

The Societal Costs and Benefits of Commuter Bicycling



- ▶ Alexandra Macmillan
- ▶ University of Otago:
Preventive and Social
Medicine
- ▶ PhD: University of
Auckland, 2012



- ▶ Alistair Woodward
- ▶ University of Auckland:
Medical and Health Sciences
- ▶ Head of School of
Population Health
2004–2012

More authors!

Jennie Connor U of Otago, Dunedin, Department of Preventative and Social Medicine

Karen Witten Massey U, Auckland, Social and Health Outcomes Research and Evaluation

Robin Kearns U of Auckland, School of Environment

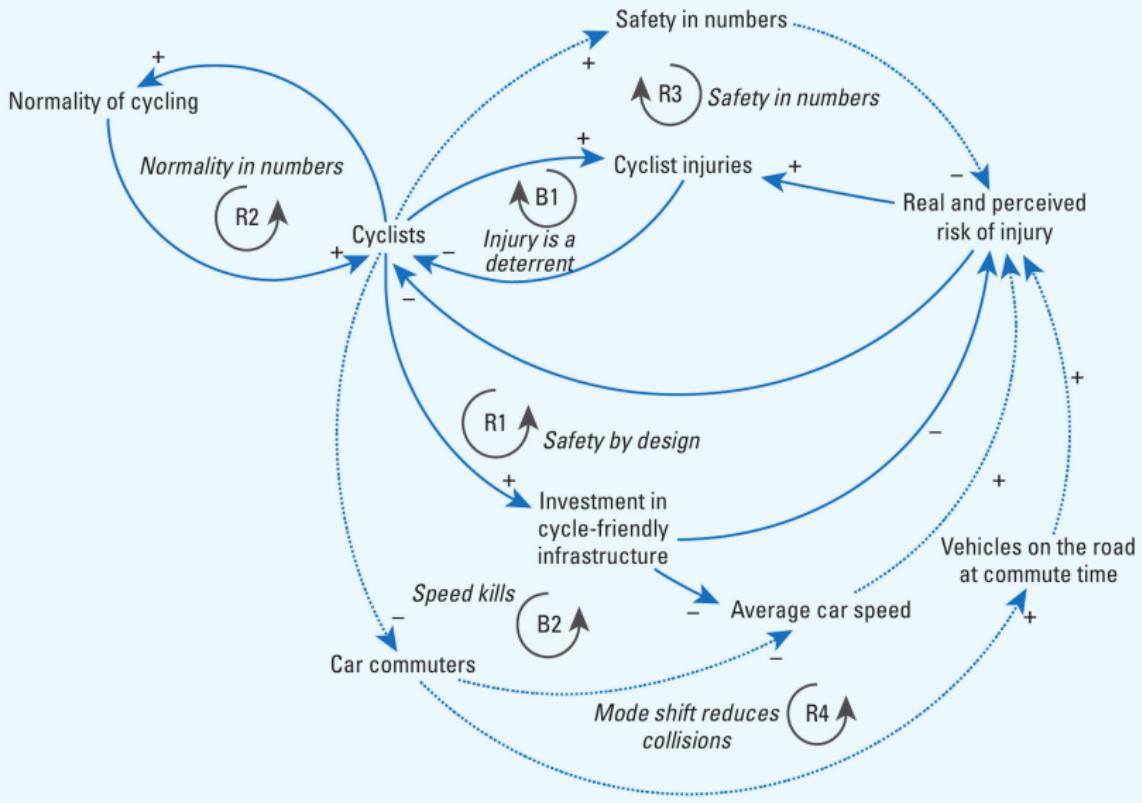
David Rees Synergia Ltd, Auckland

Environmental Health Perspectives: impact factor ≈ 8

Why bike?

- ▶ Health
- ▶ Social equity
- ▶ Minimise expenses
- ▶ Pollution / climate

Objective: Increase bicycling in a car-dominated city



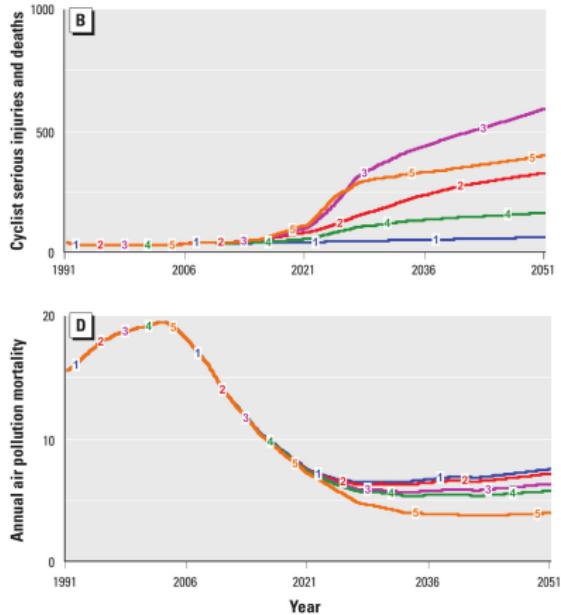
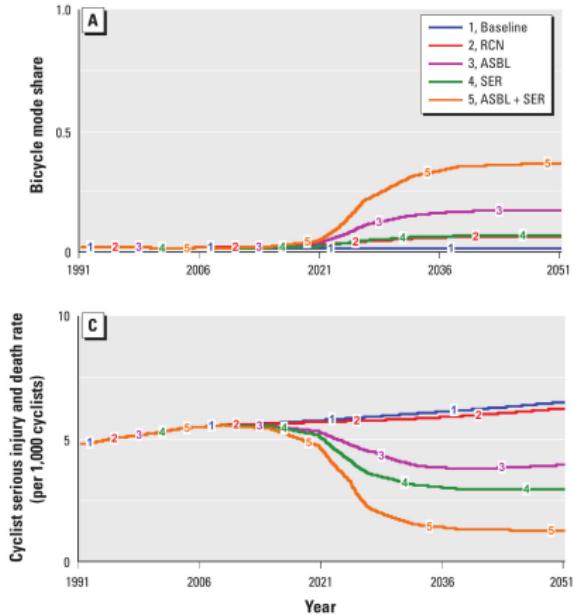
Details

- ▶ Population 400,000, growing 40%, same demographic
- ▶ Light vehicle 0.85, bicycling 0.02, walking 0.055, public transport 0.075
- ▶ Bikeable: ≤ 6 km (50%). Walkable: ≤ 2 km (27%).
- ▶ Bike commuting relative risk: 0.72

Table 2. Effects used in the simulation model for the policy scenarios.

Policy scenario and effects modeled	Studies used	Estimate of effect
RCN: On-road lanes		
Risk of collision with a motor vehicle	Elvik et al. 2009; Jensen 2008; Reynolds et al. 2009	0.9
Perception of bicycling safety	Garrard et al. 2008; Jensen et al. 2007; Kingham et al. 2011	4% increase per 10% of network treated
Perception of bicycle commuting	Dill and Carr 2003; Jensen 2008	3% increase per 10% of network treated
RCN: Off-road shared bicycle and foot paths		
Risk of collision with a motor vehicle	Aultman-Hall and Hall 1998; Aultman-Hall and Kaltenecker 1999; Elvik et al. 2009	1.0
Perception of bicycling safety	Garrard et al. 2008; Goldsmith 1992	5% increase per 10% of network treated
Perception of bicycle commuting	Aultman-Hall et al. 1997; Buehler and Pucher 2011; Kingham et al. 2011; Larsen 2010	2% increase by doubling km/100,000 population
RCN: Shared bus and bicycle lanes		
Risk of collision with a motor vehicle	Newcombe and Wilson 2011	1.0 at mean lane width
ASBL		
Risk of collision with a motor vehicle	Elvik et al. 2009; Gårdér et al. 1998; Jensen 2008; Lusk et al. 2011; Turner et al. 2011	0.72 midway collisions, 0.8 intersection treatments
Perception of bicycling safety	Garrard et al. 2008; Jensen et al. 2007; Kingham et al. 2011;	6% increase per 10% of network treated
Perception of bicycle commuting	Dill and Carr 2003; Jensen 2008	4% increase every 10% of network treated
SER		
Mean local road vehicle speed	Charlton et al. 2010	Proportional increase up to 15 km/hr
Risk of collision with a motor vehicle	Bunn et al. 2003; Charlton et al. 2010; Elvik 2009; Grundy 2009; OECD and European Conference of Ministers of Transport 2006	10-km/hr reduction in speed reduces collisions by 60%
Vehicle volume on local roads	Charlton et al. 2010; Elvik 2009	Proportional increase to 25% reduction
Proportion of bicycle trip distance on local roads	Modest effects based on local expertise	Proportional increase from 50% to 70%
Perception of bicycling safety	Modest effects based on local expertise	Proportional increase up to 10%
Perception of bicycle commuting	Modest effects based on local expertise	Proportional increase up to 10%
Perception of light vehicle convenience	Modest effects based on local expertise	Proportional decrease up to 30%

Outcome	RCN (monetized)	ASBL (monetized)	SER (monetized)	ASBL + SER (monetized)
Cycling mode share by 2051 (%)	5	20	5	40
LV mode share by 2051 (%)	75	65	55	40
Proportion of people considering cycling always/mostly safe by 2040	0.4	0.7	0.3	0.9
LVKT (billion km)	-3.5	-7	-10	-18.5
Cyclist injuries				
Fatalities	200 (620)	360 (1,100)	85 (250)	250 (850)
Serious injuries	4,000 (1,300)	7,000 (2,300)	1,600 (500)	5,000 (1,600)
Car crashes				
Car occupant fatalities	-70 (-220)	-120 (-370)	-170 (-527)	-340 (-1,000)
Air pollution				
Mortality	-10 (-7.5)	-20 (-15)	-40 (-30)	-80 (-60)
Hospitalizations	-5 (-0.02)	-15 (-0.04)	-20 (-0.06)	-40 (-0.12)
COPD incidence	-10 (-0.75)	-30 (-2.25)	-55 (-4)	-90 (-6.75)
Restricted activity days	-12,500 (-1)	-37,200 (-4)	-57,700 (-6)	-112,200 (-11)
Air pollution total	(-9)	(-21)	(-40)	(-78)
All-cause mortality	-650 (-2,000)	-1,850 (-5,700)	-650 (-2,000)	-4,000 (-12,400)
Greenhouse gas emissions (megatons)	-3 (-120)	-8 (-360)	-13 (-520)	-26 (-1040)
Fuel cost (\$NZ million)	(-600)	(-1,800)	(-600)	(-3,900)
Infrastructure cost (\$NZ million)	(45)	(250)	(380)	(630)
Net benefit (\$NZ million)	-770	-2,550	-1,780	-13,090
Benefit-cost ratio	18	18	6	24



Results

- ▶ No observed safety-in-numbers effect (so set a threshold?)
 - ▶ cf. Elvik and Goel, 2019 found regression coefficient ≈ 0.4

The travel and environmental implications of shared autonomous vehicles



- ▶ Daniel Fagnant
- ▶ (now) University of Utah,
Dept of Civil &
Environmental Engineering
- ▶ PhD: University of Texas,
Austin, 2014

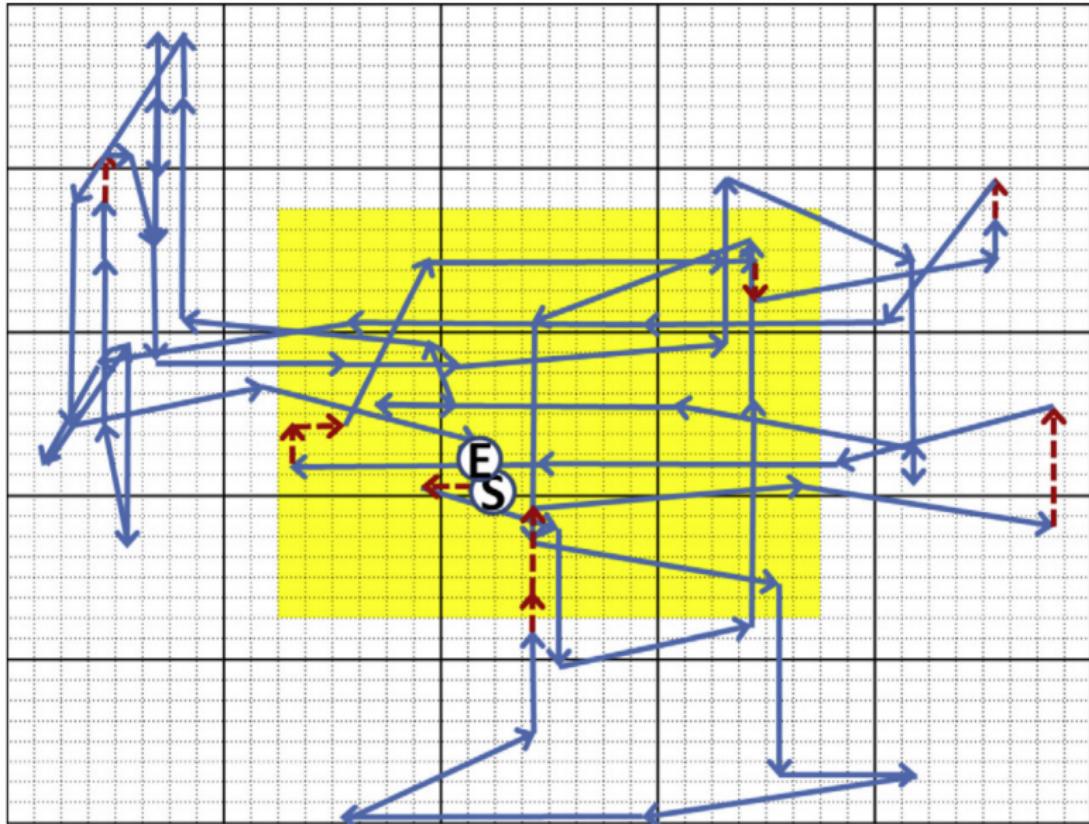


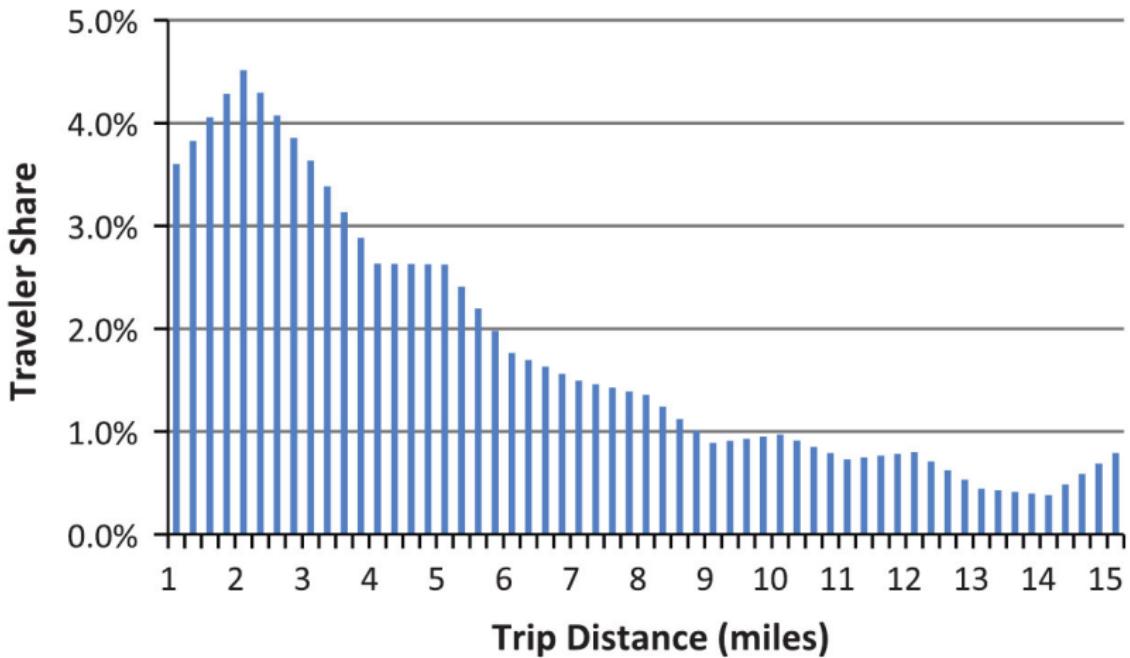
- ▶ Kara Kockelman
- ▶ University of Texas, Austin,
Dept of Civil, Architectural,
Environmental Eng
- ▶ PhD: Berkeley, 1998

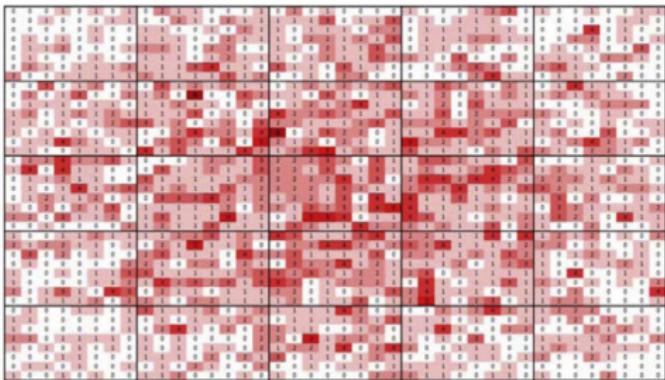
Transportation Research Part C: emerging technologies. I.F. ≈ 6

Why share cars?

- ▶ More utility, less responsibility
- ▶ Reduce demand for parking
- ▶ Reduce parking-seeking congestion
- ▶ Autonomous vehicle safety
- ▶ Environmental benefits?
 - ▶ Reduce trips by car?!
 - ▶ Reduce parking surface area (e.g. from 14%)
 - ▶ Increase fleet turnover
 - ▶ Reduce cold starts
 - ▶ Embedded energy (reduce # cars by factor of 9–12)







(a)

-4	-4	-9	3	5
-1	8	5	9	-1
2	4	-3	-3	12
3	0	-6	0	-3
2	0	-8	-6	-5

(b)

-4	0	-6	3	5
0	1	4	5	3
2	4	-3	2	3
3	-2	-4	0	1
2	-3	-5	-6	-5

1	0	0	1	0	0	1	1
0	0	0	0	0	1	1	0
0	0	4	0	0	1	0	0
0	2	2	0	0	1	0	1
0	1	0	1	0	0	3	0
1	1	1	0	2	2	1	0
2	3	1	1	0	0	0	0
0	1	1	0	0	2	0	0

(c)

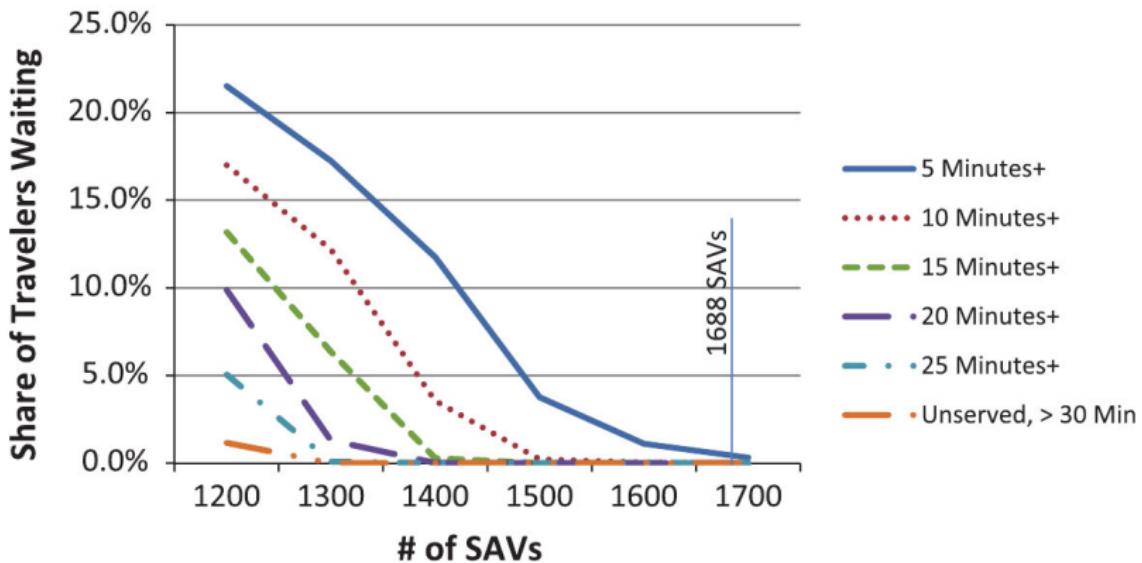
2	2	1	1	1	4	0	4
3	2	4	1	1	1	1	2
2	2	1	1	2	1	3	2
1	1	1	2	0	1	2	3
2	3	0	1	1	1	1	1
0	4	1	0	1	1	3	1
2	4	1	1	1	0	1	1
2	5	1	0	2	3	0	1

(d)

Category	Measure	Mean	S.D.
Trips & SAVs	# Person-trips per day	60,551	336
	# SAVs	1688	0
	# Person-trips per SAV per day	35.87	0.20(5.15)
Wait time	5-min wait periods	249	109
	Avg. wait time per person-trip	0.295	0.014(0.61)
	# Un-served person-trips (across all days)	0	0
Trip miles	% Waiting 5 min+	0.4%	0.2%
	Total VMT per day	332,900	2200
	Unoccupied VMT per day	32,060	350
	Avg. person-trip distance (mi.)	5.43	0.01(3.33)
	Unoccupied miles per person-trip	0.53	0.011
Usage	% Induced travel (added VMT)	10.7%	0.1%
	Min. # SAVs not in use	19	11
	Min. # SAVs unoccupied	54	22
	Max # share in use / moving	98.87%	0.63%
Vehicle Starts	Max # share occupied	96.80%	1.35%
	SAV warm starts per person-trip	0.73	0.01
	SAV cold-starts per person-trip	0.054	0.001
	# Warm-starts per day	44,190	370
	# Cold-starts per day	3287	53

Environmental Impact	Sedan (passenger car) life-cycle inventories (values not shown for pickup trucks, & SUVs)				Average US light-duty vehicle vs. SAV sedan emissions inventories			
	Operating (running)	Manufac.	Parking	Vehicle starts	Average LDV	SAV Total	Difference	% Change
Energy use (GJ)	890	100	15	0	1230	1087	-144	-12%
GHG (metric tons)	69	8.5	1.2	0	90.1	85.0	-5.1	-5.6%
SO ₂ (kg)	3.9	20	3.6	0	30.6	24.6	-5.9	-19%
CO (kg)	2100	110	5.2	1400	3833	2546	-1287	-34%
NOx (kg)	160	20	6.4	32	243	200	-43	-18%
VOC (kg)	59	21	5.2	66	180	92	-88	-49%
PM ₁₀ (kg) ^a	20	5.7	2.7	2.0	28.2	26.4	1.8	-6.5%

Category	Scenario	Description	# SAVs in fleet	Person-trips per SAVs	5-min wait intervals	Avg. wait time	% induced travel	Cold starts per person-trip
Base case	S0	Base case scenario	1688	35.9	249	0.30	10.7%	0.054
Trip generation	ST1	Double trips generated	3245	37.1	226	0.14	7.3%	0.052
	ST2	Half trips generated	859	33.9	16	0.56	12.2%	0.060
	ST3	Quarter trips generated	433	31.7	301	0.92	13.8%	0.068
Centralization	SC1	Greater trip centralization	1652	36.2	341	0.31	16	16
	SC2	Lesser trip centralization	1712	16	213	16	16	16
Service area	SA1	Greater service area	2272	33.7	337	0.33	16	0.059
	SA2	Smaller service area	1053	40.3	154	0.26	16	0.048
Return-home trips by SAV	SH1	Greater rate of trips returning home	1674	35.3	206	0.29	16	16
	SH2	Lesser rate of trips returning home	1676	16	240	16	16	16
Peak congestion	SP1	Lesser peak congestion	1517	40.0	214	16	16	0.048
	SP2	Greater peak congestion	1872	32.3	519	0.35	10.4%	0.060
SAV demand	SD1	Greater AM & PM peak SAV use	2134	28.3	293	0.24	8.9%	0.096
Relocation strategies	SR0	No relocation	1691	16	2425	0.69	4.9%	0.067
	SR1	Only R1	1674	36.5	433	0.46	7.3%	0.061
	SR2	Only R2	1707	16	519	0.42	6.4%	0.061
	SR3	Only R3	1677	16	1750	0.51	7.0%	0.060
	SR4	Only R4	1689	16	1644	0.57	4.9%	0.066
	SRM1	All R minus R1	1690	16	576	0.34	8.7%	16
	SRM2	All R minus R2	1704	35.5	239	16	9.5%	0.057
	SRM3	All R minus R3	1688	16	280	0.36	8.6%	0.056
	SRM4	All R minus R4	1697	16	258	0.31	16	16
	SL1600	SAVs limited to 1600	1600	37.9	694	0.38	16	0.050
Limitations on # of SAVs	SL1500	SAVs limited to 1500	1500	40.5	2422	0.59	16	0.047
	SL1400	SAVs limited to 1400	1400	43.5	9505	1.24	16	0.043
	SL1300	SAVs limited to 1300	1300	47.0	22,718	2.38	16	0.039
	SL1200	SAVs limited to 1200	1200	50.9	41,469	3.98	16	0.035



Weird...

- ▶ Demand is exogenous?
 - ▶ Shaheen and Cohen (2013) estimate 27% reduction in trips
 - ▶ Seems at odds with lots of research on induced demand...
 - ▶ Uber+Lyft generating huge increase in trips, pollution, congestion, accidents
- ▶ Relocation strategy?
- ▶ Would delay shift to electric vehicles?

Transition challenges for alternative fuel vehicle and transportation systems



- ▶ Jeroen Struben
- ▶ (now) McGill University,
System Dynamics
- ▶ PhD: MIT 2006



- ▶ John D Sterman
- ▶ PhD: MIT Sloan, 1982
- ▶ Wrote the book.
- ▶ Lots of fancy awards and stuff... .

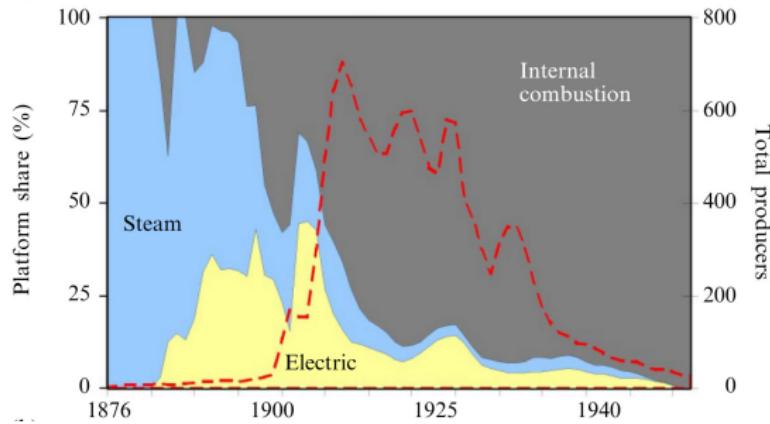
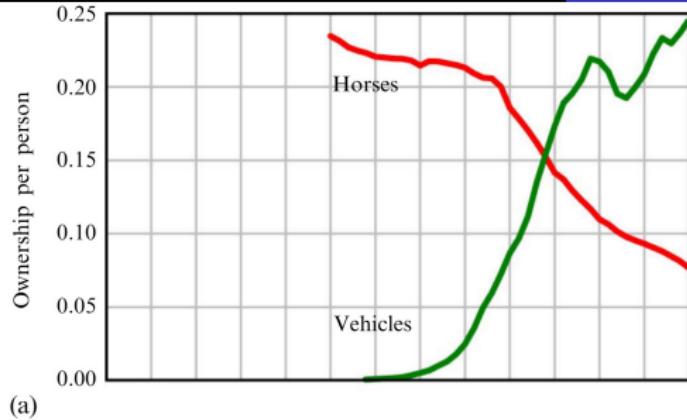
Environment and Planning B (urban analytics): I.F. $\lesssim 3$

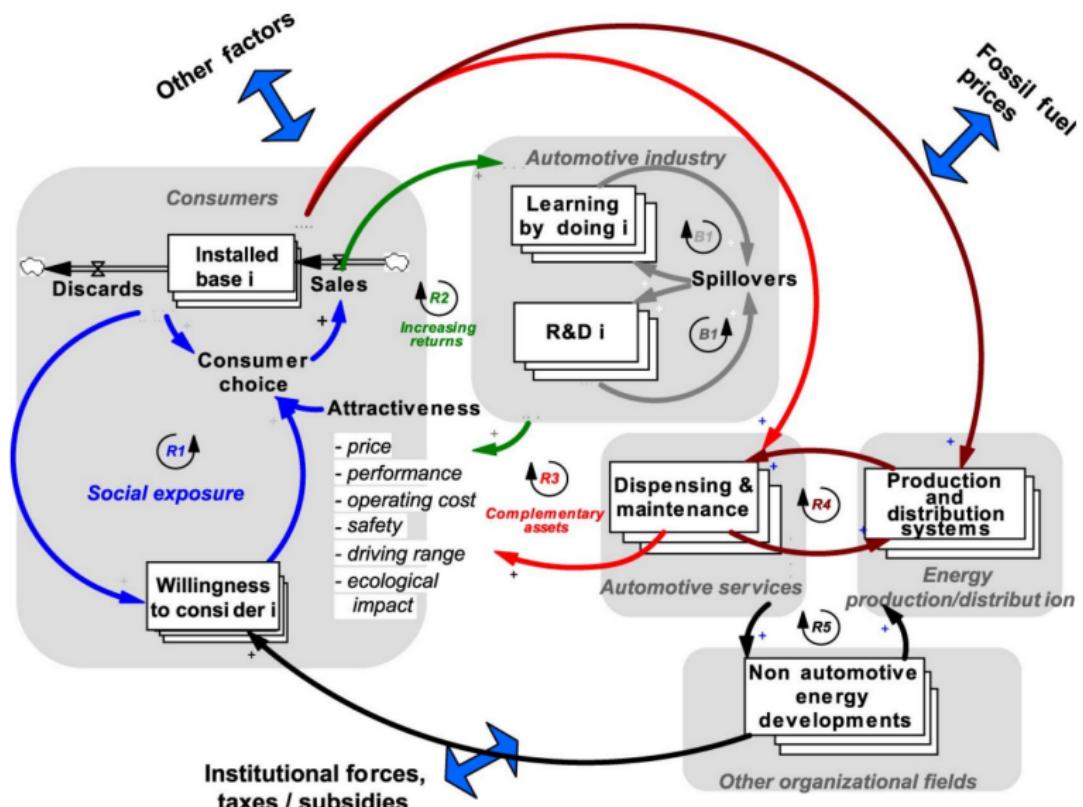
Why?

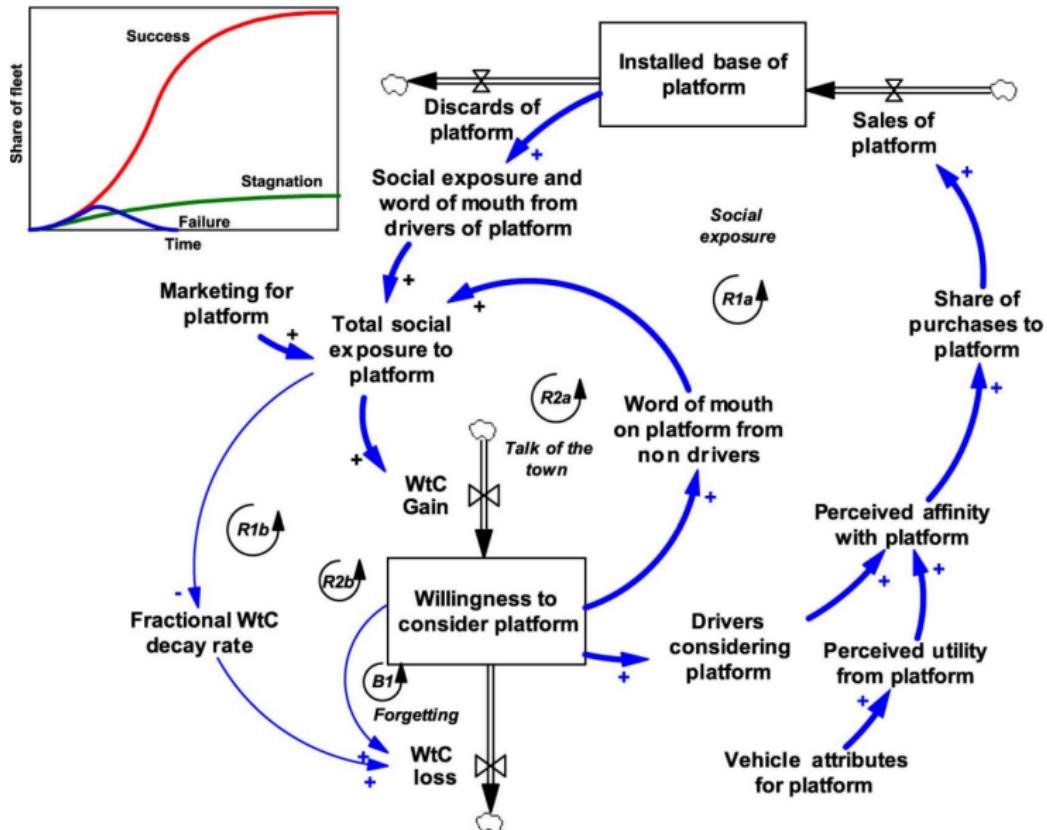
Adoption of alternative-fuel vehicles (AFV) is driven by:

- ▶ Advertising
- ▶ Word of mouth from owners
- ▶ Gossip from non-owners
- ▶ Feature parity
- ▶ Fueling infrastructure (chicken-and-egg)

Main result: adoption governed by critical-mass threshold



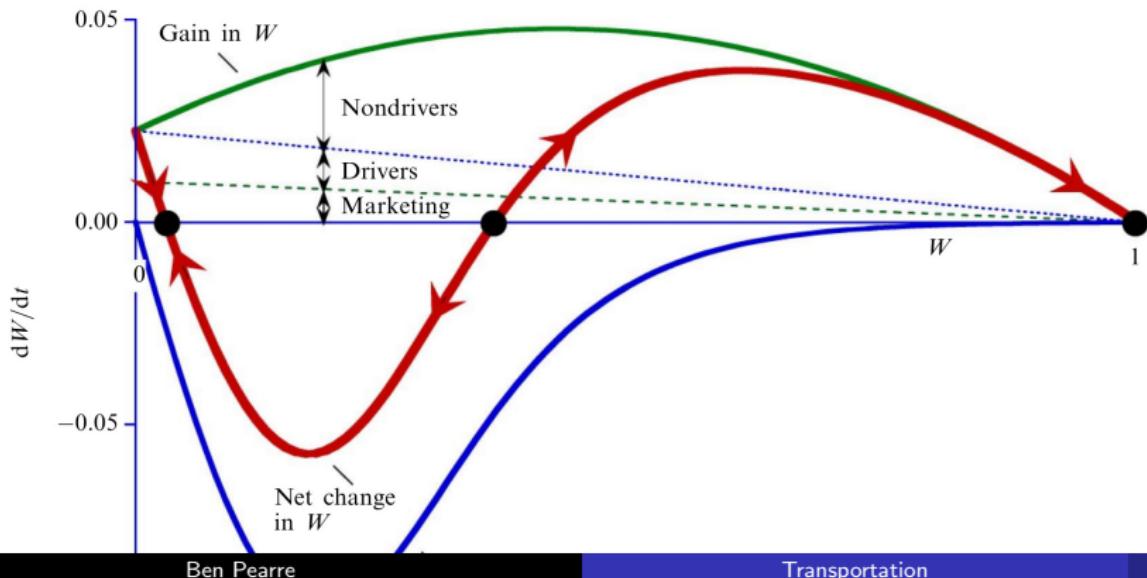




$$\frac{dW_{ij}}{dt} = \eta_{ij}(1 - W_{ij}) - \phi_{ij}W_{ij}$$

η_{ij} : Social exposure

ϕ_{ij} : Willingness-to-convert half-life (?)



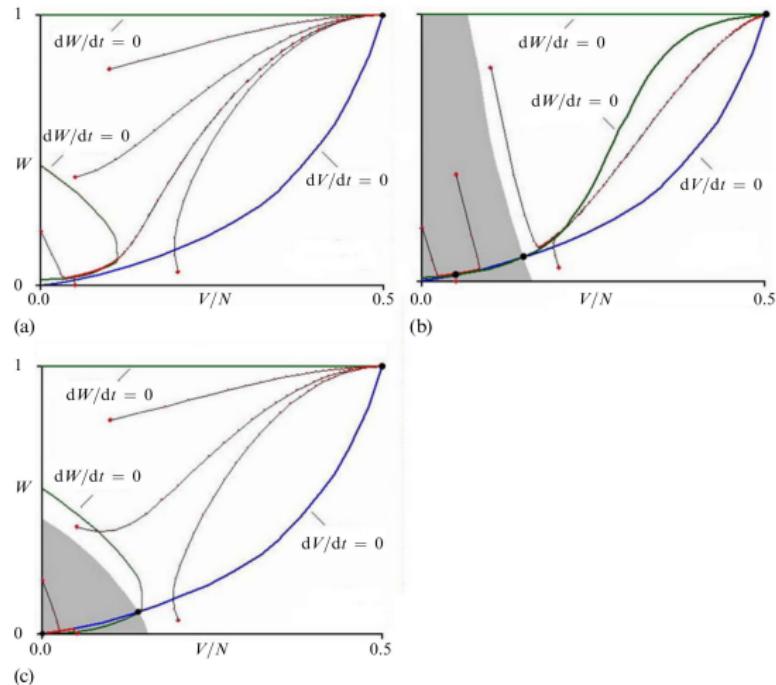


Figure 5. [In color online.] Phase space for a two-dimensional system with endogenous willingness to consider and vehicle installed base. Fixed points exist at intersections of nullclines; dots show sample trajectories. The grey area shows the basin of attraction for the low-diffusion equilibrium. The strength of marketing, α , and nondriver word of mouth, c_{ijk} are: (a) $\alpha = 0.01$, $c_{121} = 0.15$; (b) $\alpha = 0.01$, $c_{121} = 0.00$; (c) $\alpha = 0.00$, $c_{121} = 0.15$. Other parameters are as given in table 2.