Mobility On Demand: A Market Economy of

Dimitris Papanikolaou, Smart Cities group, dimp@media.mit.edu
Group Director: Prof William J. Mitchell
The Present: Existing Reality in

**Private Automobiles:** Parking unavailability, Pollution, Congestion

*In congested areas about 40% of gasoline use is in cars looking for parking (Imperial College Urban Energy Systems Project)*

**Public Transportation:** Inflexible Schedules and Inadequate Coverage, First Mile-Last Mile Problem

**The Need:** Personal Customized Mobility on Demand
Mobility-on-Demand (MoD)

A self-optimized ‘one-way’ sharing system of electric vehicles that provides citizens with a convenient, green, yet personal urban transportation on demand.

MoD consists of:

2. A fleet of shared foldable lightweight electric vehicles, to minimizing parking space and carbon emissions
3. A network of deployable charging stations placed in the city, to maximize level of service and accessibility
4. An intelligent self-correcting management system that uses Dynamic Pricing to give incentives to users to efficiently redistribute the scooters to the stations.

How it works:

Simply swipe your credit card in a station, pick-up a vehicle, ride and drop off to any other station. Like having valet parking everywhere.
City Car
RoboScooter
GreenWheel

Zigbee Control Box

Throttle Controls
The Future: Vehicle Sharing Systems

Transportation distribution networks in which users pick up and drop off vehicles from a shared fleet and use them to travel in a network of stations

- Classified into Two-Way and One-Way:
  - Two Way: Pick Up from a station and Drop Off to the same station (Zip Car)
  - One Way: Pick Up from any station and...
The Problem: Fleet Distribution Asymmetries

- **Fleet Management Problem**
  - Since Demand and Supply Rates vary randomly in the stations, many stations end up having no vehicles, while other stations end up reaching capacity, reducing therefore the level of service of the system.

- **Existing solutions**
  - Use of a centrally managed secondary transportation mode to redistribute the fleet
    - Velib in Paris uses trucks
    - Honda DIRACC in Singapore used employees that run with the subway
    - Zipcar asks users to return the car to the same location
MOD: A Market Economy of Trips
Price Structure

- Drop-Off Price

*Trip Price = Pick-up Price + Distance Price + Drop-off Price*
- Pickup Price depends on Origin Inventory
- Trip Price depends on Traveled Distance
- Drop-off Price depends on Destination Inventory
How it Feels to Drive in MoD

3 main contract options:
- User pays before trip (no risk)
- User pays after trip (high risk)
- User pays before trip the forecasted price upon expected arrival (medium risk)
Trip Market Characteristics

- Each player is both seller and buyer of the same commodity (trip)
- Total number of commodities is fixed in the system

**Decision Making:**
- Generally a user is willing to trade his trip if the price from the current location to the new destination plus the price from the new destination to the final destination with the competitor mode is less than the initial price from the current location to the original destination plus a premium for the time loss and inconvenience. Of course this assumes rational thinking and information availability.
User Choice

High Demand + Low Vehicle Stock = Low Drop-Up Price

$\$\$

High Demand + Low Vehicle Stock = High Pick-Up Price

Trip Origin

Cheapest Trip Choice

Low Demand + High Vehicle Stock = High Drop-Up Price

Trip Destination

$\$\$

Low Demand + High Vehicle Stock = Low Pick-Up Price

$
How Dynamic Pricing Works

- By intelligent forecasting, each station ‘knows’ in advance how many vehicles it needs on real time;

- By comparing this number to the actual number of vehicles that it currently has, it regulates the pick-up and drop-off prices accordingly

- Similarly to an hydraulic system, MoD self balances inventories
Describing concept as a feedback loop

- Ensure System Stability from price fluctuation
  - Rate of change of price is different than the rate of change according which the system rebalances inventories

- Ensure System Sustainability
  - money received from penalized users is
Research Goal

• Prove that for any given urban area and transportation demand pattern:

• there is an optimum combination of:
  – minimum Fleet Size,
  – minimum number of stations, and
  – Pricing Policy (ratio of Distance Pricing versus Parking Pricing)

• that
  - Maximizes Performance Rate
Capacity, Usage, and Performance Rates

- System Capacity Rate
  - the maximum service rate that the system can provide when demand rate distribution is uniformly distributed
  - if Average Trip Time is ATT, then each vehicle can serve maximum $1/\text{ATT}$ users per hour. For example, if the average trip time is 15 min, then each vehicle can serve up to 4 users per hour. Therefore:
Initial Modeling Approach in System

Simulate the flow between a node and the rest of nodes
Dynamic Pricing Example: Simulation of a Rack

Loop Number 2 of length 9

- Demand Rate
- Users in Queue
- Departure Rate
- Vehicles in Rack
- Inventory Shortfall

Simulation Analysis
Current Modeling Approach in System

- 100% of the Racks with 20% of Demand Rate in T1, have 20% of Demand Rate in T2
- 25% of the Racks with 80% of Demand Rate in T1, have 20% of Demand Rate in T2
Discussion: Smart Houses and Smart Grids

- Application to Energy Trading for Smart Houses, private renewable energy generators, and small energy storage devices connected to Smart Grids?

- Battery technology for domestic use is still expensive, therefore an energy trading policy employing dynamic pricing between smart houses would greatly reduce total energy production and energy storage needs.