Personal opinions and sharing for HKS autonomous vehicles policy initiatives only
Disclaimers

This is not a silicon valley thing - it is boring and should be

There are moving pieces with a complex system and conflicted interests

You cannot be agile in some scenarios, no A/B testing with lives
Outcomes

- Gain interests in applying technology in mature sectors
- Give you the frameworks to continue that exploration
- Get to appreciate patience and dedication is key
What to cover

1. **State of the art of AV trucking**
   - What is it? What are the key differences

2. **State of the Market**
   - What is the landscape and problem to solve

3. **Use cases and business models**
   - How do we develop and commercialize it? What are the major models and trade-offs?

4. **Outlook of the market and challenges**
   - What will happen in the next 3-5 / 10 years?

5. **Government's and regulator's roles**
   - Broader insights for AV policies and innovative technology policies
1. State of the art of AV trucking technology
AV basics (SAE J3016)

SAE J3016™ LEVELS OF DRIVING AUTOMATION

What does the human in the driver’s seat have to do?

- **LEVEL 0**: You are driving whenever these driver support features are engaged - even if your feet are off the pedals and you are not steering.

- **LEVEL 1**: You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety.

- **LEVEL 2**: When the feature presents, you must drive.

- **LEVEL 3**: These automated driving features will not require you to take over driving.

- **LEVEL 4**: These automated driving features are engaged - even if you are seated in the driver’s seat.

- **LEVEL 5**: You are not driving when these automated driving features are engaged.

What do these features do?

- **Example Features**
  - Automatic emergency braking
  - Line departure warning
  - Lane centering DAS
  - Adaptive cruise control
  - Lane centering ASD
  - Adaptive cruise control at the same time
  - Traffic jam chauffeur
  - Manual drivers taxi
  - Pedals and/or steering wheel may or may not be installed
  - Same as level 4, but feature can drive everywhere in all conditions

These are driver support features

These are automated driving features

Source: SAE J3016 automated-driving graphic
My simplified version

L0  L1  L2  L3  L4  L5
Nothing 1D  2D  PG  AV Somewhere  AV Everywhere

We are here  Trying to get here

- The complexity is not about technology only, but also business models and other factors like liabilities.
- There are L2+ and L3-, where the differences lie in “who bear the liabilities when it fails”
How AV work? Which part is the hardest?

- Most parts are well researched and applied (with lots of literature).
- But planning requires a lot of original work - that is difficult and resource consuming.
Autonomous Trucking is more than just autonomous driving technology

**Technology:** Software + Hardware

**Infrastructure:** HD Map, Systems, Connectivity, Maintenance, Fleet Management, Portals...

<table>
<thead>
<tr>
<th>Onboard</th>
<th>AI Solutions</th>
<th>Operations Management</th>
<th>Communication services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camera</td>
<td>Modelling &amp; Algo</td>
<td>Operations software</td>
<td>V2V</td>
</tr>
<tr>
<td>Sensors</td>
<td>Training</td>
<td>Monitoring</td>
<td>V2I</td>
</tr>
<tr>
<td>Computing power</td>
<td>Cloud</td>
<td>Response &amp; Recovery</td>
<td>V2X</td>
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<tr>
<td>Cyber Security</td>
<td>Toolchain</td>
<td>Fleet Management</td>
<td></td>
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<tr>
<td>ECU (Electronic Control Units)</td>
<td>Maps</td>
<td>Refueling</td>
<td></td>
</tr>
<tr>
<td>Wiring</td>
<td></td>
<td>Maintenance</td>
<td></td>
</tr>
<tr>
<td>Power, cooling</td>
<td></td>
<td>Depot management</td>
<td></td>
</tr>
<tr>
<td>Ruggedization and automotive grade components</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Paul Lam, CFA, FRSA  
For Autonomous Vehicles Policy Initiative Only
2. State of the market and problem to solve
Road Freight dominates

Source: ATA, A.T.Kearney State of Logistics 2021
$800bn+

US Total Addressable Market for Autonomous Trucking

Source: Investor Presentations by Plus AI, Aurora, TuSimple and other investment broker reports by Citi, MS and AB
Value bridge for Autonomous EV

**ARK’s estimate**

<table>
<thead>
<tr>
<th>Human Driven Diesel Truck vs. Autonomous Electric Truck</th>
<th>Cost Savings Per Ton-Mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Driven Diesel Truck</td>
<td>$0.12</td>
</tr>
<tr>
<td>Electric Vehicle Savings</td>
<td>$0.82</td>
</tr>
<tr>
<td>Autonomous Vehicle Savings</td>
<td>$0.96</td>
</tr>
<tr>
<td>Autonomous Electric Car Emissions Effects</td>
<td>$0.01</td>
</tr>
<tr>
<td>Autonomous Electric Trucks</td>
<td>$0.02</td>
</tr>
<tr>
<td>Total Cost Savings</td>
<td>$0.93</td>
</tr>
</tbody>
</table>

**Source:** Tasha Keeney, ARK Analyst, and Sam Korus, ARK Analyst

**TRR’s Cost Analysis of Driverless Truck Operations**

**Abstract**

Road freight transport is believed by many to be the first transport domain in which driverless (DL) vehicles will have a significant impact. However, in current literature almost no attention has been given to how the diffusion of DL trucks might occur and how it might affect the transport system. To make predictions on the market uptake and to model impacts of DL truck deployment, valid cost estimates of DL truck operations are crucial. In this paper, an analysis of costs and cost structures for DL truck operations, including indicative numerical cost estimates, is presented. The total cost of ownership for DL trucks compared with that for manually driven (MD) trucks has been analyzed for four different truck types (16-, 24-, 48-, and 64-ton trucks), for three scenarios reflecting pessimistic, intermediate, and optimistic assumptions on economic impacts of driving automation based on current literature. The results indicate that DL trucks may enable substantial cost savings compared with the MD truck baseline. In the base (intermediate) scenario, costs per 1,000-ton-kilometer decrease by 45%, 37%, 33%, and 29% for 16-, 24-, 40-, and 60-ton trucks, respectively. The findings confirm the established view in the literature that freight transport is a highly attractive area for DL vehicles because of the potential economic benefits.

**Source:** Transportation Research Record Volume 2674, Issue 9, September 2020, Pages 511-524
Going up, volatile, seasonal

Source: DAT.com, as of September 2022.

Source: https://www.dat.com/
The Business Challenges

- Increasing freight rates
- Crippling profit margins for carriers
- Labor costs and Shortage of drivers (9% or 160,000 by 2028, source: American Transportation Research Institute)
  - Increase in e-commerce (less efficient freight modes - like parcel and LTL)
  - Aging workforce
  - Tough jobs away from family
- Fuel costs, highway toll cost and insurance premium increase
Labor shortage is the fundamental issue

- It’s not just about money (paying more isn’t the solution)
- Repetitive nature
- Away from home
- Turnover rate of 100%
- E-commerce (least-efficient mode of transport) increases demands
Why is it important?

Benefits

- Productivity Gain (Utilization % increase)
- Sustainability (fuel saving of 15-20%)
- Cost efficiency (labor, fuel)
- Improved Health and Safety
- Digitalization of Freight Industry (positive externality above AV)

Bigger picture (Strategic)

- Business continuity and availability of logistics (trickle down effect)
- Anti-inflationary and improve competitiveness
Summary

<table>
<thead>
<tr>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Market</strong></td>
</tr>
<tr>
<td>• A total of $1.2 Trillion Annual Market in China and US by 2024</td>
</tr>
<tr>
<td>• 800bn in US Truck Freight Market</td>
</tr>
<tr>
<td>• 175bn miles driven with 2.3m Class 8 Semi-Trucks</td>
</tr>
<tr>
<td><strong>Value proposition</strong></td>
</tr>
<tr>
<td>• Increased utilization time, Fuel efficiencies, Labor cost reduction, Carbon emission reduction</td>
</tr>
<tr>
<td>• Cost efficiencies – 45% in total cost of ownership, 38% in operating cost</td>
</tr>
<tr>
<td><strong>Regulations</strong></td>
</tr>
<tr>
<td>• Incentives &amp; Selective cities for pilots; US policies remain supportive, iterative and empirical</td>
</tr>
<tr>
<td>• Public perceptions, lack of standards about safety and cybersecurity are concerns</td>
</tr>
<tr>
<td><strong>Technical routes</strong></td>
</tr>
<tr>
<td>• 2 different ways:</td>
</tr>
<tr>
<td>○ Directly target L4;</td>
</tr>
<tr>
<td>○ Starting from L2.5 to L3 for pilot commercialization</td>
</tr>
<tr>
<td><strong>Business Model</strong></td>
</tr>
<tr>
<td>• Fleet as a service – charging fleet service fee</td>
</tr>
<tr>
<td>• Autonomy as a service – technology solution provider</td>
</tr>
<tr>
<td><strong>Partnership &amp; Ecosystem</strong></td>
</tr>
<tr>
<td>• 4 key types of players – Autonomous vehicle (solution providers), OEMs, Fleet &amp; Logistic network, Upstream suppliers</td>
</tr>
</tbody>
</table>
3. Use cases and business models
Segmentations of use cases

Passenger
- Special purpose Passenger AV
  - Value parking, airport shuttles
- Robobus / Roboaxi
  - Weride, Apollo, Waymo, Argo.ai, Pony.ai

Cargo
- Special purpose Commercial AV
  - Airport/port freight, mines
- Autonomous trucking / last-miles
  - Plus, Tusimple, Embark, Aurora, Inceptio, Nuro

Closed
Open roads
Key consideration factors

1. Value creation and cost of provision (is it useful?)
2. Monetization (willingness and structure to pay)
3. Strategic and Supply chain relationships (how the pie is split? how would the ecosystem plays out?)
4. Technology readiness and advantages (is it possible?)
5. Safety and public perception
6. Regulatory and government support
## Major trade-offs in choosing scopes

<table>
<thead>
<tr>
<th>EASY</th>
<th>HARD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Content</strong></td>
<td></td>
</tr>
<tr>
<td>Cargo</td>
<td>Passengers</td>
</tr>
<tr>
<td><strong>Vehicles</strong></td>
<td></td>
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<tr>
<td>Sedan</td>
<td>Class-8</td>
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<tr>
<td>Specialized</td>
<td></td>
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<tr>
<td>Light-duty</td>
<td></td>
</tr>
<tr>
<td>Buses</td>
<td></td>
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<tr>
<td><strong>Environment Complexity</strong></td>
<td></td>
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<tr>
<td>Highway</td>
<td>Urban</td>
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<tr>
<td>Rural</td>
<td></td>
</tr>
<tr>
<td>Suburb</td>
<td></td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td></td>
</tr>
<tr>
<td>Low-speed</td>
<td>High-speed</td>
</tr>
<tr>
<td>Medium-speed</td>
<td></td>
</tr>
<tr>
<td><strong>Weather</strong></td>
<td></td>
</tr>
<tr>
<td>Dry</td>
<td>Various Snow, rain, windy</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6 important decisions about business model

1. Regional vs. Global
2. Catch-all (both passenger) vs. only trucking
3. Closed region vs. Highway
4. Hub-to-hub (middle mile) vs. end-to-end
5. Progressive vs. Direct
6. SaaS vs. FaaS
Regional vs. Global

Shares of traffic and revenues

- Interstate 10: 7% | 29.7bn
- Interstate 80: 7% | 29.3bn
- Route 40: 6% | 27.1bn
- Interstate 75: 5% | 22.3bn
- Interstate 95: 5% | 20.5bn

Source: DOT, FHA

Start with highway, and ideally sunbelt

Note: Major flows include domestic and international freight moving by truck on highway segments with more than twenty five FAF trucks per day and between places typically more than fifty miles apart.

Passenger vs. Commercial

- Shortage of labor in commercial vehicle (not much in passengers, and people still enjoy driving)
- Working conditions, repetitive driving, health & safety in commercial vehicle is worse
- An existing pricing model for trucking (standardized)
- "Driverless" ≠ no one on the vehicle; where there is someone then it is also a ‘social problem’ to solve:
  - “You could have passed that light”
  - “That brake was too harsh - you could have done better"
Passenger vs. Commercial

The technology stack is different. Your driving license does not allow you to drive commercial vehicles. They are different:

1. **Perception**
   a. Longer distance
   b. Severe vibration / special image processing
   c. Different corner cases on highways

2. **Prediction**
   a. Longer horizon with buffer/fuel saving, 5s+ vs. 3s for passenger
   b. Larger scope

3. **Planning**
   a. Safety, fuel efficiency and different requirements such as loads considered
   b. More sophisticated modeling like changing wind/rolling resistance
   c. On-Road negotiations (lane biases)

4. **Control**
   a. Multi-rigid bodies, higher centroid and changing mass
   b. Lacks redundant, functional-safety compliant product
2. Closed-region vs. Road

- Closed-region will be more for captive (mining companies, port operators, etc.)
  - contracts are lumpy in size and customized
  - usage require more industry specific knowledge
  - Hard to transfer (e.g. every airport is a different ODD)
- You may gain time given contract manufacturing (better hardware integration and skip OEM)
- VC prefers open roads due to scale and return profile; closed-region will be more a strategic play
3. Hub-to-Hub Model

- Hub to Hub model reduces the complexity
- It maximizes the AI applicability and generate the most value
- It will change the market into ‘middle mile’ and the ‘last-mile drayage’
- It makes sense in US given the concentration of road freight on long journey and specific highways
- This model preserves jobs (and drivers can stay local with better lifestyles and close to family)

Direct or Progressive?

The Direct-to-L4 roadmap is focused on route-by-route expansion, while the progressive roadmap tries to ensure generalization from the beginning.

- Progressive may distract business to step into the more difficult research and development
- Progressive technology development is not aligned with the hub-to-hub model given the ODD is already restricted. It may be better for end-to-end or robotaxi where the routes are not predefined
- There are technological barriers for using the data collected from L2/3 for L4. It also is a different planning methodology (e.g. L4 does not need to include considerations of HMI, human-machine interactions; it does not need to consider what reactions it need to take to correct human error like not seeing the cars or excessive lane biases, because L4 will prevent that from the start)
AaaS vs FaaS

- **Autonomy as a service.** Partner with OEM to sell autonomous trucks and autonomy driving solutions. Carriers manage the fleet. Customer purchases truck from OEM and subscribes Autonomous Driving Services.

- **Fleet-as-a-service.** The autonomous trucking company run the fleet itself and provide freight service. The autonomous trucking company will just list on brokers as others and shippers and book.

<table>
<thead>
<tr>
<th>Tier 1</th>
<th>OEM</th>
<th>Trucking Companies</th>
<th>Freight Forwarder/Brokers</th>
<th>Shippers</th>
</tr>
</thead>
</table>

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For Autonomous Vehicles Policy Initiative Only

HARVARD Kennedy School TAUBMAN CENTER for State and Local Government
**AaaS vs FaaS**

**Production Vehicles**

**OEM**
- Pre-installed/ Retrofit

**AV**
- Data / Technology

**Freight Companies**
- Ops

**Demands**
- Pre-installed/ Retrofit

**Technology + Operations to provide full freight service**

- "Drivers" as a product
- Subscriptions/charging per miles with multiple companies; scale faster
- Standardized model with asset-light model / easily commoditized in the future
- Ecosystem partnerships

- “Road Freight Services” as a product
- Face the end users (shippers), integrate service and ecosystem better, iterate on products, close-ended business model
- Fleet management is operation-easy, heavy assets, limit growth

**Different models change the customer, partner and competitor relationships AV companies face**
6 important decisions about business model

A preliminary choice based on the market

1. Regional vs. Global
2. Catch-all (both passenger) vs. only trucking
3. Closed region vs. Highway
4. Hub-to-hub (middle mile) vs. end-to-end
5. Progressive vs. Direct
6. SaaS vs. FaaS
4. Outlook and Challenges
Share prices collapse

Self-Driving Startups Have Lost $40 Billion In Stock Market Valuation In 2 Years

John Koetsier, Contributor @
John Koetsier is a journalist, analyst, author, and speaker.

Source: Forbes, Crunchbase

Public Market Performance Of Funded Companies Tied To Autonomous Driving And Related Technologies

<table>
<thead>
<tr>
<th>Company</th>
<th>Valuation At IPO**</th>
<th>Valuation Today*</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aurora</td>
<td>$14,000M</td>
<td>$2,617M</td>
<td>-81%</td>
</tr>
<tr>
<td>TuSimple</td>
<td>$8,500M</td>
<td>$1,516M</td>
<td>-82%</td>
</tr>
<tr>
<td>Luminar</td>
<td>$7,000M</td>
<td>$2,453M</td>
<td>-65%</td>
</tr>
<tr>
<td>Embark Technology</td>
<td>$5,160M</td>
<td>$141M</td>
<td>-97%</td>
</tr>
<tr>
<td>Velodyne Lidar</td>
<td>$4,000M</td>
<td>$203M</td>
<td>-95%</td>
</tr>
<tr>
<td>Aeva</td>
<td>$2,100M</td>
<td>$435M</td>
<td>-79%</td>
</tr>
<tr>
<td>Afeye</td>
<td>$2,050M</td>
<td>$778M</td>
<td>-91%</td>
</tr>
<tr>
<td>Ouster</td>
<td>$1,900M</td>
<td>$148M</td>
<td>-92%</td>
</tr>
<tr>
<td>Innoviz</td>
<td>$1,400M</td>
<td>$655M</td>
<td>-53%</td>
</tr>
<tr>
<td>Copter</td>
<td>$1,400M</td>
<td>$570M</td>
<td>-74%</td>
</tr>
<tr>
<td>Zoloto</td>
<td>$1,400M</td>
<td>$400M</td>
<td>-97%</td>
</tr>
<tr>
<td>Quanergy Systems</td>
<td>$1,100M</td>
<td>$160M</td>
<td>-99%</td>
</tr>
<tr>
<td>Arbe</td>
<td>$722M</td>
<td>$357M</td>
<td>-50%</td>
</tr>
<tr>
<td>CYNK</td>
<td>$198M</td>
<td>$32M</td>
<td>-84%</td>
</tr>
<tr>
<td>Total</td>
<td>$50,880M</td>
<td>$9,158M</td>
<td>-81% average decline</td>
</tr>
</tbody>
</table>

*Market cap as of Oct. 10, 2022 source Yahoo Finance
**Source: Crunchbase data
Work on the numbers (top down only on labor)

<table>
<thead>
<tr>
<th>Economic benefits</th>
<th>Financial Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Driver Cost %</strong></td>
<td><strong>$ bn</strong></td>
</tr>
<tr>
<td>Truck-load</td>
<td>40% 123</td>
</tr>
<tr>
<td>LTL</td>
<td>30% 21</td>
</tr>
<tr>
<td>Private</td>
<td>40% 123</td>
</tr>
<tr>
<td>E-commerce Parcel</td>
<td>20% 24</td>
</tr>
<tr>
<td><strong>Labor Cost Saving</strong></td>
<td><strong>$ bn</strong></td>
</tr>
<tr>
<td></td>
<td>290</td>
</tr>
</tbody>
</table>

Rough estimates of the economic and financial value based on the 2020 public data
Work on the numbers (bottom up)

### Assumptions

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Truck Rates</td>
<td>$/mile</td>
<td>2.5</td>
</tr>
<tr>
<td>2023 Truck miles</td>
<td>bn miles</td>
<td>200</td>
</tr>
<tr>
<td>2033 Truck miles</td>
<td>bn miles</td>
<td>300</td>
</tr>
<tr>
<td>2023 Trucking for Class-8</td>
<td>$bn</td>
<td>500</td>
</tr>
<tr>
<td>2033 Trucking for Class-8</td>
<td>$bn</td>
<td>750</td>
</tr>
</tbody>
</table>

### Cost Structure

<table>
<thead>
<tr>
<th></th>
<th>% of total</th>
<th>% for AV</th>
<th>Value</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor</td>
<td>42%</td>
<td>100%</td>
<td>210</td>
<td>315</td>
</tr>
<tr>
<td>Equipment</td>
<td>24%</td>
<td>50%</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>Fuel</td>
<td>24%</td>
<td>15%</td>
<td>18</td>
<td>27</td>
</tr>
<tr>
<td>Other costs (insurance, license, toll)</td>
<td>10%</td>
<td>25%</td>
<td>13</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>-</td>
<td>301</td>
<td>451</td>
</tr>
</tbody>
</table>
Ecosystem Challenges

4 Ecosystem Partners:
1. Autonomous driving companies
2. Truck OEMs
3. Shippers and Freight Companies
4. Tier-1 and Supply Chain

Challenges:
- Due to multiple interests, no one company can ‘do-it-all’, it requires partnerships upstream and downstream.
- It is also tricky for how AV companies position themselves to manage the intricacy of customer, partnership and competitor relationships with all.
- The ecosystem is not yet ready in many senses (tier 1 and OEM not ready for providing redundancy and reliable hardware). There are also conservatism within other ecosystem players to ‘wait and see’.
- The focus of ecosystem players will be placed on EV in the shorter term because they provide more ROI and certainty, compared to AV.
The market is segregated

- According to American Trucking Associations, there are 3.5 million truckers in the United States, and of those, 800,000 are owner operators.
- Unlike other sectors where the smaller customers adopt first, it is difficult to penetrate the smaller shops.
- Larger companies are the adopters - but they don’t own the market.
- Consolidation will happen with AV trucking.

Source: ATA, AllianceBernstein
The gating factors are beyond ‘autonomy’, that are ‘operational’

- Maintenance
- Brokerage
- Digitalization of the sector - Fleet Management
- Insurance
- Changing warehouse and peripheral infrastructure
- Rationing of tasks

Require ecosystem thinking
Conflicts at every level

AV trucking is a difficult challenge that needs infusion of all knowledge that are not originally compatible and require time for teams and different mindsets to work together.

How can we get the “silicon valley” and work with the “rust belts”

- Old vs New
- Hardware vs Software
- Technology vs Engineering
- Productivity vs Safety
- Agile vs waterfall
- Product vs Services
- Long term vs short term
3-5 more years?
The evolution... (if all goes well)
5. Policy Considerations and Challenges
Policy plays a role

1. Today’s technology is tomorrow’s infrastructure and public utility.
2. Strong policy leadership is needed to ensure that the benefits of innovation in the industry are shared broadly.
3. Cyber-physical systems need a strategic orchestrator and ecosystem facilitator.
### Key Regulators

<table>
<thead>
<tr>
<th>Federal</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. FMCSA - Federal Motor Carrier Safety Administration regulates commercial vehicles in interstate; setting qualifications and hours, etc.</td>
<td>2. State DOT enacts and enforces traffic laws and regulations, and insurances</td>
</tr>
<tr>
<td>3. FHWA - Federal Highway Administration oversees highways and national standards for traffic control</td>
<td></td>
</tr>
</tbody>
</table>
State regulations differ

Source: TuSimple Public Investor Presentation
Key Challenges

1. Transitioning
2. Hard to proof what is “good enough”
3. Uncertainty is built-in
4. Lack of standards
5. Public perceptions
6. Collaborations
7. Labor
1. Transition

Stage 1

Stage 2

Stage 3
2. Hard to proof what is “good enough”

How long should one have been driving on provisional licenses before they can drive on roads?

Table 1. Examples of Miles and Years Needed to Demonstrate Autonomous Vehicle Reliability

<table>
<thead>
<tr>
<th>Statistical Question</th>
<th>Benchmark Failure Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) without failure to demonstrate with 95% confidence that their failure rate is at most...</td>
<td>(A) 1.09 fatalities per 100 million miles?</td>
</tr>
<tr>
<td>(2) to demonstrate with 95% confidence their failure rate is within 20% of the true rate of...</td>
<td>275 million miles (12.5 years)</td>
</tr>
<tr>
<td>(3) to demonstrate with 95% confidence and 80% power that their failure rate is 20% better than the human driver failure rate of...</td>
<td>8.8 billion miles (400 years)</td>
</tr>
<tr>
<td></td>
<td>11 billion miles (500 years)</td>
</tr>
</tbody>
</table>

* We assess the time it would take to compare the feasible miles with a fleet of 100 autonomous vehicles (larger than any known existing fleet) driving 24 hours a day, 365 days a year, at an average speed of 25 miles per hour.

Source: Rand Corporation

Dedicated lanes, digital twin (simulation), collaborative mapping and testing will all help to accelerate the testing
3. Uncertainty is built-in

- AV’s view of the world grows steadily but is intrinsically incomplete
- Regulation and data-sharing can help in managing that residual uncertainty.
4. Lack of standards

- **ISO**: safety [as the] absence of unreasonable risk” and “risk [as the] combination of the probability of occurrence of harm and the severity of that harm
- **Koopman and Wagner, 2018**: For initial deployment, evaluation of what might constitute a ‘reasonable risk’ will be influenced by public policy decisions.
- But that line is very vague right now - because not only actual safety matters, perceived risks matter too. Reporting is also inconsistent making it vague. Contents of California’s mandatory disengagement reports show a lack of uniform reporting by developers
5. Public perceptions

- Unrealistic claims of near perfection on the part of AV boosters
- The utilitarian argument that AVs are expected to lower the annual numbers of deaths and injuries from car crashes substantially can be offset or even outweighed in popular perception by a single AV crash
- Similar to aviation
6. Collaborations

- Aviation safety is sometimes suggested as an arena for comparison as AVs evolve.
- The carriers in the aviation field have agreed to cooperate rather than compete on safety - aviation death hurts the whole industry.
- Government involvement is more accepted by industry.
7. Labor

FIGURE 2: Most likely automation scenario, absent policy intervention

Source: Driverless? Autonomous Trucks and the Future of the American Trucker - UC Berkeley Labor Center
## AV Driving 4.0 (skeleton guidelines)

**AV 4.0 | US Department of Transportation**

<table>
<thead>
<tr>
<th>Pillars</th>
<th>Principle #</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Protect Users and Communities</td>
<td>1. Prioritize safety&lt;br&gt;2. Emphasize security and cybersecurity&lt;br&gt;3. Ensure privacy and data security&lt;br&gt;4. Enhance mobility and accessibility</td>
</tr>
<tr>
<td>B. Facilitate and Coordinate Efforts</td>
<td>1. Protect American Innovation and creativity&lt;br&gt;2. Modernize regulations</td>
</tr>
<tr>
<td>C. Promote Efficient Markets</td>
<td>1. Promote consistent standards / policies&lt;br&gt;2. Ensure a consistent federal approach&lt;br&gt;3. Improve transportation system-level effects</td>
</tr>
</tbody>
</table>

**Source:** NTSB, DOT
6. My wider takes about innovation and policies
Infrastructure and industrial innovation policies

1. Do the **basics** - supportive, progressive and empirical
2. Take an **ecosystem view** - be strategic
3. **Build common infrastructure** to improve collaborations
Not all problems are technology

- You can develop the best AI to solve a difficult business problem.
- Or you can simplify the problem first then solve it with AI.
Take an ecosystem view - 1

VC (Autonomous Vehicle)  Industrial (Logistics) / Infrastructure (Roads)

Uncertain               Steady Cash Flow
High risks              Low risks
Take an ecosystem view - 2

Policies and ecosystem as a bridge

VC
Industrial / Infrastructure
Take an ecosystem view - 3

Autonomous Vehicles

Electric Vehicles

Connected Vehicles

Smart Cities

Digital Twin

= System of Systems
Build common infrastructure to improve collaborations

- Promote testing in a common environment
- Use of common scenarios
- Common testing code and procedure
- Common high-definition mapping and associated simulation
Low hanging fruits: funny road signs that are not funny to AV scientists

Can cost up to a million USD to solve this problem (or never, because AI can’t do common sense)
Thank you!
Sources and Useful Resources

- How Many Miles of Driving Would It Take to Demonstrate Autonomous Vehicle Reliability?
- Measuring Automated Vehicle Safety: Forging a Framework | RAND
- Driverless? Autonomous Trucks and the Future of the American Trucker - UC Berkeley Labor Center
- Heading to A Future with Driverless Freight Transportation
- 自动驾驶卡车，智周万物，量产在即
- 2021-2022中国自动驾驶产业年度总结报告
- Plus Investor Presentation (SEC)
- TuSimple Investor Presentation (SEC S-1)
- Embark Investor Presentation (SEC)