Future of Urban and Autonomous Mobility: Bringing Autonomy On and Beyond the Streets of Boston
Why does the World Economic Forum care about self-driving vehicles?

**Improved road safety**
- 90% of accidents today occur due to human error
- Reduction in accidents by 70%¹ feasible if self-driving vehicles represent considerable share of car fleet

**Decrease in pollution**
- Better fuel efficiency of ~20% can lower overall pollution (absent an increase in mileage)
- Even higher decrease of emissions possible with electrification

**Freed up space**
- Need for parking space in the city can be reduced by up to 60%¹

**Increased traffic efficiency**
- Traffic congestion can be improved by ~70%¹ due to smoother traffic flow and fewer cars on the road

**Reduced public transport spending**
- Reduction in losses from often non-profitable public transport service in lower density areas

**Less waiting time**
- Seamless, multi-modal end-to-end mobility can be offered to consumers

**Productivity boost**
- Over 1.2B hours of pure driving time savings over 10 years possible

**Decreased cost of mobility**
- Cost savings of up to 50% per km for ride shared self-driving taxi service vs. traditional car ownership

**Equitable access to mobility**
- Elderly, children and people with disabilities can make use of new end-to-end mobility options

---

¹ After 10 years; Note: Potential rewards calculated for a model city of ~5M inhabitants; Source: International Organisation for Road Accident Prevention, European Parking Association, UCS, World Economic Forum; BCG analysis
The World Economic Forum

The International Institution committed to improving the state of the world through public-private cooperation in the spirit of global citizenship

Non profit, international organization founded by Prof. Klaus Schwab in 1971.

Impartial: tied to no political, partisan or national interests.

Global: based in Geneva, with offices in New York, Beijing and Tokyo.

Belief: economic progress and social development are essential to creating a sustainable future.
Multi year Forum initiative to shape the future of urban mobility

- Develop vision for mobility and strategy for autonomous vehicles (AV)
- Support the set-up of AV testing
- Extend AV strategy to include goods mobility
- Contribute to a network of cities to share best practices and key learnings on the global level

Traffic management
- Benchmarking of traffic management concept in leading cities

Self-driving vehicle (SDVs)
- Analysis of obstacles in regulation, society, and technology
- Customer research
- City policy maker interviews

Intermodal travel assistants
- Benchmarking of currently available implementations

Future urban mobility scenarios
- Scenarios for urban mobility

Source: World Economic Forum; BCG analysis
The City of Boston realized first tests in 4 months, now three AV partners approved.
A phased incubator approach is instrumental to scale technology and business model trials in a controllable environment.

### Testing phases

**A** Off-site testing

**B1** 100 miles, Marine Industrial Park, day time only, good weather

**B2** 100 miles, Marine Industrial Park, day and night time, mixed weather

**C1** 200 miles, South Boston Waterfront, day time only, good weather

**C2** 200 miles in South Boston Waterfront, day and night, mixed weather

**D1** 400 miles in City of Boston, day time only, good weather

**D2** City of Boston day and night time, mixed weather

**Detail testing site for phase C1**

**Raymond Flynn Marine Park Seaport District**

- Testing permitted on City roadways.
- MassPort roadways pending approval.

Source: World Economic Forum; nuTonomy, MassDOT, City of Boston, BCG analysis
Impact simulation: We built a real-life traffic model for downtown Boston

We took a real world environment incorporating geospatially accurate data ...

... and simulated traffic flows in its streets

<table>
<thead>
<tr>
<th>Traffic participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars</td>
</tr>
<tr>
<td>Taxis</td>
</tr>
<tr>
<td>Pedestrians</td>
</tr>
<tr>
<td>Buses</td>
</tr>
<tr>
<td>Minibuses</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environment and infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic lights</td>
</tr>
<tr>
<td>Streets</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dynamic behaviors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Following distance</td>
</tr>
<tr>
<td>Speed</td>
</tr>
<tr>
<td>Traffic rules</td>
</tr>
<tr>
<td>Capacity</td>
</tr>
</tbody>
</table>

0.45 km² study area
12.6 km of streets
22.8 km of sidewalks
12 bus routes
53 traffic signals

Source: World Economic Forum; BCG analysis in cooperation with MIT Media Lab
We looked at one evolutionary and one revolutionary scenario.

**Boston today**
- **Primary transport modes**
  1. Public transit: 56%
  2. Personal car: 33%
  3. Taxi and e-hailing: 11%
- **Today's status quo in Boston downtown study area**
  - Most trips into and out of study area are work commutes
  - Public transit and personal car as key transport modes

**Private Car Evolution**
- **Primary transport modes**
  1. Public transit: 50%
  2. Shared self-driving taxi: 22%
  3. Self-driving personal car: 11%
  4. Traditional personal car: 11%
- **Shift to autonomous technology with increased sharing**
  - Many car owners switch to self-driving cars or using shared self-driving taxis
  - Some public transit shifts to shared taxi

**Robo-Transport Revolution**
- **Primary transport modes**
  1. Public transit: 34%
  2. Self-driving mini-bus: 28%
  3. Self-driving taxi: 24%
  4. Shared self-driving taxi: 14%
- **Disruptive shift to shared, autonomous transportation**
  - Shift from personal car to (shared) self-driving taxi and minibus
  - Considerable shift from public transit to minibus

Note: Model assumes simplified modal mix without walking and cycling. Boston today modal mix representative of study area only. Modal mix expressed as % of trips taken.

Source: World Economic Forum; BCG analysis in cooperation with MIT Media Lab
Number of vehicles: Considerable reduction due to sharing

- **Private car evolution** (-11%)
  - Increase in shared self-driving taxis from personal car
  - Counterbalanced by shift from bus to shared self-driving taxi (occupancy of 2-3 PAX)

- **Robo-transport revolution** (-28%)
  - Strong increase in use of shared modes
  - Slightly counterbalanced by bus trips shifting to smaller capacity minibuses (occupancy 2-15 PAX)

Source: World Economic Forum; BCG analysis in cooperation with MIT Media Lab
**Average travel speed**: Significant improvements of up to 30% possible

---

**Total average speed in km/h for private cars**

- **Private car evolution** +15%
  - Driven by small reduction in the number of vehicles (-11%)
  - Lower safety distance between autonomous vehicles
  - Traffic flow is improved

- **Robo-transport revolution** +30%
  - Driven by strong reduction in the number of vehicles (-28%)
  - Large share of autonomous vehicles with lower safety distance
  - Traffic flow is considerably improved

---

Source: World Economic Forum; BCG analysis in cooperation with MIT Media Lab
In both scenarios we found significant impact along key KPIs

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Private car evolution</th>
<th>Robo-transport revolution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of vehicles</strong></td>
<td>-11%</td>
<td>-28%</td>
</tr>
<tr>
<td><strong>Vehicle distance traveled</strong></td>
<td>+13%</td>
<td>+6%</td>
</tr>
<tr>
<td><strong>Average travel time</strong></td>
<td>-11%</td>
<td>-30%</td>
</tr>
<tr>
<td><strong>CO2 emissions</strong></td>
<td>-42%</td>
<td>-66%</td>
</tr>
<tr>
<td><strong>Parking space needed</strong></td>
<td>-16%</td>
<td>-48%</td>
</tr>
</tbody>
</table>

Source: World Economic Forum; BCG analysis in cooperation with MIT Media Lab
Six key takeaways from the collaboration with the City of Boston

1. Autonomous vehicles are a crucial building block to make transportation more **accessible, safe and reliable**

2. Autonomous vehicles **enhance, but do not replace public transit**

3. Getting used to AVs takes time—**public’s awareness** for them must be **created early on**

4. City of Boston does **not want to own assets** for shared mobility models

5. Boston envisions **one city-wide mobility platform** where all its mobility offers converge

6. **Experimentation with different industry partners** key to learn, always in close cooperation with state level

Source: World Economic Forum; BCG analysis; City of Boston
Outlook: The project focusses on 5 key topics in 2017

1. **Urban logistics models**
   - Analyze new business models for urban goods delivery

2. **AV testing**
   - Assist in expanding autonomous vehicles testing in Boston

3. **Impact study AVs**
   - Broaden scope of traffic simulation

4. **Mobility Platform**
   - Develop framework for city mobility platform

5. **City Network**
   - Facilitate a best and worst practice on autonomy leveraging digital capabilities and existing city networks & collaborations
Autonomous mobility landscape 2016: Variety of categories emerged

- Connectivity tools – speech recognition, wireless connection, wearable, infotainment systems
- Connection between connected cars and advanced driver's assistance – external information/input needed to operate vehicle
- Unmanned aerial vehicle, autonomous robotics
- Self-driving fleets, electric autonomous vehicles, driverless last-mile transportation
- Control units and electronics
- Software systems, CPU, low power programmable processors, electronic perception technology
- Image processing sensors, optical distance measurement, 3D image sensors
- Machine learning, unsupervised
- Lane departure, collision warning, localization and mapping, real-time 3D mapping, smart 3D sensing

Source: BCG analysis with Quid
From control units to autonomous vehicles and AI in ~15 years

2000
33 companies

2008
55 companies

2016
115 companies

Connected car systems and Control units were already in vehicles

Unmanned drones were the earliest form of 'autonomous vehicles'

Deep-learning and A.I. is a completely new cluster. Large growth in Sensor technology and Advanced driver assistance

Source: BCG analysis with Quid