THE INTERNET OF ROADWAYS

Colorado’s vision, strategy, and approach to building the United States’ first connected vehicle network
Intelligent Transportation Systems at CDOT (overview)

Smart Mobility Planning

Fiber Planning

Building Colorado’s Internet of Roads (Connected Vehicle (V2X) Network)

Discussion
CDOT’s Intelligent Transportation Systems (ITS) branch exists to improve the safety and efficiency of Colorado’s transportation system through advanced technology deployment.

Principally, CDOT ITS seeks to realize a connected and autonomous mobility future in Colorado through three main pillars:

- Innovation
- Infrastructure
- Information System
ACTIVE TECHNOLOGY PLANNING EFFORTS

CDOT Effort

CDOT Smart Mobility Plan

Statewide Plan

Mobility Choice Blueprint

CDOT, DRCOG, RTD Effort

Colorado’s Strategic Approach to Implementing Technology

CDOT Effort
PLANNING FOR SMART MOBILITY

- Smart Mobility Plan
- Existing & Future Technologies
- Internet of Roads (Connected Vehicle Network)
- Fiber Master Planning

Unified Approach for Advancing Intelligent Transportation
Steps toward Autonomous & Future Mobility
Near-term Technology Revolution
Principal Foundation for Intelligent Transportation
PLANNING FOR SMART MOBILITY

Unified Approach for Advancing Intelligent Transportation

Steps toward Autonomous & Future Mobility

Near-term Technology Revolution

Principal Foundation for Intelligent Transportation
CDOT’s Smart Mobility Plan will...

• Create a 5 to 10 year vision and plan for maximizing the benefits of new technologies in the transportation sector.

• Define goals to improve safety and efficiency of Colorado’s transportation system through the use of technology.

• Prepare CDOT’s assets, data management, communications systems and infrastructure to maximize the benefits of connected and autonomous vehicles.
The Technology Toolbox will Provide a Pipeline for Accelerating Innovation

CONCEPTUAL  PILOT  MAINSTREAM
PLANNING FOR SMART MOBILITY

Phase 1: Visioning

Phase 2: Regional Planning

Phase 3: Statewide Plan

January      May        September      December
Plan for Smart Mobility

- Regional Technology Plans

- Link to Other Transportation Planning Efforts

- Budgetary & Institutional Support

- Smart Technology Future for Colorado

- Colorado Smart Mobility Plan

- Regional Technology Plans

- • Transparent, articulate and integrated approach to cutting edge technology deployment in Colorado

- • Continued State and Federal support
  • Line items for technology projects
  • Other cost shares where appropriate

- • Broad-spanning partnerships to align larger statewide plan with other relevant planning efforts

- • 5 to 10 year summary plan for statewide technology deployment + tech toolbox
  • Dynamic technology committee

- • Foundation to build unified support and planning for innovative local & regional technology projects
PLANNING FOR SMART MOBILITY

- **Smart Mobility Plan**
- **Existing & Future Technologies**
- **Internet of Roads (Connected Vehicle Network)**
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**Unified Approach for Advancing Intelligent Transportation**

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Fiber Planning, the foundation...

- Develop a 5-10 year fiber and network strategy to support the future transportation network with connected and autonomous vehicles.
- Identify routes based on a weighted factors, which include CDOT Region input, economic development and public safety needs.
- Building blocks to the Smart Mobility Plan.
Building Partnerships to expand CDOT’s fiber footprint…

- Opportunities to partner with Public and Private organizations come to CDOT in many forms.

- Once an opportunity is identified, the entity submits a Unsolicited Proposal to ITS Planning.

- ITS Planning, who chairs Fiber Management Team (FMT) will present the opportunity to the FMT to review and approve.

- Once the terms and conditions are ironed out, ITS Planning submit to the appropriate State and CDOT Departments for finalization.
P3s, why are these partnerships important...

- Create an environment that fosters communications & technology advancement for ALL of Colorado
- Improve community and State resiliency
- Promote economic development
- Grow an interoperable and consistent transportation network system
- To expand information networks while leveraging the existing transportation “hard” infrastructure
- Collecting data to create thoughtful, informed decisions to improve our transportation network, while enhancing technology abilities locally
PLANNING FOR SMART MOBILITY

Smart Mobility Plan

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Principal Foundation for Intelligent Transportation
CDOT is building a new digital infrastructure from scratch

Transportation systems are becoming information systems

Roadways will be influenced by digital messages, not just physical infrastructure

Need to maintain our ability to influence and improve roadway conditions

Build where the problems are

Deploy holistic network, not piecemeal
Panasonic = CV Foundation

iOS platform

C-V2X, DSRC neutral

Open, interoperable

How do we build a meaningful CV network at a scale that begins solving problems?
FACTORS OF CONSIDERATION

Safety
Mobility
Freight
First-ever methodology created by CDOT Traffic Safety

**Conservative Assumptions:**
- CV App = CMF safety benefit
- CV Apps are customized, relevant, just-in-time
- Only three CV apps shown = hundreds possible
- Market penetrations of 5-10%
- Does not consider benefits operational V2I improvements
- Handful of corridors

### Quantifying the safety benefits of connected vehicles

<table>
<thead>
<tr>
<th>CV Application</th>
<th>CMF Equivalent</th>
<th>Reduction % (PDO, Injury, Fatality)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot Weather Warning</td>
<td>Variable Message Signs (VMS)</td>
<td>25%</td>
</tr>
<tr>
<td>Roadway Departure Warning</td>
<td>Rumble Strips</td>
<td>11%-16%</td>
</tr>
<tr>
<td>Queue Warning</td>
<td>Queue Ahead Warning</td>
<td>16%</td>
</tr>
<tr>
<td>Dynamic Speed Harmonization</td>
<td>Variable Speed Limits (VSL)</td>
<td>19%</td>
</tr>
</tbody>
</table>
Quantifying the safety benefits of connected vehicles

EXAMPLE: I-25 in Region 1

Total Benefit = $24 million (10%)

Total Cost = $3,300,000 ($50k/mile)

Estimated Benefit/Cost Ratio = 7.4 to 1
FACTORS OF CONSIDERATION

- Fiber
- Air Quality
- Regional Coverage
- Interstate Corridors

Planned Fiber
Existing Fiber
**Conservative Assumptions:**

- 5% market penetration in 2021, 15% in 2022, 25% in 2023, 40% in 2024 and 50% in 2025
- DRCOG CMAQ Guidelines default value of 3.5 miles/hour (MPH) for increase in speed and reduction in pollutants
- Weekday peak periods (6AM to 9AM and 3PM to 6PM) were used (40% of average daily traffic (ADT))
- IoT installation (RSUs) and Ecosystem

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**CV ANNUAL ADDITIONAL EMISSIONS/AIR QUALITY BENEFITS**

<table>
<thead>
<tr>
<th>Year</th>
<th>CO (tons/yr)</th>
<th>CO2 (tons/yr)</th>
<th>VOC (tons/yr)</th>
<th>NOX (ton/yr)</th>
<th>All Pollutants</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021</td>
<td>24</td>
<td>1,850</td>
<td>1.4</td>
<td>.7</td>
<td>1,876.1</td>
</tr>
<tr>
<td>2022</td>
<td>51</td>
<td>3,303.4</td>
<td>2.6</td>
<td>1.3</td>
<td>3,358.2</td>
</tr>
<tr>
<td>2023</td>
<td>30.6</td>
<td>1,873.4</td>
<td>1.6</td>
<td>0</td>
<td>1,905.7</td>
</tr>
<tr>
<td>2024</td>
<td>34.7</td>
<td>2,656.1</td>
<td>2.3</td>
<td>-.5</td>
<td>2,692.6</td>
</tr>
<tr>
<td>2025</td>
<td>10.2</td>
<td>981.3</td>
<td>.8</td>
<td>-.4</td>
<td>992</td>
</tr>
<tr>
<td>Total Reduction</td>
<td>150.5</td>
<td>10,664.2</td>
<td>8.7</td>
<td>1.1</td>
<td>10,824.5</td>
</tr>
</tbody>
</table>

**IoR installation (RSUs) and Ecosystem. The dollars per ton/per year for all pollutants reduced in 2021 is $4,872.00**

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First-ever methodology created by NavJoy
### CONNECTED ECOSYSTEM V2X

<table>
<thead>
<tr>
<th>Year</th>
<th>Phase</th>
<th>Description</th>
<th>Funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>Phase 0</td>
<td>Planning</td>
<td>$7 m Funded</td>
</tr>
<tr>
<td>2018</td>
<td>Phase 1</td>
<td>V2I</td>
<td>$12 m Funded</td>
</tr>
<tr>
<td>2019</td>
<td>Phase 2</td>
<td>I2V</td>
<td>$20 m Funded</td>
</tr>
<tr>
<td>2020</td>
<td>Phase ¾</td>
<td>V2V Analytics</td>
<td>$20 m</td>
</tr>
<tr>
<td>2021</td>
<td>Phase 5</td>
<td>System integration</td>
<td>$20 m</td>
</tr>
</tbody>
</table>

### WHAT ARE WE BUILDING 2017-2021 Statewide Brain + 170

<table>
<thead>
<tr>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software Hardware Design Plan</td>
<td>100 Connected Vehicles 120 RSUs Working V2I Software (Quarterly Release)</td>
<td>1700 Connected Vehicles Quarterly Software I2V Ops Center Integration</td>
<td></td>
<td>Full System + Upgrades in Perpetuity</td>
</tr>
</tbody>
</table>

### WHAT DRIVERS/CDOT GET

- Crash Notification
- Road Conditions
- Travel Time
- Queue Detection
- Rerouting
- Construction Alerts
- Dynamic Weather Alert
- Red Light Violation
- Variable Speed Limits
- Snow Plow Priority
- Full Situational Awareness Emergency Deployment

### ROAD PROJECT EQUIVALENT

- PEL/EA
- Design Early Action (ROW/Utilities)
- Final Design Early Construction
- Construction
- Final Project Delivery

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**I2V** = Infrastructure to Vehicle  
**V2I** = Vehicle to Infrastructure  
**V2V** = Vehicle to Vehicle  
**RSU** = Road Side Unit
BUILDING STATEWIDE V2X SYSTEM

2021

TOYOTA + Volkswagen + Ford + VOLVO = Connected Vehicle

Road-Side Sensors + Fiber - Wireless + Network Connection = Streaming Data Realtime
Stage 1 timeline alignment: 2018-2021

500+ miles

Ready for automaker rollout (2021)

Provides smart systems approach

Aligns with Panasonic V2X timeline
Funded ✓

Total Miles: 200

Managed Lanes, Panasonic

- I-70 W
- I-70 Central
- I-25 N (sect 7-8)
- I-25 S Gap
- C-470
Funded ✔️ ($10 million)

Additional Miles: 300

Total Miles: 500+

Stage 1 Cost: $17 million
Additional Miles: 500
Total Miles: 1,000+
Stage 2 Cost: $30M
Total Cost: $47M
V2X BUILDOUT - STAGE 3

Additional Miles: 1,000

Total Miles: +2,000

Stage 3 Cost: $250M

Total Cost: $297M

* Assumes CDOT fiber build, no P3 leveraged funds
Potential for 4 states
CO, WY, UT, NV

I-70, I-15, I-80

1,500 additional miles

2,500 total miles

RSU coverage will vary depending on power, terrain, other factors
Additional Considerations

SPaT and MAP Controllers
Infrastructure
CDOT Regional Control
Signal ownership
Intersection dynamics
Municipal participation

Additional Applications

Intelligent/Adaptive Signal Timing
Signal priority/preemption
Red light running warning
Pedestrian in crosswalk
Dynamic speed harmonization
Trial and learn on five intersections

1. Johnson and 6th Ave
2. US40 and 6th Ave
3. Colfax and Interplaza (fleet yard)
4. Arapahoe and Havana
5. Colfax and Tower

Provide CDOT install expertise, learning, ownership

Baseline cost, labor, equipment

SCHEDULE = Summer 2018
From intersections to corridors

1. Arapahoe Rd
2. Wadsworth

- Arterials of significance
- Upgraded signal controllers
- Fiber

Regional experience

- Local CV Integration
- Design starting ASAP
- Snowplow Priority
- FHWA AID grant application

SPAT CHALLENGE - STAGE 1
Analysis underway (corridors not proposed yet)

Scale from SPaT Challenge

Lower cost – complete R1 coverage possible

Fiber needed on some corridors

2020-2022
COLORADO SPRINGS SIGNALIZED CORRIDORS - STAGE 2

- Major corridors
- Metro area coverage
- City partnership potential
- Analysis TBD
Nation’s first methodology for selecting CV corridors

Nation’s first large-scale deployment

Industry-moving potential

Pennies on the dollar compared to new physical infrastructure

Flexible and adaptable infrastructure for virtually limitless roadway applications
DISCUSSION