Toward the Realization of Sustainable Mobility

March 14, 2008
Toyota Motor Corporation
Senior Technical Executive
Hiroyuki Watanabe
What Mobility Has Given us
And What’s Left
Achievements of Automobiles

Greater movement ability (persons, things)
Freedom and convenience: anytime, anywhere, to anyplace

Movable personal space

The development of mobility supports economic growth, as well as social and cultural expansion.
Challenges in Mobility

Environment & Energy
1. CO2 Emission
2. Oil depletion, need for alternative energy
3. Air pollution

Society
4. Traffic Accident
5. Traffic Congestion
6. Regional gap of mobility access
Environmental Energy Issue 1: CO2 Emission

<Global CO2 Emission (by source, 2002)>

- Transport sector accounts for 23% of total emission
- Integrated approach is necessary in each sector

Source: IEA/WEO 2004
Extractable volume of crude oil may peak in 20 - 50 years.
Amount of Bio Resources

- Forests (wood) 3007 EJ
- Vegetation (grasslands) 484 EJ
- Ocean 935 EJ
- Agricultural waste 49 EJ
- Livestock waste 43 EJ
- Wood waste 37 EJ
- Crops (food crops, etc.) 21 EJ

Currently useable liquefied fuel converted from biomass resources 19EJ

Use of forests, vegetation (2%) 19EJ

EJ = 10^{18} J

Energy consumed globally by automobiles (2002) 65EJ

2020
130~150EJ
Since 1980, deforestation in Indonesia and elsewhere is mainly as a result of plantations. Due to forest development, various organisms native to the rainforest are facing extinction. Plantation development is accompanied by illegal felling (increased illegal felling of inland forests).

If we seriously engage in bio-fuels as a business, it will be vital to stop environmental destruction (regulations etc.)
Future Energy Sources for Automobiles

- Electricity (Hydrogen)
- Sweden 2030
- METI 2100
- Shell 2050
- METI 2030

Source: Toyota Motor Corporation
Changes in Mobility

1. Shift to Hybrid (driven by electric power)
   - Plug-in Hybrid
   - Fuel Cell Hybrid
   - Electric Vehicle

2. Shift to Ubiquitous World

3. Robotization

4. Shift to HMI (Human–Machine Interface) to connect human’s hearts with machine
LS600h
Note: Based on the internal measured figure of Toyota Motor Corporation
Plug In HV Systems (PHV)

Potential for diversification of energy sources (flex-fuels), fading out from fossil fuel dependence and reduction of CO₂

Well to Wheel CO₂ reduction

<table>
<thead>
<tr>
<th>Country</th>
<th>Well to Wheel CO₂ reduction (Prius = 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>USA</td>
</tr>
<tr>
<td>Gasoline</td>
<td>1.0</td>
</tr>
<tr>
<td>Japan</td>
<td>0.5</td>
</tr>
<tr>
<td>E85</td>
<td>0.5</td>
</tr>
<tr>
<td>France</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Outlet for Household supply

Two way

Well to Wheel CO₂ reduction (Prius = 1)
Inductive Charging System
TOYOTA performed freeze start and driving performance tests at Timmins, Canada.

(Minimum temperature: -37°C)

The driving performance immediately after start-up was the same level as conventional gasoline-powered vehicles.

No major problem occurred in the FC unit.
Actual cruising range of 500 km is required to be competitive with gasoline engine vehicles.

Improved TOYOTA FCHV, which is 25% more fuel efficient and can store approx. 1.9 times the amount of hydrogen as the ’05 model, successfully traveled between Osaka and Tokyo (560 km) without refueling.
Power plant efficiency  \[ \eta = \frac{P_d}{F_1} \]  

\(P_d\) : Driving power  
\(F_1\) : Input fuel energy flow  

\[ P_d = D \cdot V \]  
\[ D = D \text{ (Driving resistance, acceleration force)} \]
Mobility Performance Index

\[ I_m = \frac{W_0 \cdot V}{F_0} \]  

\( W_0 \cdot V \): Mobility Effect

\( W_0 \): Weight of object to be moved (Payload)

\( V \): Vehicle cruising velocity

\( F_0 \): Input primary energy flow

(Differentiated by time)
Mobility Performance: Improvement

- **Performance figure: 7**
  - Suburban driving
    - Corolla, 2-4 passengers, IW = 1,200 kg
  - City driving
    - Single-passenger vehicle, IW = 300 kg
- **Performance figure: 0.86**
  - Single-passenger Tundra in LA
- **Performance figure: 1.0**
  - Single-passenger Corolla in Tokyo

Average speed (km/h)

Energy consumption ratio (per passenger) (KJ/sec-person)
Innovation of Mobile Units and Energy Conversion

- Reducing size and weight, automated driving, and automated platoon operation
- Plug-in hybrid vehicles, electric vehicles, fuel-cell vehicles

Combining urban transit innovation with urban development

- Upgrading the urban and road infrastructure
- Introduction of ITS
- Transportation demand management (TDM)

Ubiquitous Technology

- Automated parking

Smooth traffic flow

Optimal combination of diverse transport modes

Reduction of energy consumption

Energy consumption ratio (per passenger) (KJ/sec-person)

Average speed (km/h)

Performance figure: 1.0

Single-passenger vehicle, IW = 300kg

Corolla in Tokyo

Performance figure: 0.86

Single-passenger Tundra in LA

Performance figure: 7

Suburban driving

Corolla, 2-4 passengers, IW = 1,200kg

City driving

Single-passenger vehicle, IW = 300kg

Performance figure: 7 times

6 passengers

Large bus

20-30 passengers

Walk

Bicycle

10

0

10

20

30

40

50

60

70

80

90

100

110

120

130

140

6 passengers

1 passenger

30 passengers

Performance figure: 7 times

7 times

Energy consumption ratio (per passenger) (KJ/sec-person)
Cutting congestion and CO₂ emission by half
Reducing traffic fatality to zero

Goals:

- Rebirth of urban traffic systems
  without congestion, CO₂ emission and accidents
- New generation logistic systems
  for timely delivery at competitive cost

Actions:

- Concurrent efforts from diverse perspectives
  1) Effective deployment of transportation infrastructure
  2) Active application of advanced IT and ITS technologies
  3) Market penetration of new generation vehicles
  4) Awareness and participation by citizens and industries
  5) Strategic policy decision and its implementation
# Transportation and Logistics Renaissance

## Road Map

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry Taskforce</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model city selection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task and target setting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model city selection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test plan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluation method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task and target setting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model city selection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test plan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluation method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task and target setting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model city selection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test plan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluation method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task and target setting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model city selection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test plan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluation method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task and target setting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model city selection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test plan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluation method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task and target setting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model city selection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test plan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluation method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task and target setting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model city selection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test plan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluation method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task and target setting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model city selection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test plan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluation method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Large Scale Field Operation Test (FOT)

**Through Field Evaluation Test (FOT)**

1. More advanced technologies applied
2. Larger number of cities participated

<table>
<thead>
<tr>
<th>&lt;Target Items&gt;</th>
<th>1) Congestion</th>
<th>2) CO₂ emission</th>
<th>3) Fatality</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>&lt;Phase I&gt;</th>
<th>1) 20% reduction</th>
<th>2) 20% reduction</th>
<th>3) 20% reduction</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>&lt;Phase II&gt;</th>
<th>1) 30% reduction</th>
<th>2) 30% reduction</th>
<th>3) 30% reduction</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>&lt;Phase III&gt;</th>
<th>1) 50% reduction</th>
<th>2) 50% reduction</th>
<th>3) Zero</th>
</tr>
</thead>
</table>

## Implementation

- Practical operation
- Deployment and penetration (Confirmed at FOT, operation spreads)
The Project of Accelerating Reduction to the Society aims to visualize for the citizen the outcome of large demonstration projects at a model city/line in a selected district, and to accelerate the application of successful practice on other areas. The special committee for new transportation & logistics in ITS Japan is taking initiatives in collaboration with industry, committed for realization with government.

Plan:

“The Project of Accelerating Reduction to the Society” aims to visualize for the citizen the outcome of large demonstration projects at a model city/line in a selected district, and to accelerate the application of successful practice on other areas. The special committee for new transportation & logistics in ITS Japan is taking initiatives in collaboration with industry, committed for realization with government.

General Science & Technology Conference
Project of accelerating reduction to the society
Road Transport System (ITS) Task Force
Policy-making, budget allocation, project promotion
Leader: Councilor Mr. Okumura
Member: Cabinet secretary, Police Agency
Ministry of Internal Affairs and Communication
Ministry of Economy, Trade, and Industry
Ministry of Land, Infrastructure, Transport and Tourism
Specialist: Intellectuals, ITS Japan

Council on Competitiveness - Nippon
- Make direction
- Promote a plan

Transport & Logistics Renaissance Project
- Make a proposal
- Launch the organization
- Support promotion
- Follow up outcome

Academia

ITS Japan
The special committee for new transport & logistics
Project proposal & promotion

Town revival WG
Auto manufacturers
Electronic manufacturers
City developer
Model city/local district etc.

Advanced logistics WG
Auto manufacturers
Electronic manufacturers
Transport company
Highway company
Railway company etc.
Example) Nantes, France: Mobility Demand and Change of Travel Method

Traffic became smooth due to park & ride, despite population growth and increasing dependence on automobile.
Integrated Safety Concept

“Coordination of safety systems”

“All driving stages”

Integrated Safety Concept
Automotive Evolution

Pre-crash Safety System
Lane keeping Assist
Radar cruise control
VSC (Vehicle Stability Control)
Automotive to “Robomotive”

**Recognition**
- Driver status (face direction, etc.)
- Vehicle behavior, etc.
- External environment recognition

**Decision**
- DSS computer (Danger prediction: Optimal control according to extent of danger)
- Integrated control system

**Action**
- HMI
- Vehicle control
- External communications

**Robotization**
- i-unit
- Toyota Partner Robot
Achieving Sustainable Mobility
Creating affluence for people, societies, and the world

- Expanding the scope of activities -
  Ubiquitous technology
  Anytime, anywhere, to anyplace
  Security, safety, comfort, freedom

- Connecting -
  IT-ITS
  RT

- Diversification of mobility

- Fusion -
  Automated platoon driving
  Robots

- Harmonizing -
  Jidoka technology
  Diversifying values
  Appeal, vitality
  Aging society

- Coordination -
  Urban spaces, infrastructure
  Technology for smoothing traffic flow
  Health
  Communities
  History, culture

People and lifestyles

Heart and feelings technology
Thank You for Your Attention.