Autonomous vehicles:

HDOT engaged BCG to evaluate opportunity to launch autonomous in O'ahu via a shuttle pilot at the airport
  • We engaged island stakeholders, experts like State reps, U of HI professor, and auto dealers

The Autonomous Vehicle Committee consist of:

  • Panos D. Prevedouros, PhD., Department Chairman & Professor of Transportation Engineering
  • Dave Rolf, Executive Director, Automobile Dealers Association
  • Lynette Marushige, Operational Assistant to the Deputy Director of Airports, Commercial Vehicles
  • Robert Lee, Special Assistant to Director of Transportation
  • Ford Fuchigami, Director of Transportation

Autonomous technology represents a near-term opportunity for Hawai‘i to be a leader on the national stage as the first airport pilot in open traffic, and a longer-term opportunity for sustainable advantages in technology and innovation
## U.S. DOT's scale for grading autonomous technologies

<table>
<thead>
<tr>
<th>No.</th>
<th>Capability of Technology</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hands on</td>
<td>Controls speed or steering not both simultaneously</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• (Parallel) park assist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Adaptive cruise control</td>
</tr>
<tr>
<td>2</td>
<td>Hands off</td>
<td>Controls speed and steering simultaneously</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Emergency breaking</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Lane keeping assist</td>
</tr>
<tr>
<td>3</td>
<td>Eyes off</td>
<td>Operates independently human intervenes when system error</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Lane change assist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Highway autopilot</td>
</tr>
<tr>
<td>4</td>
<td>Mind off</td>
<td>Operates with no driver interaction technology stops itself if system fails</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Urban autopilot</td>
</tr>
<tr>
<td>5</td>
<td>No wheel</td>
<td>Operates without driver in all driving modes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Fully autonomous driving (i.e. autopilot in stop-and-go traffic)</td>
</tr>
</tbody>
</table>

Source: U.S. DOT 'Federal Automated Vehicles Policy,' September 2016
A broad set of autonomous features being developed for cars

- **2006** Parallel-park assist
- **2008** Emergency braking
- **2014** Lane keeping assist
- **2016** Highway autopilot
- **2016** Traffic jam assist
- **Planned: ~2018** Autonomous valet
- **Planned: ~2025?** Full autonomy

Level 1: 2006 Parallel-park assist
Level 2: 2008 Emergency braking
Level 3: 2014 Lane keeping assist
Level 4: 2016 Highway autopilot
Level 5: Planned: ~2018 Autonomous valet

Buses lag behind, but similar rapid development expected

Source: BCG analysis
Autonomous vehicle pilot

What success looks like

- National leader
- Flexible technology
- Sets model for the state
- Fits within airport context
Overall methodology

Fleet sizing and demand considerations
- Passenger throughput
- O&M schedule
- Size of buses

Autonomous vehicles
- Level of autonomy that will be safe by 2018-2020
- Long-term vision for AVs in Hawai‘i
- Lifetime total costs

Power train
- Technologies implementable by 2018
- HDOT and HI's short and long term energy goals
- Lifetime total costs

Implementation plan
- Infrastructure investments
- Space requirements
- Preferred vendors
- Business model
- RFP
# What a pilot could look like leveraging retrofit technology

## Three phases to complete pilot

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>'Test and Learn'</strong></td>
<td><strong>'Build out of autonomous capabilities'</strong></td>
<td><strong>'Trial technology'</strong></td>
</tr>
<tr>
<td><strong>Timing</strong></td>
<td>~6-12 months data mining, developing algorithms</td>
<td>~6-12 months testing autonomous technology</td>
</tr>
<tr>
<td>1 year driving typical route</td>
<td></td>
<td></td>
</tr>
<tr>
<td>~100 mi/day</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Goals</strong></th>
<th><strong>Prerequisites to entering phase</strong></th>
<th><strong>Prerequisites to entering phase</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Technology to 'Test and Learn' in environment; gather data</td>
<td>• Confirm shopping list for autonomous parts</td>
<td>• Get regulatory approval to operate autonomous capabilities</td>
</tr>
<tr>
<td>• Familiarize customer with autonomous bus potential</td>
<td>• Write RFP to bid for parts providers</td>
<td>• Approve with insurance provider bus has appropriate level of liability coverage for autonomous operation</td>
</tr>
<tr>
<td></td>
<td>• Identify ideal bus for pilot</td>
<td>• Prepare area for early tests of autonomous capabilities (i.e. utilize parking facility at off-peak timing)</td>
</tr>
<tr>
<td></td>
<td>• Work with Roberts to identify bus for pilot</td>
<td></td>
</tr>
</tbody>
</table>
Three AV options evaluated

1. Magnetic way finding
   - Street tracking technology
   - Current status: Operates in protected lane

2. Embedded
   - Technology & shuttle
   - Current status: Operates in protected lane

3. Retrofit / mounted
   - Technology on bus of choice
   - Current status: Public street test and learn
What retrofit looks like

Regular shuttle of today

AV shuttle of tomorrow

- LIDAR
- Cameras
- GPS
- Ultrasonic
- Radar
Essential components for retrofitting a bus with AV technology

**GPS (1)**
Combine with readings for accurate positioning
Cost: $80–$1,000

**Ultrasonic sensors (12)**
Measure the position of objects close to bus
Cost: $15–$20

**Odometry sensor (1)**
Complement GPS information
Likely built in current bus

**Central ECU (1)**
Analyzes all sensor input, applies rules of the road, operates steering, the accelerator, and the brakes
Cost: about 50%–200% of sensor costs

**360 Lidar (1) or 120 Lidar (4)**
Monitors bus surroundings: road, other vehicles, and pedestrians
Cost: $90–$8,000

**Video cameras: Stereo / Mono (6)**
Monitor the vehicle’s surroundings; reads traffic lights
Cost: $125–$200

**Radar sensors (6)**
Monitor the vehicle’s surroundings
Cost: $50–$150

**Data connectivity**
Provides updates via cellular networks, i.e. for maps & software
Likely built in current bus

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**Existing technology**—Available, commercially viable technologies

**Technology needing development**—Cost estimates are highly variable; different tech specifications are used in different applications

Draft—for discussion only

Source: BCG research and analysis; expert interviews
Success of pilot based on execution within airport context

Current airport shuttle loop for pilot

What success looks like for pilot

Move fast
- Launch in 2018 to build and maintain first mover advantage

Operate within current airport context
- No dedicated lane or changes to airport infrastructure
- Requires managing complexity of current loop

Additional requirements for long term success:

Technology fit for the future
- Learnings from testing in open traffic to be leveraged across O‘ahu’s commercial fleet

Maintains safety and service standards
- Performance of the shuttle services not compromised; travelers get great first impression of O‘ahu

Source: Roberts, AvAirPros, HDOT interviews

Current shuttle route

Graded ramps

Multiple merges

Draft—for discussion only
# Overview of current technologies

<table>
<thead>
<tr>
<th>Model bus pilot</th>
<th>Eugene, Oregon</th>
<th>South Perth, Australia</th>
<th>Reno, Nevada</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emerald Express</strong></td>
<td><strong>RAC Intellibus pilot</strong></td>
<td><strong>Proterra/UNR/City pilot</strong></td>
<td></td>
</tr>
<tr>
<td>First line open in 2007; 4 miles</td>
<td>Began in August 2016; buses being tested in protected lane</td>
<td>Mounted autonomous technology on Proterra bus</td>
<td></td>
</tr>
<tr>
<td>Today, buses in operation for 12+ miles in dedicated lanes</td>
<td>Base bus seats 15 passengers</td>
<td>Bus operating on public streets</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pros and cons</th>
<th>Pros and cons</th>
<th>Pros and cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>✅ Mature technology; bus operation not reliant on evolving autonomous technology</td>
<td>✅ Offers highest level of autonomy available for shuttles</td>
<td>✅ Bus is in-service on public street</td>
</tr>
<tr>
<td>Technology untested in open traffic</td>
<td>Technology untested in open traffic</td>
<td>Technology added to bus of choice; power train agnostic</td>
</tr>
<tr>
<td>Cost, time for infrastructure changes; magnets/lane dev.</td>
<td>Current buses &lt;15 seats</td>
<td>Pilot requires selection of autonomous technology</td>
</tr>
</tbody>
</table>

Source: Eugene Mayors Innovation Project; US DOT, RAC WA; Proterra; Reno Gazette, University of Nevada at Reno
2018 pilot would enable HNL to be the first of its kind in the nation and build an exportable capability in AV

Level of autonomy

Timeline

Description

Plan
- Procure autonomous technology for bus
- Get team in place
- Select bus for pilot

Test & Learn
- Mount autonomous equipment (video cameras etc.) onto existing bus
- Launch pilot publically

Build out capabilities
- Create 3D map of route
- Develop algorithm to enable autonomous features

Trial tech
- Test coded technology in airport environment
- Refine to reach higher levels of autonomy

Note: Pilot first in non-dedicated lane
Source: University of Nevada at Reno

~8 months
Pilot set up

12 months
Phase 1

12-16 months
Phase 2

TBD
Phase 3

Pilot can launch as first in the nation to pilot at an airport

Speed of execution

Draft—for discussion only
Pilot acts as unifying platform to build out an autonomous ecosystem

Broad set of public, private and academic stakeholders should be engaged...
State of Hawaii
Department of Transportation

Mahalo!