Reinventing the Automobile
Personal Urban Mobility for the 21st Century
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In Memory of William J. Mitchell (1944-2010)
Professor of Architecture and Media Arts and Sciences

Reinventing the Automobile
Personal Urban Mobility for the 21st Century

William J. Mitchell, Christopher E. Borroni-Bird, and Lawrence D. Burns
Big Problem: Buildings and Transportation

In the 21st century about 90% of population growth will be in urban areas; these will account for 60% of the population and 80% of the wealth. Hence, the pattern of future energy demand will increasingly be determined by urban networks.

Transportation and building operations typically account for at least 60% of urban energy use.

In congested urban areas, about 40% of total gasoline use is in cars looking for parking.

*Imperial College Urban Energy Systems Project*
Congestion and Pollution (Taiwan Case)

5.7 million cars
13.56 million motorcycles/scooters.
3.5% of the growth

11 percent of the air pollution is caused by scooters.

2 person per scooter (average)
4 person per car (average)
6.3 car per parking space

9.8 scooters per parking space

33% cars
33% scooters
10% taxi
24% mass transit
Current Problems in Cities
Congestion, Carbon Emissions, Poor Land-Use

1. **Private Automobiles** – Major source of pollution and carbon emissions; massive congestion, parking, and noise problems

2. **Public Transportation** – Does not cover the entire city; inconvenient and inflexible schedules

3. **First Mile-Last Mile Problem**
The Emergence of Vehicle Sharing

1. Bicycle Sharing is exploding: By 2008 more than 80 cities around the world will offer the service. In Paris, 30,000 bicycles are rented daily.

2. Car Sharing systems like ZipCar are rapidly expanding.

3. 5000 cars in the US, 10% adoption rates in cities, over 600 cities in the world have it.
Mobility-on-Demand Systems

A Lightweight Electric Vehicle Ecosystem

RoboScooter

GreenWheel

CityCar
In-Wheel Electric Motor Technology (Wheel Robots)
The RoboScooter Folding Electric Motor Scooter

A collaboration with:
Sanyang (SYM) and Industrial Technology Research Institute (ITRI) of Taiwan

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RoboScooter Video
The GreenWheel Smart Bicycle

Integrated in-wheel motor and battery hub system
GreenWheel
Cut-away

300W Electric Motor
Planetary Gearbox
Lithium Nanophosphate Cells (by A123 Systems)
GreenWheel Video
CityCar Video
Access and Maneuverability
Energy and Space Efficient

Ford Explorer 3950 lbs
Toyota Prius 2932 lbs
CityCar 1000 lbs

Smart Car 1609 lbs
Exploded View: Modules and Components
Exploded View: Modules and Components

- **Rear Module**: Storage and Supplementary Power
- **Battery and Systems Control**: Li-ion and control bus
- **Aluminum Exoskeleton**: Safety Cage and folding Chassis
- **Polycarbonate Shell**: Structural Protection and glazing
- **Interior Module**: Vehicle Control and passenger seating
- **Wheel Robots**: In-Wheel Drive-by-Wire Electric Motor, Suspension, and Steering

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CityCar Half-Scale Prototype
CityCar Folding Sequence
CityCar Folding Chassis
Smart Grids | Electric Charging Infrastructure
Renewable Power, Energy Storage, and Smart Grids

With large-scale use, car stacks throw enormous battery capacity into the electrical grid.

Effective utilization of inexpensive, off-peak power and clean but intermittent power sources – solar, wind, wave, etc.

A smart, distributed power generation system composed of these sources (the entire city as a virtual power plant) minimizes transmission losses.
Developing Electric Charging Infrastructure

Integrate transformers into nearby buildings or use existing building electrical infrastructure.
Battery Performance and Specifications

Lithium-ion battery cells based on nano-phosphate electrode technology to provide low impedance batteries that can be rapidly recharged. Typical battery cost is about 300-700 Euros per Kilowatt-hr.

**26650 Cell:** Delivers 2.3 Amp-hours at 3.3V
- Fast charge (15 min) at 10A to 3.6V (36 Watts/cell).

**HD Prismatic Cell:** Delivers 20 Amp-hours at 3.3V
- Fast charging research in progress by EVT.
- Similar rapid-charging characteristics as 26650.

**CityCar:** 5 to 15 kW/hr battery pack. Using 10 kW/hr as benchmark:
- Target weight of vehicle is 1000 lbs ≈ 450 kg
- Approx. 150 Watt-hrs/mile
- Requires ~1320 26650 cylindrical cells or ~150 HD prismatic cells
- Target cost < 2000 Euros per 5 kW/hr battery pack
# Vehicle Charge Times by Power Source

*Times calculated using ideal calculations given 100% power transfer*

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Pack Size (kWh)</th>
<th>120V, 15 A: 1.8 kW</th>
<th>220V, 50 A: 11 kW</th>
<th>220V, 200 A: 44 kW</th>
<th>480V, 400 A: 330 kW*</th>
<th>480V, 1000 A: 830 kW*</th>
</tr>
</thead>
<tbody>
<tr>
<td>GreenWheel</td>
<td>0.2</td>
<td>7 min</td>
<td>1 min</td>
<td>&lt; 1 min</td>
<td>&lt; 1 min</td>
<td>&lt; 1 min</td>
</tr>
<tr>
<td>RoboScooter</td>
<td>0.5</td>
<td>17 min</td>
<td>3 min</td>
<td>&lt; 1 min</td>
<td>&lt; 1 min</td>
<td>&lt; 1 min</td>
</tr>
<tr>
<td>Motorcycle (60 mi)</td>
<td>5</td>
<td>3 hours</td>
<td>27 min</td>
<td>7 min</td>
<td>&lt; 1 min</td>
<td>&lt; 1 min</td>
</tr>
<tr>
<td>CityCar</td>
<td>10</td>
<td>6 hours</td>
<td>55 min</td>
<td>14 min</td>
<td>2 min</td>
<td>&lt; 1 min</td>
</tr>
<tr>
<td>Sedan (100 mi)</td>
<td>30</td>
<td>17 hours</td>
<td>3 hours</td>
<td>41 min</td>
<td>6 min</td>
<td>3 min</td>
</tr>
<tr>
<td>Taxi (180 mi)</td>
<td>60</td>
<td>34 hours</td>
<td>6 hours</td>
<td>2 hours</td>
<td>11 min</td>
<td>5 min</td>
</tr>
<tr>
<td>Public Shuttle Bus</td>
<td>150</td>
<td>84 hours</td>
<td>14 hours</td>
<td>3 hours</td>
<td>27 min</td>
<td>11 min</td>
</tr>
</tbody>
</table>

* 3-phase power: Power = \( \sqrt{3} \times \text{Current} \times \text{Voltage} \)
Contactless Inductive Charging
Fleet Management | System Dynamics, Logistics, and IT
Dynamic Pricing
Dynamic Pricing

High demand + low vehicle stock =
low drop-off price

High demand + low vehicle stock =
high pickup price

Low demand + high vehicle stock =
high drop-off price

Low demand + high vehicle stock =
low pickup price

Trip origin

Trip destination

Cheapest trip choice

$
Urban Implications and deployment
Case studies in Singapore, Boston, Taipei, Florence
Parking Ratios: 3 to 1

Folded CityCar vs. conventional 4-door sedan
Parking ratio = 3.3 : 1
Parking Ratios:
3 to 1
Autonomous Parking + Folding

$ 29,000 savings per vehicle for parking garage construction

270 sq ft per car @ $150/ sq ft = $40,500 per car
X 50 cars = $2,025,000 for parking structure

77 sq ft per car @ $150/ sq ft = $11,550 per car
X 50 cars = $577,500 for parking structure
Typical Manhattan block (86 parking spaces)

CityCar parking with 8 stations with 12 cars each (96 cars)
Taipei City
Implementation

Within 3 minutes car or scooter driving distance from MRT stations, 95% of the urbanized areas are covered. That means any place inside Greater Taipei Area can be reached within 3 minutes from MRT stations. With the density of schools and convenient stores and MRT stations in greater Taipei area, LEV network can be a one-way rental system and can be easily accessed from every corner of the city. LEV system will not only serve as a transportation system, but also will be a urban catalyst for its ultra-convenience.
Boston, MA
Florence, Italy
“It’s important to get the technology and the policy right, but in the end, the way you break a logjam is by engaging people’s imagination, people’s desire, by creating things that they never thought of before.”

-- William J. Mitchell
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