

# AUTONOMOUS ELECTRIC VEHICLES FOR MOBILITY AS A SERVICE: WHAT CHARGING INFRASTRUCTURE IS REQUIRED?

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# Emerging Trend of Shared Mobility

## Mobility as a Service (MaaS)

- Car sharing
- Ride sharing/hailing
- Bike sharing
- Integration with public transit for first mile/last mile transportation



# Growth of Car-sharing and Ride-hailing Services

Enabled by information technology, shared-vehicle service companies offer inexpensive, flexible, convenient personal transportation options that are rapidly growing in popularity

- Car-sharing companies had nearly 5 million members worldwide in 2014 (including 1.6 million in the U.S.), up from 350,000 in 2006, and is projected to exceed 23 million globally by 2024<sup>1,2</sup>
- Ride-hailing company Uber took 5 years to deliver its first billion rides, but delivered its second billion in the first half of 2016 alone<sup>3</sup>

1. "Faster toward the future of mobility," Deloitte Review, issue 20, Jan 23, 2017, <http://tinyurl.com/fmobility>

2. Shaheen, S., Cohen, A. (2016). Innovative mobility carsharing outlook. University of Berkeley, California.

3. Solomon, B. (2016). Uber just completed its two billionth ride. Forbes. July 18, 2016. <http://tinyurl.com/uber2b>

# Car-sharing Business Models

Car-sharing services provide convenient short-term vehicle rental options with a range of pricing, vehicle sizes, and fuel options

## 1. Round trip model

- Customer must return the vehicle to the designated parking spot

## 2. One-way model

- Customer can drop off the vehicle at any designated parking lot

## 3. Free-floating model

- Customer can drop off vehicle anywhere within designated geographic area

Examples:



# Ride-sharing Business Model

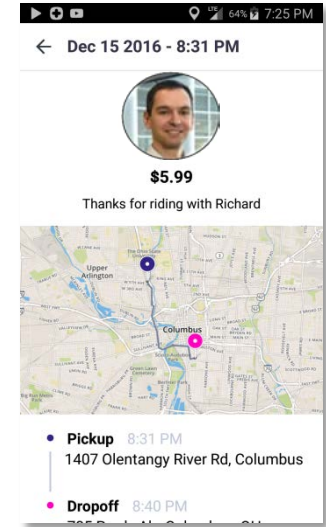
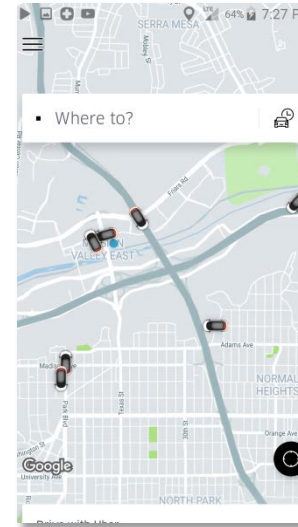
Transportation network companies (TNC) provide platforms to enable peer-to-peer ride sharing

Ex: Uber, Lyft

Also known as ride-hailing, ride-sourcing, or taxi-booking companies

TNCs employ an “asset-light” model

- Provide information technology tools to connect privately-owned vehicle drivers with riders
- Streamlined payment process
- Driver/passenger ratings promote good behavior



# Opportunities for Electric Shared Mobility Today

## Reduce cost

- Low operating cost of plug-in electric vehicles (PEV) amplified by high utilization

## Maintain flexibility

- Trip-specific vehicle selection removes “one size fits all” barrier to PEV adoption for private ownership

## Displace petroleum

- Growth in shared mobility market means electrifying only a fraction of car/ride-sharing VMT would displace significant petroleum consumption and tailpipe emissions

# Challenges for Electrification of Shared Mobility Today

Battery life? (Subject for another day)

Down time for charging has a true financial cost

- Without well planned charging infrastructure matched with vehicle range and charge power rating, the opportunity cost of “fueling” PEVs can be prohibitive
- This is illustrated by the following example of a single free-floating car-sharing vehicle



# Free-floating car sharing home area

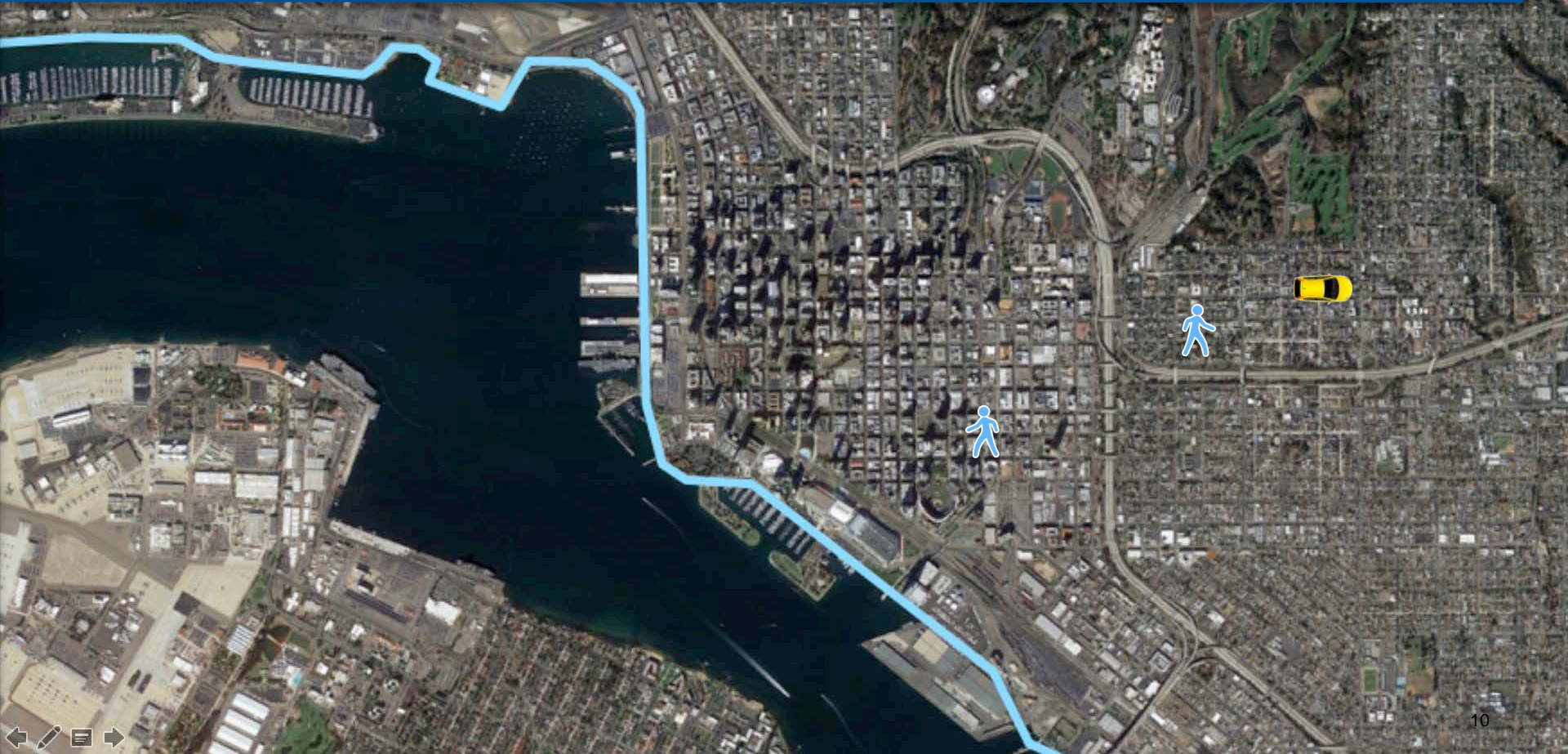




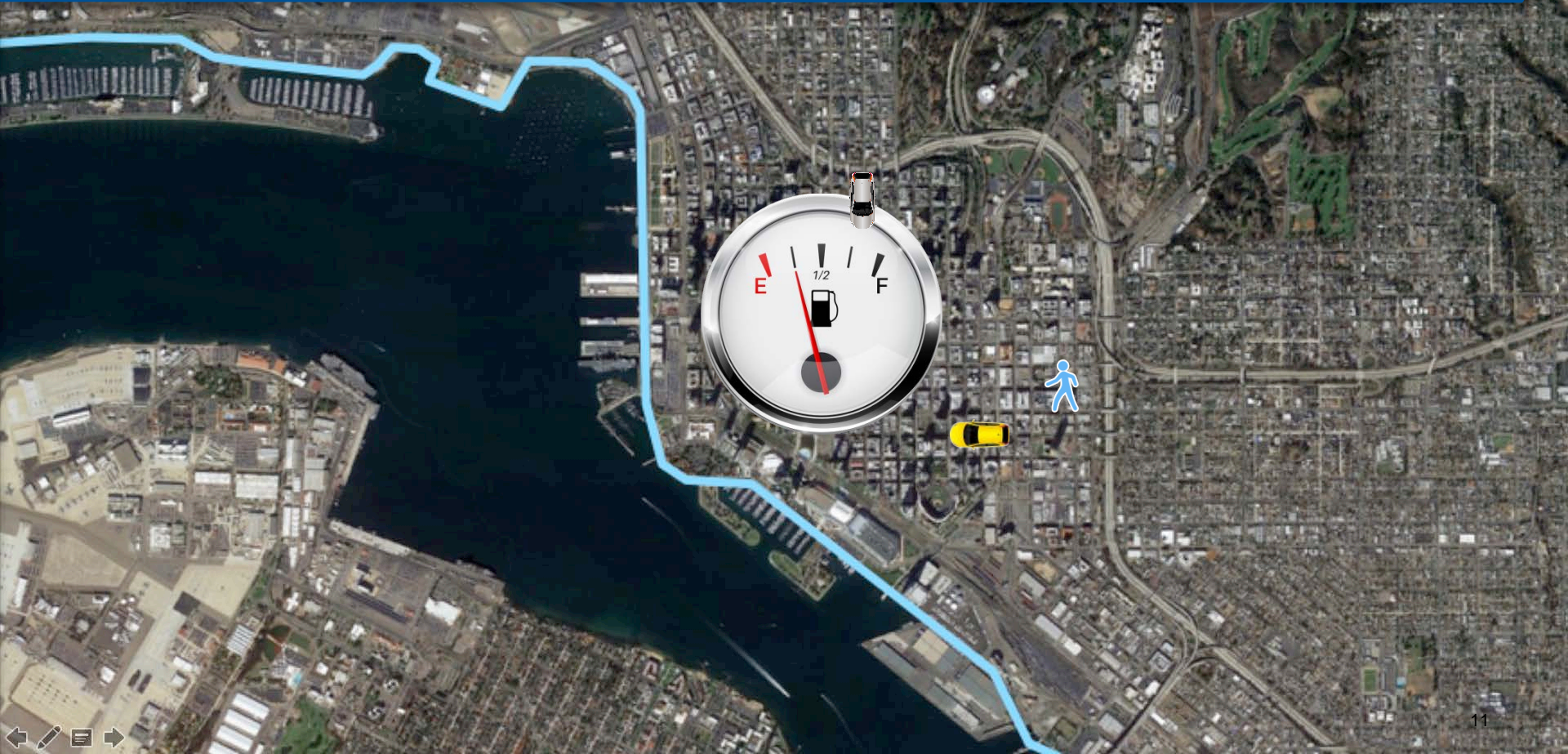




# Customer uses car-sharing for a trip downtown

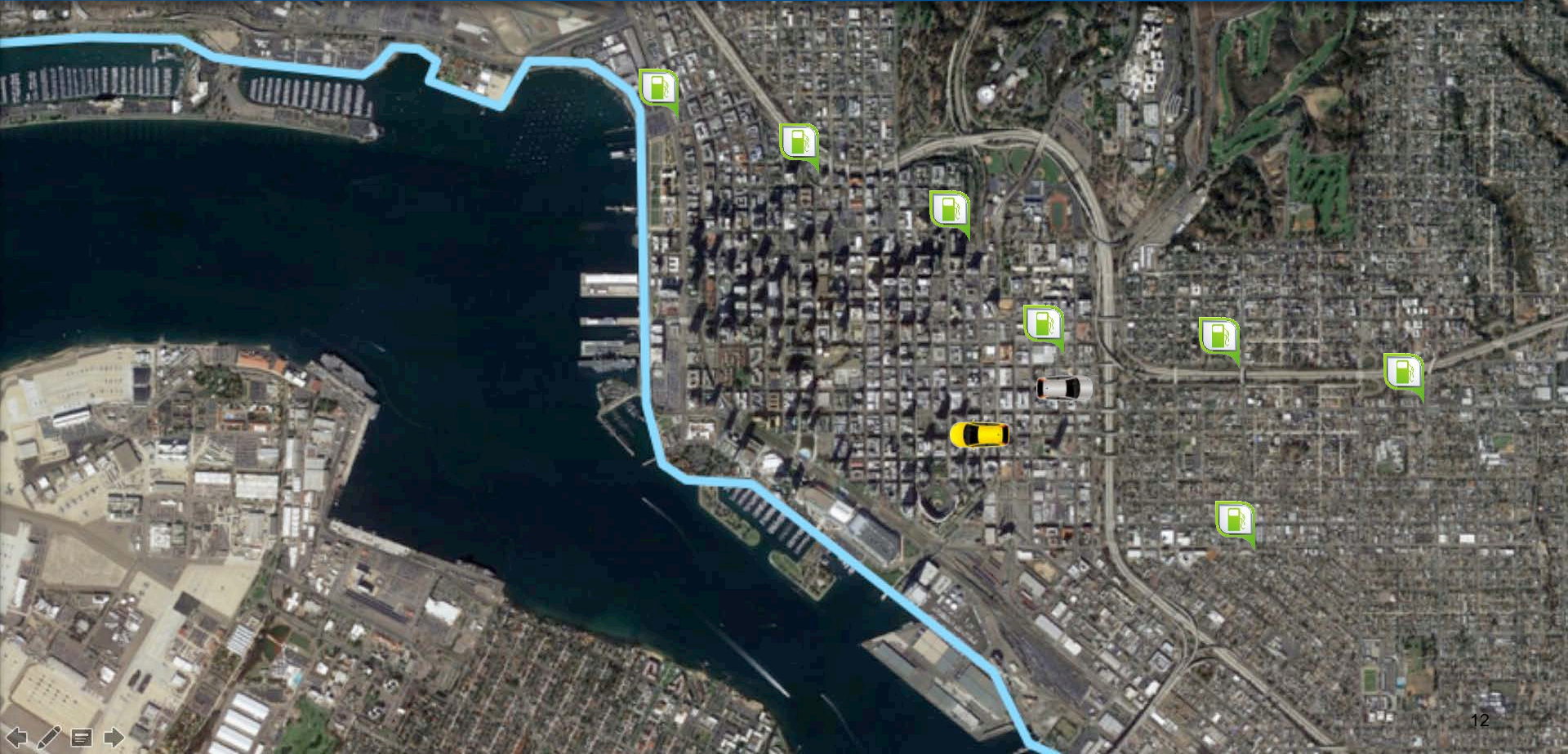


# Fleet managers monitor fuel level and refuel vehicle when necessary



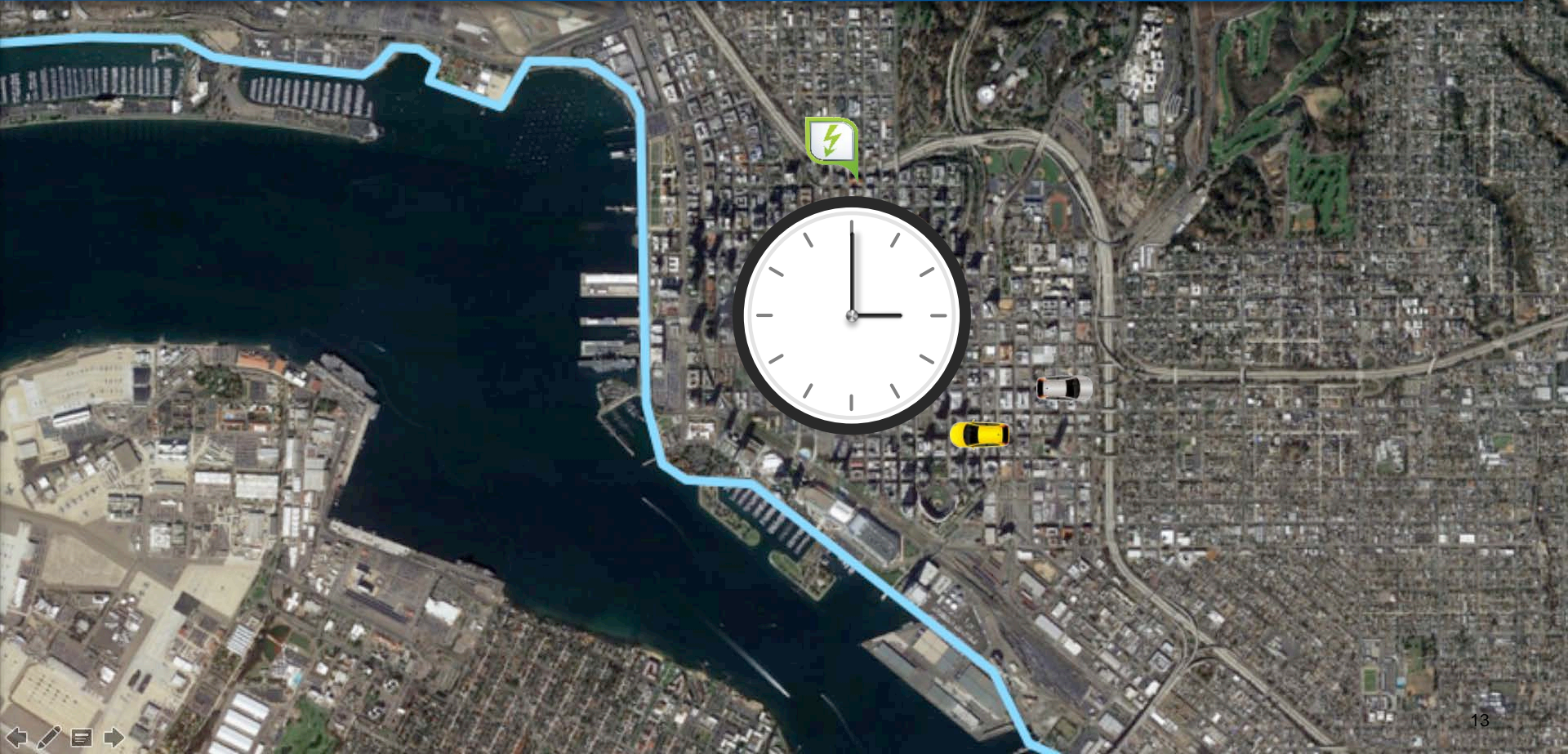


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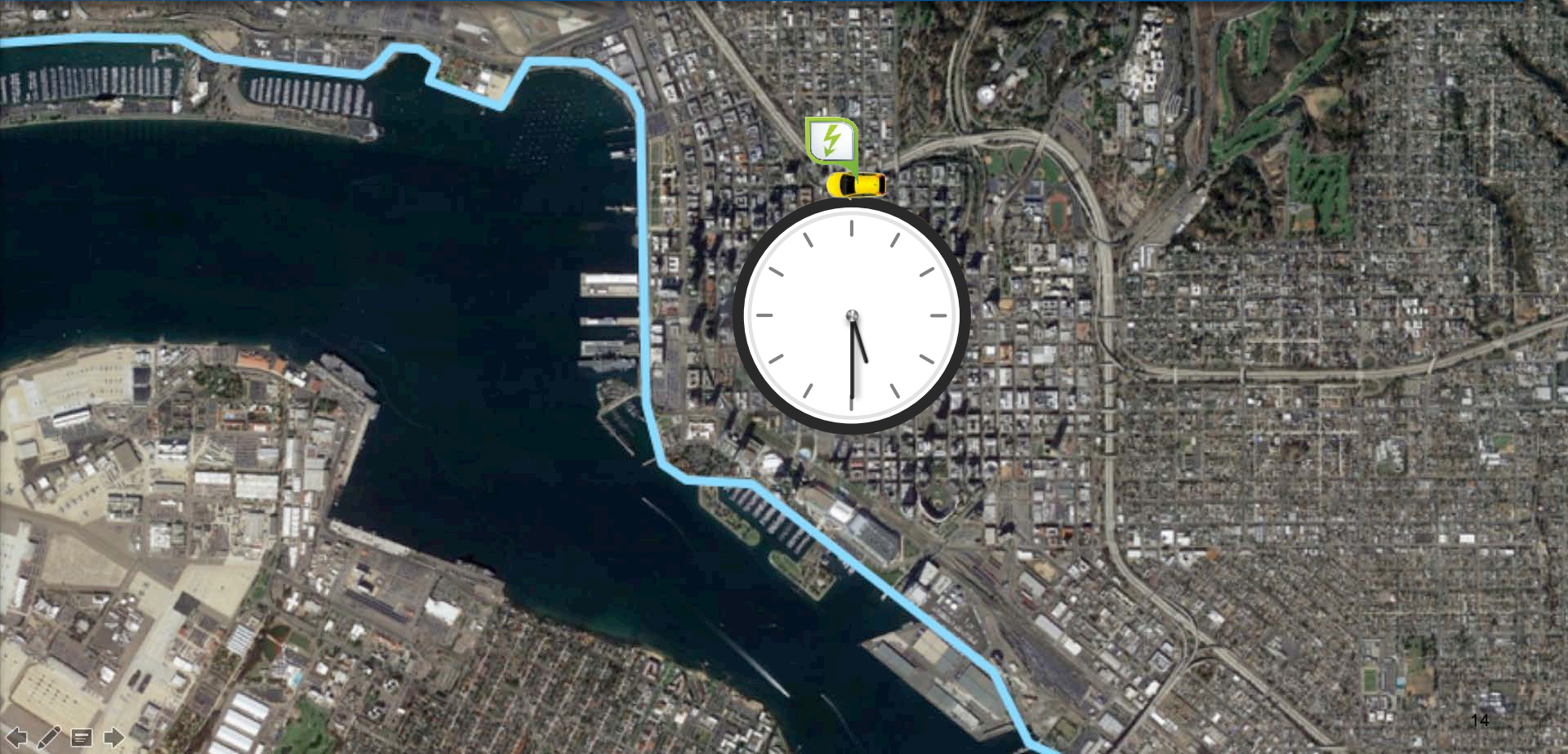




# Difficulty with PEV charging



# Difficulty with PEV charging



# Potential Solutions for Charging Infrastructure of Shared Vehicles

- ~~Ubiquitous AC Level 2 street-side charging so customers can plug in vehicles after use~~
- ~~Numerous dedicated parking lots with AC Level 2 charging~~
- Strategically located fast charging stations

Expensive, if not impossible in most cities

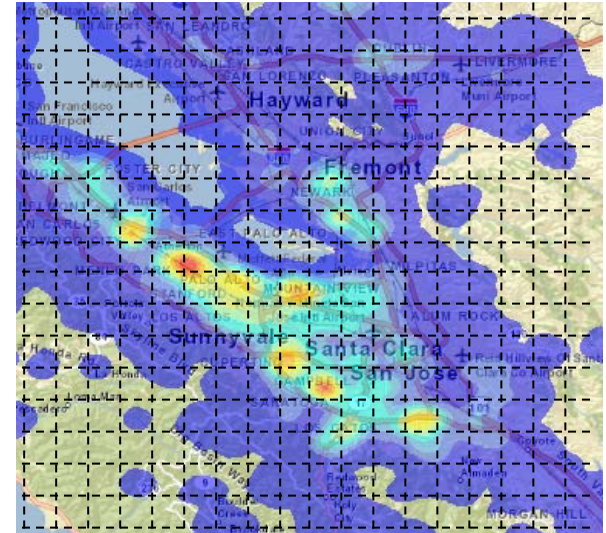
Neither works for ride-sharing

Fine for round-trip and one-way but defeats the purpose of free-floating model



# Data-driven DC Fast Charger Siting

- Least-cost / shortest-path optimization using machine learning to determine the fewest number of charging stations and where they should go
- Must consider trade-off with increased battery size / vehicle range
  - Rolling stock analysis
- Project started Oct 1, 2016





# What Changes with Fully Automated Vehicles?

Business models merge

## **Car sharing**

Fleet asset ownership  
and management



Autonomous  
mobility on  
demand

## **Ride hailing**

Vehicle dispatching

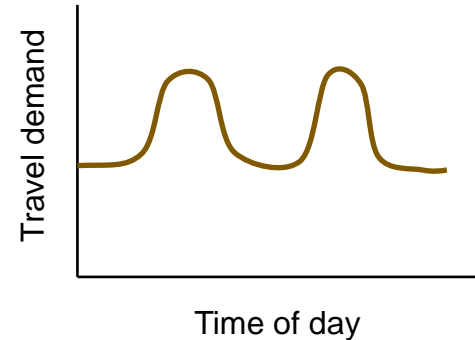
**Home  
area = Automated  
mobility  
district**

# Additional Degrees of Freedom for Fleet Management

With fully automated vehicles, vehicles can be dispatched to:

- Provide rides
- Deliver goods
- Charge at opportune time
- Stay connected to provide grid services

based on real-time and forecasted demand vs. cost



**Ultimate solution:  
Real-time asset management**

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