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Innovative Applications of Wireless Charge Transfer for Smart Vehicle Electrification

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Outline

- Introduction
  - Why EVs?
  - Current Technology for Wireless Transfers
- Case Study 1: Charging Buses at Bus Stops
- Case Study 2: Vehicle to Vehicle Wireless Charging
- Conclusions

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WHY EVs?

In President's Obama's 2011 State of the Union address, he called for putting 1 million electric vehicles on the road by 2015. This goal was meant to reduce the country's dependence on oil!

- Regular Gasoline Powered Vehicles Disadvantages
  - Environmental Concerns
    - General pollution including air emissions
    - Availability of fossil fuels in the future
  - Health Concerns
    - Exposure to gasoline can lead to cancer (long term)
  - Political Issues
    - Reliance on countries

- EV Disadvantages
  - Driving Range
  - Recharge Time
  - Availability of charge stations

	Vehicle Name	Charging Time*	Driving Range
Low Speed Vehicles	Dynasty iT Sedan	6 hours	30 miles
	ZENN (Zero Emissions, No Noise)	6 – 8 hours	30 – 50 miles
	Chrysler GEM Car	6 – 8 hours	30 – 40 miles
City Speed Vehicles	Citroen C1 ev'ie	6 – 7 hours	60 – 70 miles
	NICE Mega City	8 hours	60 miles
	Stevens Zecar	6 – 8 hours	50 miles
Highway Vehicles	BMW Mini E	3.5 hours	100 miles
	Chevrolet Volt (2013)	3 hours	38 miles
	Fiat 500e	4 hours	80 miles
	Ford Focus BEV	4 hours	76 miles
	Mitsubishi MiEV i	7 hours	62 miles
	Nissan Leaf	8 hours	73 miles
	Tesla Roadster	3.5 hours	200 miles
	Toyota RAV4	5 hours	80 – 100 miles

Current Battery Charging Methods

Method	Requires Changes to Infrastructure	Requires Uniformity in Battery Placement and Type
Plug-in Charging	Yes	No
Battery Swapping	Yes	Yes
Inductive Power Transfer (IPT)	No	No

- Recharge time
  - Swap batteries – Better Place
  - Quick charge stations – Tesla
- IPT
  - Traffic Light
  - Roadway Strips
  - Parking Lots
  - Bus Stops

Current research has focused on building larger batteries to drive further distances.

- Increase costs
- Larger battery = heavier vehicle = requires more energy to drive distances = not a lot more range.

Current IPT Technology

	Name	Technology	Efficiency*	Distance	Transfer Rates (in sec)
Companies	Bombardier	PRIMOVE			Up to 200 kW
	Qualcomm	Qualcomm Halo			Up to 7 kW
	Siemens		>90%	15 cm	3.6 kW
Research Groups	ORNL		90 – 94%	25 cm	7 kW
	KAIST	OLEV	85%	20 cm	180 kW at 60 Hz
	Stanford		>97%	6.5 feet	10 kW
Start-Ups	Eaton	HyperCharger			200 kW – 1MW
	EvaTran	Plugless Power	>90%	10 cm	3.3 kW
	WiTricity		>90%	10 – 20 cm	3.3 kW

- Measurement of efficiency varies. Typically measured from wall plug to EV battery.
- References: Company websites.

Case Study 1

CHARGING BUSES AT BUS STOPS

Opportunity

- 28% of all greenhouse gas emissions in 2011 for the United States were from transportation related sources (EPA)
- United States is also the second highest carbon dioxide emitter after China
- bus transit is the second leading carbon emitter per passenger mile after private commuting vehicles
- Adoption of electric vehicles by commercial fleets is an easier implementation strategy for these vehicles since commercial fleets typically have predetermined routes and scheduling

STUDY

- Determine whether wireless charging at specifically designated bus stops throughout New York City can help to increase the feasibility of electric buses for city use both from an operational and a financial standpoint
- MTA
  - 5900 buses and 2000 vans/cabs for para transit
  - Hybrid bus
- Other ongoing trials
  - 5-year trial in United Kingdom
  - 3 month zero-emissions trial in Bangalore, India

Case Study 2

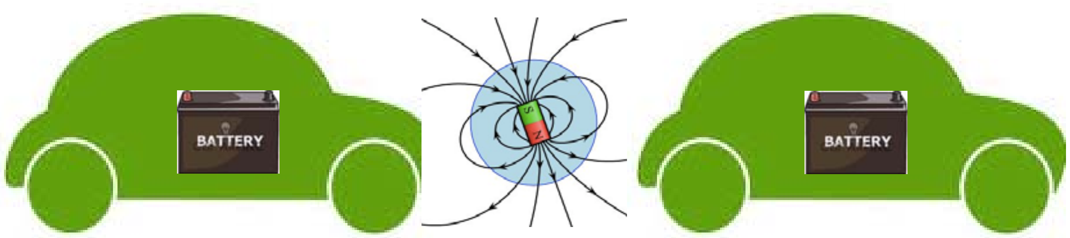
VEHICLE TO VEHICLE WIRELESS CHARGING: TAXIS

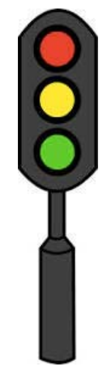
Basic Idea: Wireless V2V Charge Sharing Network

Objective: To increase the effective driving range of EV without changing current infrastructure or battery/charging technology.

Implications: Increase the fraction of users who can use EVs for daily commutes and local trips.

Current proposals for using IPT as a method to charge EVs, do NOT utilize vehicle-to-vehicle charging systems. Our proposal to use this method is NOVEL!





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FEASIBILITY ANALYSIS

- Types of Charging
  - Quick Charge*
  - Fast Charge*
- Battery Charge Rate
  - Varies by Battery Type; Higher C indicates faster charge rates possible
- Overall Battery Life
  - Affects overall battery capacity by 1%/year
- Heat Generation

Nissan Leaf Example:

$$\frac{100\ miles}{10\ minutes} * \frac{1\ minute}{60\ seconds} * 30\ seconds = 5\ miles/traffic\ light$$

$$\frac{80\ miles}{30\ minutes} * \frac{1\ minute}{60\ seconds} * 30\ seconds = 1.3\ miles/traffic\ light$$

Reference:
*Charles Botsford, Adam Szczepanek. “Fast Charging vs. Slow Charging: Pros and cons for the New Age of Electric Vehicles.” EVS24, Norway, May 2009.

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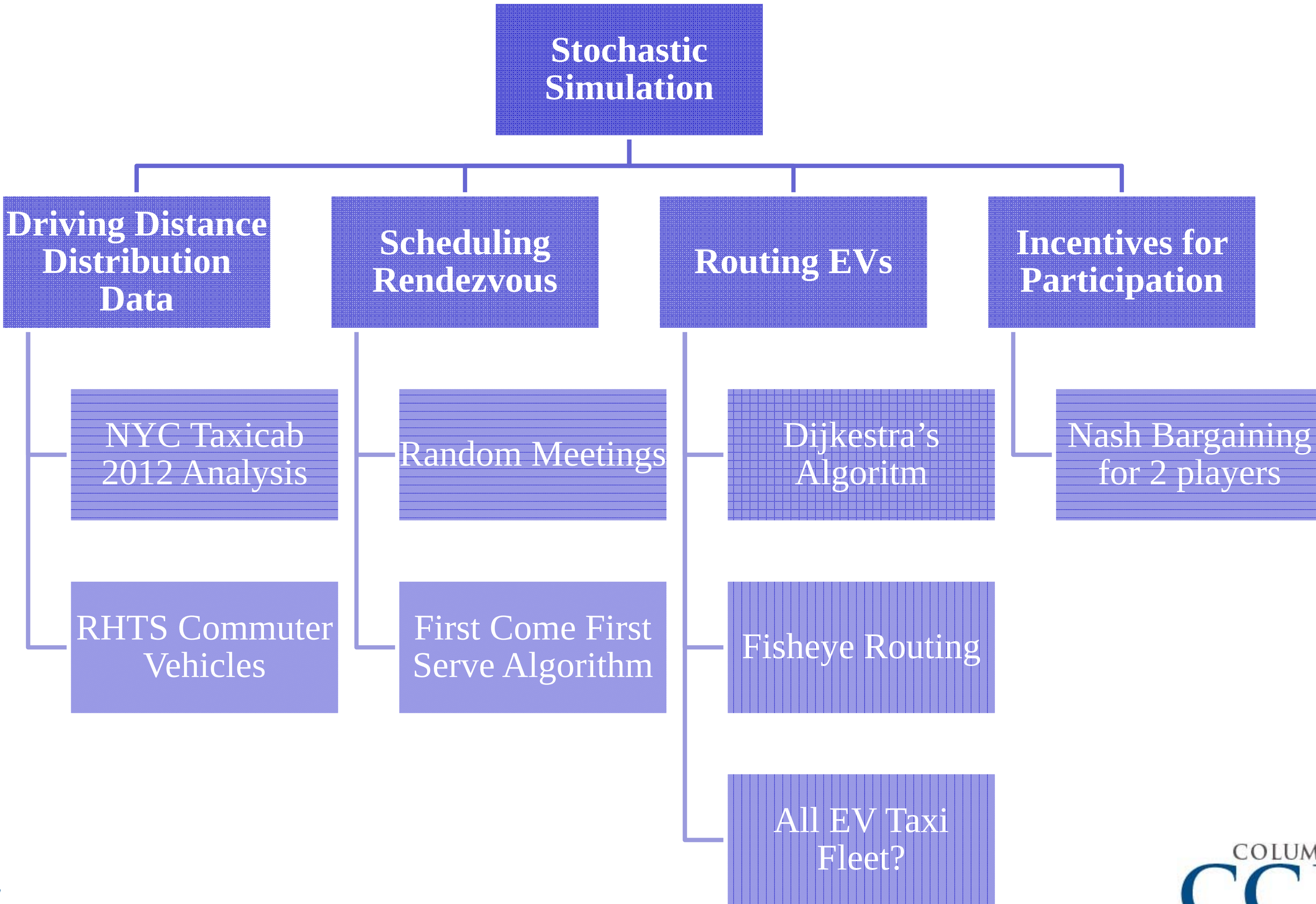
V2V Wireless Charging Model Framework



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NYC Taxicab Driving Data Set

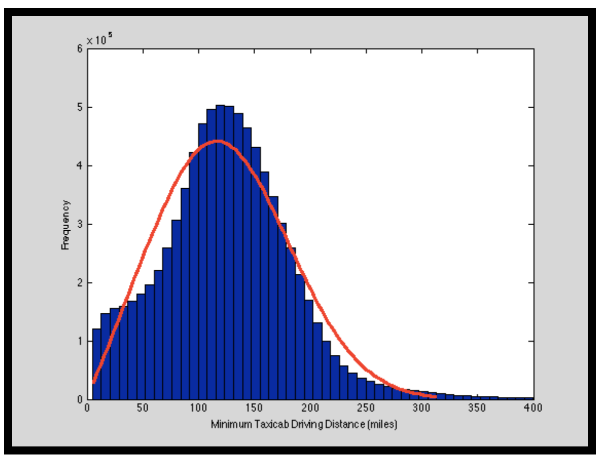
- Available via OpenFOIL bill
  - Similar to Oakland, CA and Chicago, IL
- 192 million entries in two csv files
  - Medallion number, drivers license ID, pick up date and time, drop off date and time, passenger count, trip time, trip distance, pickup latitude and longitude, drop off latitude and longitude, ….
- Accuracy of data
  - Depends on method utilized by driver for meter

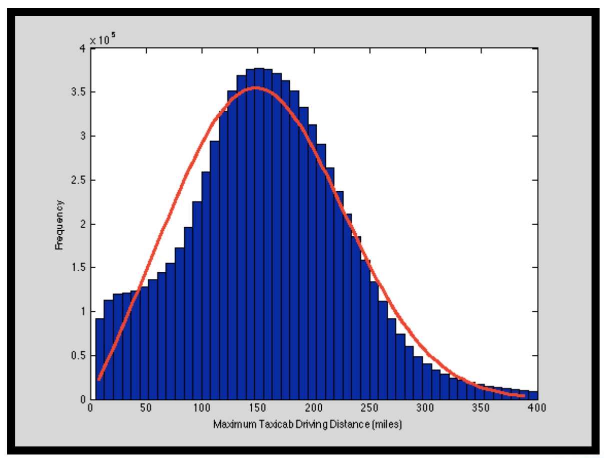
Application: Feasibility of All Electric Taxi Fleet

- Calculate cumulative driving distance of taxicabs during a shift:

$$\text{total\_distance} = \sum \text{disatance with paid customer} + \text{distance to find next customer}$$

- Distribution: Rician
- Two estimates based on distance calculation for finding new passenger
- Without charge transfer: failure rate: approx 18.8%-29.7%





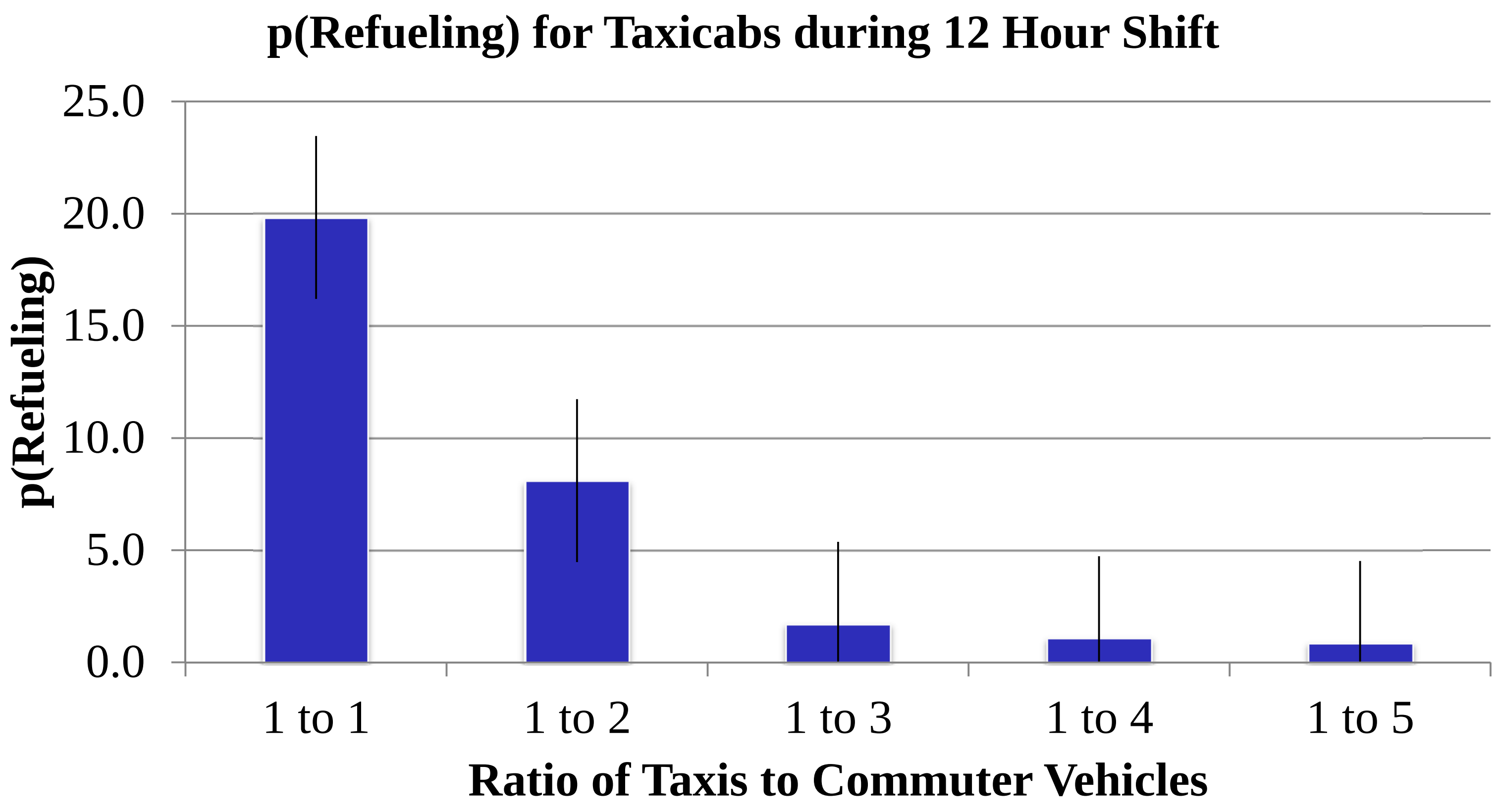
V2V Simulation

- Assumptions:
  - All cars enter the system with 100 units of charge
  - Charge and travel distance normalized (1 unit charge = 1 mile travel distance)
  - Charge transfer occurs at a traffic light intersection wherein cars are stopped for 30 seconds
  - Assume loss-less transfers
  - External factors that can cause a car to use more than 1 unit of charge to travel 1 mile are NOT included in the model

Step 1: Add Cars → Step 2: Drive Cars → Step 3: Calibrate Cars → Step 4: Remove Cars

Evaluation of V2V

- Probability of refueling a vehicle is highly dependent on assumed driving distribution



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The End

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Questions?

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