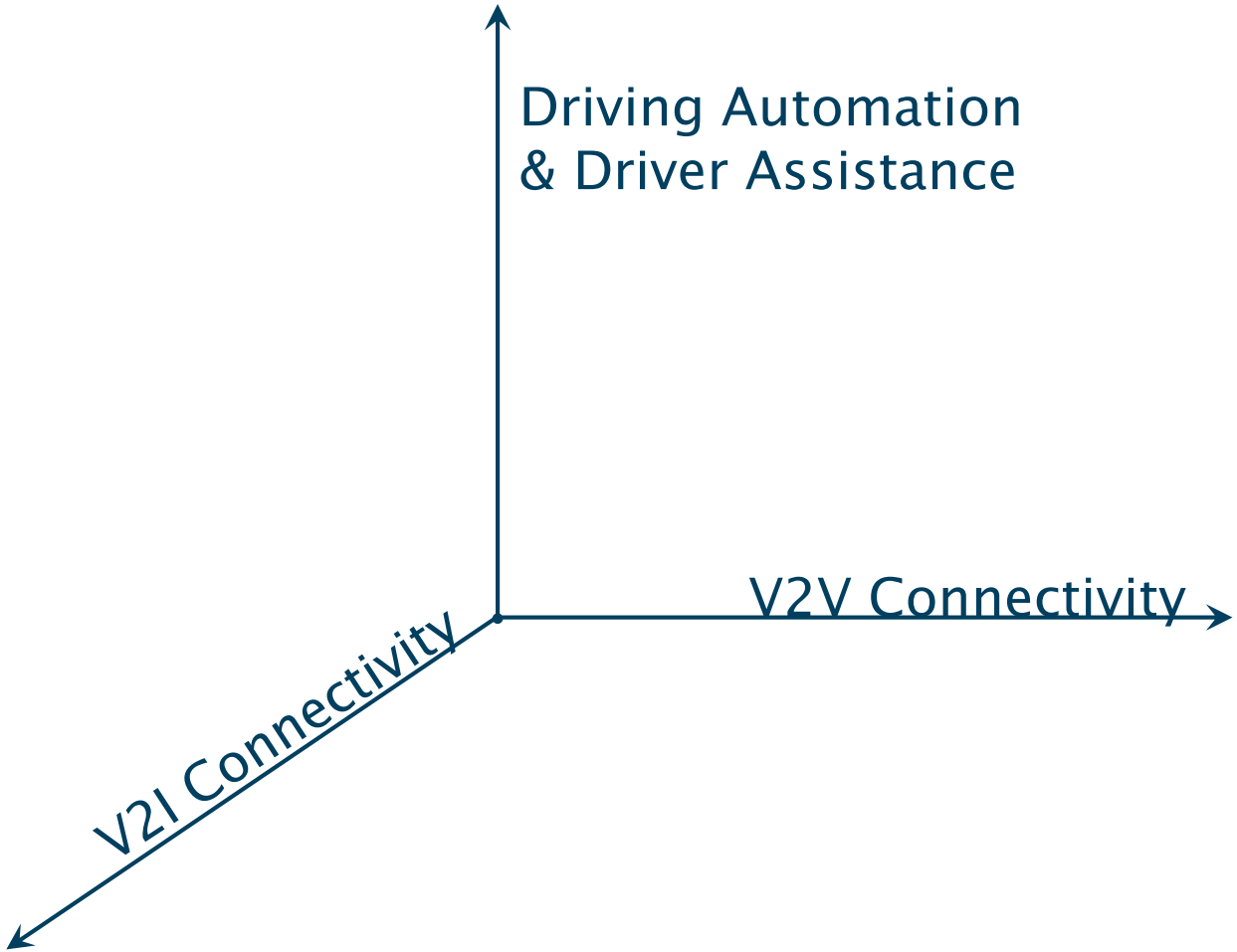
3 Dimensions of Connected & Automated Vehicles

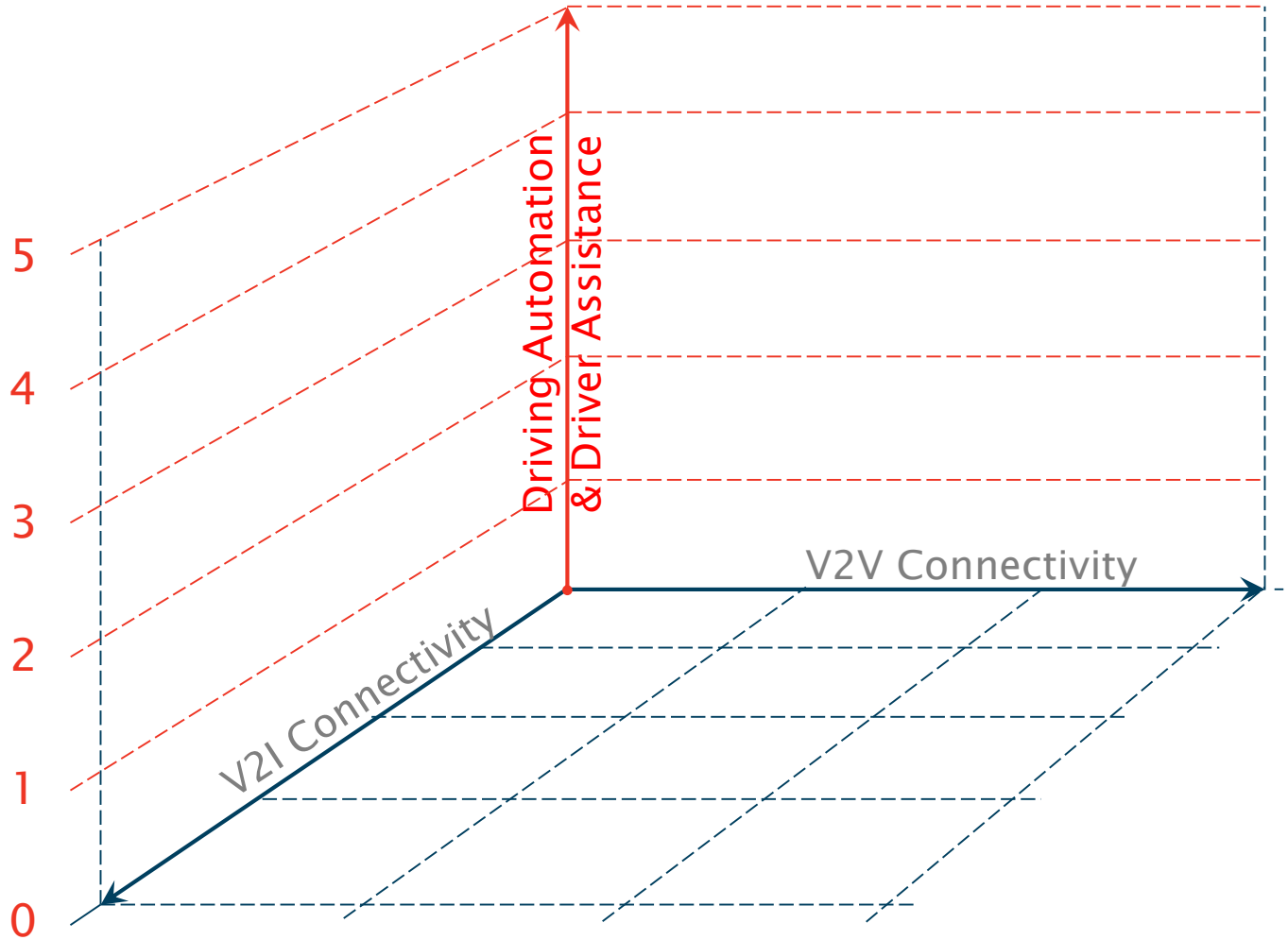
Ray Starr
Minnesota DOT
December 12, 2016
for
Regional Council of Mayors

We all have a stake in A B

3 Dimensions of CAV



Driving Automation & Driver Assistance



Level 5 Full Driving Automation

Photo Source: Wikipedia
Central Power & Light Co

- Car performs all driving tasks
- All environments

Level 4 High Driving Automation

Photo Source: NAVYA

- Car performs all driving tasks
- Limited environments

Level 3 Conditional Driving Automation

Photo Source: Wired.com
OTTO

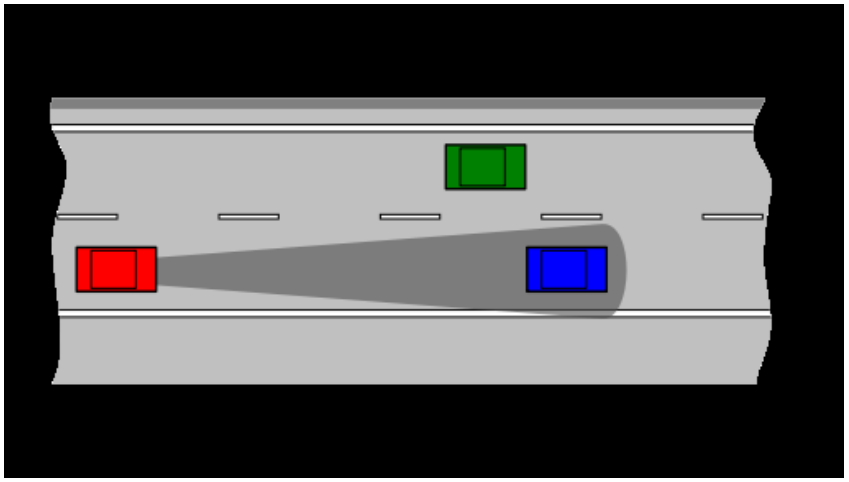
- Car performs all driving tasks under some environments
- Graceful transition to human driver when out of automated environment

Level 2 Partial Driving Automation

Photo Source: caranddriver.com

- Car controls longitudinal AND lateral movement
- Human must always monitor
- Possibly limited environments

Level 1 Driver Assistance



Schema_ICC.PNG: M.Minderhoud derivative work: Malyszkz – This file was derived from Schema ICC.PNG

- Car controls longitudinal OR lateral movement
- Human must always monitor
- Possibly limited environments

Level 0 No Driving Automation

- No sustained movement control
- Human must always monitor and control

Truck Platooning

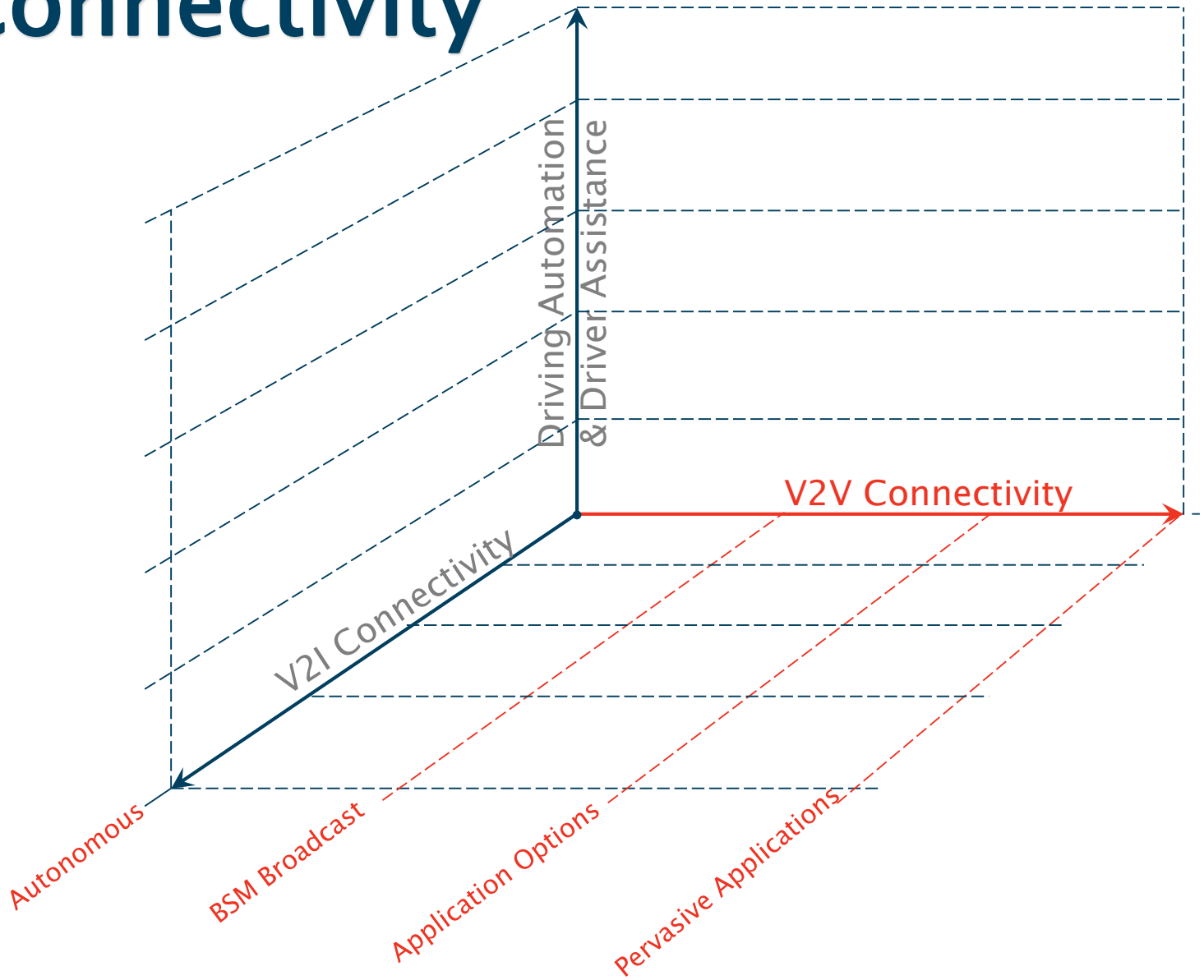
- Trucks automatically follow lead truck
- Short headways
- Reduces fuel usage, emissions and costs

Driving Automation & Driver Assistance

Transportation Agencies Should:

- Consider regulatory issues
- Consider impacts on signs, markings, other traffic control devices
- Consider impacts on 20 year plans

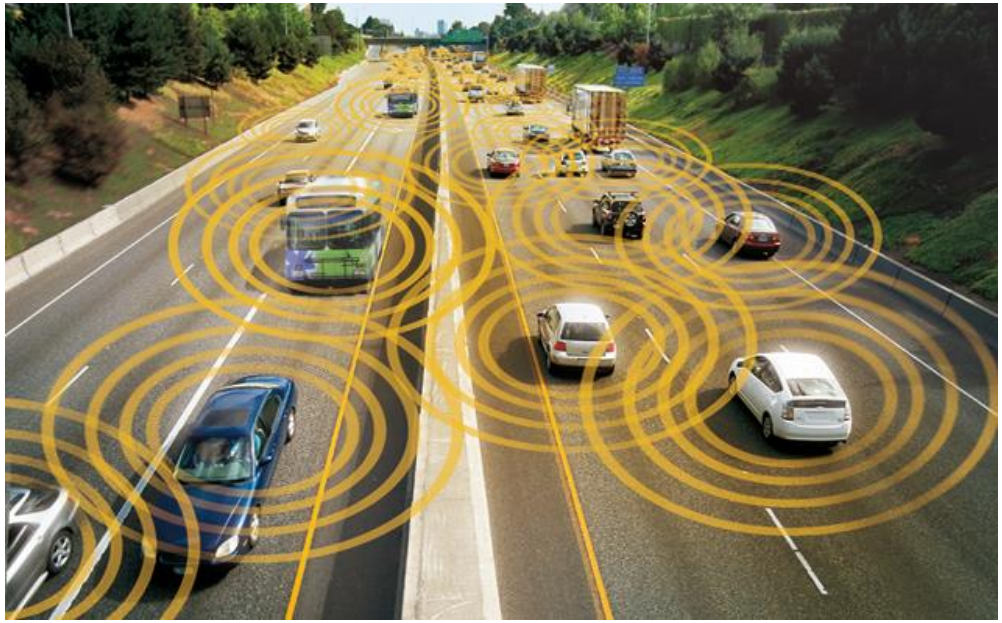
V2V Connectivity



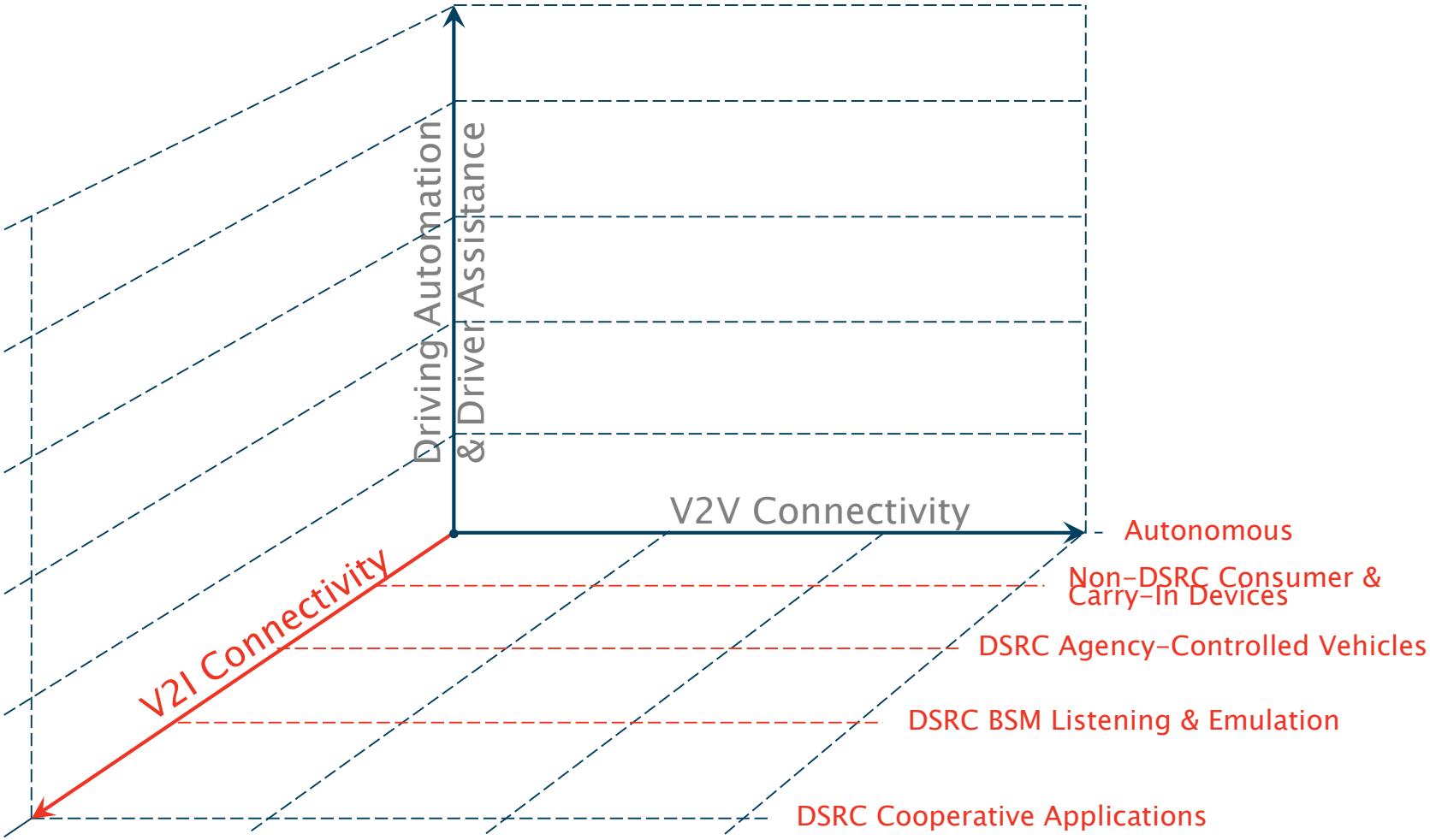
V2V Connectivity

Transportation Agencies Should:

- Stay informed



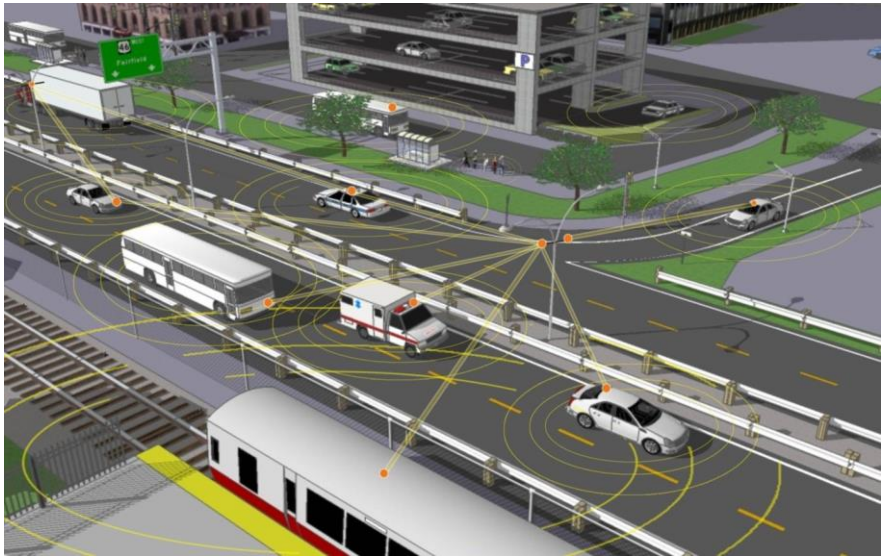
V2I Connectivity



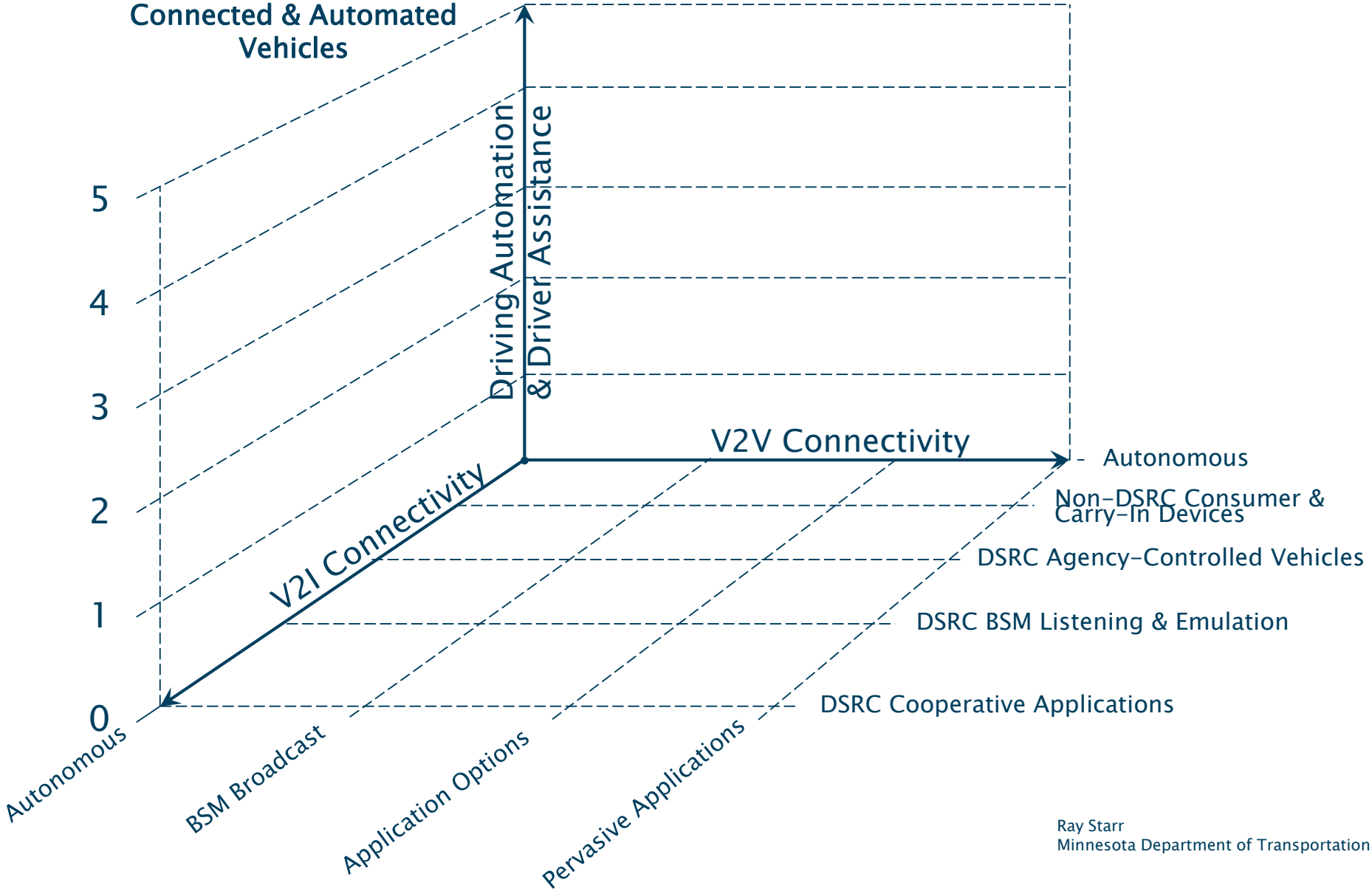
V2I Connectivity

Transportation Agencies Should:

- Work with vehicle manufacturers
- Use agency controlled vehicles
- Create business plan



Three Dimensions of Connected & Automated Vehicles



Ray Starr
Minnesota Department of Transportation

Connected Automation

Autonomous Vehicle

Operates in isolation from other vehicles using internal sensors

Connected Automated Vehicle

Leverages autonomous and connected vehicle capabilities

Connected Vehicle

Communicates with nearby vehicles and infrastructure

U.S. Department of Transportation
ITS Joint Program Office

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MinnesotaGO

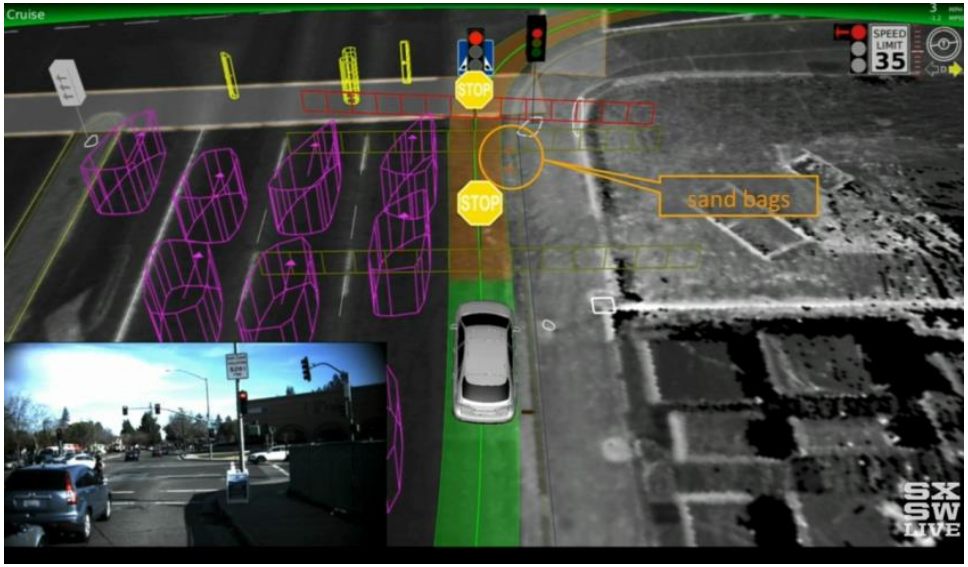
A Collaborative Vision for Transportation

Statewide Multimodal Transportation Plan

PLANNING FOR AUTONOMOUS VEHICLES

Safety

- Autonomous vehicles do not get distracted / tired
- Potential reduction in traffic fatalities/serious injuries by several orders of magnitude



Capacity

- Safe drivers leave 1 car length per 10 MPH between cars
- Autonomous systems react faster, thus reducing safe following distance
- Could see theoretical freeway lane capacity double

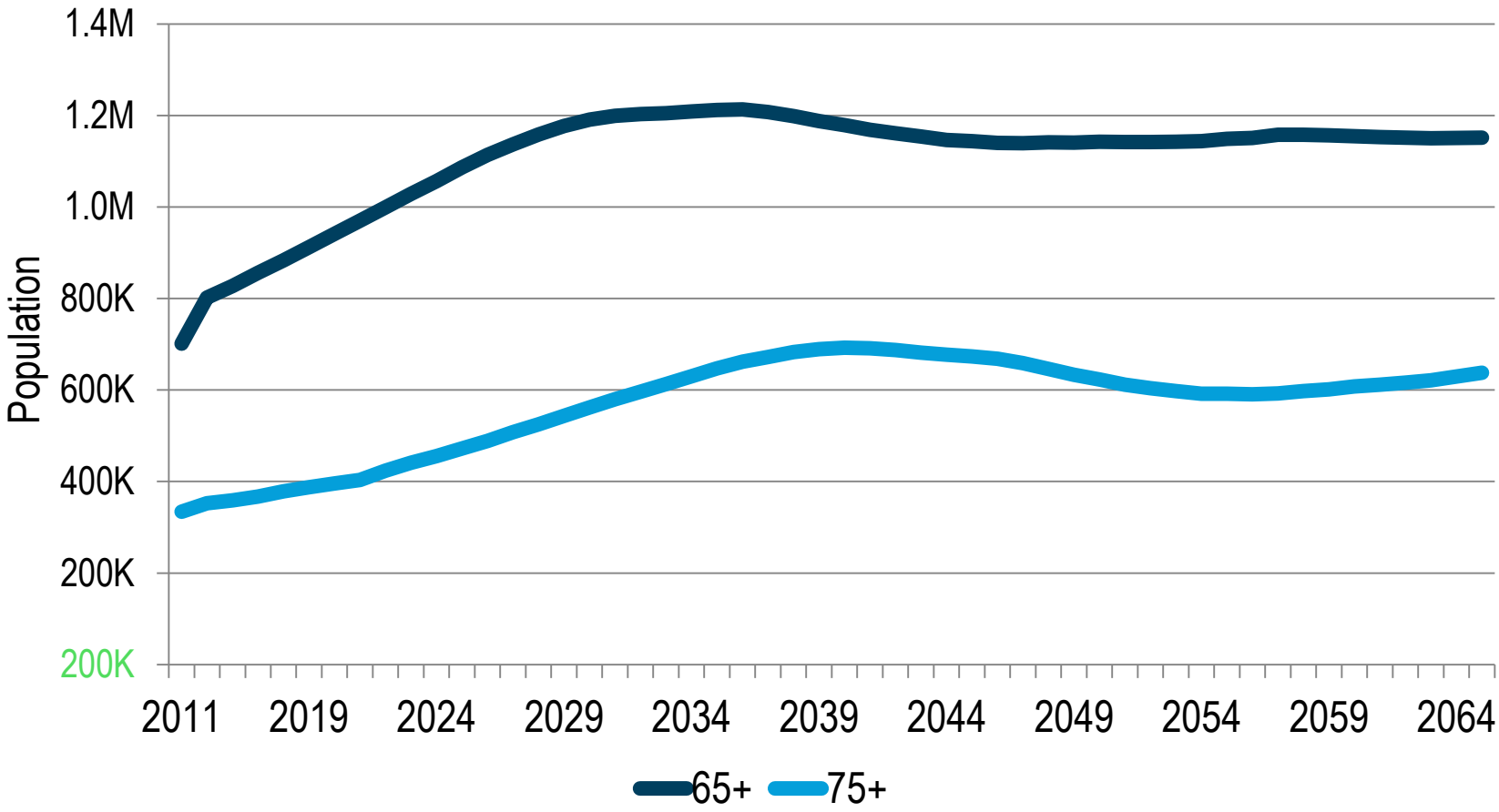
Routing

- People drive 20% less direct than optimal
- Connected vehicles & on-the-fly route updates

Mobility for All

- Convenience of driving for those who can’t/don’t want to drive

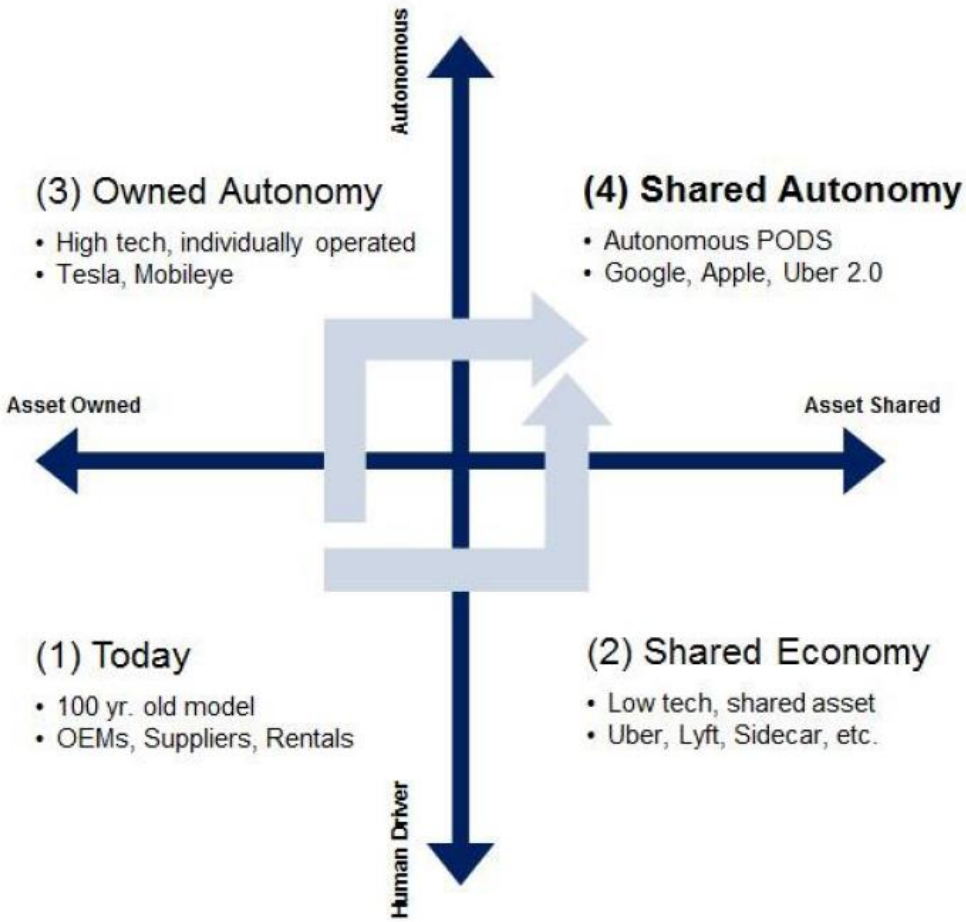
Minnesota's Senior Population



Mobility for People with Disabilities

- Huge potential, but <u>not</u> a given
- Many user-interface and vehicle design questions

Ownership



"Telling the story of this chart will occupy the remainder of my professional life."

- *Adam Jonas, Morgan Stanley auto analyst*

Parking

- Potential changes in parking demands largely driven by ownership models
  - Owned autonomy will likely not reduce parking dramatically
  - Shared autonomy could lead to massive reduction in required parking
    - Potential new requirement: loading/un-loading zones
    - Design new parking structures with other uses in mind

Transportation Cost

- Owned vehicle costs likely to increase in short term
- Operational costs likely lower
- Potential savings related to ownership
  - Shared autonomy would save money for people who travel <u>less</u>
  - Safety benefits may lower insurance rates
- Car2Go experience raises equity concerns

Residential Preferences

- "Up" and "Out" patterns of development
  - Movement into cities, drawn by amenities
    - More likely with greater vehicle sharing
  - Movement away from cities, due to ease of long-distance travel
    - More likely with owned autonomy

Congestion???

- Despite crash reductions, increased lane capacity and more direct routing, congestion impact remains uncertain
  - Increased willingness to travel longer distances
  - Empty vehicles
  - Not the only trend affecting peak period travel patterns

Thinking beyond the car

Autonomous trucks & truck platooning

"Ground drones"

Transit

- May be adopted by or replace para-transit/dial-a-ride
- Could displace low-ridership routes, but…
- Autonomous vehicles will <u>not</u> eliminate transit need

Level of Confidence

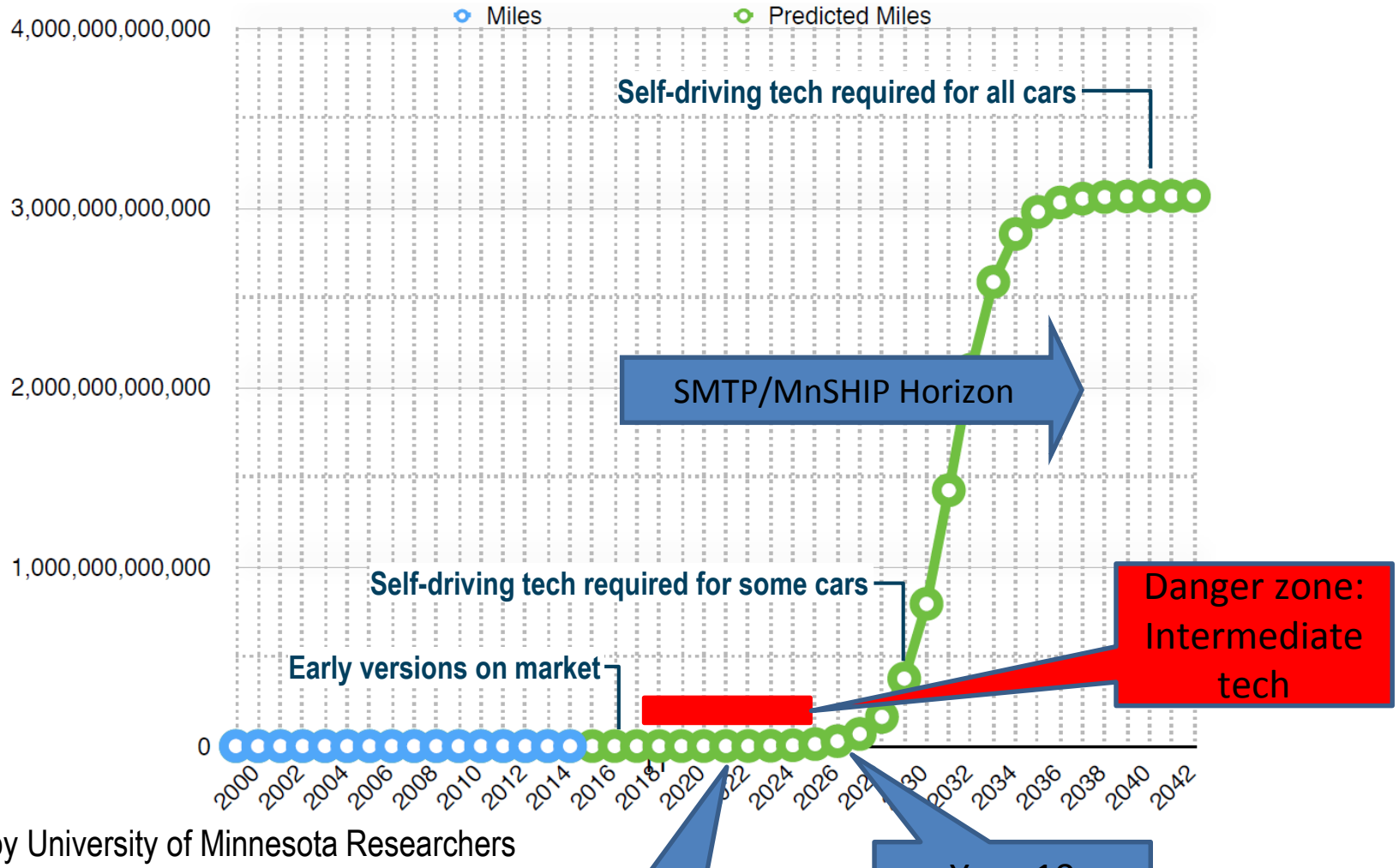
Change	Conf.	Description
Safety	High	One of the most highly touted benefits of AVs
Lane Capacity	High	Shorter following distances likely increase capacity
Parking	Med	"Mobility as a Service" model may significantly reduce parking need
Road Design	Med	"Our philosophy has always been, it has to work with the existing infrastructure" – Chris Urmson, Google
Mobility for people with disabilities	Med	Likely significant improvement in service, but not a given and may not work well for all types of disability
Congestion	Low	Despite likely reduction in crashes and increased throughput, we could see dramatic increase in VMT
Timeline	Low	Exact timeline for adoption remains unclear – "inflection point" likely mid-to-late 2020s.
Vehicle Ownership	Low	Uber/Lyft vs. Tesla Models – likely some combination of both
Residential Preference	Low	Vehicle ownership model will likely have large impact on where people will choose to live – **both** "Up" and "Out" scenarios plausible


CAUTION
TRANSITION
AHEAD

Experience with Airline Industry Raises Human Factors Concerns for levels 2 & 3

First generation may not handle WINTER well

Autonomous Vehicle Adoption



*forecast by University of Minnesota Researchers

When should we design for AVs?

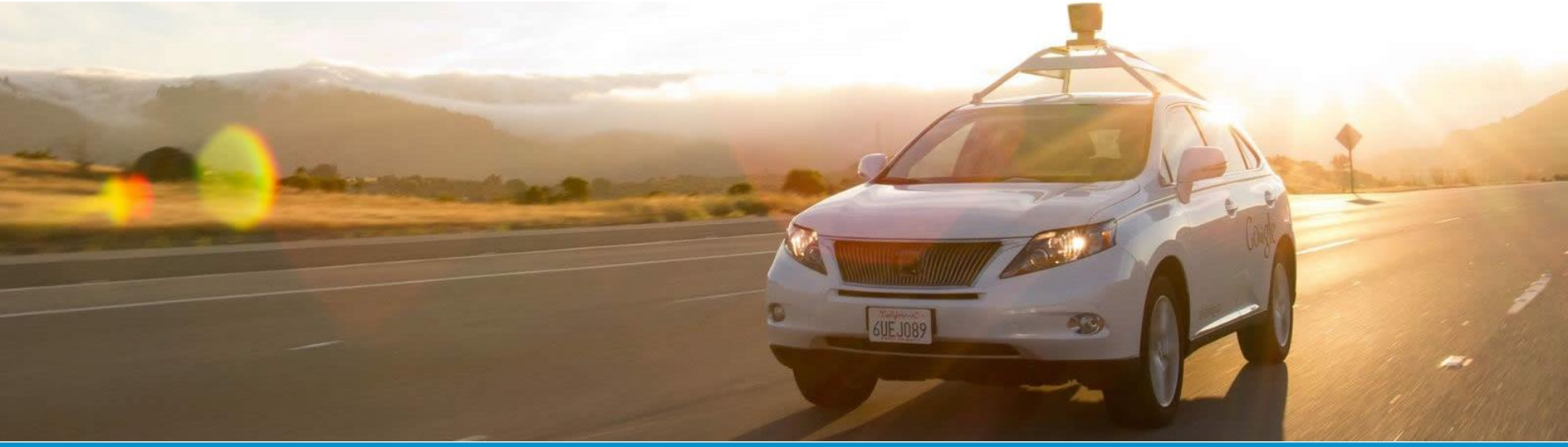
- Every bridge we build today will have AVs use it

  …but there will be many non-AVs too

- And we don’t know exactly when the majority of vehicles will be AV nor exactly how they will function in the real world

Current Approach

- Study and pursue targeted pilot projects
- Wait until 3-5% of on-road vehicles are Level 3+ AV before adjusting road design
- Continue flexible and performance-based design efforts



MinnesotaGO
A Collaborative Vision for Transportation

Statewide Multimodal Transportation Plan

Contact Information

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Self Driving Vehicles

Frank Douma

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OF PUBLIC AFFAIRS
UNIVERSITY OF MINNESOTA

LEGAL AND INSURANCE ISSUES

Self-Driving Cars are Probably Legal . . . .

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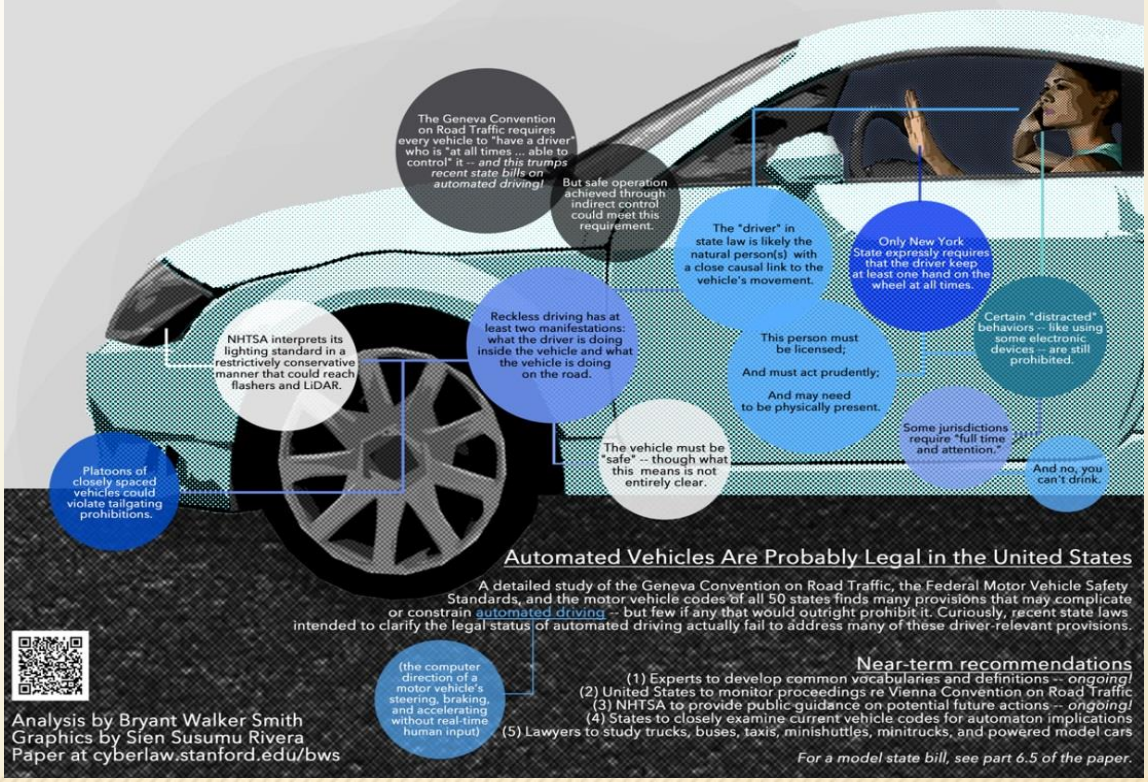
UNIVERSITY OF MINNESOTA

Bryant Walker Smith, *Automated Vehicles are Probably Legal in the United States*

Not explicitly prohibited equals *probably* permitted



Self-Driving Cars are Probably Legal . . . .

National Traffic and Motor Vehicle Safety Act (1966)

- Creates NHTSA
- Authorizes Motor Vehicle Safety Standards

Feb. 4, 2016 letter to Google

- NHTSA equates "self-driving System" to Driver

Federal Automated Vehicle Policy (9/20/2016)

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- Vehicle Performance Guidance for Automated Vehicles
  - 15 point Safety Assessment
- Model State Policy
  - Clear distinction between Federal and State responsibilities for regulation
- Current Regulatory Tools
  - Outline Current regulations that can be used to safe development.
- Modern Regulatory Tools
  - Identify potential new regulatory tools that may aid the deployment

U.S. Department of Transportation

NHTSA

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Self-Driving Cars are Probably Legal . . . .

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- States with laws allowing testing:
  - Nevada, California, Florida and Michigan (also District of Columbia)
- Complications in CA
  - Regs prohibit Level 5 vehicles
- Complications in MI
  - Law as passed prohibited

  Except for testing
  - Required new legislation

  In 2016

Self-Driving Cars are Probably Legal . . . .

- States where testing is occurring without legislation
  - Texas
  - Pennsylvania
  - Arizona
  - New Jersey
  - Washington
  - . . .

Self-Driving Cars are Probably Legal . . . .

- Trucks are operating without Legislation too
  - Colorado, I-25, October 2016
  - Ohio, Route 33, November 2016

http://www.sfgate.com/business/article/Otto-driverless-truck-delivers-beer-in-Colorado-10303218.php

SO WHAT IF SOMETHING DOES GO WRONG?

For example, at levels 1 – 3, (or 4?)

“Danger Zone” . . .

Current "Products Liability"

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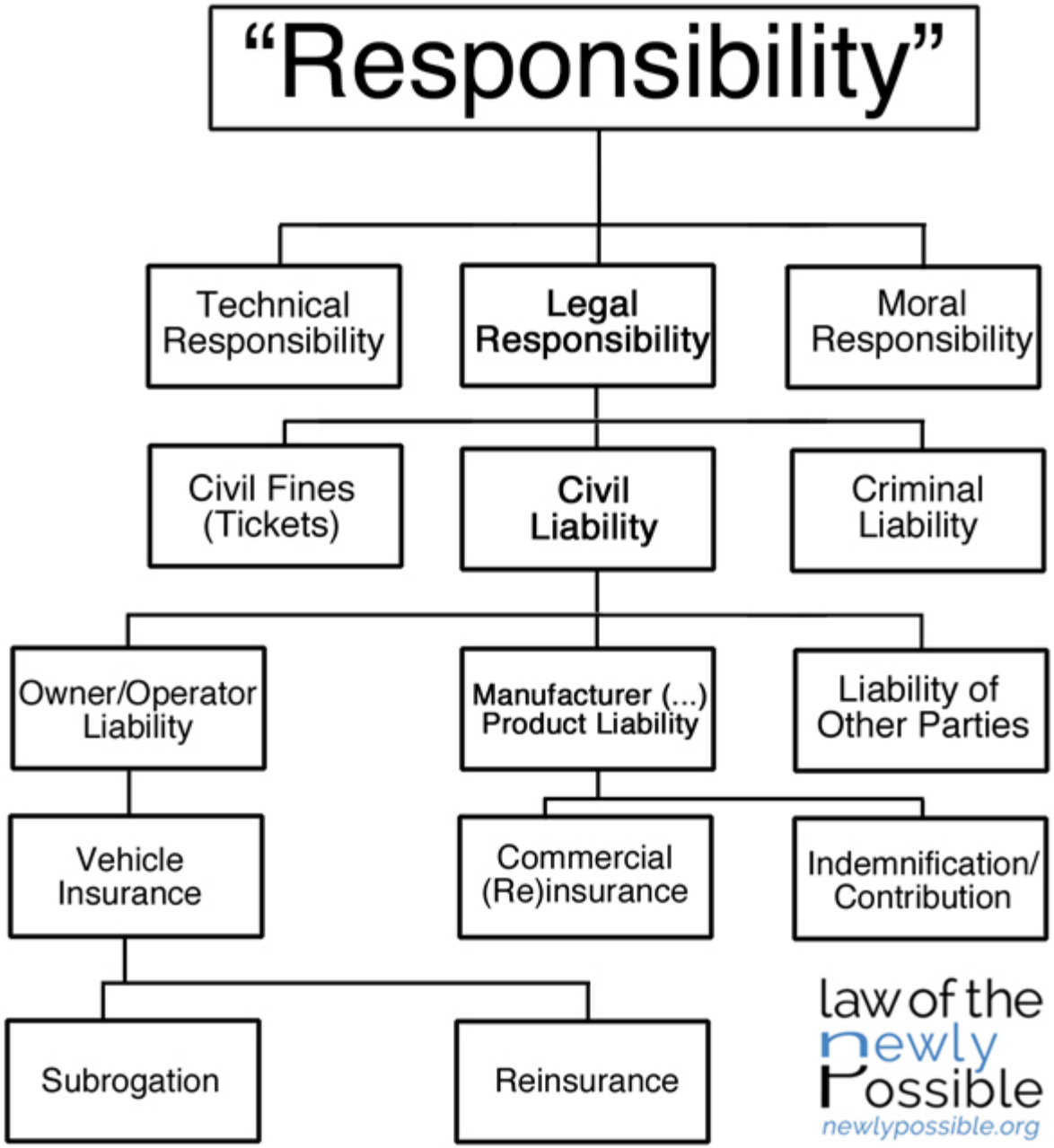
- If Caused Only by Defect in Manufacture, Design, Warning, Instructions—The OEM and Others in the Chain.
- Move OEMs from Current 2% responsibility to 80%-100% responsibility?
  - Defect in Manufacturer—Does not Meet OEM's Design Specs.
  - Warnings and Instructions—Absence of Warning, Over Promotion, Ineffective Manuals.
  - Duty to Update
  - Foreseeable Use/Misuse—Tesla Backseat Drivers!
- BUT . . . Google, Mercedes, Volvo already on the record as accepting all liability



law of the newly possible
newlypossible.org

http://cyberlaw.stanford.edu/blog/2015/05/tesla-and-liability

One more thought . . .

"Mobility for All"

- Americans with Disabilities Act
- Olmstead Plan
  - People with disabilities will have access to reliable, cost-effective, and accessible transportation choices that support the essential elements of life such as employment, housing, education, and social connections. They will have increased access to transit options and transportation modes.
  - 50% increase in Greater MN Transit trips by 2025 (Goal 2)
  - Expand transit coverage so that 90% of the public transportation service areas in Minnesota meet minimum service guidelines for access by 2020 (Goal 3)
- Legal Requirement to Allow Automated Vehicles???

- A couple additional sources . . . .

- Smith, Bryant Walker, "Automated Vehicles Are Probably Legal in the United States" 1 Tex. A&M L. Rev. 411 (2014), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2303904

- Riehl, Damien, "Car Minus Driver: Autonomous Vehicle Regulation, Liability and Policy, Part II" *Bench and Bar of Minnesota* November 2016

- Any thoughts or questions?

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- Kory Andersen
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MN

Electric Vehicles and Cities

Regional Council of Mayors Meeting

Monday, December 12, 2016

Arrival of the “mass market” EV

Chevy Bolt EV

- 238 miles of range per charge
- Starting at $37,495 ($29,995 after federal tax credit)
- Currently under production at Orion Assembly Plant in Michigan

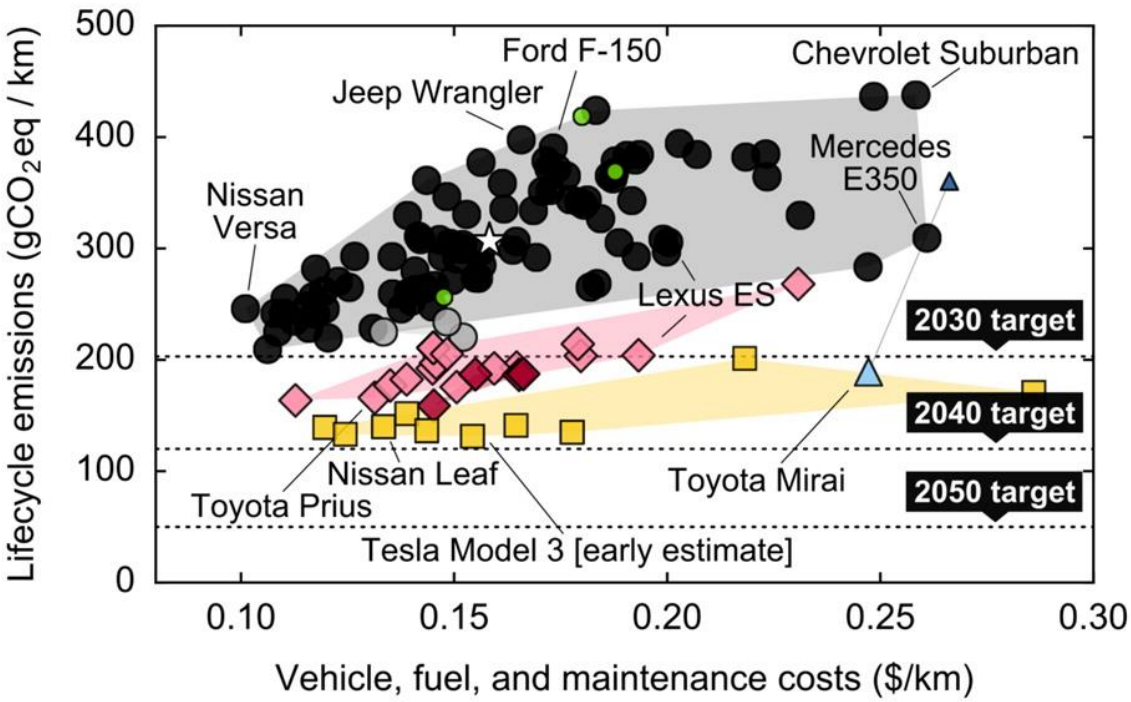
Tesla Model 3

- 215 miles of range per charge
- Starting at $35,000 ($27,500 after federal tax credit)
- Starting production in mid-2017
- 325,000 pre-orders in one week, over 400,000 total pre-orders

Rapid growth projected in EV market

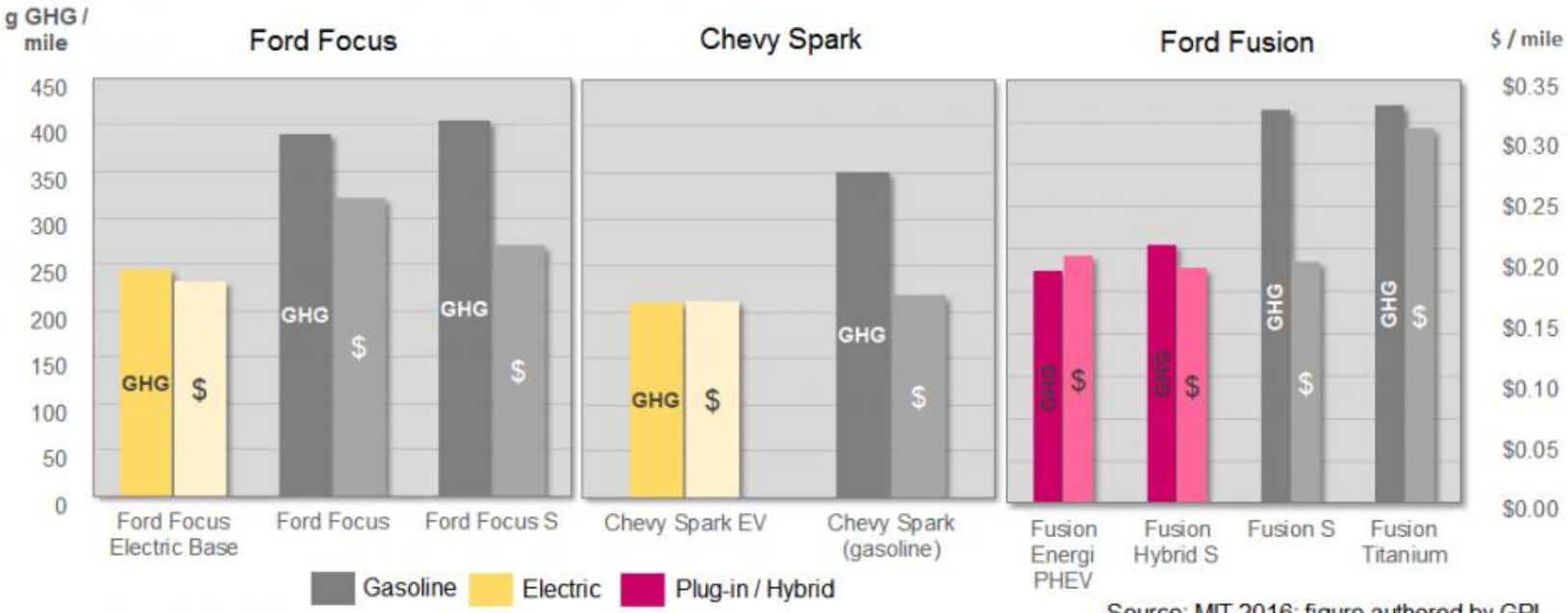
- EVs to be 35% of global new car sales by 2040.
- During 2020s, EVs will be a more economic option than gasoline cars, *without a tax credit.*
- Lithium-ion battery costs dropped 64% since 2010, falling further in the future.
  - Bloomberg New Energy Finance

EVs are *already* the cheapest and cleanest



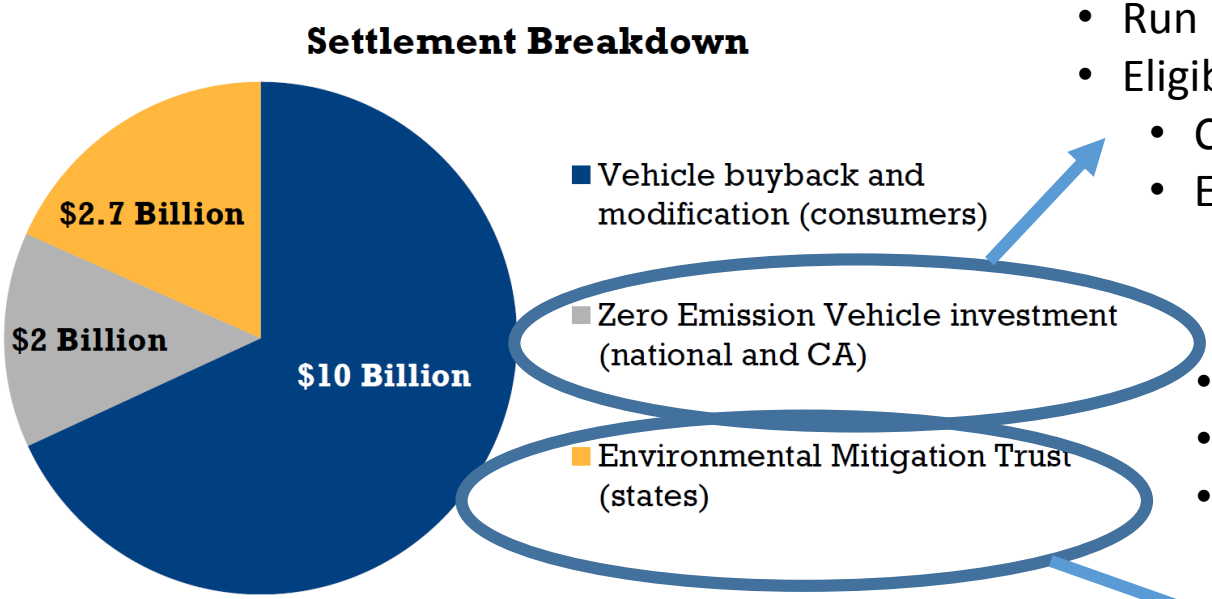
- Out of 125 vehicle models on the road today, plug-in hybrid and battery electric vehicles are most often cheaper than their fossil fuel counterparts *over the lifetime of the automobile.* They also offer the lowest GHG emissions.
  - MIT

EVs are *already* the cheapest and cleanest



Source: MIT 2016; figure authored by GPI.

Volkswagen settlement – opportunity for progress in MN



- $2 billion for U.S.
- Run by VW
- Eligible activities:
  - Charging stations
  - Education and outreach

- $43 million for MN
- Run by MPCA
- Eligible activities:
  - Charging stations
  - EV vehicles (transit buses, school buses, trucks, shuttle buses, etc)

EVs and Cities – fleet vehicles

MN Dept of Admin Committment:

- Acquire 25 PEV/ZEVs in 2017
- Install 15 level 2 charging stations in FY 2017
- Require all new vehicles to have EPA ratings of 7 or higher
- Achieve a fleet composition of 20% PEV or ZEV by 2027

POSSIBLE ROLE FOR CITIES:

- Collaborate w/ MN Dept of Admin on joint discount “bulk buy”.
- Adopt similar fleet commitments
- Be part of a State of MN “Zero Emission Fleet Challenge”

EVs Cities – Other Vehicles

Volkswagen Settlement can help support adoption of electric vehicles in various categories:

- Replace **Class 8 truck** with EV truck
- Replace **Class 4-7 Medium truck** with EV truck
- Replace **Class 4-8 School Bus, Shuttle Bus, or Transit Bus** with EV bus
- Other categories:
  - Freight switchers
  - Ferries/tugs
  - Ocean going vessel shorepower
  - Airport ground support equipment
  - Forklifts
- Minnesota has $43 million to support these activities, available over 10 years.

EVs and Cities – Charging Infrastructure

- Volkswagen settlement can support installation of Light Duty Vehicle charging equipment (up to 15% of $43,000,000 allocated to MN)
  - They want to see evidence that chargers will be used (combine charging strategy w/ EV adoption strategy)
- Does your city have an EV Charging Plan?
  - Workplace charging
  - Multi-family buildings
  - Public charging
  - City-owned facilities
  - DC Fast Charger Corridors

EVs and Cities - Building codes

- Create “EV Ready” Multi-family, Workplace, Business.
- Inexpensive to add conduit up front to parking ramps and parking lots, very expensive to retrofit.

EVs and Cities – Outreach and Education

Possible activities:

- Ride-and-drive events
- EV displays at city festivals

EVs and Autonomous Vehicles

- If autonomous vehicles are EV:
  - They will have lower lifecycle emissions and zero tailpipe emissions, enhancing the impact
  - They will help justify investments in EV charging infrastructure through greater utilization.
  - They will increase deployment and manufacturing of EV batteries, resulting in continued cost decreases.
  - EVs are higher upfront-cost, lower lifecycle cost – the more you drive, the cheaper they are. Clear advantage for shared AV fleets.

Shared Autonomous Vehicles and Land Use

Thomas Fisher
Minnesota Design Center
University of Minnesota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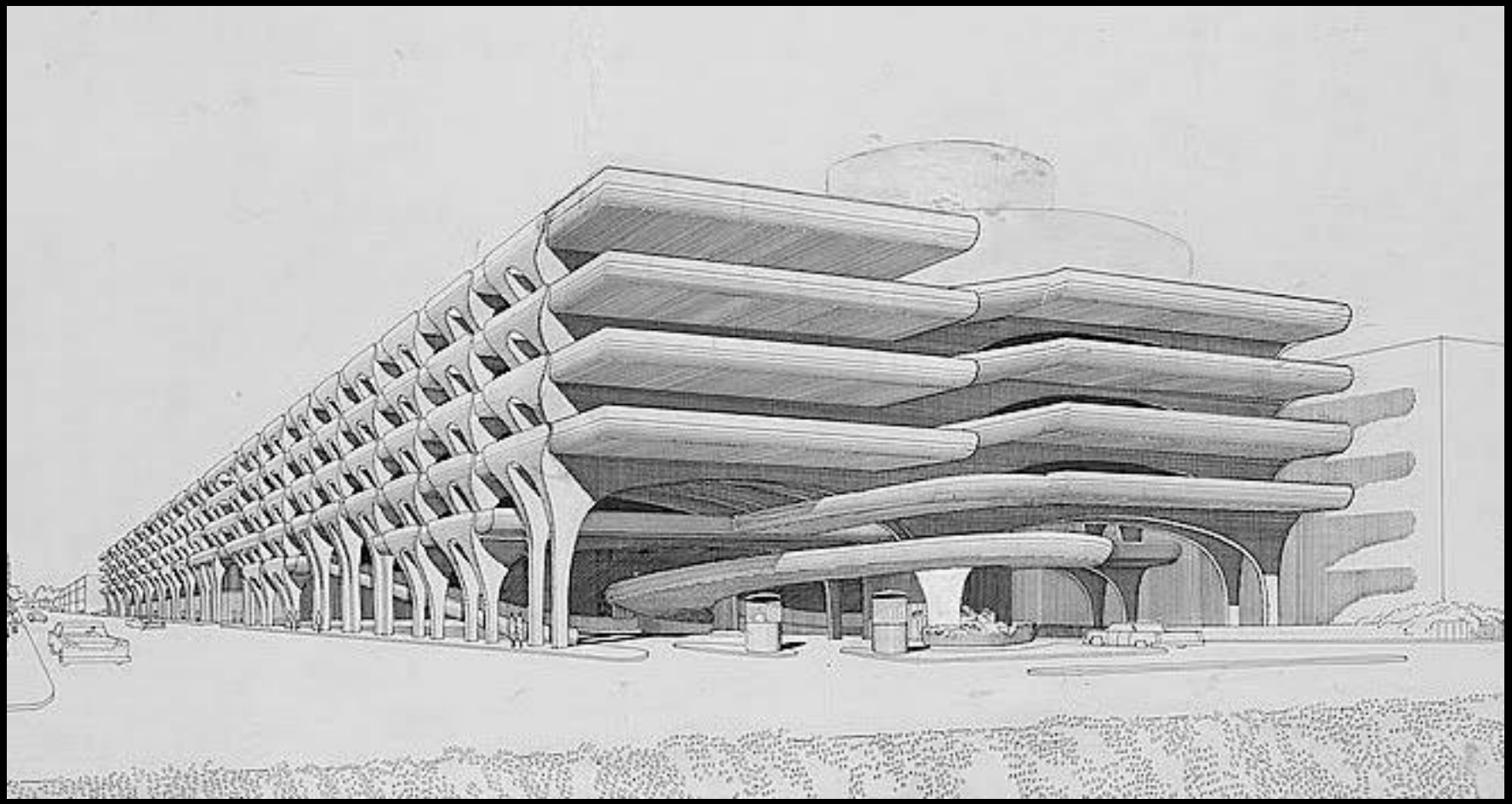
Parking



Phase 1: 2018-2025

Garage adapts to autonomous vehicles.

Today, the typical car is used only 5% of the time.

(95% of the time it is parked in a garage, at a house, or on the street.)

However, by the time today's garages are built, self-parking cars and shared fleets will likely be a reality.

Driverless vehicle storage is packed in hyper-efficient rows on the top level.
Garages designed for autonomous or self-parking vehicles can substantially increase their efficiency and use **60% less space.**

Floor-to-floor heights are designed to accommodate future uses such as residential or office.

Conventional parking on lower levels for increased accessibility.

By 2025, fully autonomous cars are expected to be available to the general public for an additional $10,00.

Source: Boston Consulting Group

ARROWSTREET

Phase 2: 2025-2035

Building adapts to fully autonomous vehicles and new uses.

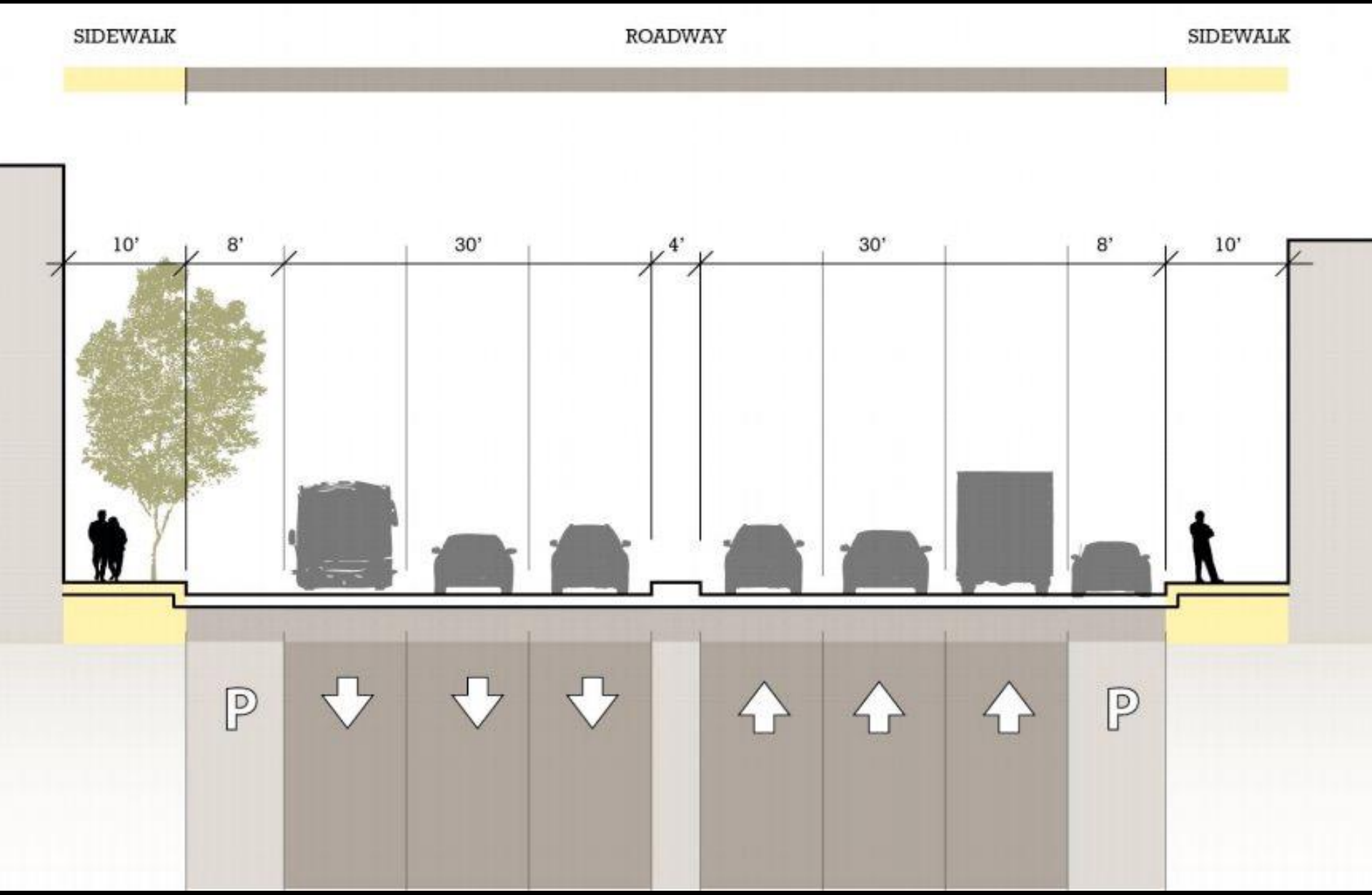
As car ownership evolves to a subscription service with intelligent fleets, there will be less need for parking.

Garages are transformed into other uses, such as offices, residential, and hotels.

In 2035, the need for parking is estimated to decline by more than 5.7 billion square meters in the United States.

(This equates to half the size of Connecticut) Source: The McKinsey & Co.

Streets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ROADWAY
SIDEWALK
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30'
4'
30'
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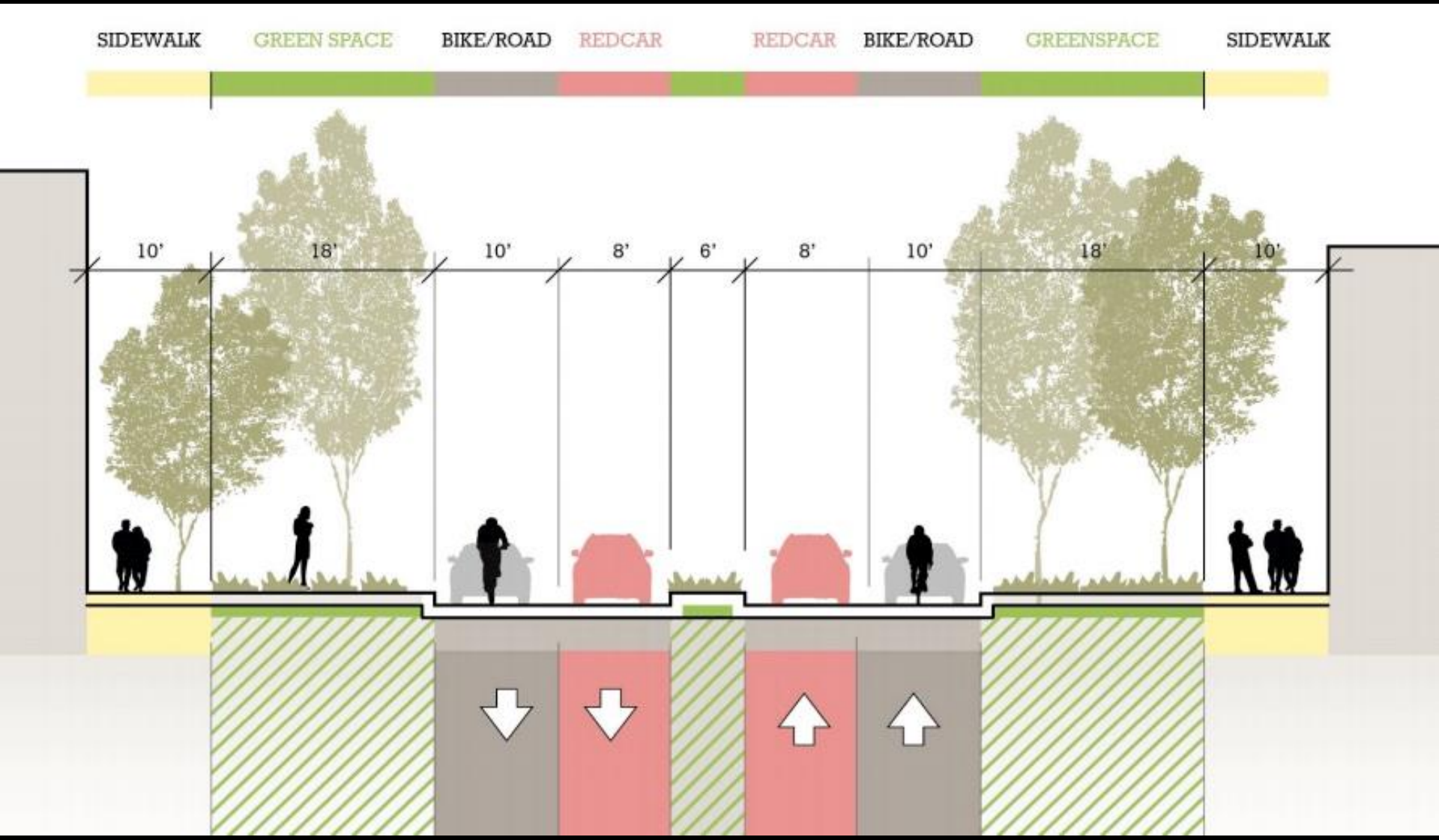
SIDEWALK
GREEN SPACE
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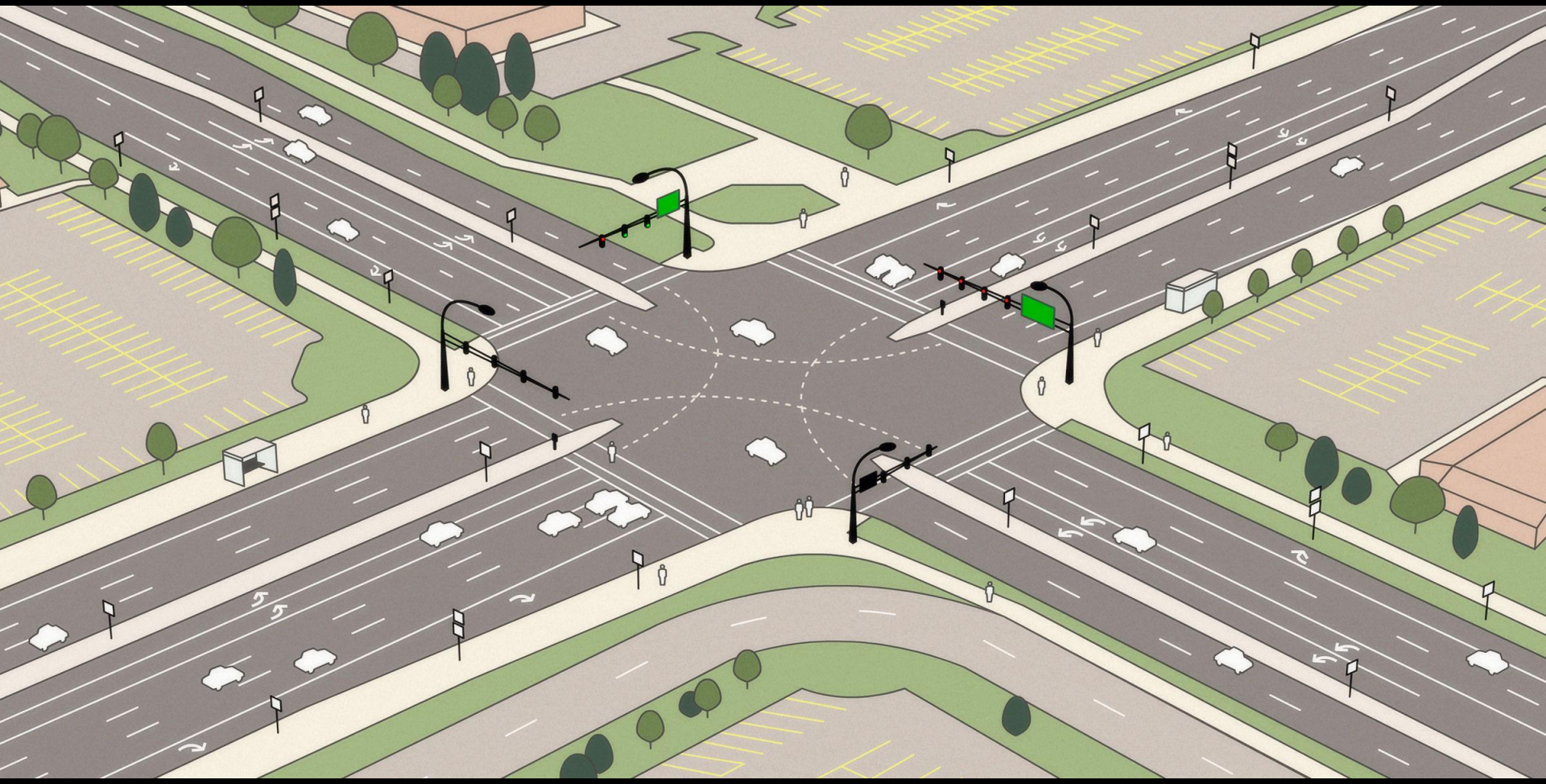
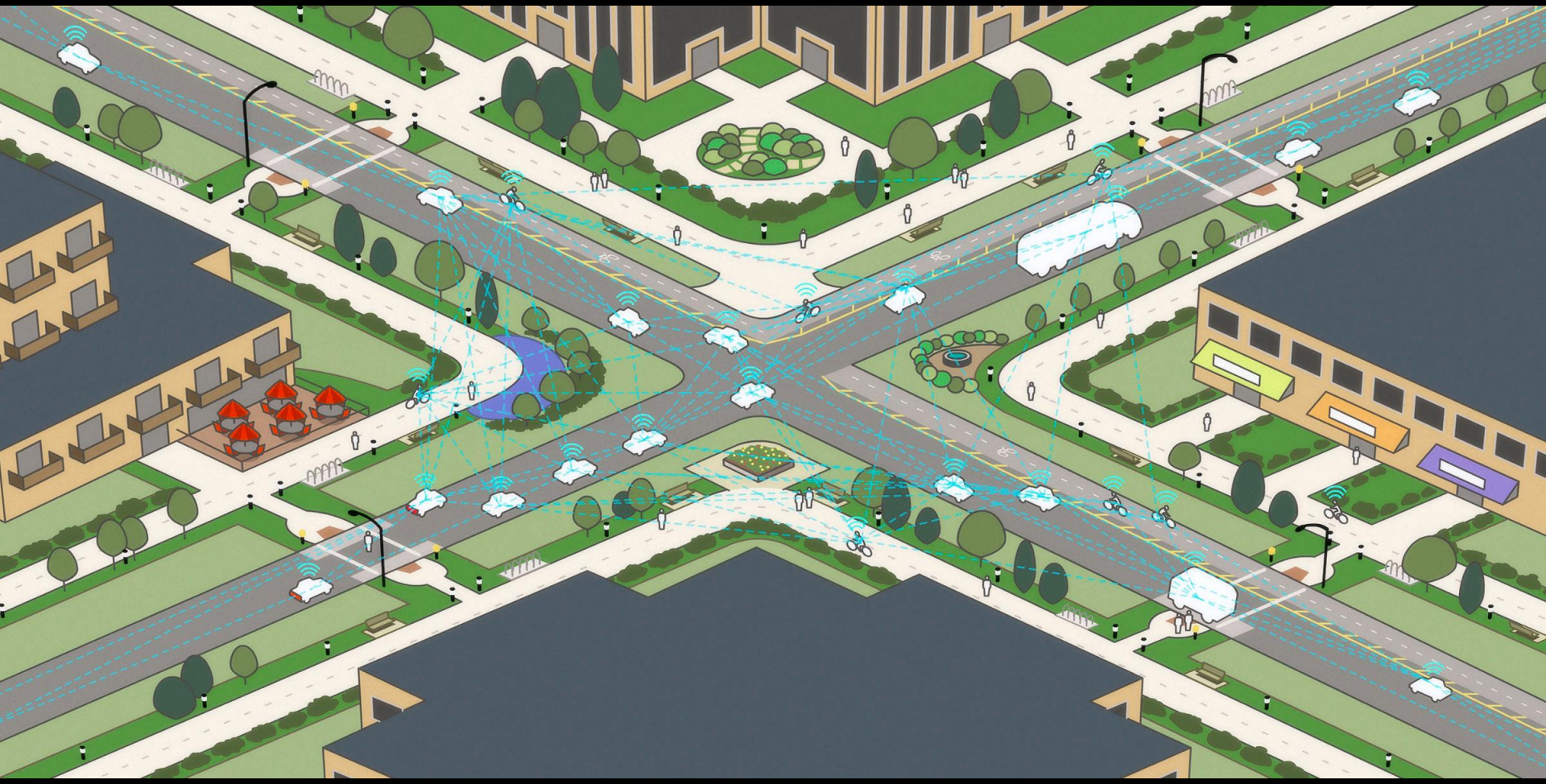
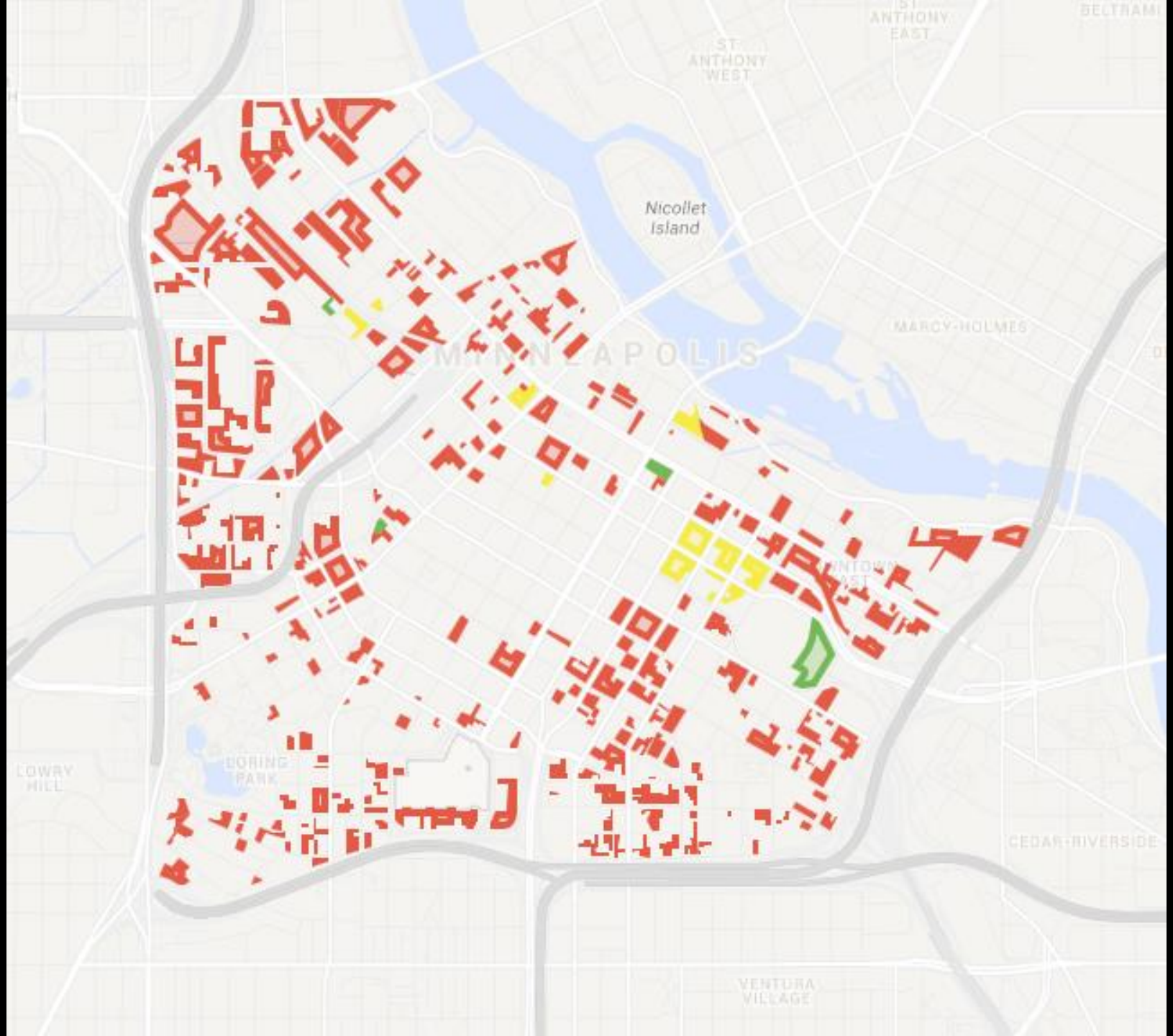




Land Use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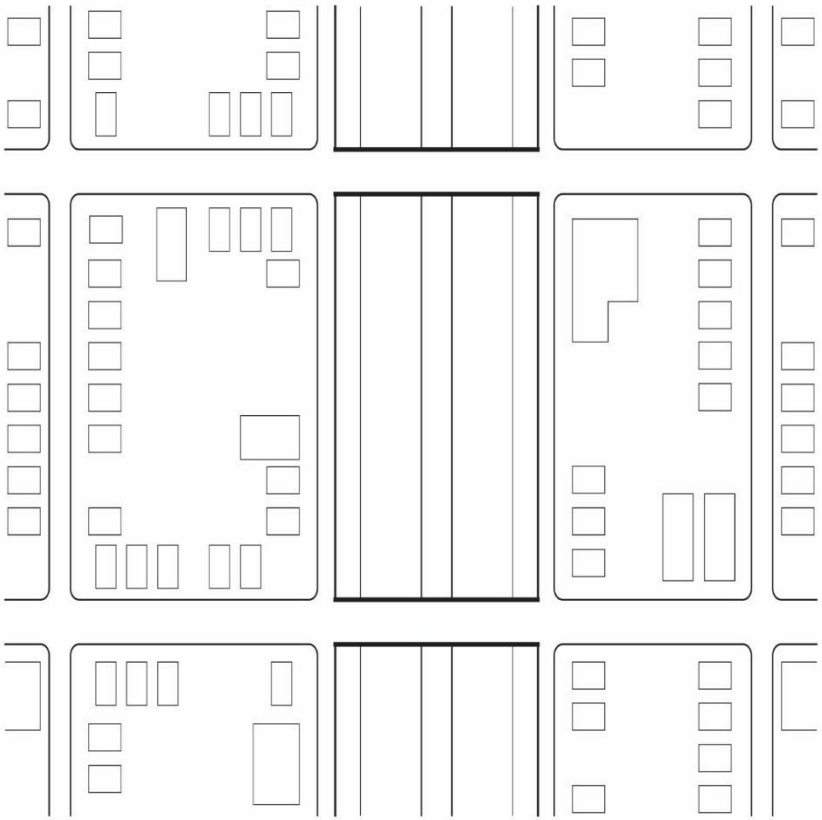
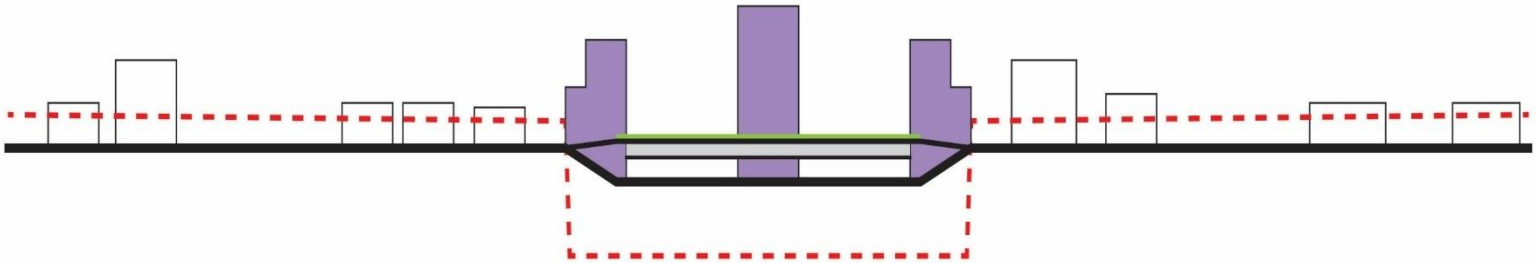
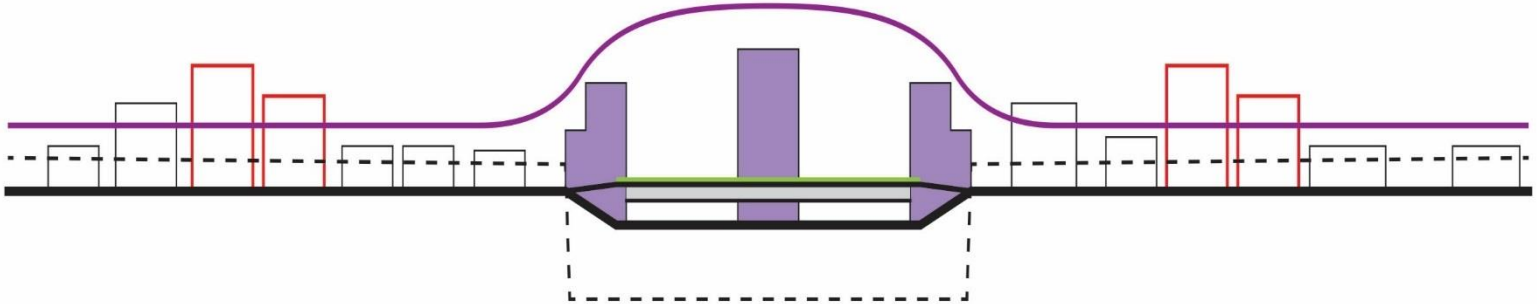
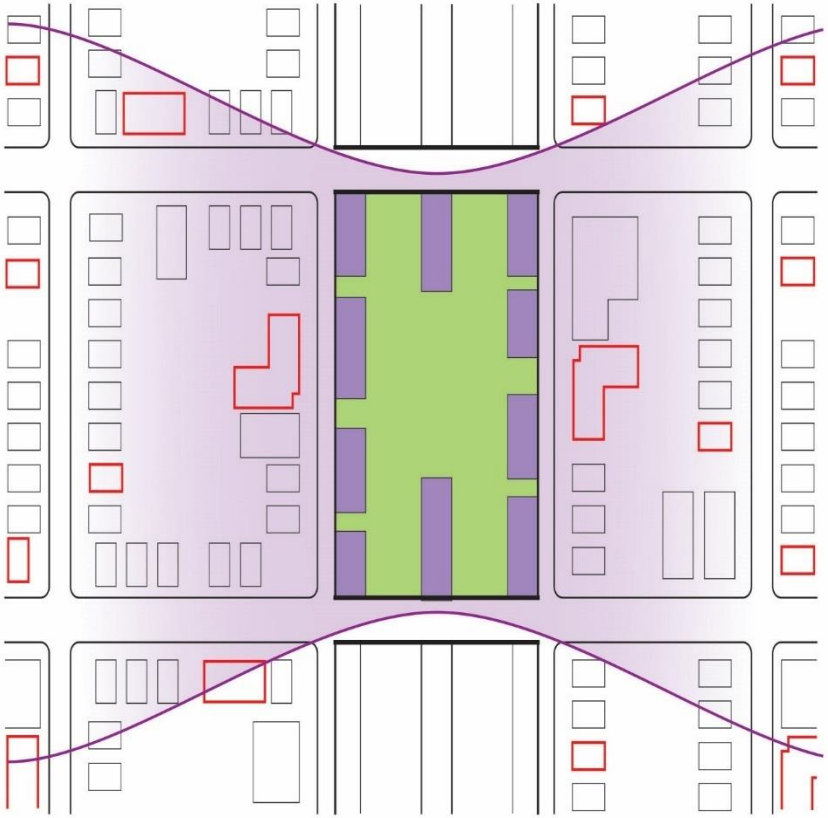
MINNEAPOLIS
DOWNTOWN EAST
LOWRY HILL
LORING PARK
CEDAR-RIVERSIDE
VENTURA VILLAGE







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Nicollet Ave
1st Ave


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