The Societal Costs and Benefits of Commuter Bicycling

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- University of Otego: Preventive and Social Medicine
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More authors!

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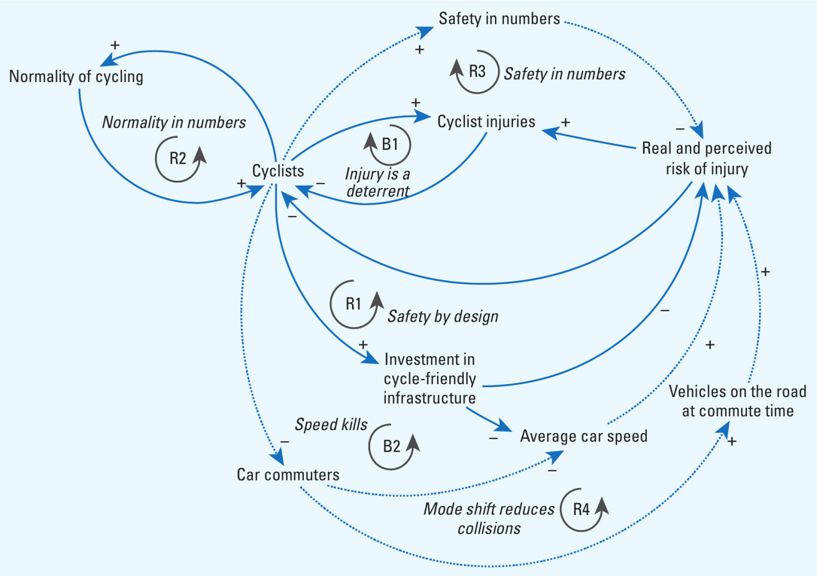
Environmental Health Perspectives: impact factor ≈ 8

Why bike?

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

Objective: Increase bicycling in a car-dominated city


Safety in numbers
Normality of cycling
R3
Safety in numbers
Normality in numbers
Cyclist injuries
B1
R2
Real and perceived risk of injury
Cyclists
Injury is a deterrent
R1
Safety by design
Investment in cycle-friendly infrastructure
Vehicles on the road at commute time
Speed kills
Average car speed
B2
Car commuters
Mode shift reduces collisions
R4

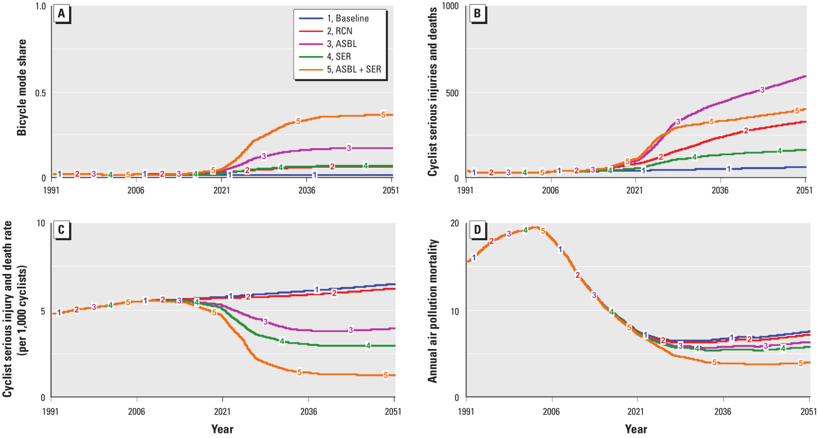
Details

- 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; Gårder 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


A
1, Baseline
2, RCN
3, ASBL
4, SER
5, ASBL + SER
Bicycle mode share
1.0
0.5
0
1991
2006
2021
2036
2051
B
Cyclist serious injuries and deaths
1000
500
0
1991
2006
2021
2036
2051
C
Cyclist serious injury and death rate
(per 1,000 cyclists)
10
5
0
1991
2006
2021
2036
2051
Year
D
Annual air pollution mortality
20
10
0
1991
2006
2021
2036
2051
Year

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

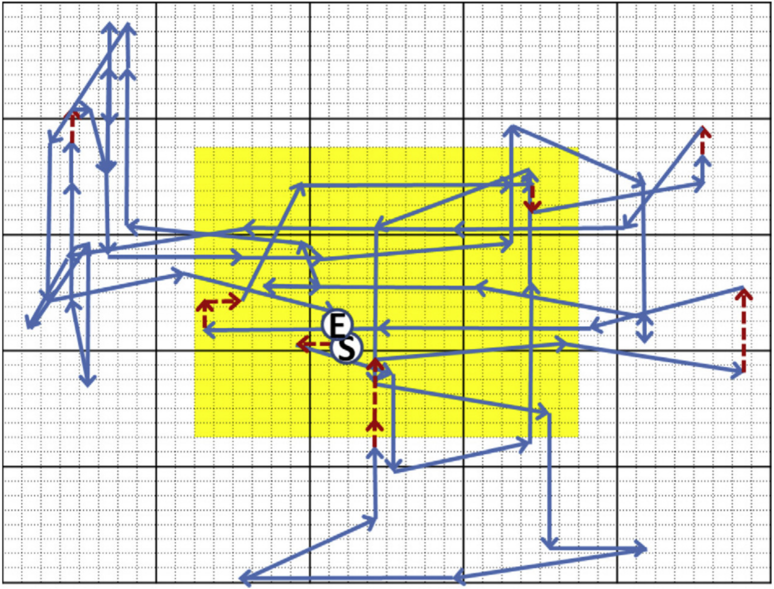
- Daniel Fagnant
- (now) University of Utah, Dept of Civil & Environmental Engineering
- PhD: University of Texas, Austin, 2014

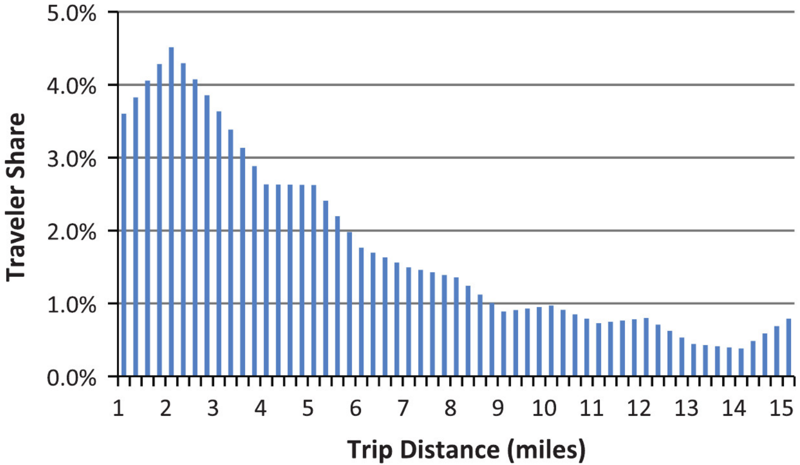
- Kara Kockelman
- University of Texas, Austin, Dept of Civil, Architectural, Environmental Eng
- PhD: Berkeley, 1998

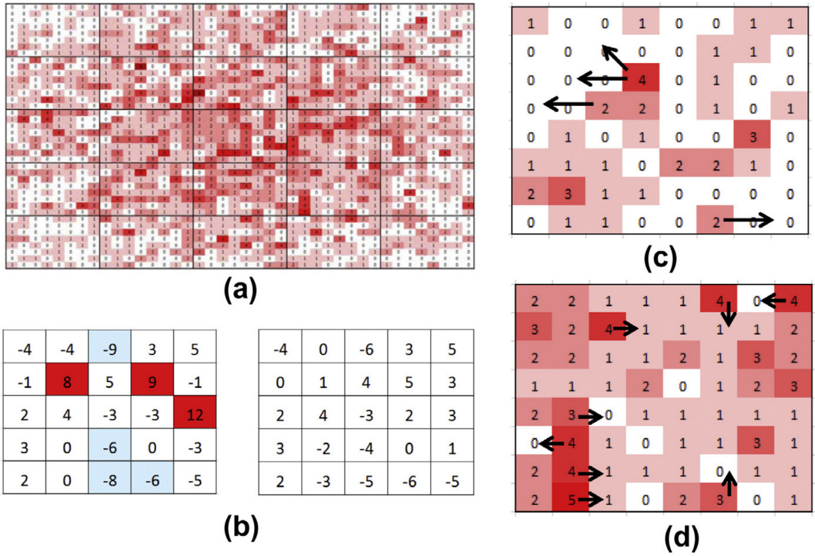
Transportation Research Part C: emerging technologies. I.F. ≈ 6

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)


E
S

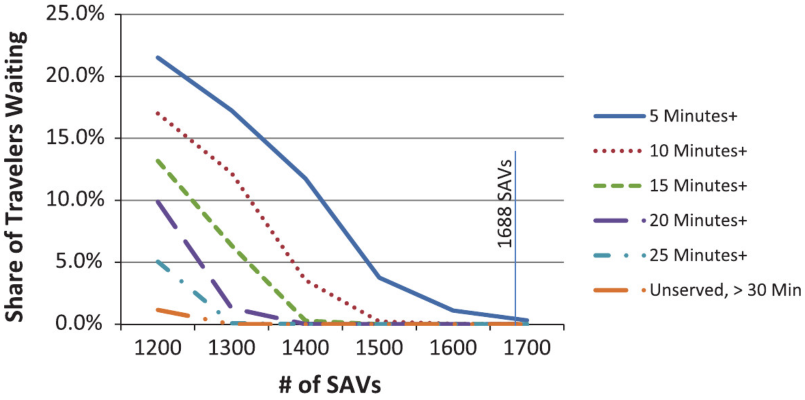

5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
Traveler Share
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Trip Distance (miles)


(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
-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
(b)
1 0 0 1 0 0 1 1
0 0 0 0 0 1 1 0
0 0 0 4 0 1 0 0
0 0 2 2 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
	% Waiting 5 min+	0.4%	0.2%
Trip miles	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
	% Induced travel (added VMT)	10.7%	0.1%
Usage	Min. # SAVs not in use	19	11
	Min. # SAVs unoccupied	54	22
	Max # share in use / moving	98.87%	0.63%
	Max # share occupied	96.80%	1.35%
Vehicle Starts	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	*	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	*	*
	SC2	Lesser trip centralization	1712	*	213	*	*	*
Service area	SA1	Greater service area	2272	33.7	337	0.33	*	0.059
	SA2	Smaller service area	1053	40.3	154	0.26	*	0.048
Return-home trips by SAV	SH1	Greater rate of trips returning home	1674	35.3	206	0.29	*	*
	SH2	Lesser rate of trips returning home	1676	*	240	*	*	*
Peak congestion	SP1	Lesser peak congestion	1517	40.0	214	*	*	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	*	2425	0.69	4.9%	0.067
	SR1	Only R1	1674	36.5	433	0.46	7.3%	0.061
	SR2	Only R2	1707	*	519	0.42	6.4%	0.061
	SR3	Only R3	1677	*	1750	0.51	7.0%	0.060
	SR4	Only R4	1689	*	1644	0.57	4.9%	0.066
	SRM1	All R minus R1	1690	*	576	0.34	8.7%	*
	SRM2	All R minus R2	1704	35.5	239	*	9.5%	0.057
	SRM3	All R minus R3	1688	*	280	0.36	8.6%	0.056
	SRM4	All R minus R4	1697	*	258	0.31	*	*
Limitations on # of SAVs	SL1600	SAVs limited to 1600	1600	37.9	694	0.38	*	0.050
	SL1500	SAVs limited to 1500	1500	40.5	2422	0.59	*	0.047
	SL1400	SAVs limited to 1400	1400	43.5	9505	1.24	*	0.043
	SL1300	SAVs limited to 1300	1300	47.0	22,718	2.38	*	0.039
	SL1200	SAVs limited to 1200	1200	50.9	41,469	3.98	*	0.035


25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
Share of Travelers Waiting
1200
1300
1400
1500
1600
1700
# of SAVs
1688 SAVs
5 Minutes+
10 Minutes+
15 Minutes+
20 Minutes+
25 Minutes+
Unserved, > 30 Min

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. . .

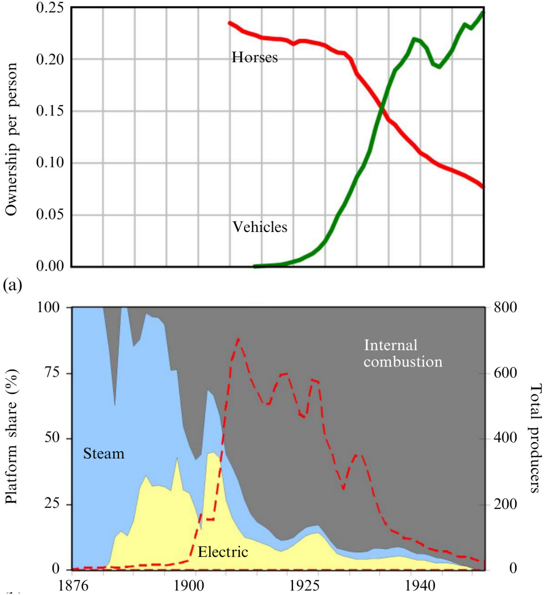
Environment and Planning B (urban analytics): I.F. $\lesssim 3$

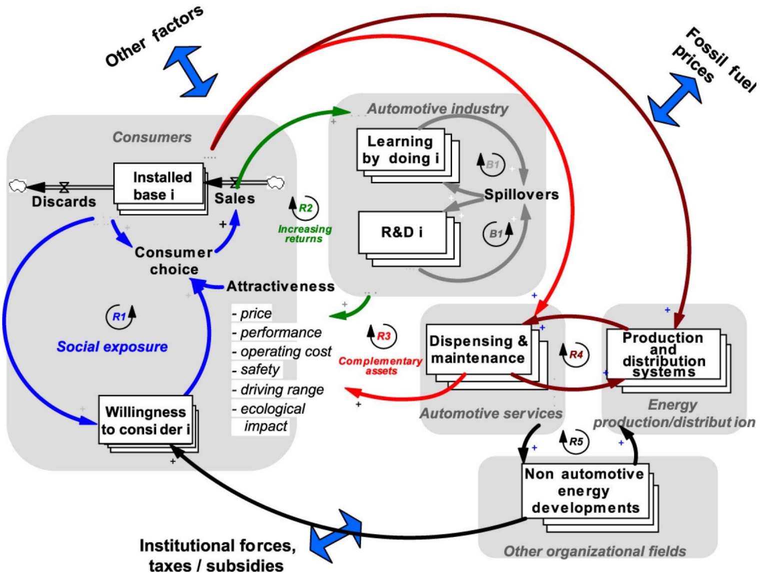
Why?

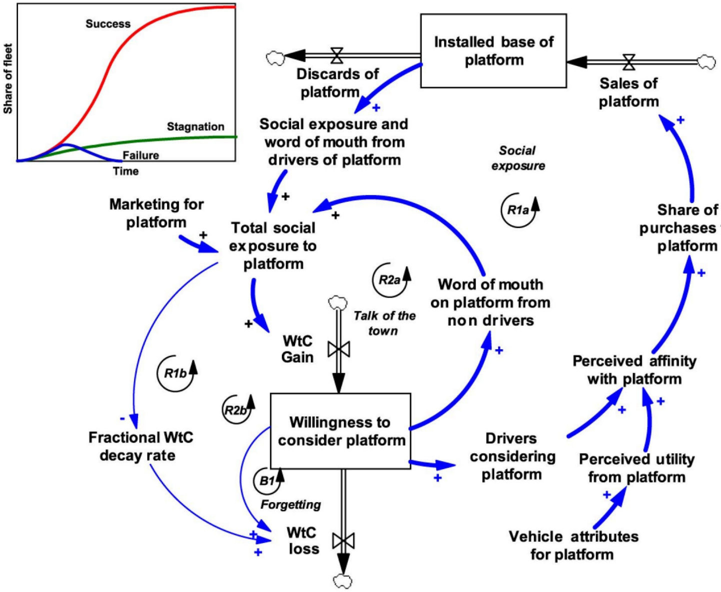
Adoption of alternative-fuel vehicles (AFV) is driven by:

- 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


0.25
0.20
0.15
0.10
0.05
0.00
Ownership per person
Horses
Vehicles
(a)
100
75
50
25
0
Platform share (%)
800
600
400
200
0
Total producers
Internal combustion
Steam
Electric
1876
1900
1925
1940

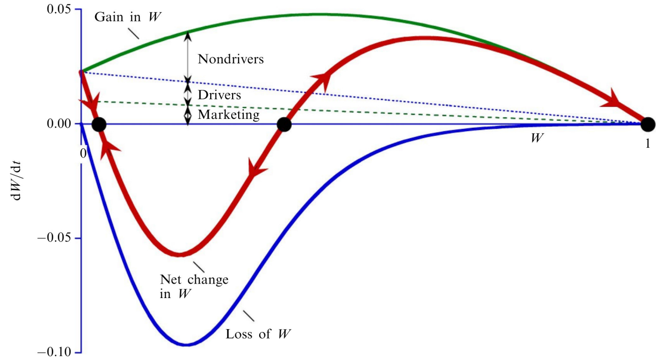

Other factors
Fossil fuel prices
Consumers
Installed base i
Discards
Sales
Consumer choice
Attractiveness
- price
- performance
- operating cost
- safety
- driving range
- ecological impact
R1
Social exposure
Willingness to consider i
R2
Increasing returns
Automotive industry
Learning by doing i
R&D i
Spillovers
B1
B1
R3
Complementary assets
Dispensing & maintenance
Automotive services
R4
Production and distribution systems
Energy production/distribution
R5
Non automotive energy developments
Other organizational fields
Institutional forces, taxes / subsidies


Share of fleet
Success
Stagnation
Failure
Time
Installed base of platform
Discards of platform
Sales of platform
Social exposure and word of mouth from drivers of platform
Social exposure
R1a
Share of purchases to platform
Marketing for platform
Total social exposure to platform
R2a
Word of mouth on platform from non drivers
Talk of the town
WtC Gain
R1b
R2b
Perceived affinity with platform
Fractional WtC decay rate
Willingness to consider platform
Drivers considering platform
Perceived utility from platform
B1
Forgetting
WtC loss
Vehicle attributes for platform

$$\frac{\mathrm{d}W_{ij}}{\mathrm{d}t} = \eta_{ij}(1 - W_{ij}) - \phi_{ij} W_{ij}$$

η_{ij} : Social exposure

ϕ_{ij} : Willingness-to-convert forgetfulness



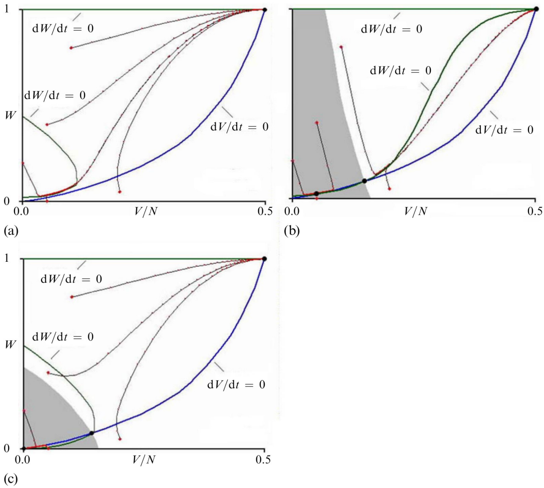


Figure 5. [In color online.] Phase space for a two-dimensional system with endogenous willingness to consider and vehicle installed base. Fixed points exist at intersections of nullclines; dots show sample trajectories. The grey area shows the basin of attraction for the low-diffusion equilibrium. The 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.

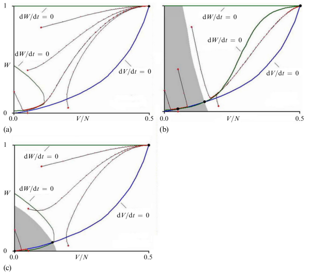
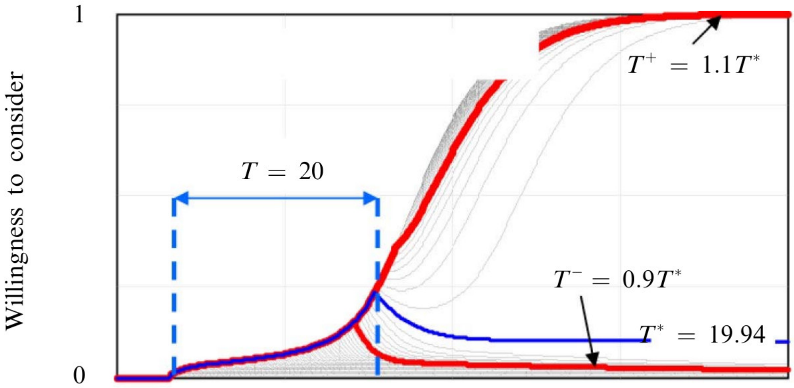
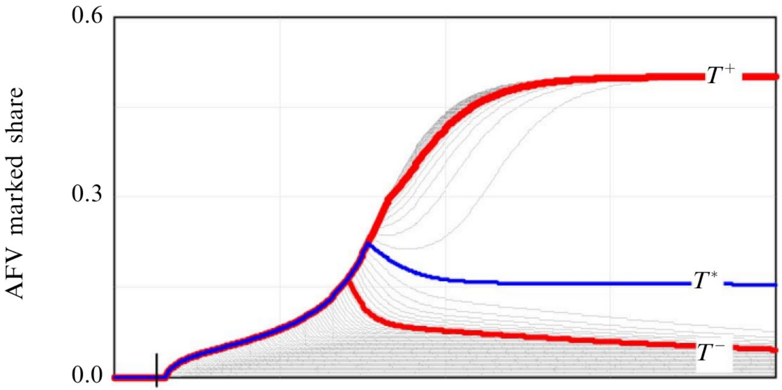
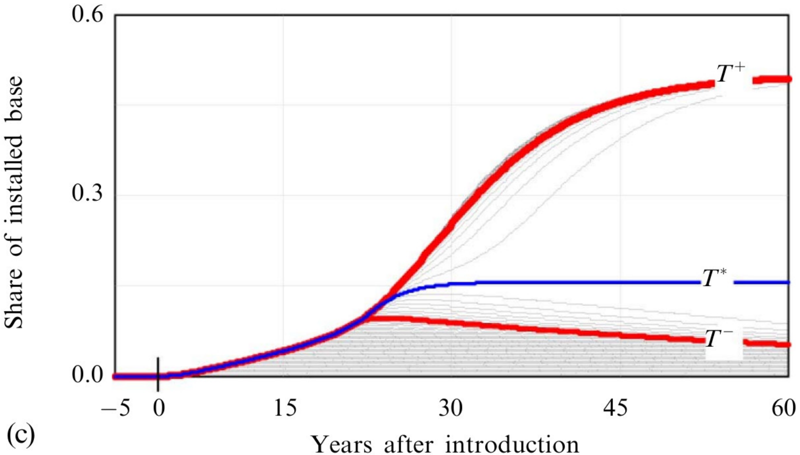


Figure 5. [In color online.] Phase space for a two-dimensional system with endogenous willingness to consider and vehicle installed base. Fixed points exist at intersections of nullclines; dots show sample trajectories. The grey area shows the basin of attraction for the low-diffusion equilibrium. The 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.

$$
\begin{aligned}
\frac{\mathrm{d}V_2}{\mathrm{d}t} &= \frac{\sigma_{22}V_2 + \sigma_{12}(N - V_2) - V_2}{\lambda} \\
\sigma_{i2} &= \frac{W_{i2}a_{i2}}{W_{i1}a_{i1} + W_{i2}a_{i2}} \\
a_{ij} &: \text{affinity}
\end{aligned}
$$


1
0
Willingness to consider
T = 20
T+ = 1.1T*
T− = 0.9T*
T* = 19.94


AFV marked share
0.6
0.3
0.0
T^+
T^*
T^-


0.6
0.3
0.0
Share of installed base
T^+
T^*
T^-
−5
0
15
30
45
60
(c)
Years after introduction

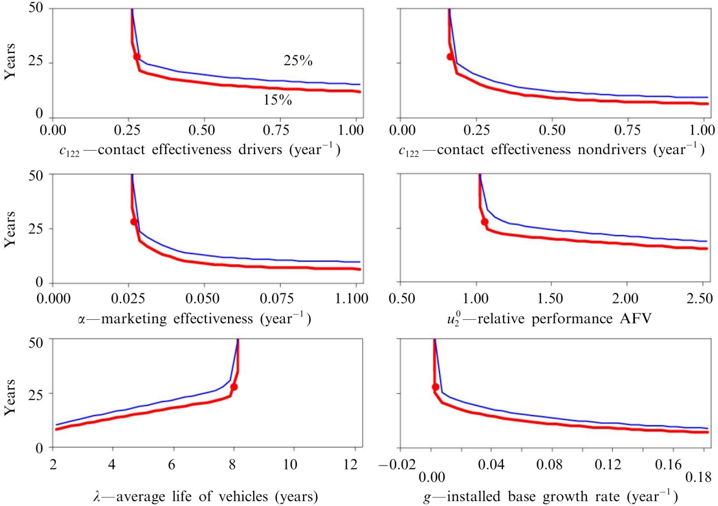


Figure 7. [In color online.] Sensitivity of the alternative fuel vehicle (AFV) installed base share to key parameters. Each panel shows the time required for the AFV to achieve 15% and 25% share of the total installed base. The reference points (dots for 15% market share) indicate the values in the base run (figure 6) with an aggressive promotion and subsidy program lasting twenty years.

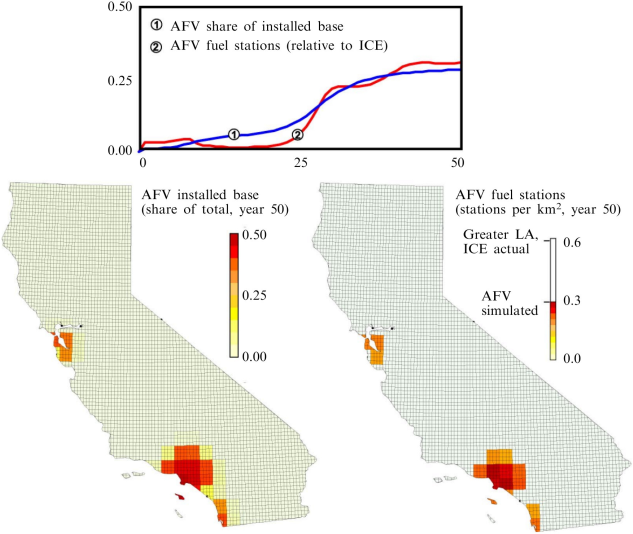


Figure 9. [In color online.] Behavior of the spatially disaggregated model, calibrated for California. AFV and ICE denote alternative fuel vehicle and internal combustion engines, respectively.

Discussion

- Installed base vs. replacement rate vs. cars-per-driver
- Car sharing may increase versatility
- How compelling would new cars have to be? (here ≤ 2.5)
- Who Killed The Electric Car: why didn't competitors jump in?
- Didn't anticipate targeted advertisement
- cf. Tesla

Synergies

- How does Struben&Sterman's analysis relate to bike vs. car?
- How do recent developments affect:
  - Self-driving: how compelling new cars are vs. old (safety/insurance, opportunity cost. . .)?
  - OTA updates: rate of obsolescence?