THE FUTURE OF TRANSPORTATION DESIGN WITH AV/CV TECHNOLOGY

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Technology Trends

Future-Proofing Roadways

Timelines
Autonomous Vehicle & Connected Vehicle Investments

2035 = $587 Billion
The Autonomous Vehicle Space ...

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CB Insights Unbundling the Autonomous Vehicle 10.31.18 https://www.cbinsights.com/research/startups-drive-auto-industry-disruption/
PROVIDING MAJOR FIRST-LAST MILE BENEFITS

- Improves **SAFETY**
- Enhances **FREQUENCY**
- **REDUCES** CO2 emissions
- **NO SPECIFIC** infrastructure required
- **INCREASE** in productivity
- **IMPROVEMENT** of work conditions
- **REDUCED** congestion
- **INCREASE** in public transportation utilization
100% AUTONOMOUS

15 PASSENGERS/SHUTTLE

35 MPH OPERATING SPEED

9h AVERAGE BATTERY LENGTH

100% ELECTRIC
CAV Shuttle Safety Features

Localisation Using Data Fusion
1. Lasers  2. Cameras  3. GPS
4. Odometry  5. IMU

Decision-Making Safety Chain
1. Emergency Stop Buttons x3
2. Certified Industrial Grade Safety Control Units
3. Obstacle Detection Lasers
4. Braking Systems & Failsafe Parking Brake
CAV Shuttle US Deployments Heat Map: Over 50 since 2017
Critical Enabling Technologies Allows CAV to Operate ... Today

Connected and Autonomous Vehicles

- V2V, V2I, V2X
- Operator "free" travel – eliminates or greatly reduces role of driver
- Safety improvements
- Reduced operational costs

Enabling Technologies

- Connected Vehicle Dedicated Short Range Communications
- 4G/5G Cellular/Wireless
- LiDAR, Radar, Vision-based cameras
- Ultrasonic sensors, GPS
Emerging Technologies will Allow CAV to Flourish … Tomorrow

**Transit Specific Technologies**
- Retrofit pedestrian and vehicle detection and warning systems
- Fully autonomous transit vehicles
- Alternative fuel technology

**Enabling Technologies**
- Connected Vehicle Dedicated Short Range Communications
- Vision-Based cameras/sensors
- Battery technology
- Inductive charging systems
Future Technology Integration will Allow CAV to Truly Connect

Truly Connected Travelers
• Communicates directly with vehicles in real-time
• Travel information is readily accessible
• Enables dynamic trip requests/routing
• Pedestrian warning systems
• Enhanced fare payments

Enabling Technologies
• Connected Vehicle Dedicated Short Range Communications
• 4G/5G Cellular/Wireless
• Dual-Chip fare cards/transit fare collection
• Mobile Phone payment systems
FUTURE-PROOFING ROADWAYS
Dedicated Short Range Communications (DSRC) or Micro-Cell Equipment (5G) Needs:

- Access to power
  - 110V
  - Power-over-Ethernet
- Communications backhaul
  - Fiber
  - Copper Wire
  - Millimeter Wave or other “fast” wireless
- Mounting locations and space in NEMA Enclosures
DATA AND PROCESSING

Vehicles providing data as fast as 10 Hz

- Data Storage
  - To Cloud or not to Cloud
  - Security and privacy

- Data Processing
  - Use of data
    - Daily operations:
      » Decision support system
      » Real-time data processing
    - Long-term planning
      » Data mining/spectral analysis

- Availability of data
  - Revenue model
  - Open sharing
AUTONOMOUS VEHICLE ASSISTANCE

Infrastructure Benefitting Autonomous Vehicles

- **Lane Keeping Assistance**
  - Visual reference markers for optically based AVs
  - Radar/Lidar friendly reference markers
  - Reflective lane markings
  - Position correction broadcasts (Assisted GPS Correction Factors)
  - Map updates

- **Warning Systems**
  - Radio transmissions for roadway guidance and wayfinding
  - Roadway configuration/warning
Redesigning Roadways?

- Roadway Configurations
  - Exclusive AV lanes
  - Modular Lanes/Dynamic Restriping
  - Curve/Turning radius and banking
  - Access and Egress from dedicated lanes

- Pavement Considerations
  - Full-depth hard shoulder
  - Less wheel-load distribution
    - More wear and tear on vehicle tire tracks
    - Denser concrete
POLICIES & PROCEDURES

Changing How We Do Business

- Construction
  - Pavement markings during construction
  - Wayfinding with smart traffic cones
  - Timing for restriping
- Traffic Control
  - Incident management
- Identifying Vehicles in Autonomous Mode
- Licensing
- Traffic Routing and Operations
  - HOT Lanes or Personal Freight?
  - Mixed Use Vehicles (Passenger, Transit, Freight)
  - Where and When for AV?
Tremendous Data Signatures

6 CAMERAS / 3 VLP LIDARS / 7 SCALA LIDARS / 4 RADARS / 4 ODOMETRY SENSORS / 2 GNSS ANTENNAE / 1 INERTIAL MEASUREMENT UNIT / V2X / 4G
What Are Our Takeaways?

1. Technology is always changing – there is always something better!

2. Even if you select the “wrong” technology – as long as it met the needs, you can still get significant return-on-investment

3. Vehicle and Communication Technologies dictate infrastructure components

4. Data is King
TIMELINES
Market Forces for Adoption

Graph showing the adoption rates of various technologies over time, including:
- Telephone
- Electricity
- Automobile
- Color TV
- Air Conditioning
- VCR
- Computer
- Internet
- HDTV
- Tablet

The graph indicates the percentage of universal adoption for each technology.
Autonomous and Connected Vehicle Adoption Rates

<table>
<thead>
<tr>
<th>Year</th>
<th>Autonomous</th>
<th>Connected</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>0-10%</td>
<td>0-10%</td>
</tr>
<tr>
<td>2030</td>
<td>10-40%</td>
<td>40-60%</td>
</tr>
<tr>
<td>2040</td>
<td>20-85%</td>
<td>80-100%</td>
</tr>
<tr>
<td>2050</td>
<td>40-100%</td>
<td>~100%</td>
</tr>
<tr>
<td>2060</td>
<td>65-100%</td>
<td>~100%</td>
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Set the Stage for CV Technology Adoption
Set the Stage for AV Technology Adoption
Embrace a Fully Connected Transportation Network while Increasing AV Facilities
Set the Stage for AV Technology Adoption
FUTURE PROOFING TAKEAWAYS

- We are still learning what needs to be done for future-proofing
- Future-Proofing crosses all aspects of transportation
- Infrastructure will continue to lag vehicle technology – BUT
  It is not “ALL or NOTHING!”