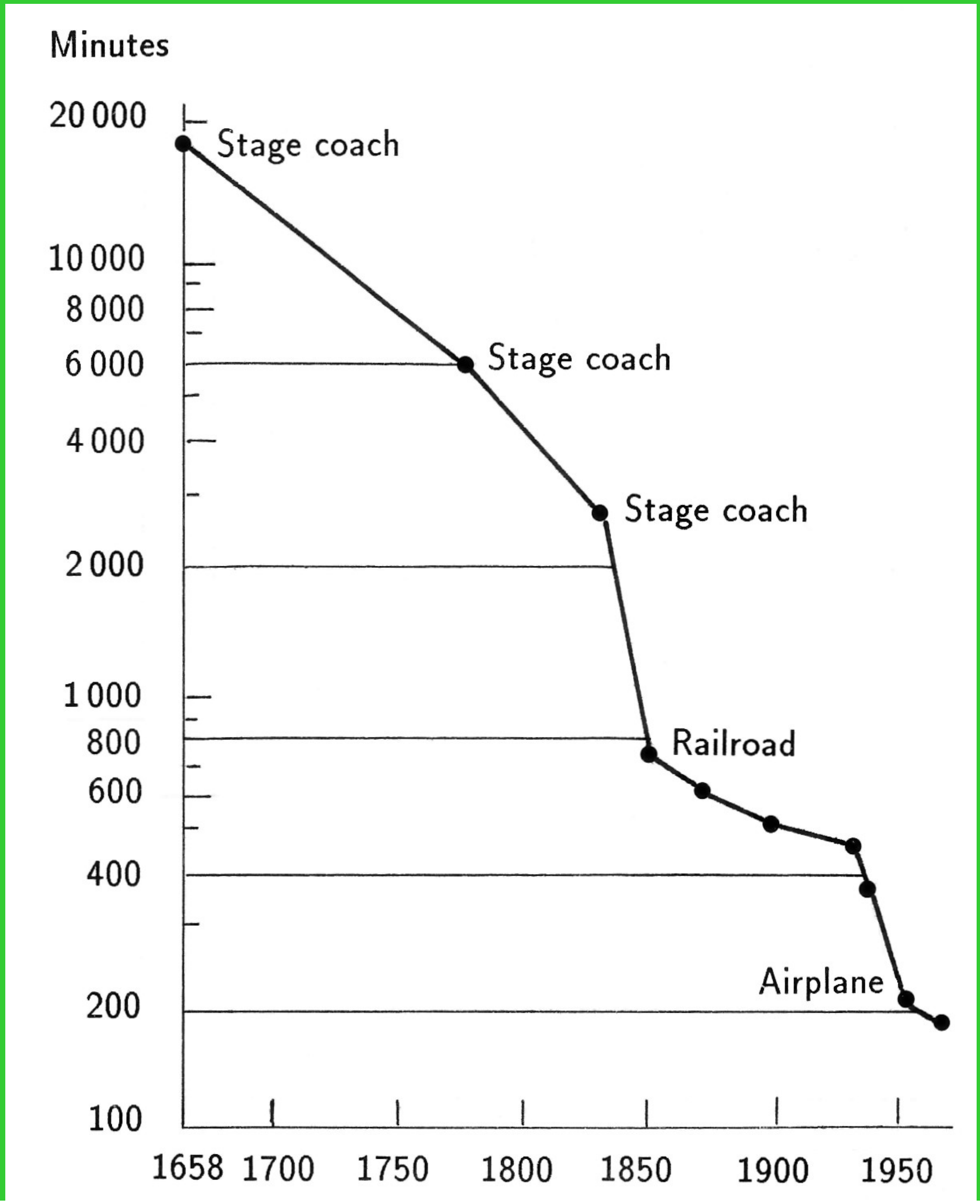
- Time
- Money
- Space (congestion)

Mediator: Lifestyles & Policy

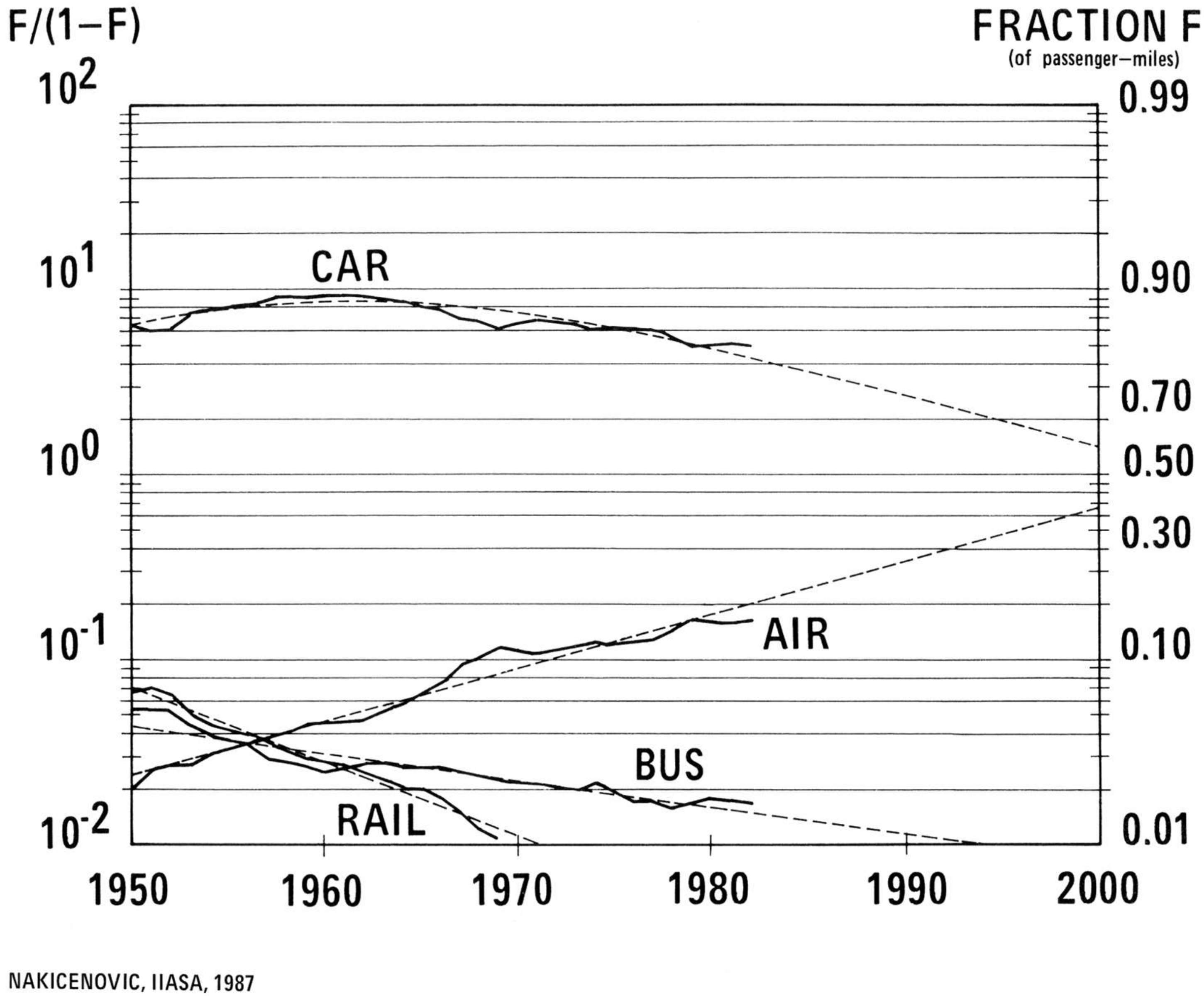
FRANCE: 1913 FF GNP AND TRANSPORT TON- AND PASS-KM



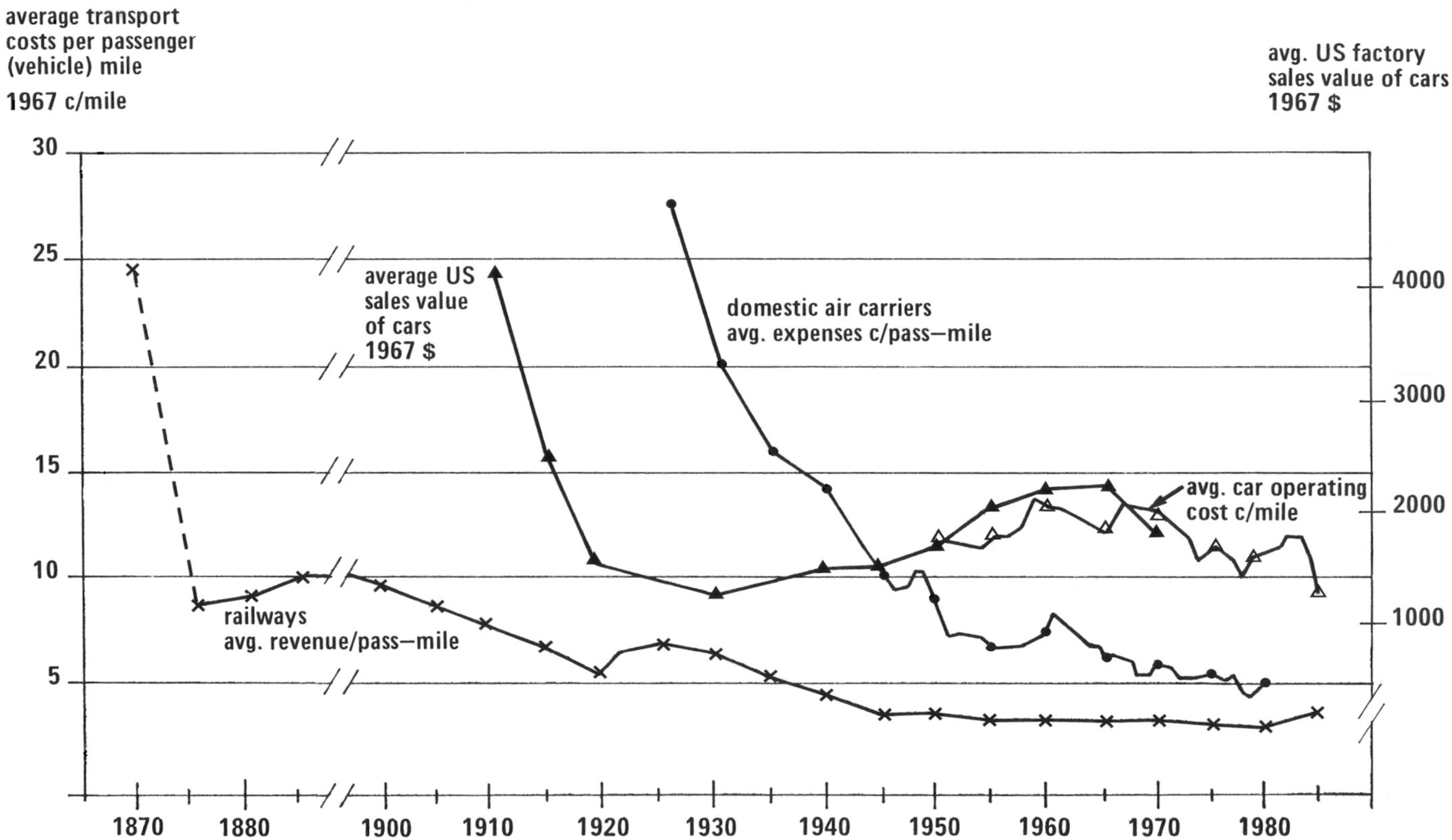
London – Edinburgh Travel Time



USA - INTERCITY PASSENGER TRANSPORT



USA - AVERAGE PASSENGER TRANSPORT COST RAIL-CAR-AIR

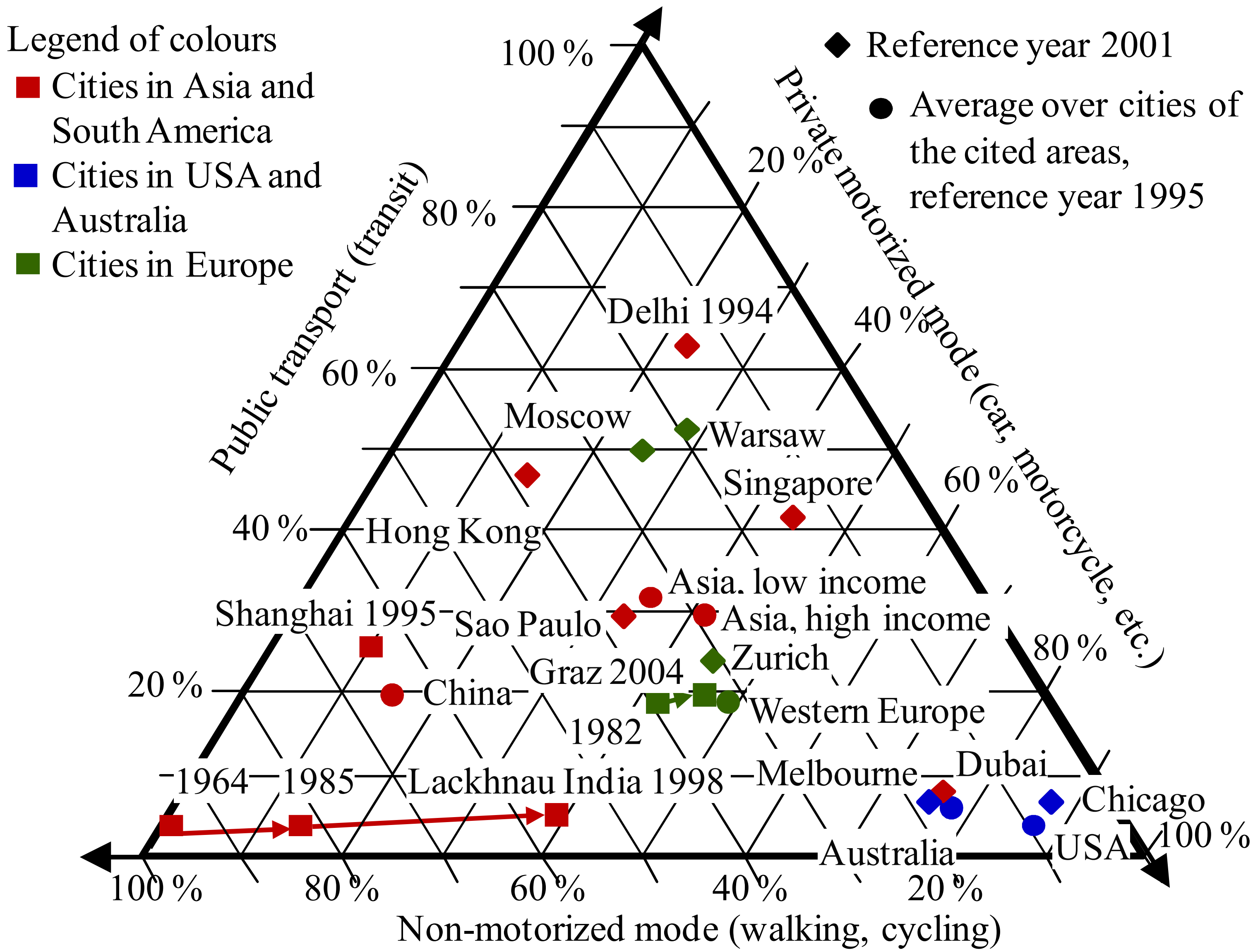


Data Source: Garrison, 1988 and US DOC, 1975 & 1987

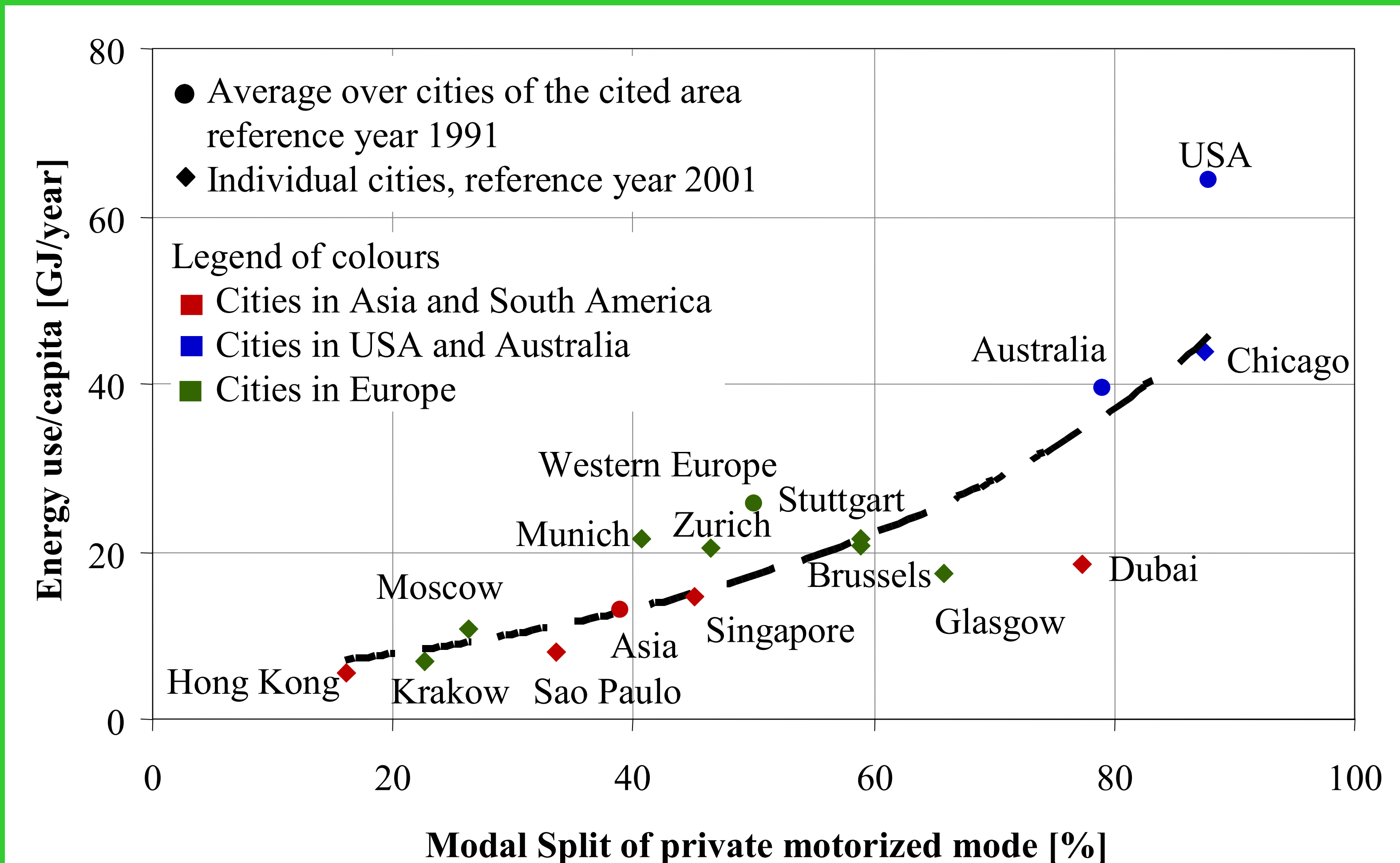
A. Grübler, IIASA, 1988

Urban Transport Modal Split

(share in # of trips) Source: GEA KM18 (2012)



Transport Energy Use vs. Modal Split



Source: GEA KM18 2012

Y. Zahavi's Transport Demand Model

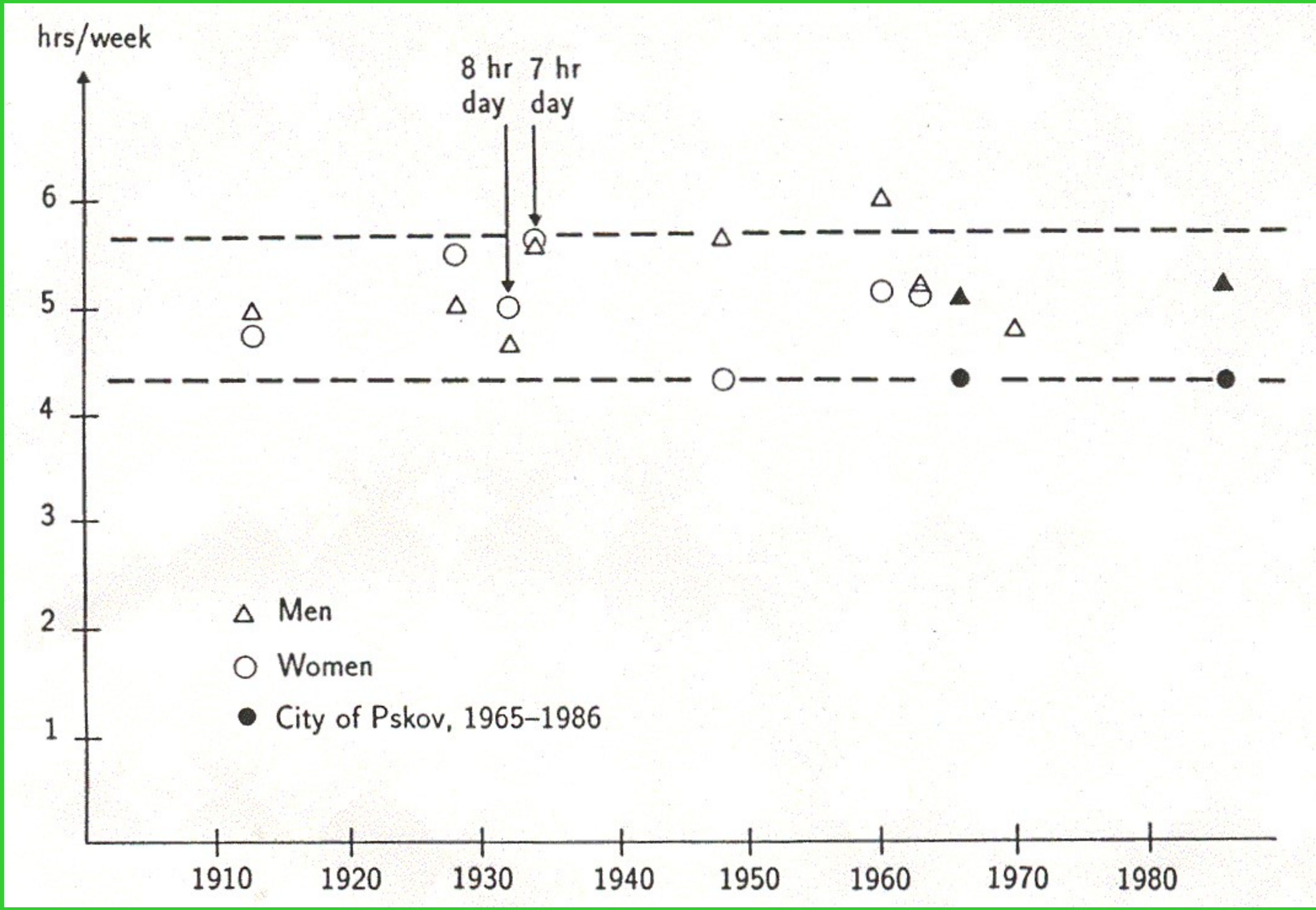
(controversial theory but sound empirics)

- 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

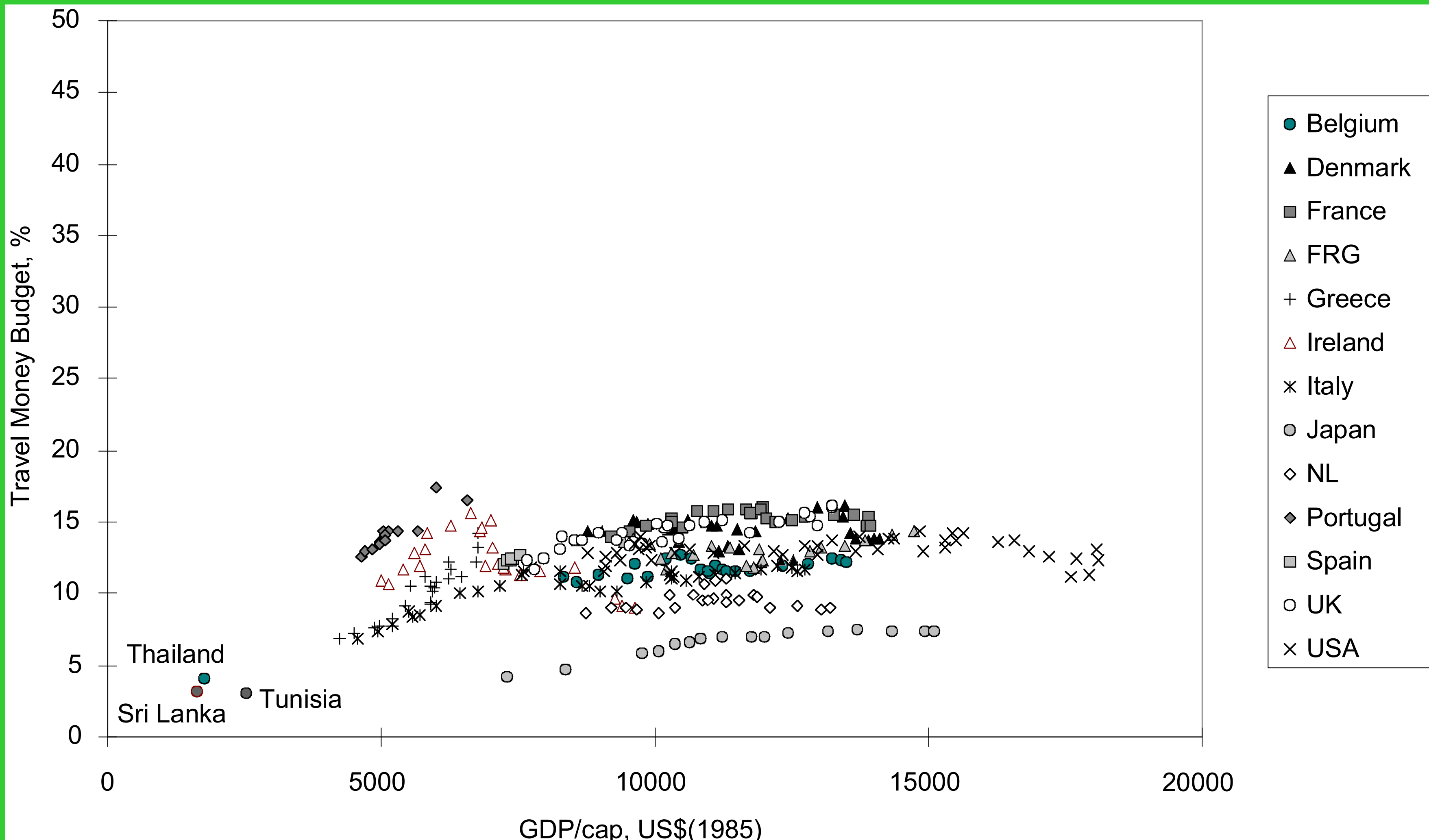
Weekly Travel Time Budgets in the USSR

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



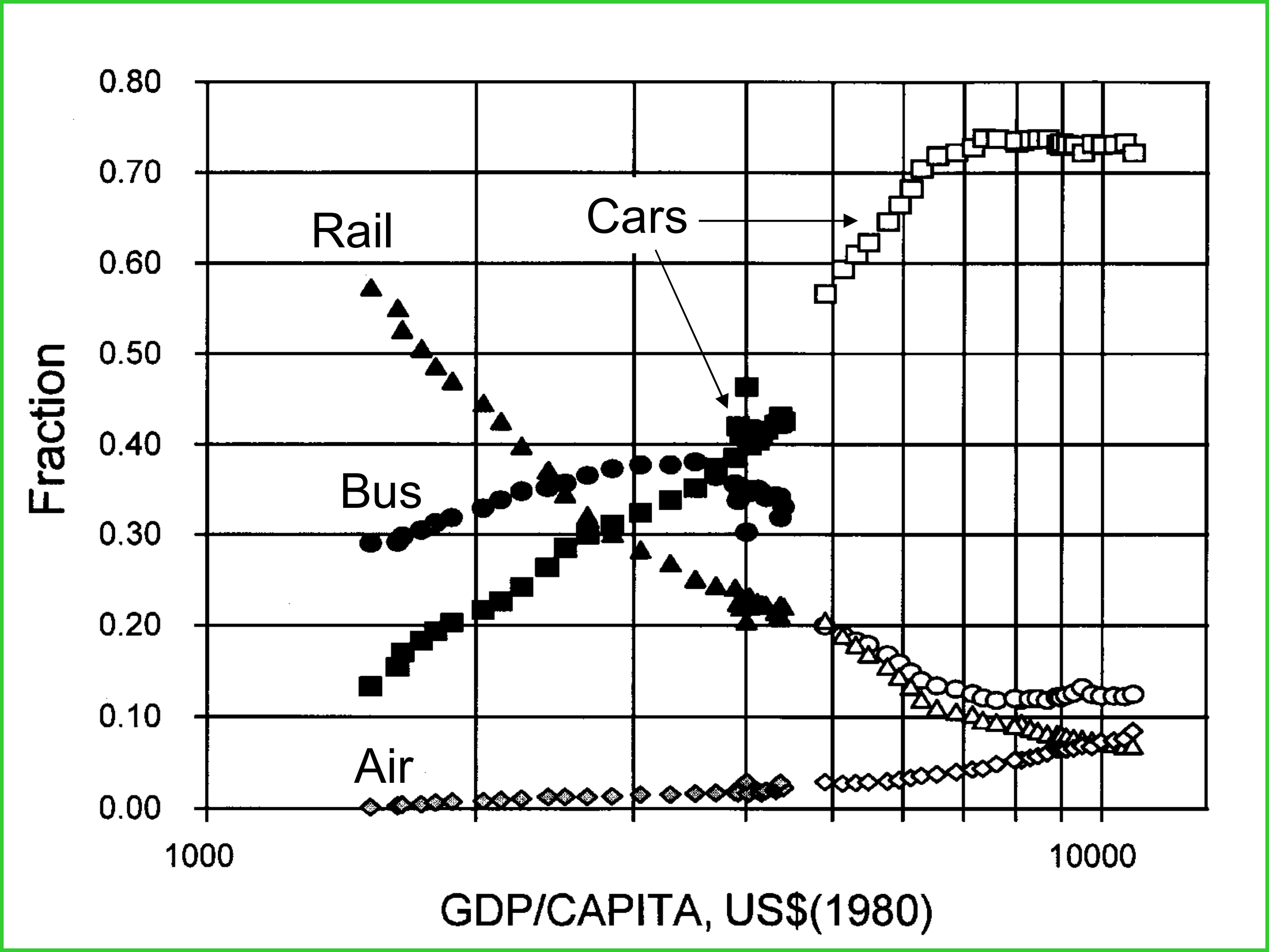
Travel Money Budgets (% of Income)

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



Western and Eastern Europe Passenger Modal Split

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



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

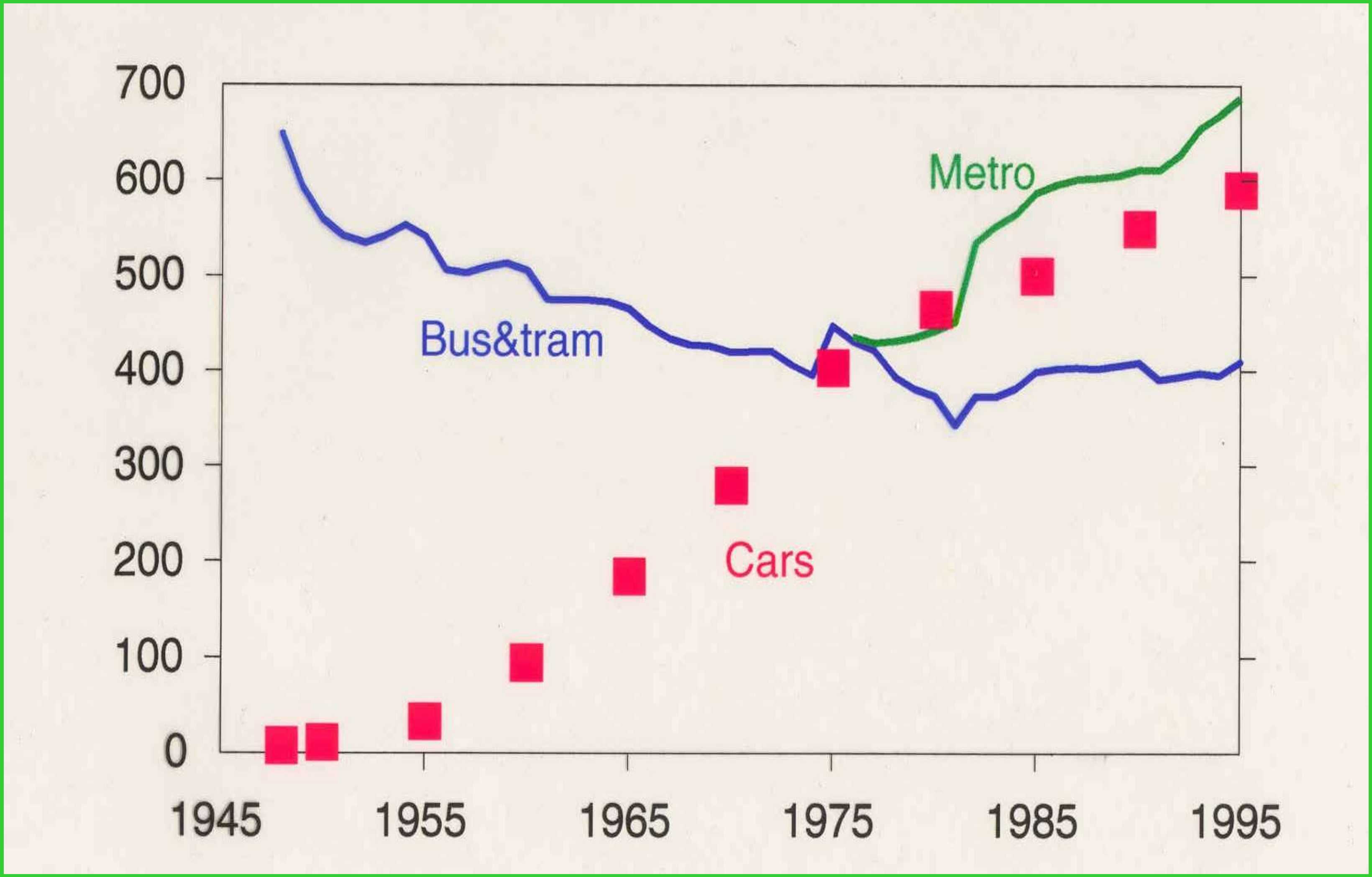
*Trip purpose**	*10^9 pass-km*	*Percent*
Work (commute)	1,190	17.7%
Family & HH	2,981	44.5%
Leisure#	2,484	37.0%
“go for a ride”	55	0.8%
TOTAL US	6,710	100.0%
Total mobility in:		
China	607	
Ex-USSR	1,770	
France	704	
Norway	47	

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

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

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



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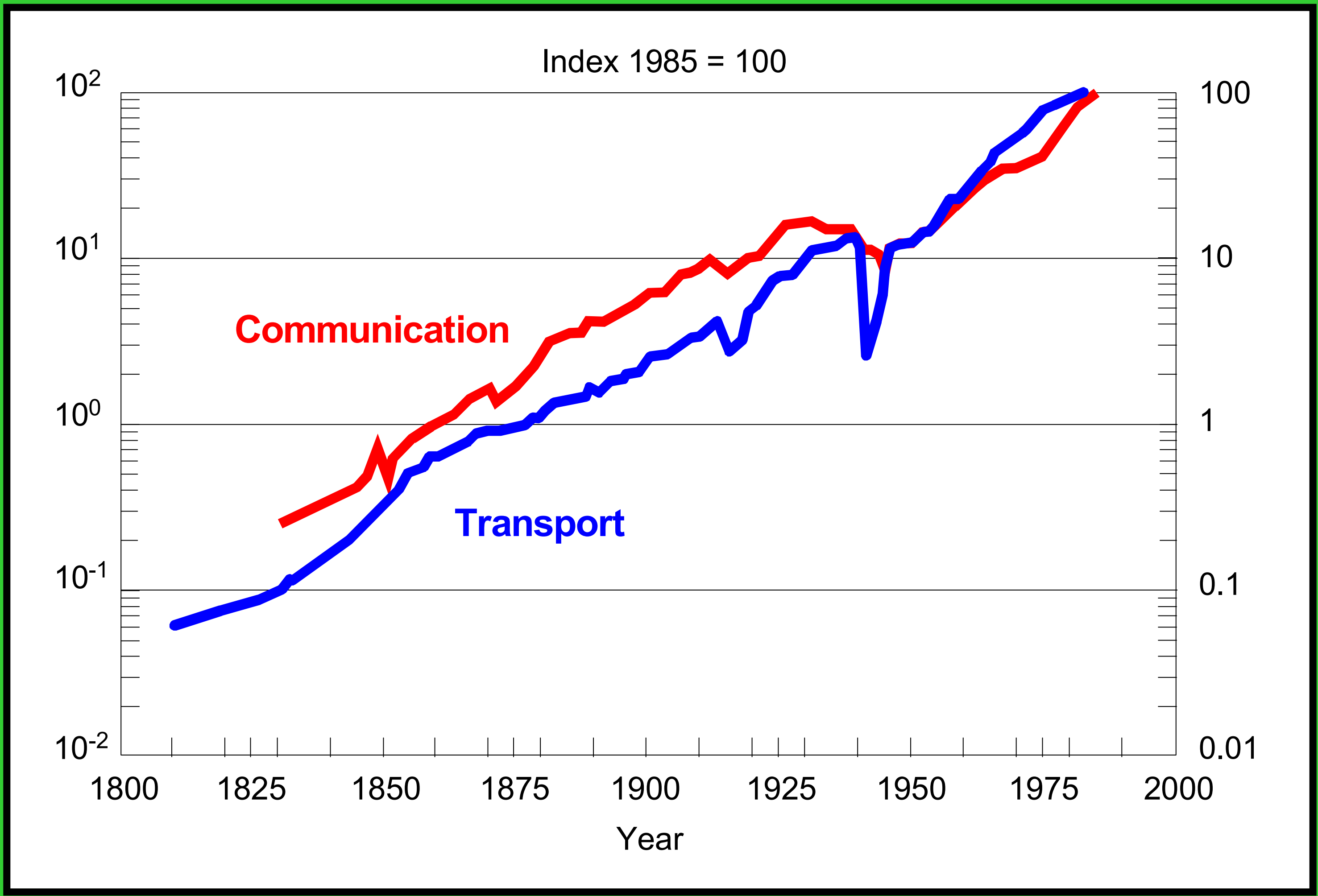
Transport & Environment

- 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)

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



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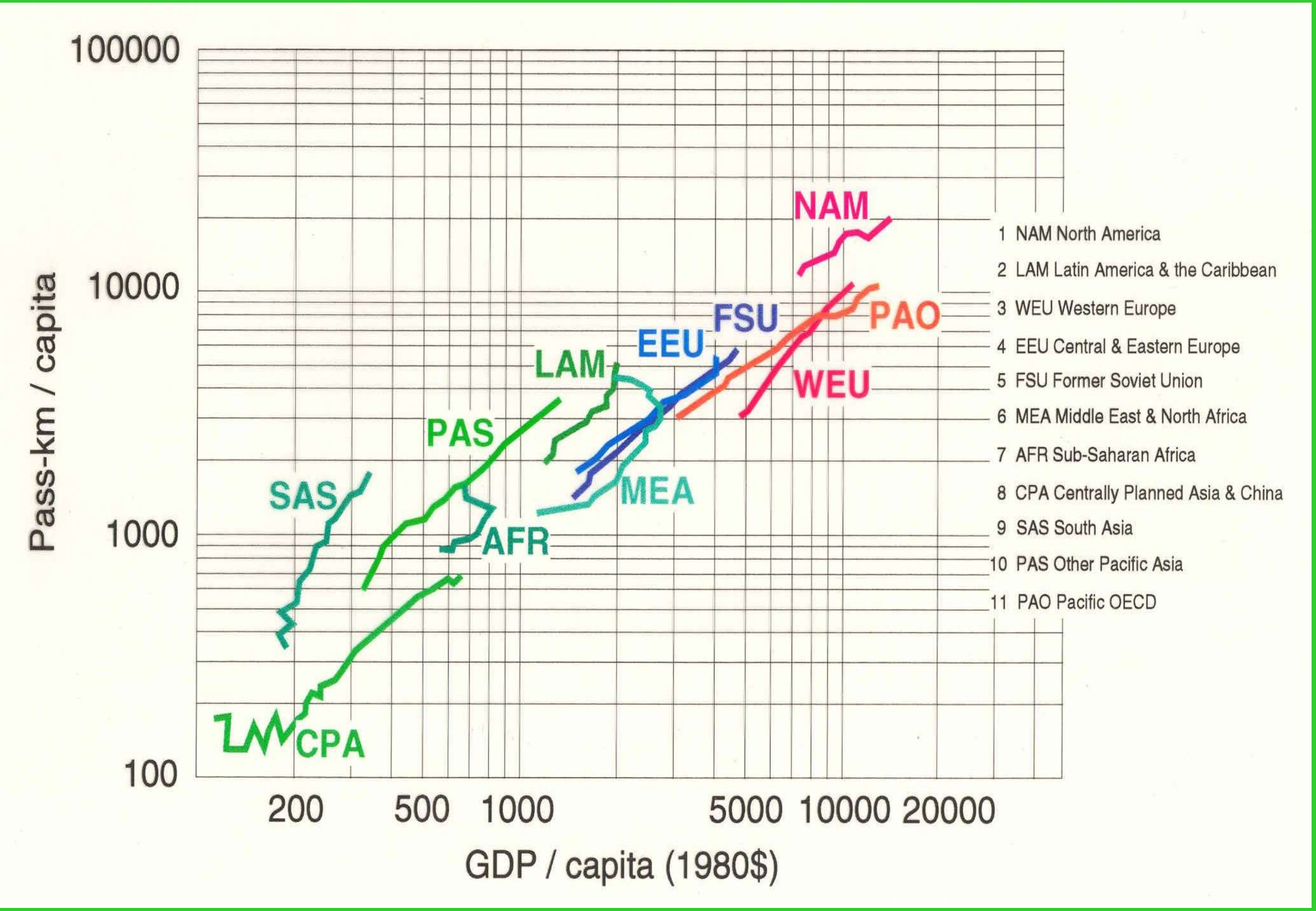
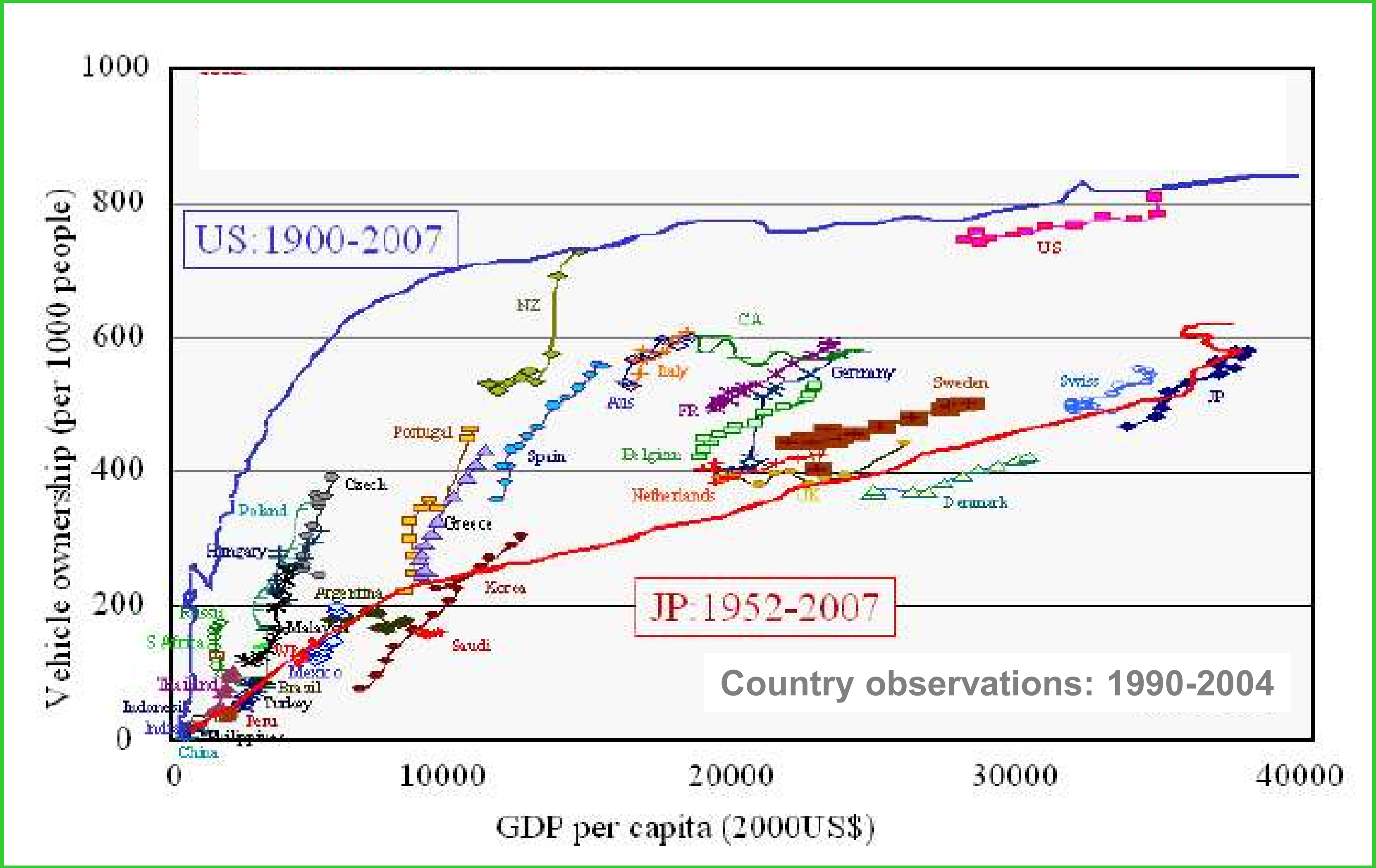
Motorized Mobility vs GDP/capita

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



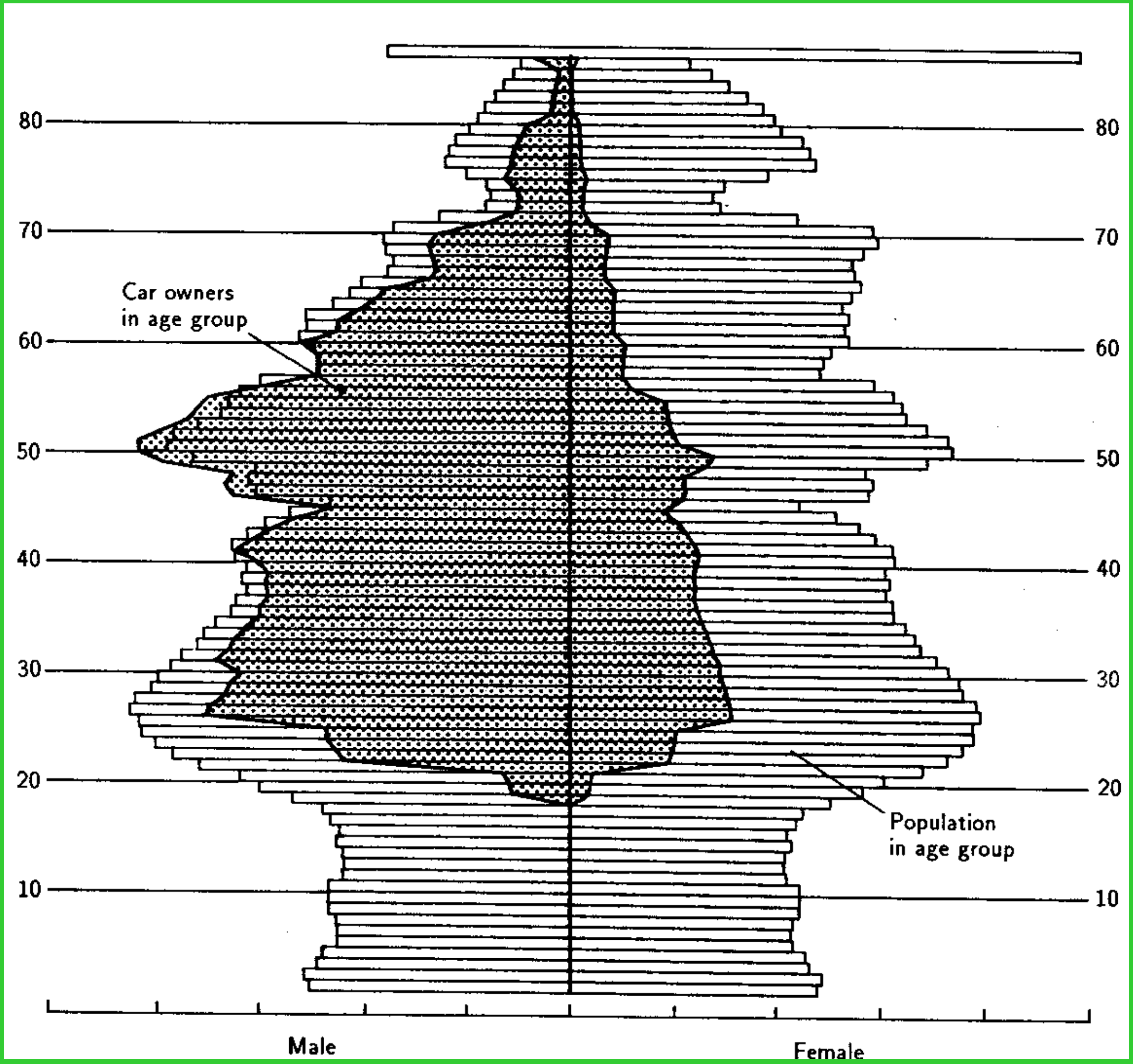
Path Dependent Vehicle Ownership Trends



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

Germany: Car Ownership by Gender and Age Cohorts

Source: Buttner&Grubler, 1995.



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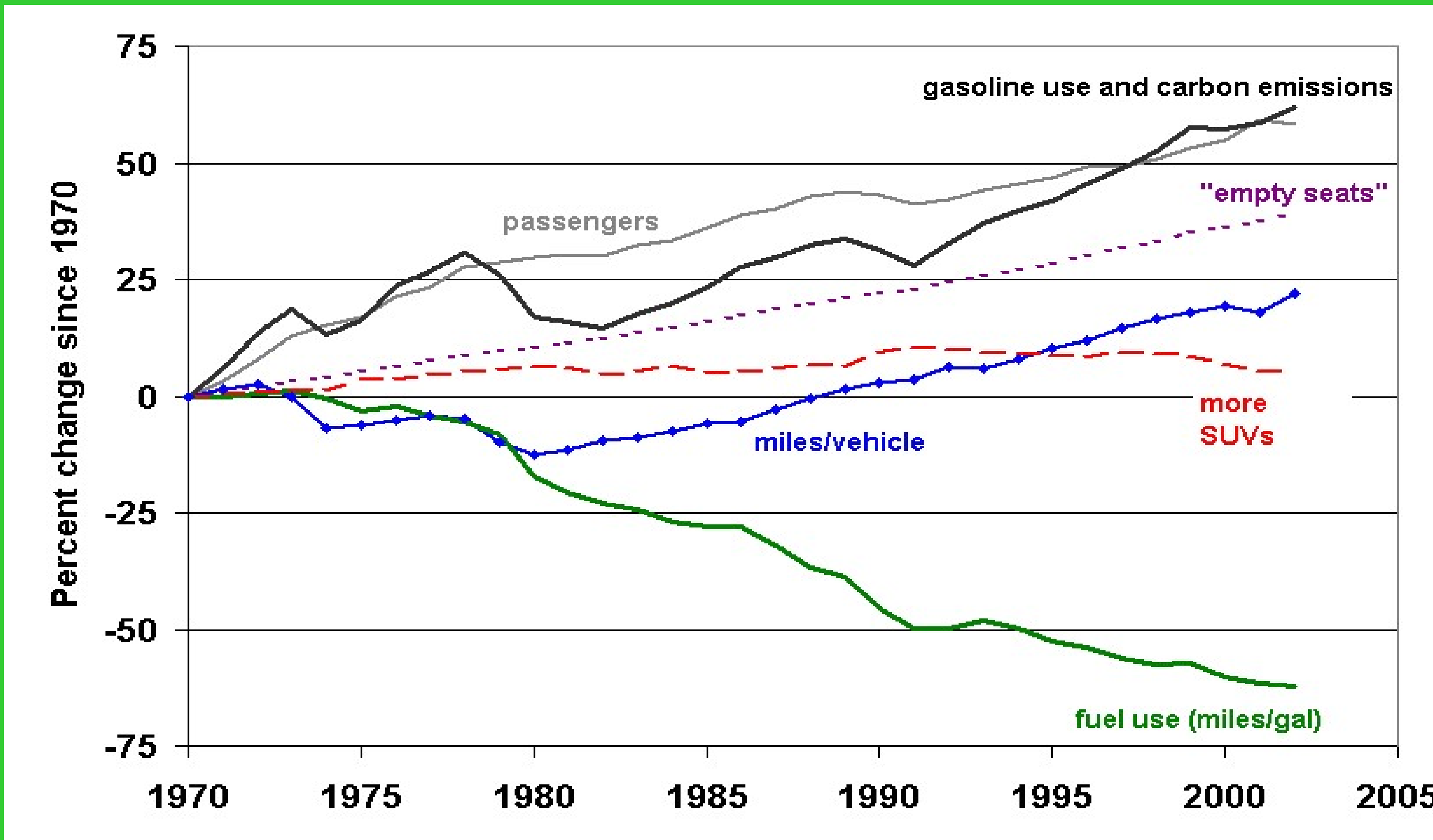
“Take-back” Effects

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



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

Toyota Prius

50 miles/gal

1 Yalie in Zipcar

1.5

Cadillac Escalade

15 miles/gal

Soccer mom + 3 kids

1.25

8 miles/gal

Driver +
20 school children

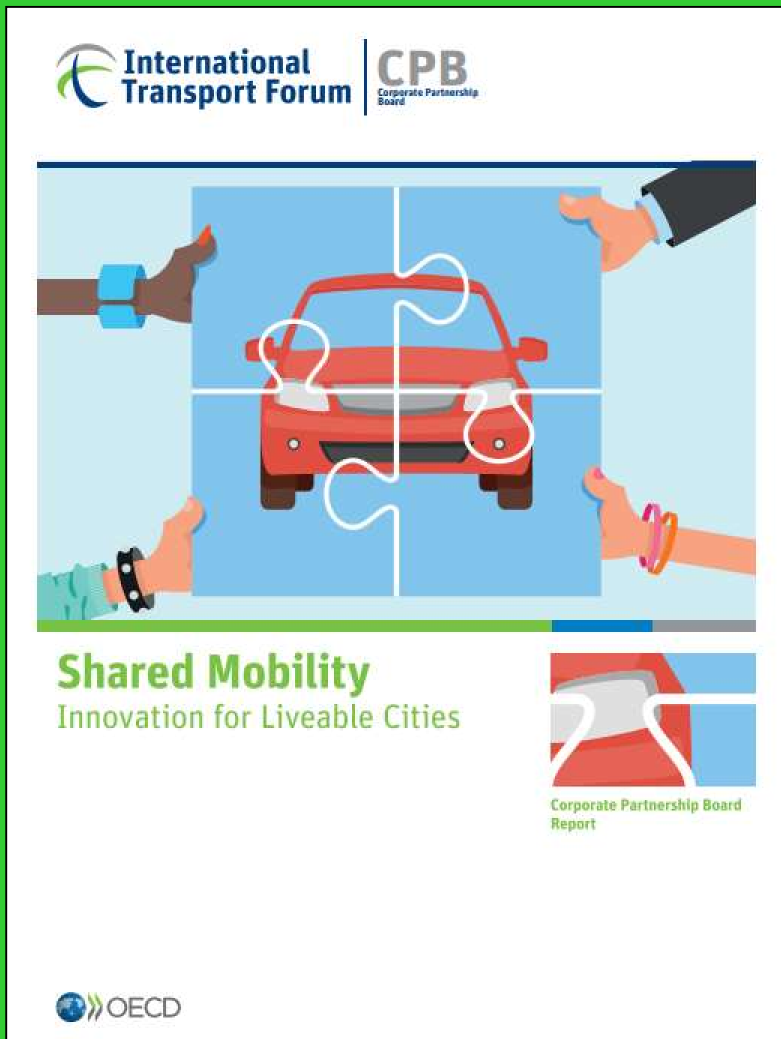
0.50

Distance traveled (all examples) : 100 km

Energy use: MJ per passenger-km traveled

US Poster From WW II

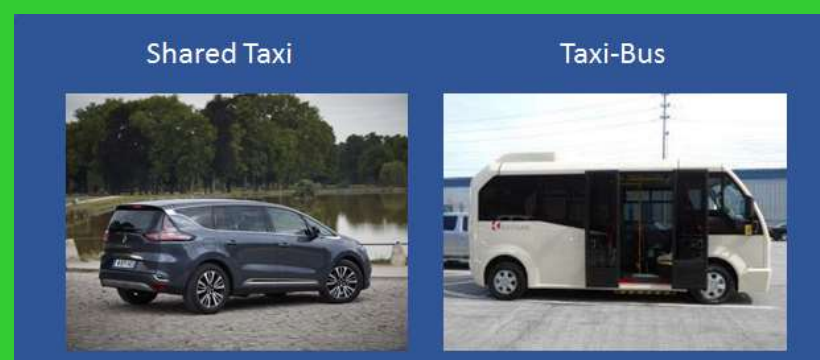
The "Sharing Economy": Mobility Case Studies



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



Disruptive Change

Source: Carbontracker, 2018

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**