Supporting Information

Manuscript: On-demand automotive fleet electrification can catalyze global transportation decarbonization and smart urban mobility

Authors: Gordon Bauer, Cheng Zheng, Jeffery B. Greenblatt, Susan Shaheen, Daniel M. Kammen

Contents: Additional information on relevant electrification policies by region; details for calculations of demand for on-demand mobility services by region; current state of electrification of bus and taxi fleets in largest Chinese cities; details on calculations and assumptions for Figure 1; key results from Bauer et al. (2020).[1]

1. Policy background:

Table S1. Summary of on-demand automotive fleet electrification policies around the world.

Location	Policy	Year	Notes	Source
Oslo, Norway	Electrification mandate	2023	100% taxi fleet electrification	[2]
Amsterdam, Netherlands	Electrification mandate	2025	100% taxi fleet electrification	[3]
Washington D.C., USA	Pilot project	2019	127 EV drivers, many complaints	[4]
New York City, USA	Electrification mandate	2013, 2020	Conducted pilot project with 5 BEVs in 2013 and planned to electrify one-third of taxi fleet by 2020; no progress made	[5]
India	Electrification mandate	2026	All new commercial vehicle sales must be electric, 40% of TNC fleets	[6]
Nagpur, India	Pilot project	2018	200 drivers given EVs, planned 50 charging piles at four locations but only 12 built. Most drivers reverted to fossil-fuel vehicles	[7]
Costa Rica	Electrification mandate	2035, 2050	70% bus and taxi electrification by 2035, 100% by 2050	[8]
London, UK	Electrification mandate, emissions fee	2018-2025	New taxis must be electric starting in 2018, emission-based congestion zone expanding in 2021, Uber plans to be fully electric by 2025	[9]
Medellin, Colombia	Electrification mandate / pilot project	2022	1,500 of 20,000 taxis will be electric	[10]
California, USA	Emissions mandate	2020-2023	Establish baseline for TNCs in 2020, establish targets by 2021 deadlines every two years starting in 2023	[11]
Bogota, Colombia	Electrification mandate	2025	50% electric taxis (progress not updated since pilot project in 2015)	[12]

In addition, 15 countries have announced sunset dates on new fossil-fuel vehicle sales.[13]

2. Data & Calculations:

Fleet demand

Table S2. Summary of data used to determine fleet VKT proportion by location.

Location	Fleet VKT	Total automobile VKT	% fleet	Sources
China	142B taxi km/yr + 48.8B pkm Didi * 2 km/pkm = 236B km/yr	15k km/yr/veh * 250M veh = 3.75T km/yr	6	[14] [15] [16] [17]
India	1.3B TNC trip/yr * 4 total/TNC * 7 pkm/trip * 2 km/pkm = 73B km/yr	12k km/veh/yr * 33M veh = 396B km	16	[18] [19] [20] [21]
South Africa	450k R/yr/veh * 20 R/mi * 200k veh * 2 km/pkm = 14B km/yr	17M hh * 0.3 veh/hh * 16600 km/veh/yr = 83 B km/yr	14	[22] [23] [24]
Germany	56k vehicles * 50k pkm/veh * 2 km/pkm = 5.6B km/yr	14k km/yr/veh * 64M veh = 893B km/yr	0.6	[25] [26]
England	62mi/p/yr * 56M ppl * 2 total/passenger * 2 (TNC + taxi)/taxi = 22B km/yr	38M vehicles UK * 7k mi/yr * 56M ppl England/66M ppl UK = 370B km/yr	6	[27] [28]
USA	38B pkm/yr * 2 km/pkm	3.2T km/yr	2	[29]
Delhi	150k veh * 100k km/yr = 15M km/yr	3M veh * 10k km/yr = 30M km/yr	33	[30]
Beijing	100k veh * 100k km/yr = 10M km/yr	6M veh * 10k km/yr = 60M km/yr	14	[31]
Mexico City	140k taxi * 100k km/yr * 2 total/taxi = 28M km/yr	5M veh * 10k km/yr = 50M km/yr	36	[32]
Bangkok	140k taxi * 100k km/yr * 2 total/taxi = 28M km/yr	5M veh * 10k km/yr = 50M km/yr	36	[33]
Cairo	80k taxi * 100k km/yr * 2 total/taxi = 16M km/yr	2M veh * 10k km/yr = 20M km/yr	44	[34]

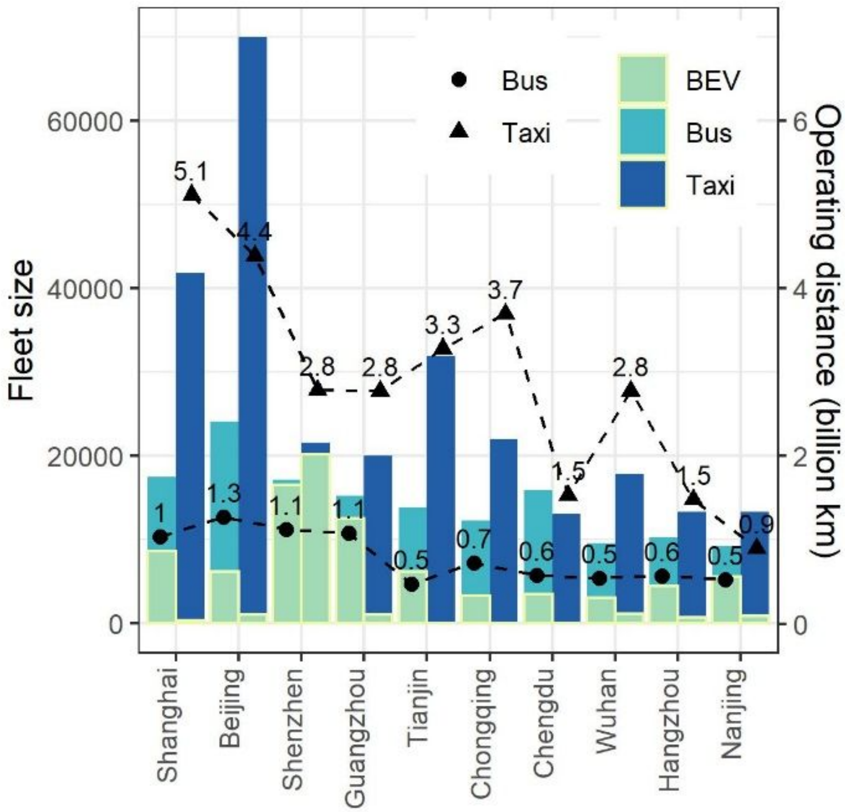

Figure S1. Number of vehicles and operating distance in bus and taxi fleets in 10 of the largest Chinese cities, along with rates of electrification. Data provided to authors by Aspiring Citizens.

Figure 1 Calculations and Assumptions:

a)

Table S3. Variable definitions and values for Figure 1a

Variable	Definition	Value	Source
fare_mi	fare per mile	$1.75	[35]
fare_min	fare per minute	$0.35	[35]
f_{base}	base fare	$2.55	[35]
v	velocity	12 miles/hour	[36]
w	wage	$24/hour	[37,38]
avg_dist	average trip distance	3 miles	[36]
t_shift	shift duration	5 hours	[37,38]
kpm	energy consumption	0.28 kWh/mile	[39]
C	TNC commission	25%	[35]
d_rel	empty distance ratio	25%	[40]
full_wage	theoretical wage if serving trips 100% of the time		
t_pass	time actually serving trips given wage rate		
t_trprel	times spent relocating to trips		
d_tot	distance traveled per hour		
t_chgrel	time spent relocating to charge		

Calculations:

*full_wage = (60 * fare_min + vel * fare_mi + vel / avg_dist * fare_trp) * (1 - C)*

*t_pass = 60 * w / full_wage*

*t_trprel = t_pass * d_rel*

*d_tot = vel * (t_pass + t_trprel) / 60*

*t_chgrel = 1 / vel * 60 / t_shift*

time required to charge *= d_tot * kpm * 60 / charger power*

total time busy with non-charging activities *= t_pass + t_trprel + t_chgrel* c)

Table S4. Variable definitions and values for Figure 1c.

Variable	Definition	Value			Sources
		SF	NYC	SZ	
fee	annual fee	\$0	\$0	\$1,344/year	[41,42]
capex	installation cost	\$50,000	\$50,000	\$24,500	[41,43]
opex	O&M cost	\$1,500/year	\$1,500/year	\$700/year	[41,43]
dmnd	demand charge	\$15.90/kW/month	\$30.9/kW/month	\$0	[41,42]
elec	electricity cost	\$0.151/kWh	\$0.061/kWh	\$0.14/kWh	[41,42]
dur	charger lifetime	10 years	10 years	10 years	[41,42]
disc	discount rate	0.05	0.05	0.05	[41,42]
power	charger rating	50kW	50kW	42kW	[41,42,44]
util	utilization rate of charging infrastructure	current: 7.5% uncoordinated: 21% coordinated: 82%	current: 7.5% uncoordinated: 48% coordinated: 78%	current: unknown uncoordinated: 18% coordinated: 34%	[1,42,45,46]

<u>Calculations:</u>

*annual kWh = util * power * 24 hours/day * 365 day/year*

discount rate = (1 + disc) ^ (1 / annual kWh) – 1

total cost per kWh =

*capex * (discount rate / (1 – (1 + discount rate) ^ (-1 * annual kWh * dur))) +*

*opex * (discount rate / (1 – (1 + discount rate) ^ (-1 * annual kWh))) +*

*fee * (discount rate / (1 – (1 + discount rate) ^ (-1 * annual kWh)))* d)

Table S5. Variable definitions and values for Figure 1d.

Variable	Definition	Value			Sources
		Coordinated BEV	Uncoordinated BEV	ICEV	
fuel_price	cost of electricity or gasoline	$0.18/kWh	$0.21/kWh	$1.02/L	[47] see Table S4
cons	rate of fuel consumption	0.2 kWh/km	0.2 kWh/km	0.075 L/km	[1,41]
bat_price	battery purchase price	$150/kWh	$150/kWh	n/a	[42]
capacity	battery capacity	80 kWh	80 kWh	n/a	[1]
cyc_deg	battery capacity degradation per cycle	.013%	.013%	n/a	[48]
soc_end	capacity at which batteries must be replaced	50%	80%	n/a	[42,48,49]
rev_loss	revenue lost due to time spent charging	$1.50/day	$15/day	$0	[1]
maint	maintenance cost	$0.015/km	$0.015/km	$0.025/km	[41,49]
dist_day	average distance traveled	306 km/day			[1]
disc	daily discount rate	0.05 / 365 = .00014			[49]
bat_dur	battery lifetime, in days				

Calculations:

*bat_dur = (100 – soc_end) / (cyc_deg * dist_day / (capacity / cons))*

total cost per km *= bat_price * capacity **

disc (disc + 1) ^ bat_dur / ((r + 1) ^ bat_dur – 1) / dist_day* +

*fuel_price * cons +*

maint +

rev_loss

3. Key technical paper results

Table S6. Summary of impacts of Shenzhen fleet interventions modeled in Bauer et al. (2020).

Strategies/ interventions	Time savings (min/vehicle/day)		Revenue generated (USD/ vehicle/day)	Electricity savings (USD/ vehicle/day)
	dayshift	total		
Optimal charging station locations	5	8	0.72	0
Optimal dispatch to charging stations	10	14	1.45	0
Flexible SOC during shift change	25	0	3.77	0.43
Optimal charging during break periods	72	123	11.16	0.58

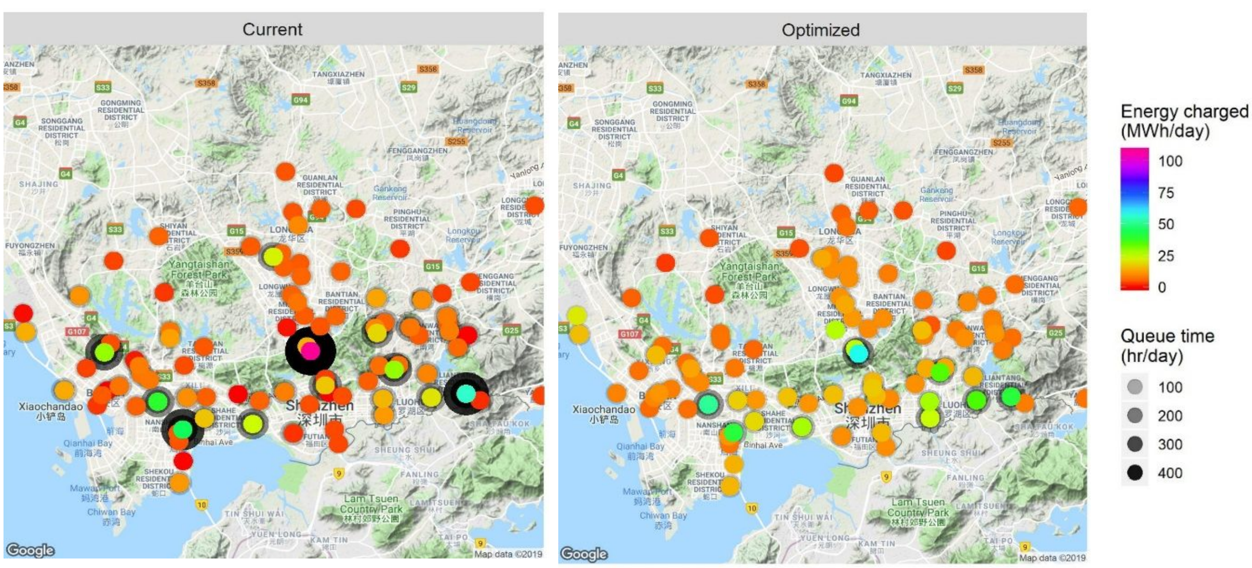

Figure S2. Heat maps depicting charger use and total queuing time (black rings) before (left) and after (right) dispatching optimization. All analysis based on GPS data from about 20,000 taxis in Shenzhen from 17 days in 2019. Queuing optimization is based on forecasts of queue times at each charging station based on a machine learning model trained on historical GPS data.

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