Preparing Future Workforce for Electrical Infrastructure Deployment

DAVID A. NOYCE
ANDREA R. BILL

FINAL REPORT

Center for Transportation Equity, Decisions & Dollars

PREPARING FUTURE WORKFORCE FOR ELECTRICAL INFRASTRUCTURE DEPLOYMENT

FINAL PROJECT REPORT

By:

DAVID A. NOYCE
ANDREA R. BILL
UNIVERSITY OF WISCONSIN-MADISON

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For:
Center for Transportation, Equity, Decisions and Dollars **(CTEDD)**
USDOT University Transportation Center
The University of Texas at Arlington
Woolf Hall, Suite 325
Arlington TX 76019 United States
Phone: 817-272-5138 | Email: c-tedd@uta.edu

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16. Abstract With the proliferation of electric vehicles, the future work force needs to be trained in the interdisciplinary nature of transportation. This is a breadth, survey course to garner further interest in in-depth curricula; focusing on the questions that should be asked and bringing the players together. This course will be developed in a modular format so that the course can be taken at any time which is beneficial for working professionals. The audience is public and private transportation organizations, utilities, car manufactures, and other interested parties.			
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Abstract

Transportation is at the cusp of a revolutionary transformation with the confluence of the rapid deployment of automation, connectivity, and electric mobility solutions in the near future. Accompanying this swift transformation is the need to inform, educate, and prepare the workforce to support and enable the deployment of these technologies in a fast and effective approach. Specifically, electrification of the transportation sector is the most imminent and requires professionals in disparate domains to be educated and trained about the interdisciplinary aspects of electric vehicles and the concomitant infrastructure and policy requirements. The objective of this proposal is to develop a course addressing the needs of working professionals in public and private transportation infrastructure organizations (at the local, state and federal level), utilities, EV manufacturers, grid operators and others. The course will be structured to address different aspects so that the course can be customized to audience requirements. The course was delivered in a virtual setting. The issue is that this course is individually focused and not saved for future use. We aim to take the best research and courses and make a virtual course that brings all the partners together.

Chapter I: Introduction

In the realm of transportation, a quiet revolution is underway: the rise of electric vehicles (EVs). With concerns about climate change, air pollution, and the finite nature of fossil fuels becoming ever more pressing, electric vehicles offer a promising solution. Unlike their traditional internal combustion engine counterparts, EVs are powered by electricity, making them cleaner, quieter, and potentially more sustainable.

The concept of electric vehicles is not new, with their origins dating back to the 19th century. However, it's only in recent years that advancements in technology, coupled with growing environmental awareness and government incentives, have propelled EVs into the mainstream. Today, they represent a rapidly expanding segment of the automotive market, with an increasing number of manufacturers investing in electrification and introducing new models to meet consumer demand.

In this exploration of electric vehicles, this course investigates the technology behind them, their environmental benefits, the challenges they face, and the broader implications for transportation and energy systems. From the sleek lines of modern electric cars to the innovative developments in battery technology and charging infrastructure, the world of electric vehicles is dynamic and full of promise. Join us as we embark on a journey to discover the electrifying future of transportation. Here's a curriculum plan for an electric vehicle (EV) course:

Course Overview:
This course introduces electric vehicles (EVs), covering their history, technology, design, operation, and environmental impact. Students will gain an understanding of EVs' role in sustainable transportation and their potential to revolutionize the automotive industry.

Course Objectives:

1. Understand the system level planning of electric vehicle technology.
2. Explore the difference in vehicle design between electric, hybrid, and automated vehicles.
3. Describe the different levels of charger product design.
4. Learn about the components and systems of charging infrastructure system design and planning.
5. Learn about the components and systems of driving infrastructure system design and planning.
6. Explore the future trends and challenges in the electric vehicle industry.

This course equips students with the knowledge and skills to understand, analyze, and contribute to the growing field of electric vehicles. By the end of the course, students had an introductory knowledge to engage with the challenges and opportunities of sustainable transportation and contribute to the advancement of electric vehicle technology.

Chapter II: Stakeholder Engagement

This chapter presents a summary of the stakeholder engagement. Creating an introductory breadth course involved stakeholder engagement. The plan involves several key steps to ensure that all relevant parties are identified, informed, and involved in decision-making processes. This process worked well and could be used for future course development.

1. Identify Stakeholders:
   - Internal Stakeholders- With a breadth interdisciplinary course, we utilized key members within the College of Engineering (Interdisciplinary Professional Programs, Civil and Environmental Engineering, Mechanical Engineering, and Electrical and Computer Engineering).
   - External Stakeholders- The external stakeholders involved were mainly from Wisconsin Department of Transportation, Wisconsin Automated Connected Electric Shared Mobility Consortium, and utility companies. Our full list of external stakeholders is listed below:
     - City of Madison
     - City of Racine
     - Electrification Coalition
     - Godfrey & Khan
     - Mandli Communications
     - Public Service Commission of Wisconsin
     - WI NAACP
     - Wisconsin Department of Transportation
     - Wisconsin Environment
     - Wisconsin Office of Energy Innovation
     - WPL/Alliant Energy
     - Xcel Energy

2. Analyze Stakeholder Needs and Expectations: The team researched the various other courses that existed and talked with the stakeholders to determine what materials should still be covered and the best method for the materials to be disseminated. Below are three examples of current trainings:
   - Electrification Coalition for an Electric Vehicle Policy Bootcamp
   - Transportation Electrification presented by Electric Power Research Institute
   - Electric Vehicle Roadman from Wisconsin Public Utility Institute
3. Establish Feedback Mechanisms: The team provided the slides and beta tested the training before providing it out to the public.

This stakeholder engagement allowed for the materials and concepts to bridge across disciplines to provide a more balanced system approach to thinking about electric vehicle opportunities and challenges in this ever-changing world. The stakeholders provided feedback through the outline development and course slides.

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University of Texas at Arlington | 601 W Nedderman Dr #103, Arlington, TX 76019
C-todd@uta.edu 817-272-5138

Chapter III: Virtual Course

This chapter describes the delivery mechanism for the course. The course was marketed through the Wisconsin Transportation Information Center and delivered by Andrea Bill. The course utilized zoom platform to enhance questions and the chat function. The first course was given on March 8, 2022, to an audience of 6 municipal engineers, public works, and law enforcement. The feedback led to a revision of the curriculum to make the class shorter and provide more time for discussion about how this can affect them and what the future workforce needs to know. The second course was delivered on May 17th, 2022, to a similar audience of 10 students. The feedback demonstrated that the time frame for the overview course was better but concerns about how to keep it up to date given the ever-changing field for electric vehicles were raised. The evaluations were completed after the course through instant feedback about what the students liked and what was confusing.

Transportation professionals in public and private workforces need to understand and manage the development, implementation, and maintenance of electrical infrastructure. These needs include:

1. Technical Knowledge: Understanding the principles of electrical systems, including power generation, distribution, and usage.
2. Regulatory Compliance: Knowledge of industry standards, safety protocols, and regulatory requirements.
3. Project Management: Skills to oversee projects from conception to completion, ensuring they stay within budget and timeline.
4. Sustainability: Integrating sustainable practices and technologies to minimize environmental impact.
5. Innovative Technologies: Staying updated with advancements in electric vehicles, smart grids, and renewable energy sources.
6. Interdisciplinary Coordination: Working with other professionals, such as civil engineers and urban planners, to integrate electrical infrastructure into broader transportation systems.

How the Course Has Addressed These Needs

1. Curriculum Design: The course provided comprehensive coverage of electrical principles, systems design, and implementation strategies.
2. Regulatory Training: Modules on industry standards, safety protocols, and compliance ensured that professionals are versed in legal requirements.
3. Sustainability Focus: The course includes content on sustainable energy solutions and their integration into transportation systems.
5. Technology Updates: Regular updates on the latest innovations in electric vehicles, smart grid technologies, and renewable energy were included to keep professionals current.
6. Interdisciplinary Approach: The course fostered collaboration through interdisciplinary projects and team-based assignments, encouraging professionals to work effectively with peers from other fields.

This comprehensive approach ensured that transportation professionals are well-equipped to meet the evolving demands of electrical infrastructure in both public and private sectors.

Chapter IV: Conclusions and Recommendations

The course brought together UW-Madison experts from utilities, powertrain, transportation infrastructure and policy in the departments of Civil and Environmental Engineering (CEE), Electrical and Computer Engineering (ECE), and Interdisciplinary Professional Development (Interpro). Faculty and staff from EPD, CEE and ECE received feedback from different stakeholders such as the Wisconsin Department of Transportation, Wisconsin Automated Connected Electric Shared Mobility Consortium, Madison Gas and Electric, and other organizations about the curriculum for an integrative course on EV infrastructure that provides a broad perspective to their professionals from multiple dimensions. The course aimed to equip students with a broad understanding of the technological, environmental, economic, and policy aspects of electric vehicles.

Through the course, students have explored the fundamental principles of electric vehicle technology, including battery systems, electric drive trains, and charging infrastructure. They have also delved into the environmental benefits of EVs, such as reduced greenhouse gas emissions and decreased reliance on fossil fuels. Additionally, the course has addressed the economic implications of EV adoption, highlighting the potential for cost savings and the impact on the automotive industry.

Recommendations

1. Curriculum Enhancement:
   - Include Emerging Technologies: Continuously update the course content to incorporate the latest advancements in EV technology, such as solid-state batteries, wireless charging, and autonomous driving systems.
   - Case Studies: Integrate a broader range of case studies from different regions and market segments to provide students with a diverse perspective on EV adoption and challenges.

2. Hands-on Learning:
   - Laboratory Sessions: Introduce practical laboratory sessions where students can work with EV components and systems, gaining hands-on experience and a deeper understanding of the technology.
   - Industry Partnerships: Establish partnerships with EV manufacturers and industry stakeholders to facilitate internships, guest lectures, and field visits, bridging the gap between academia and industry.

3. Interdisciplinary Approach:
   - Collaborate Across Disciplines: Encourage collaboration with other departments, such as environmental science, economics, and public policy, to provide an interdisciplinary approach to EV education.
   - Focus on Sustainability: Emphasize the role of EVs in sustainable transportation and integrate topics related to renewable energy sources, smart grid technology, and lifecycle analysis.

The EV survey course can maintain its relevance and effectiveness in preparing students for careers in the burgeoning field of electric mobility. The goal is to create a dynamic, engaging, and informative course that not only imparts knowledge but also inspires students to contribute to the advancement of electric vehicle technology and sustainable transportation solutions.

Appendix A: Course Slides

Preparing Future Workforce for Electric Vehicle Infrastructure Deployment

Instructor: Andrea Bill
Director, Wisconsin LTAP
Principal Investigator: David A. Noyce
Professor, Civil and Environmental Engineering
Executive Associate Dean, College of Engineering
University of Wisconsin-Madison

Wisconsin Traffic Operations and Safety Laboratory
Department of Civil and Environmental Engineering
University of Wisconsin – Madison

Center for Transportation Equity, Decisions & Dollars

Wisconsin TOPS

Get to know you

INTRODUCTIONS

EXPERIENCE WITH ELECTRIC VEHICLES (EV)

OPPORTUNITIES AND CHALLENGES

EV Updates

President Biden goal of 50% of all new vehicle sales be electric by 2030

[EV Acceleration Challenge]

- Tools and Resources
- Consumer Education and Support
- EV Fleet Expansion
- Community Charging

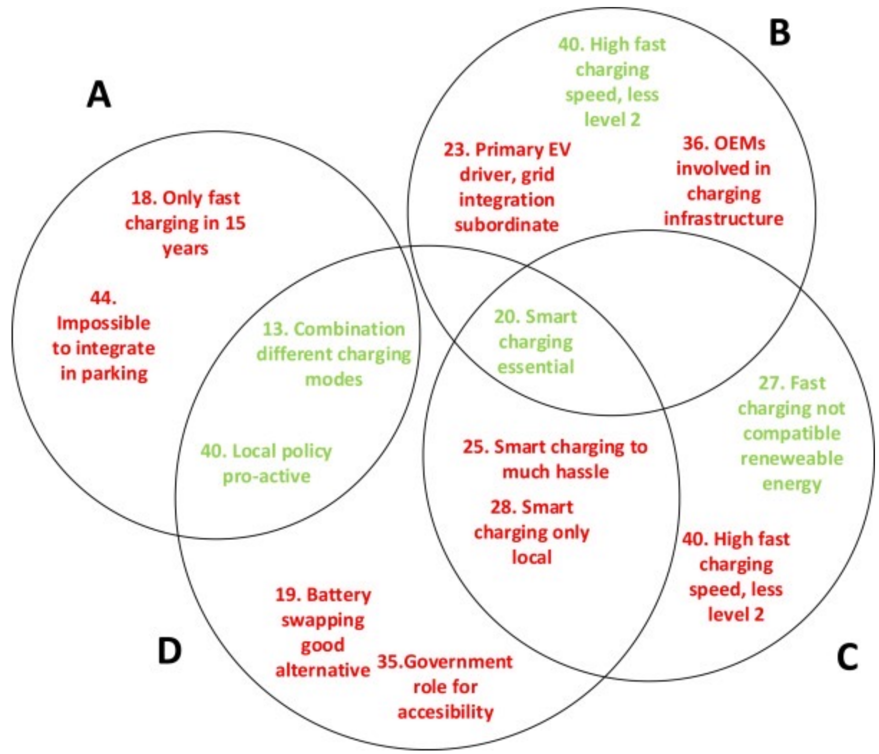
National Electric Vehicle Infrastructure (NEVI) Formula Funding

EV Updates

- **Battery Technology Advances**:
  - Improved energy density and efficiency, leading to longer driving ranges.
  - Faster charging times with advancements in fast-charging technology.
  - Reduction in battery costs, making EVs more affordable.
- **Increased Model Variety**:
  - More automakers are entering the EV market, offering a wider range of models to choose from.
  - Expansion beyond sedans to include SUVs, trucks, and even electric vans.
- **Infrastructure Expansion**:
  - Growth in the number of charging stations, including high-speed chargers along highways and in urban areas.
  - Integration of charging stations into public parking lots, workplaces, and residential areas.
- **Government Incentives and Regulations**:
  - Implementation of incentives such as tax credits, rebates, and subsidies to promote EV adoption.
  - Stricter emissions regulations pushing automakers to invest more in electric vehicle development.
- **Technological Integration**:
  - Integration of advanced driver-assistance systems (ADAS) and autonomous driving features in EVs.
  - Connectivity features, including remote monitoring and control via smartphone apps.
- **Environmental Benefits**:
  - Reduced greenhouse gas emissions compared to traditional internal combustion engine vehicles.
  - Potential for renewable energy integration, further reducing environmental impact.
- **Consumer Adoption**:
  - Growing consumer awareness and acceptance of EVs due to environmental concerns and lower operating costs.
  - Increasing number of EVs on the roads, leading to a shift in consumer preferences and market dynamics.
- **Challenges and Opportunities**:
  - Addressing concerns about range anxiety and charging infrastructure reliability.
  - Opportunities for innovation in battery technology, renewable energy integration, and sustainable manufacturing processes.

System Level

- Regulatory
  - State
  - Federal
- Policy
  - Electrification Coalition
    - Purchase incentives
    - Charging infrastructure funding
    - Federal fleet electrification funding
    - EV manufacturing and supply chain funding
  - Global Deployment
- Coordination
  - Governments
  - Car makers
  - Battery makers
  - Mining industry
  - Energy providers
  - Supply chain operators



Source: https://doi.org/10.1016/j.futures.2020.102610

System Level

- Benefits (modeling)
  - What
  - How
- Equity
  - EVI-Equity: Electric Vehicle Infrastructure for Equity Model
  - Vehicle purchase
  - Charging cost
  - Actual or perceived vehicle range
  - Perceived or actual lack of charging infrastructure
  - Other costs?
- Financial
- Standardization
- Privacy and Cyber Security Issues

System Level- Financial

- **Charging Stations**
  - Installation and maintenance of various types of chargers (Level 1, Level 2, DC fast chargers)
  - Cost of land acquisition or leasing for charging station sites
  - Upgrading existing electrical infrastructure to support EV charging
- **Grid Upgrades**
  - Enhancements to the electrical grid to manage increased load and prevent outages
  - Implementation of smart grid technologies to optimize EV charging and distribution
- **Initial Vehicle Purchase Costs**
  - Higher upfront cost of EVs compared to internal combustion engine vehicles
  - Incentives and subsidies to reduce the purchase price for consumers and fleets
- **Total Cost of EV Ownership (TCO)**
  - Lower fuel costs (electricity vs. gasoline/diesel)
  - Reduced maintenance costs due to fewer moving parts in EVs
  - Depreciation rates and resale values of EVs
- **Energy Costs**
  - Cost of electricity for charging EVs
  - Potential for dynamic pricing and time-of-use rates
- **Maintenance and Repair**
  - Long-term maintenance and repair costs for EVs
  - Availability and cost of spare parts and specialized labor
- **Government Incentives**
  - Federal, state, and local tax credits and rebates for EV purchases and infrastructure development
  - Grants and funding opportunities for EV infrastructure projects
- **Utility Programs**
  - Rebates and incentives offered by utility companies for installing charging stations
  - Special rates or programs for EV owners
- **Public-Private Partnerships**
  - Collaborations between government entities and private companies to fund and deploy EV infrastructure
  - Investment opportunities for private capital in EV infrastructure projects
- **Funding Mechanisms**
  - Bonds, loans, and other financial instruments to raise capital for EV projects
  - Return on investment (ROI) analysis for public and private stakeholders
- **Compliance Costs**
  - Meeting regulatory requirements and standards for EV infrastructure and vehicles
  - Cost of implementing and enforcing EV-related policies
- **Research and Development**
  - Investment in R&D for advancing EV technologies and infrastructure
  - Funding for pilot projects and innovation in the EV sector
- **Job Creation**
  - Economic benefits from job creation in the EV manufacturing and infrastructure sectors
  - Training and workforce development costs
- **Economic Incentives**
  - Impact on local economies from increased adoption of EVs and related infrastructure
  - Economic benefits from reduced dependency on fossil fuels and improved air quality
- **Financial Risk Mitigation**
  - Strategies to mitigate financial risks associated with EV infrastructure investments
  - Insurance costs and risk assessments
- **Market Risks**
  - Fluctuations in energy prices and their impact on EV adoption
  - Market acceptance and demand for EVs

System Level- Standardization

- **Charging Infrastructure**
  - **Connector Types and Compatibility**: Standardize EV plug types to ensure compatibility across different manufacturers and regions (e.g., CCS, CHAdeMO, Type 2).
  - **Charging Levels**: Define and standardize the levels of charging (Level 1, Level 2, and DC Fast Charging) and their associated power outputs.
  - **Payment Systems**: Standardize payment methods and interfaces to allow for seamless transactions across different charging networks.
  - **Interoperability**: Ensure that EVs can charge at any station regardless of the service provider, potentially through roaming agreements.
- **Communication Protocols**
  - **Vehicle-to-Grid (V2G) Standards**: Establish protocols for bidirectional power flow between EVs and the grid, including communication standards for energy transfer and grid support services.
  - **Smart Charging**: Standardize communication between EVs, charging stations, and grid operators to optimize charging times and loads (e.g., OCPP - Open Charge Point Protocol).
  - **Cybersecurity**: Implement standardized cybersecurity measures to protect communication channels between EVs, chargers, and the grid.
- **Safety Standards**
  - **Electrical Safety**: Establish standards for electrical safety in charging equipment and installations (e.g., IEC 61851 for conductive charging systems).
  - **Battery Safety**: Define safety standards for battery construction, usage, and disposal to prevent accidents and environmental harm.
  - **Emergency Procedures**: Standardize emergency procedures for first responders in case of EV-related incidents.
- **Performance and Testing**
  - **Range and Efficiency**: Standardize testing methods for EV range and efficiency to provide consumers with reliable information (e.g., WLTP, EPA).
  - **Durability and Reliability**: Define standards for the durability and reliability testing of EV components and systems.
  - **Environmental Testing**: Establish testing protocols for how EVs perform under various environmental conditions (e.g., temperature, humidity).
- **Environmental and Sustainability Standards**
  - **Battery Recycling**: Standardize processes for the recycling and disposal of EV batteries to minimize environmental impact.
  - **Lifecycle Assessment**: Implement standards for assessing the environmental impact of EVs throughout their lifecycle, from production to disposal.
  - **Sustainable Materials**: Encourage the use of sustainable materials in EV production through standardized guidelines.
- **Data and Privacy**
  - **Data Sharing**: Standardize protocols for data sharing between EVs, charging stations, and service providers while ensuring data privacy.
  - **Privacy Standards**: Establish standards for protecting the privacy of EV users, especially concerning location and usage data.
- **User Interface and Experience**
  - **User Information**: Standardize the type and format of information displayed to users at charging stations (e.g., charging status, cost, estimated time).
  - **Mobile and Navigation Apps**: Ensure standardization of EV-related information in mobile apps and navigation systems for locating charging stations, availability, and booking.
- **Regulatory and Policy Framework**
  - **Incentives and Subsidies**: Standardize the criteria for government incentives and subsidies for EV purchase and infrastructure development.
  - **Regulatory Compliance**: Ensure that all EV systems comply with local, national, and international regulations and standards.
- **Integration with Renewable Energy**
  - **Renewable Energy Usage**: Standardize the integration of EV charging infrastructure with renewable energy sources (e.g., solar, wind) to support green energy goals.
  - **Energy Storage Solutions**: Develop standards for using EV batteries as energy storage solutions for renewable energy.
- **Training and Certification**
- **Installer and Technician Certification**: Standardize the training and certification requirements for professionals installing and maintaining EV infrastructure.
- **User Education**: Develop standardized educational materials for EV users regarding charging, maintenance, and safety.

System Level- Privacy Issues

- **Data Collection and Usage**
  - Extensive data collection from EVs, including location, driving behavior, and personal preferences.
  - Concerns over how this data is used, stored, and shared by manufacturers, service providers, and third parties.
- **User Consent**
  - Ensuring that users are fully informed and have given explicit consent for the collection and use of their data.
  - Transparency in data handling policies and practices.
- **Anonymization and De-identification**
  - Implementing robust methods to anonymize data to protect user identity.
  - Ensuring that data cannot be easily re-identified.
- **Data Minimization**
  - Collecting only the data necessary for the intended purpose.
  - Limiting the scope and duration of data retention.
- **Cross-Border Data Transfers**
  - Managing data transfers across different jurisdictions with varying privacy laws.
  - Ensuring compliance with international data protection regulations like GDPR.

System Level- Cybersecurity Issues

- **Vehicle-to-Everything (V2X) Communication Security**
  - Protecting the communication between EVs, charging stations, and other infrastructure from interception and tampering.
  - Ensuring secure and encrypted data transmission.
- **Charging Station Security**
  - Securing charging stations from physical tampering and cyber attacks.
  - Implementing secure authentication mechanisms for users and vehicles.
- **Software and Firmware Updates**
  - Ensuring secure delivery and installation of software and firmware updates to EVs and infrastructure.
  - Protecting against the introduction of malicious code during updates.
- **Network Security**
  - Securing the networks that connect EVs, charging stations, and control systems.
  - Implementing firewalls, intrusion detection systems, and other network security measures.
- **Remote Access Vulnerabilities**
  - Protecting against unauthorized remote access to EVs and infrastructure systems.
  - Implementing strong access control and authentication mechanisms.
- **Supply Chain Security**
  - Ensuring the security of the entire supply chain for EV components and software.
  - Protecting against counterfeit parts and compromised software.
- **Incident Response and Recovery**
  - Developing robust incident response plans to quickly address and mitigate the impact of cybersecurity breaches.
  - Ensuring the ability to recover from attacks and restore normal operations.
- **Integration with Smart Grids**
  - Securing the interaction between EVs and smart grid systems.
  - Protecting against attacks that could disrupt the electrical grid or compromise its stability.

- November 2021: Adding nine Proterra electric busses to fleet
- Estimated diesel fuel usage savings: 56,000 gallons
- Estimated annual fuel cost savings: $60,000

Center for Transportation
Equity, Decisions & Dollars

Local governments are essential partners in creating a self-sustaining electric vehicle market

- ✓ Local governments can and do shape how residents and businesses take actions
- ✓ Local governments can use existing, familiar tools to foster the community's transition to EVs
- ✓ EV market transformation requires that public and private development accommodates EV charging infrastructure

GREAT PLAINS INSTITUTE | Better Energy. Better World.

WISCONSIN TOPS

EV Policy, Goals & Metrics	Regulation	Utility Engagement	Education and Incentives	Public Sector Leadership	Shared Mobility
P-1 Address EVs and EVSE in Comprehensive Plan	R-1 Enable EV and EVSE in land use regulations	U-1 Joint education and marketing with utility	EI-1 Host public education events and campaigns	L-1 Electrify public fleet	S-1 Deploy electric transit, school buses
P-2 Address EVs and EVSE in Specific-Area Plan	R-2 Incorporate EV and EVSE in parking standards	U-2 Work with utility on interconnection process	EI-2 Create EV webpage for programs, standards	L-2 Provide public chargers	S-2 Deploy electric paratransit vehicles
P-3 Address EVs and EVSE in Functional Plan	R-3 Incorporate EV and EVSE in the building code	U-3 Work with utility to promote or deploy managed charging	EI-3 EV/EVSE education of commercial property owners	L-3 ROW charging deployment	S-3 Develop electric bike or scooter opportunities
P-4 Establish a deployment benchmark and set deployment goals	R-4 Streamline EVSE permitting	U-4 Create or promote utility incentives for EV and/or EVSE	EI-4 Financial incentives for EVSE installation	L-4 Install employee-reserved EVSE	S-4 Develop car sharing program
	R-5 Require EVSE in multi-family housing	U-5 Work with utility to integrate renewable energy	EI-5 Expand local access to EV models, options		

Vehicle Product Design and Manufacturing

- EV
  - Design Process (Intellipaat)
  - Batteries
- Hybrid
  - Introduction (Prof MAD)
  - Batteries
- Automated
  - Design (Design Theory)
  - ~58% of AV passenger cars are built over an electric powertrain
  - ~21% of AV passenger cars utilize hybrid

Source: https://www.lifewire.com/ev-phev-fcev-hybrid-compared-5201137

ELECTRIC POWER RESEARCH INSTITUTE

FLEET ELECTRIC VEHICLE INFRASTRUCTURE Initiative

Communities around the world are embracing decarbonization goals to improve air quality and address climate change. Recognizing the importance of transportation electrification in reaching these goals, EPRI has launched the Fleet Electric Vehicle Infrastructure Initiative to develop the tools and resources needed for rapid expansion of fleet charging infrastructure.

Resiliency & Reliability

Provide reliable service while developing resiliency strategies to support public safety and ensure operational effectiveness regardless of climate vulnerabilities and natural disasters.

Obtain operational infrastructure that is dependable regardless of occasional external risks

Interoperability

Advance interoperability in charging hardware, physical hardware, charge management, and networking of charging hardware.

Allow any vehicle to successfully plug into any charger

Utility Planning Tools

Fleet operators and utilities need tools to design and optimize cost-effective solutions to support fleet customers and utility infrastructure solutions.

Provide R&D that will guide utilities to effective EV infrastructure

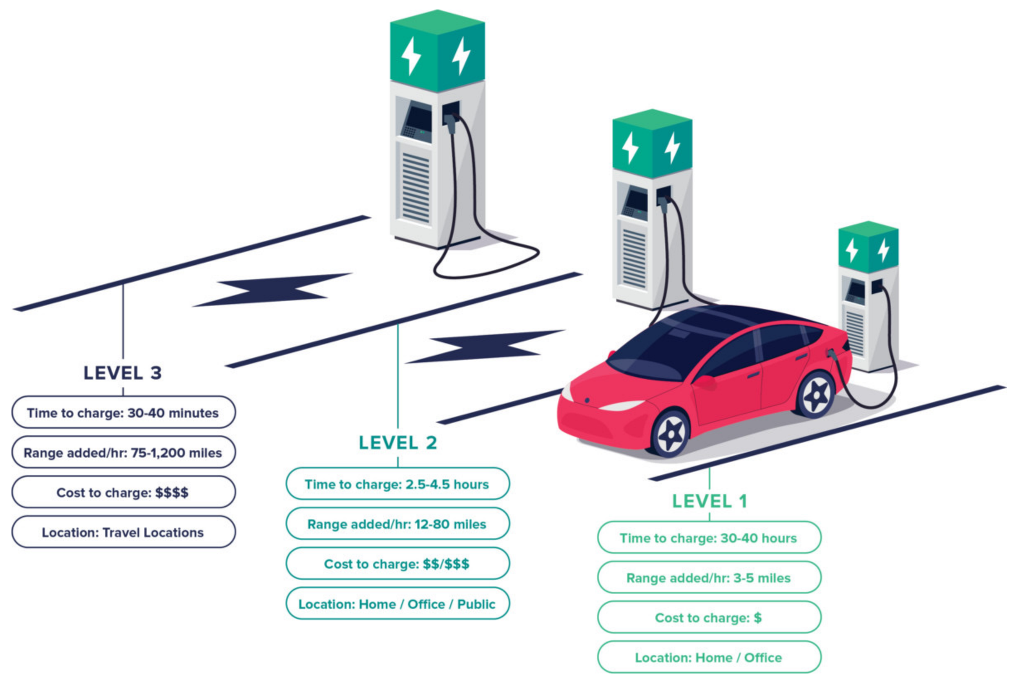
Vision of Success: A path forward for utilities and customers to effectively create fleet charging infrastructure that operates regardless of the manufacturer and external factors to support widescale adoption of electric vehicle fleets.

The initiative builds on EPRI's comprehensive Electric Transportation program, which has more than three decades of research experience. This research brings together utilities, electric vehicle manufacturers, charging station companies, and other stakeholders to identify and address challenges inhibiting large-scale deployment of electric transportation.

www.epri.com

Charger Product Design and Listing

- US
  - Level 1 & 2 - J1722 Connector
  - Level 3
    - Tesla proprietary plug
    - CHAdeMO (the Asian standard)
    - Combined Charging System, CCS or “Combo” plug
- US and International
  - Adapters



Source: https://www.ssr-inc.com/pressroom/electric-vehicle-charging-stations-101/

Charging Infrastructure System Design and Planning

- Individual EV charger technical requirements
- Electric bus depots technical requirements
- Electric utility distribution – technical considerations for adding many individual EV chargers to utility distribution systems
- Electric utility transmission – technical aspects of planning for increased demand
- Electric utility transmission – financial and regulator considerations for demand response and time-of-use rates

Individual EV charger technical requirements

1. **Voltage and Current Rating**: The charger should match the voltage and current rating of the EV's battery system. For example, in North America, residential chargers typically operate at 120 or 240 volts AC.
2. **Power Rating**: This refers to the maximum power that the charger can deliver to the vehicle. Level 1 chargers typically provide around 1.4 to 1.9 kW, while Level 2 chargers can range from 3.3 kW to 19.2 kW or higher.
3. **Connector Type**: The charger should have the appropriate connector type for the vehicle being charged. Common connector types include SAE J1772 for AC charging and CCS (Combined Charging System) or CHAdeMO for DC fast charging.
4. **Safety Features**: Chargers should have built-in safety features such as ground fault protection, overcurrent protection, and temperature monitoring to ensure safe operation.
5. **Communication Protocol**: Many modern chargers support communication protocols such as OCPP (Open Charge Point Protocol) or ISO 15118, which enable features like authentication, billing, and remote monitoring.
6. **Installation Requirements**: Chargers should be installed according to local electrical codes and regulations. This includes considerations such as proper wiring, grounding, and circuit protection.
7. **Metering and Billing**: For public chargers or chargers in commercial settings, metering and billing functionality may be required to track energy usage and bill users accordingly.
8. **Networking Capabilities**: Some chargers support networking capabilities, allowing them to be connected to a central management system for monitoring, maintenance, and firmware updates.
9. **Accessibility and User Interface**: Chargers should be accessible to users and have a user-friendly interface for initiating and monitoring charging sessions.
10. **Environmental Protection**: Chargers installed outdoors should be weatherproof and designed to withstand environmental conditions such as rain, snow, and extreme temperatures.

Electric Bus Depots Technical Requirements

- Charging Infrastructure
  - Charging stations: Installation of appropriate charging infrastructure to accommodate the number of buses and their charging requirements.
  - - Charging connectors: Selection of suitable connectors (e.g., CCS, CHAdeMO) compatible with the buses in use.
  - - Power supply: Sufficient electrical capacity to support simultaneous charging of multiple buses without overloading the grid.
- Battery Management System (BMS)
  - Integration of BMS for monitoring and managing the batteries of electric buses during charging and operation.
  - BMS should support features like state of charge (SoC) monitoring, balancing, and thermal management.
- Infrastructure Layout
  - Efficient layout to accommodate buses, charging stations, maintenance areas, and administrative facilities.
  - Adequate space for maneuvering buses in and out of charging stations and maintenance bays.
- Safety Systems
  - Fire detection and suppression systems to mitigate fire risks associated with high-voltage systems and batteries.
  - Emergency shutdown procedures and equipment to handle electrical hazards.
- Energy Management System (EMS)
  - Implementation of EMS to optimize energy consumption, scheduling charging cycles during off-peak hours to reduce electricity costs.
  - Integration with renewable energy sources like solar panels to offset electricity consumption.
- Workshop and Maintenance Facilities
  - Adequate facilities for routine maintenance, inspection, and repair of electric buses, including lifting equipment and diagnostic tools.
  - Training programs for maintenance staff to ensure they are equipped to handle electric vehicle-specific maintenance tasks.
- Environmental Considerations
  - Adequate ventilation systems to manage air quality, especially during battery charging and maintenance activities.
  - Implementation of sustainable practices such as rainwater harvesting and energy-efficient lighting to minimize environmental impact.
- Data Management and Monitoring
  - Implementation of a centralized monitoring system to track the performance of charging infrastructure, battery health, energy consumption, and operational efficiency.
  - Integration with fleet management software for scheduling and optimizing bus routes based on charging status and battery levels.
- Regulatory Compliance
  - Adherence to local regulations and standards regarding electrical installations, workplace safety, and environmental protection.
  - Compliance with standards such as ISO 14001 for environmental management and ISO 50001 for energy management.
- Future Expansion and Scalability
  - Design flexibility to accommodate future expansion of the electric bus fleet and charging infrastructure.
  - Scalability of systems and infrastructure to adapt to advancements in electric vehicle technology and changing operational requirements.

Electric utility distribution – technical considerations for adding many individual EV chargers to utility distribution systems

- **Load Management**: The increased demand from multiple EV chargers can strain the distribution system. Implementing load management strategies like demand response programs, time-of-use pricing, or smart charging algorithms can help distribute charging loads more evenly throughout the day.
- **Transformer Sizing**: Evaluate the capacity of transformers serving the charging locations to accommodate the additional load from EV chargers. Upgrading transformers may be necessary to prevent overloading and voltage drops.
- **Voltage Regulation**: Voltage fluctuations can occur due to the sudden demand from EV chargers. Voltage regulation devices such as voltage regulators or voltage control equipment can stabilize voltage levels, ensuring consistent power quality.
- **Cable Sizing and Voltage Drop**: Proper sizing of distribution cables is essential to minimize voltage drop and power losses. Calculating the cable size based on the distance from the distribution transformer to the EV charging points and the expected load will ensure efficient power delivery.
- **Power Quality**: EV chargers can introduce harmonic distortion and power factor issues. Implementing power quality mitigation measures such as harmonic filters and power factor correction capacitors can mitigate these issues and maintain grid stability.
- **Grid Integration**: Consider grid integration solutions like advanced metering infrastructure (AMI) and grid-edge technologies to monitor and manage EV charging loads in real-time. This allows utilities to optimize grid operations and respond proactively to fluctuations in demand.
- **Backup Power and Resilience**: Incorporate backup power systems or microgrid solutions to ensure uninterrupted charging during grid outages or emergencies. Battery energy storage systems (BESS) can provide backup power and enhance grid resilience.
- **Cybersecurity**: Implement robust cybersecurity measures to protect EV charging infrastructure from potential cyber threats. Secure communication protocols, authentication mechanisms, and encryption techniques are essential to safeguarding data and infrastructure integrity.
- **Interoperability and Standards**: Ensure that EV chargers comply with industry standards such as OCPP (Open Charge Point Protocol) for interoperability and seamless integration with utility systems and energy management platforms.
- **Future Growth Planning**: Anticipate future growth in EV adoption and plan for scalability in distribution system upgrades. Adopting flexible and modular infrastructure designs will facilitate easier expansion to accommodate increasing numbers of EV chargers.

Electric utility transmission – technical aspects of planning for increased demand

- **Load Growth Analysis**: Conducting comprehensive studies to forecast future electricity demand based on factors such as population growth, economic development, and industrial expansion. This analysis helps in determining the extent of additional transmission capacity needed.
- **Capacity Planning**: Evaluating the existing transmission infrastructure's capacity and identifying potential bottlenecks that may arise with increased demand. This involves assessing the capability of substations, transformers, and transmission lines to handle higher loads.
- **Transmission Line Upgrades**: Upgrading existing transmission lines or constructing new ones to accommodate higher power flows. This may involve increasing the capacity of existing lines through reconductoring or installing new high-capacity transmission lines in areas experiencing significant demand growth.
- **Voltage Support**: Ensuring voltage stability across the transmission network, especially during peak demand periods, by implementing voltage control devices such as capacitors, reactors, and voltage regulators.
- **Grid Modernization**: Integrating advanced technologies like smart grids, phasor measurement units (PMUs), and advanced metering infrastructure (AMI) to enhance grid monitoring, control, and automation. These technologies enable real-time monitoring of grid conditions and facilitate quicker response to fluctuations in demand.
- **Renewable Integration**: Planning for the integration of renewable energy sources such as solar and wind into the transmission system. This involves assessing the impact of variable generation on grid stability and implementing solutions like energy storage systems and flexible generation to mitigate intermittency issues.
- **System Reliability**: Ensuring grid reliability by implementing measures such as redundancy in transmission infrastructure, grid interconnections, and robust contingency plans to mitigate the risk of equipment failures or natural disasters.
- **Environmental Considerations**: Assessing the environmental impact of transmission projects and ensuring compliance with regulations related to land use, wildlife protection, and emissions reduction. This may involve routing transmission lines to minimize ecological disruption and adopting technologies that reduce environmental footprint.
- **Cost-Benefit Analysis**: Conducting cost-benefit analyses to evaluate different transmission expansion options and prioritize investments based on factors such as capital expenditure, operating costs, reliability improvements, and societal benefits.
- **Regulatory Approval**: Obtaining regulatory approvals for transmission projects, including permits for construction, environmental assessments, and rate recovery mechanisms. Engaging stakeholders, including local communities and environmental groups, is essential in gaining support for transmission infrastructure development.

Electric utility transmission – financial and regulator considerations for demand response and time-of-use rates

- **Regulatory Approval**: Utility companies need regulatory approval from relevant authorities to implement demand response and time-of-use rates. Regulations may vary depending on the region and jurisdiction, so understanding and complying with these regulations is essential.
- **Rate Design**: Designing demand response and time-of-use rates involves considerations such as peak demand periods, customer preferences, and market dynamics. Utility companies need to balance revenue stability with incentivizing energy conservation and load shifting.
- **Cost-Benefit Analysis**: Conducting a thorough cost-benefit analysis is crucial to evaluate the financial implications of implementing demand response and time-of-use rates. This analysis should consider factors such as infrastructure upgrades, customer participation costs, revenue impacts, and potential savings from reduced peak demand.
- **Customer Engagement**: Educating and engaging customers is key to the success of demand response and time-of-use rate programs. Utilities should communicate the benefits of participating, provide tools for managing energy consumption, and address any concerns about changes in billing structures.
- **Metering and Technology**: Implementing demand response and time-of-use rates often requires advanced metering infrastructure (AMI) and smart grid technology. Investments in these technologies enable accurate measurement of energy usage, real-time communication with customers, and automated responses to price signals.
- **Tariff Structure**: Developing a tariff structure that aligns with the goals of demand response and time-of-use rates is essential. This may involve offering different pricing tiers based on time of day, seasonality, or customer segment, while ensuring fairness and affordability.
- **Risk Management**: Utility companies need to assess and manage risks associated with demand response and time-of-use rates, including revenue volatility, customer dissatisfaction, and regulatory changes. Strategies such as hedging and diversification can help mitigate these risks.
- **Performance Metrics**: Establishing clear performance metrics allows utility companies to monitor the effectiveness of demand response and time-of-use rate programs. Metrics may include peak demand reduction, energy savings, customer satisfaction, and financial performance.
- **Integration with Energy Markets**: Utilities should consider how demand response and time-of-use rates interact with energy markets and grid operations. This may involve coordinating with wholesale markets, managing capacity constraints, and optimizing resource allocation.
- **Long-Term Planning**: Demand response and time-of-use rates should be integrated into long-term strategic planning for electric utility transmission. This includes forecasting future energy demand, assessing infrastructure needs, and adapting to evolving regulatory and market conditions.

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WISCONSIN'S CURRENT EV SUPPLY CHAIN

Parts and Materials Inputs

Company	Location	EV Focus
Modine	Racine	Thermal management for fuel cells and EV batteries
Trombetta	Milwaukee	DC Power Systems
Silantronix	Madison	Organosilicon electrolyte material

Infrastructure Equipment

ABB Group	New Berlin	EV charging stations and infrastructure

Major Suppliers

Johnson Controls	Glendale	Lithium ion and advanced lead battery research and development
Odyne Systems	Pewaukee	Plug in hybrid drive systems for medium and heavy trucks
Axletech International	Oshkosh	Engineered electric powertrain/drivetrain systems
Wells Vehicle Electronics	Fond Du Lac	Charging systems and sensors

EV Supply Chain - Pending or Implemented Agreements:

WISCONSIN TOPS

Monitoring, Communications, and Technology – technical aspects of system design and deployment

- Monitoring
  - Real-Time Data Collection and Analysis
  - Predictive Maintenance
  - Environmental Monitoring
- Communications
  - Network Connectivity
  - Protocol and Standards
  - Security
- Technology
  - Charging Infrastructure
  - Energy Storage and Management
  - Software platforms
  - Interoperability
- Deployment Considerations
  - Site Selection
  - Scalability
  - Regulatory Compliance

Automated and Safety – technical aspects of system design and deployment

- **System Architecture**
  - **Centralized vs. Decentralized**
  - **Communication Protocols**
- **Sensors and Data Acquisition**
  - **Sensor Types**
  - **Data Fusion**
- **Artificial Intelligence and Machine Learning**
  - **Perception Algorithms**
  - **Decision-Making Algorithms**
  - **Continuous Learning**
- **Networking and Connectivity**
  - **High Bandwidth and Low Latency**
  - **Edge Computing**
  - **Cybersecurity**
- **Charging Infrastructure**
  - **Smart Charging Stations**
  - **Wireless Charging**
  - **Battery Management Systems (BMS)**
- **Safety and Redundancy**
  - **Fail-Safe Mechanisms**
  - **Redundant Systems**
  - **Regular Testing and Validation**
- **Human-Machine Interface (HMI)**
  - **User-Friendly Interfaces**
  - **Emergency Protocols**
- **Regulatory and Compliance**
  - **Adherence to Standards**
  - **Liability and Insurance**
- **Environmental Considerations**
  - **Sustainability**
  - **Energy Efficiency**
  - **Integration with Existing Infrastructure**
  - **Interoperability**
  - **Scalability**

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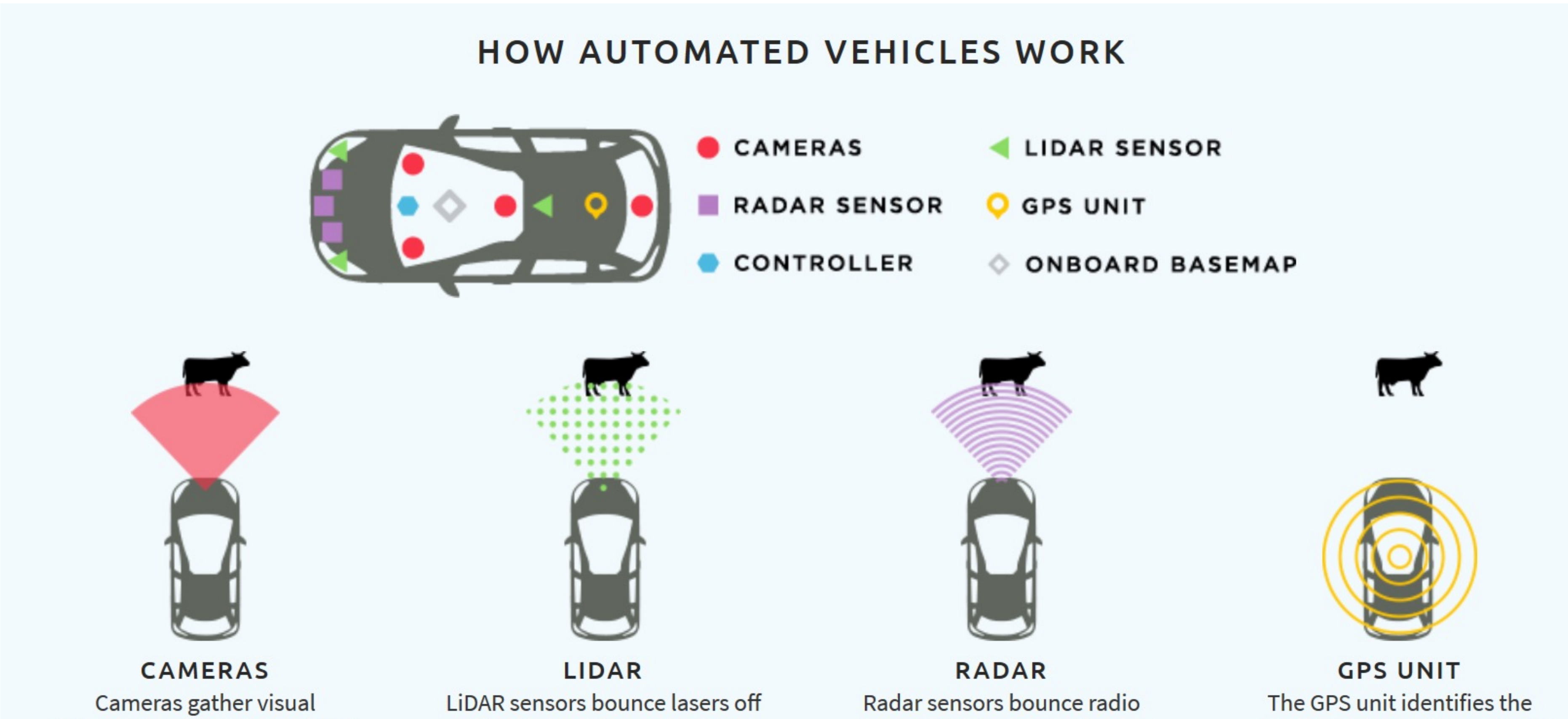

Advanced Driver-Assistance Systems (ADAS)

SAE Levels of Vehicle Automation

0

No Automation

Zero autonomy; the driver performs all driving tasks.

1

Driver Assistance

Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.

2

Partial Automation

Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.

3

Conditional Automation

Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.

4

High Automation

The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.

5

Full Automation

The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.


WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON
RACINE ON THE LAKE
GATEWAY
TECHNICAL COLLEGE
AUTONOMY BY
PERRONE
ROBOTICS
GEM

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Wisconsin TOPS

Overview of “Risk Points” along the Racine Route

Overview of what we consider "risk points" along the route.

- College Parking Lot- Cars and Pedestrians high interaction area.

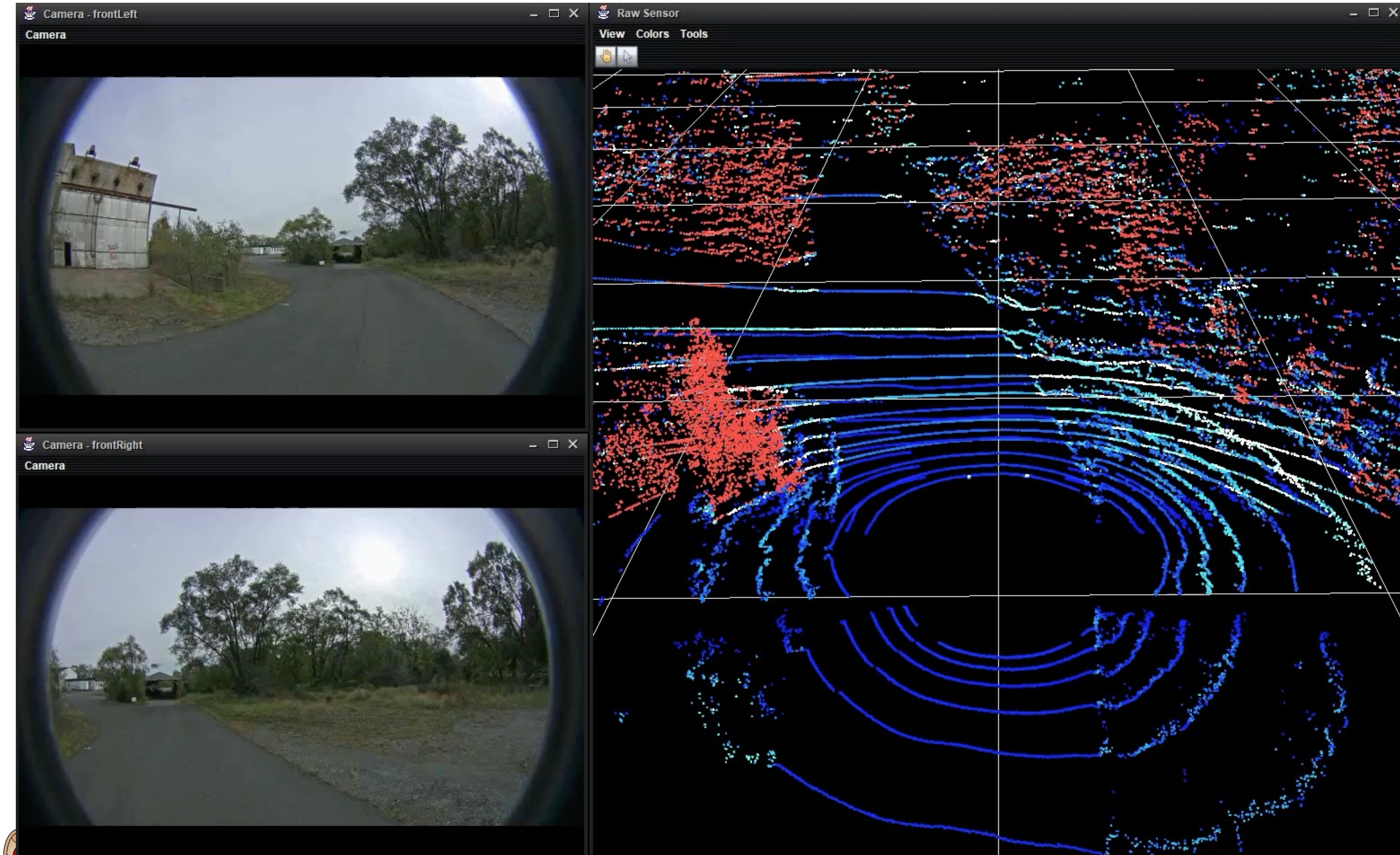
- Crosswalk on 11th Street -non-intersection, Not Programmed, approaching pedestrians will only be seen when in lane. AV Operator disengage and take-over may be needed

- Uphill slope on 11th - operator awareness of icy/slippery conditions

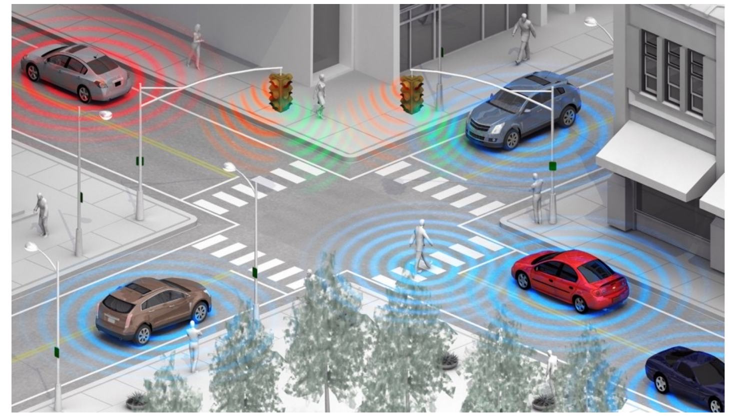
- Entering Main Street- 30 mph but traffic may be faster, AV may not see traffic approaching from the left- Operator disengage and take over may be needed.

- Stop Light at 6th Street. AV does not recognize signals. , Operator disengage and take- over **MANDATORY**.

[redacted]

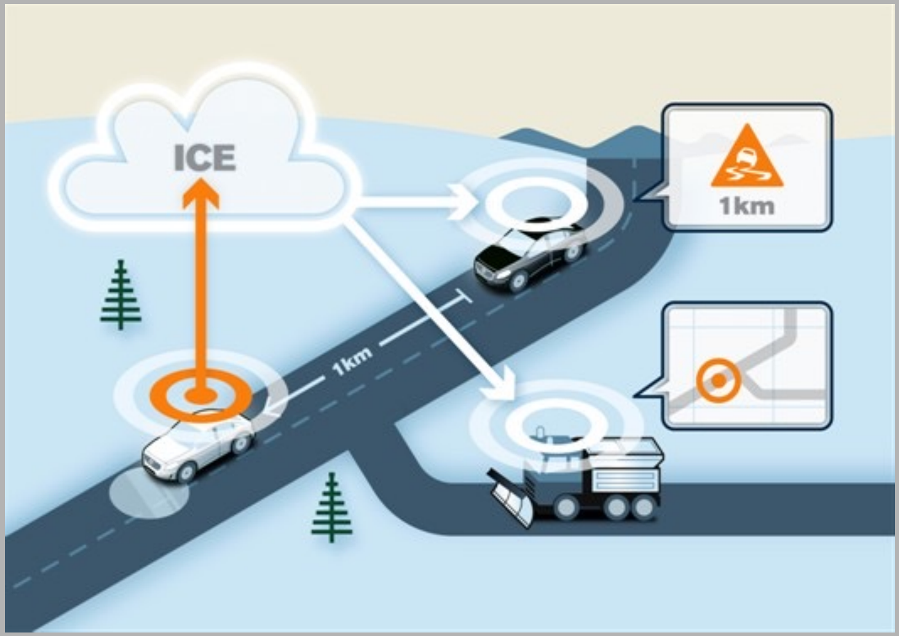

Camera - frontLeft
Camera
Camera - frontRight
Camera
Raw Sensor
View Colors Tools

Connected Vehicles – Overview



- Vehicle-to-Vehicle (V2V)
- Vehicle-to-Infrastructure (V2I)
- Vehicle-to-Anything (V2X)
  - Pedestrians
  - Bicycles / motorcycles / mopeds
- Connected everything – Internet of Things
- Basic Safety Messages (BSM) broadcast every 1/10th of a second
  - Vehicle position, speed, heading, acceleration, size, brake system status
- Vehicles and infrastructure need to be equipped to gain benefit

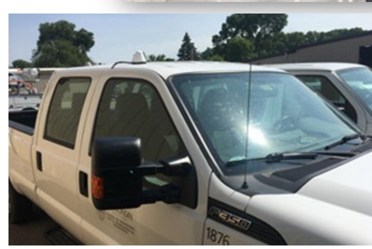
Vehicle to Vehicle Communications
Road Hazard Notification

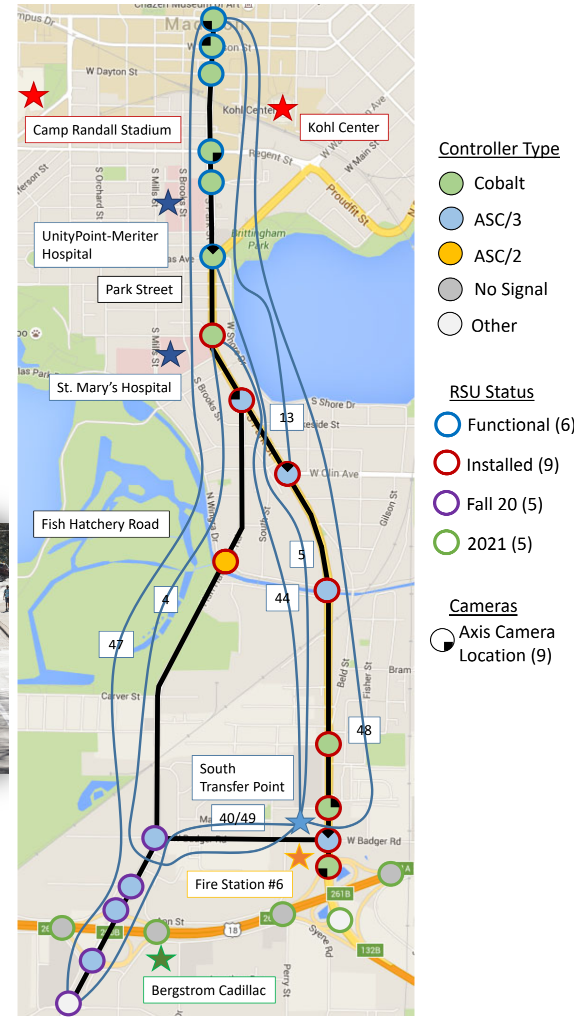


Vehicle to Infrastructure Communications Intersection Warning

City of Madison Park Street Connected Corridor

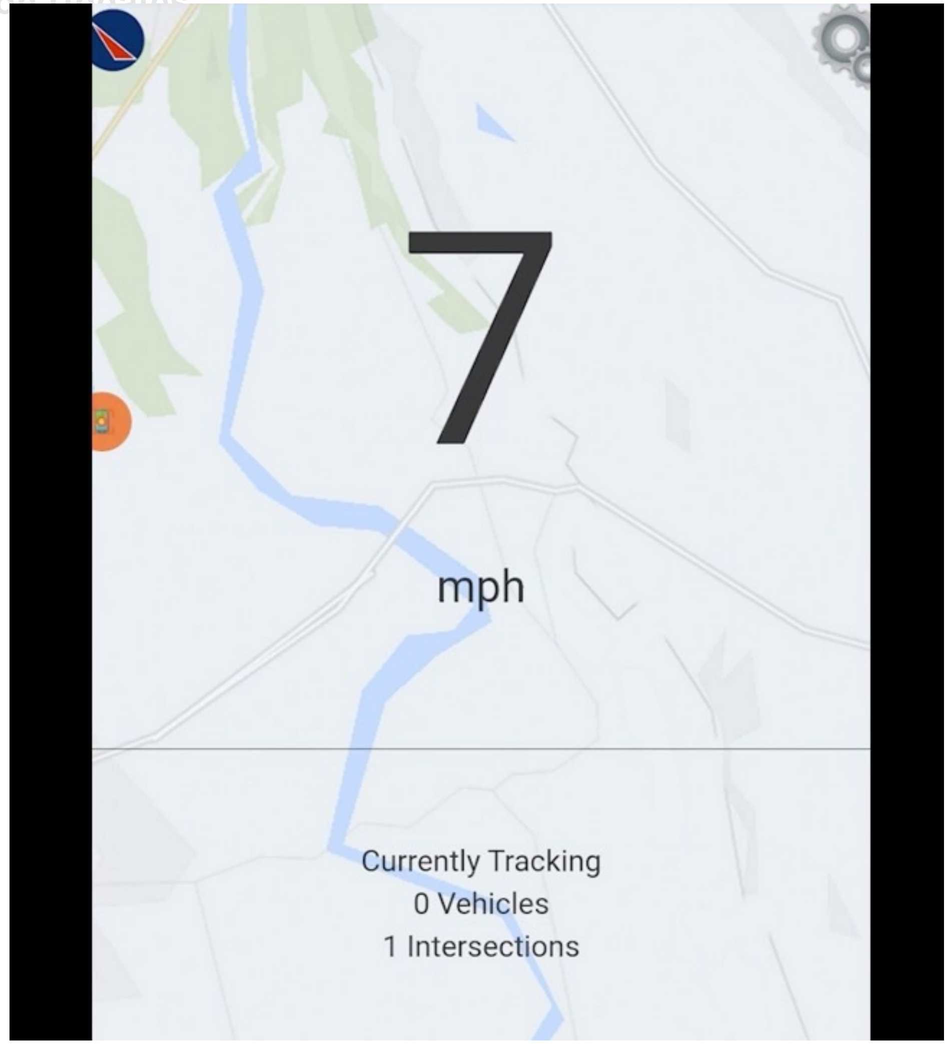
- Satisfies SPaT (Signal Phasing and Timing) Challenge
- Goal: 26 DSRC deployment
- TSP/MMITSS application
- Transit/VRU interaction apps
- Red light violation warning
- Pedestrian / bike crossing
- V2I general testing
- Simulation-to-design
- Preparation for 5G / C-V2X



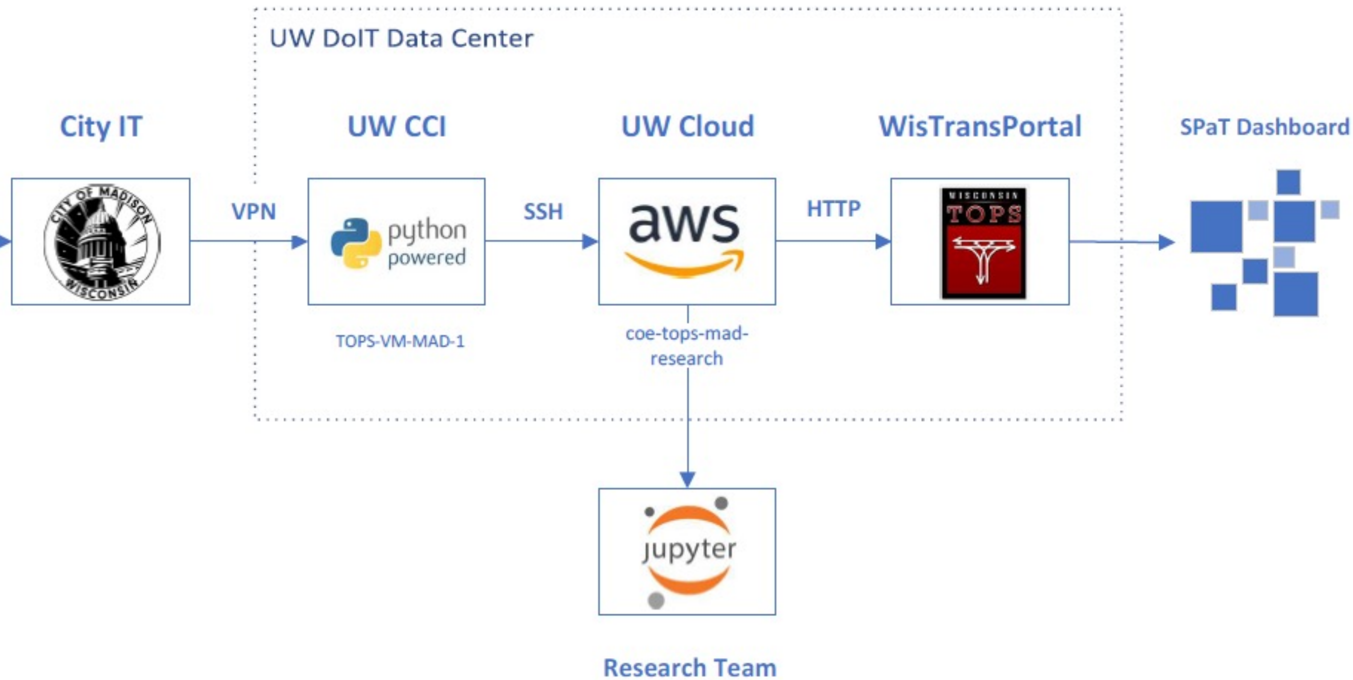


Wisconsin Connected and Automated Transportation Updates

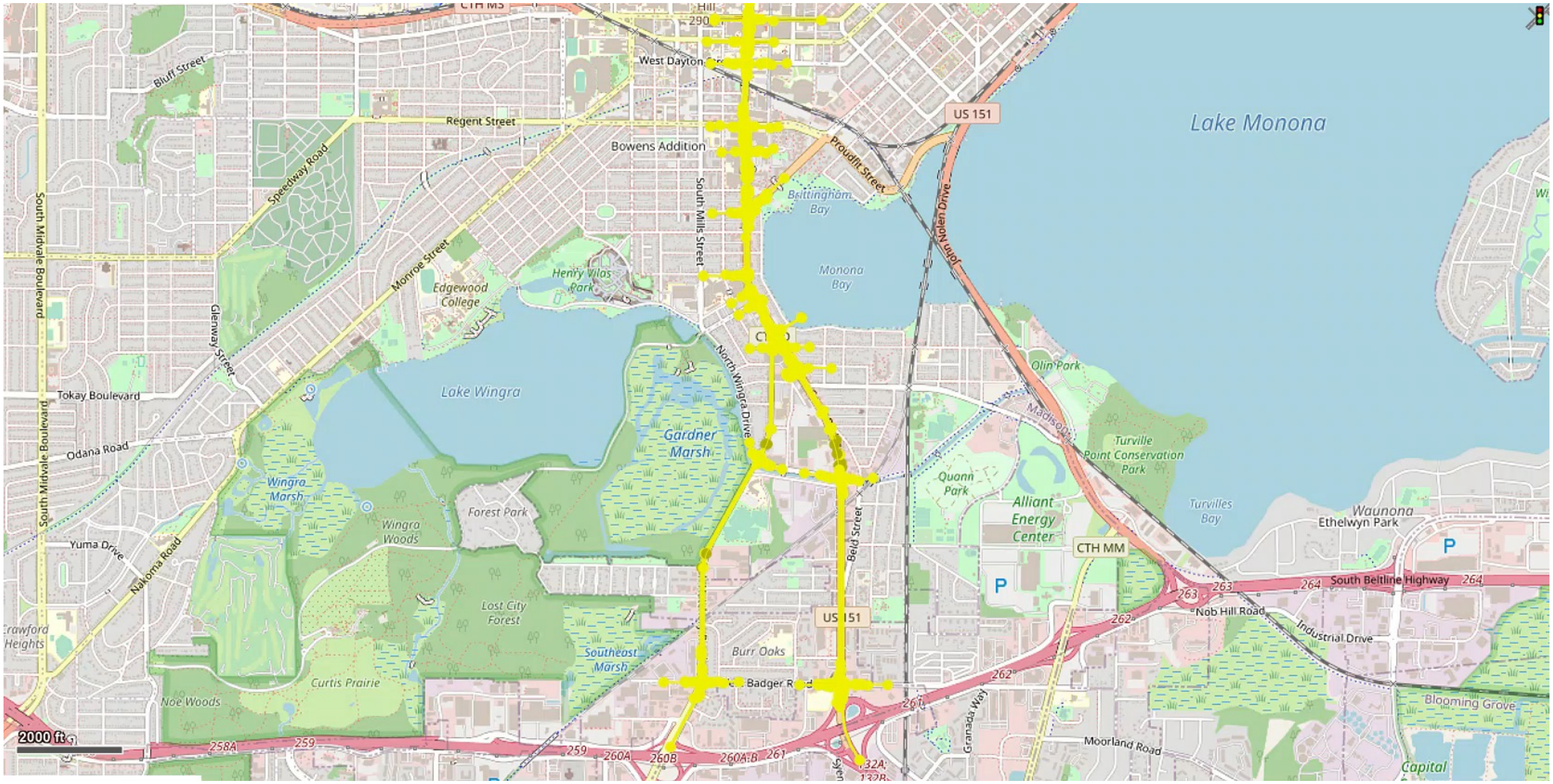
SPaT, MAP, BSM



Park Street Connected Corridor - Data Pipeline



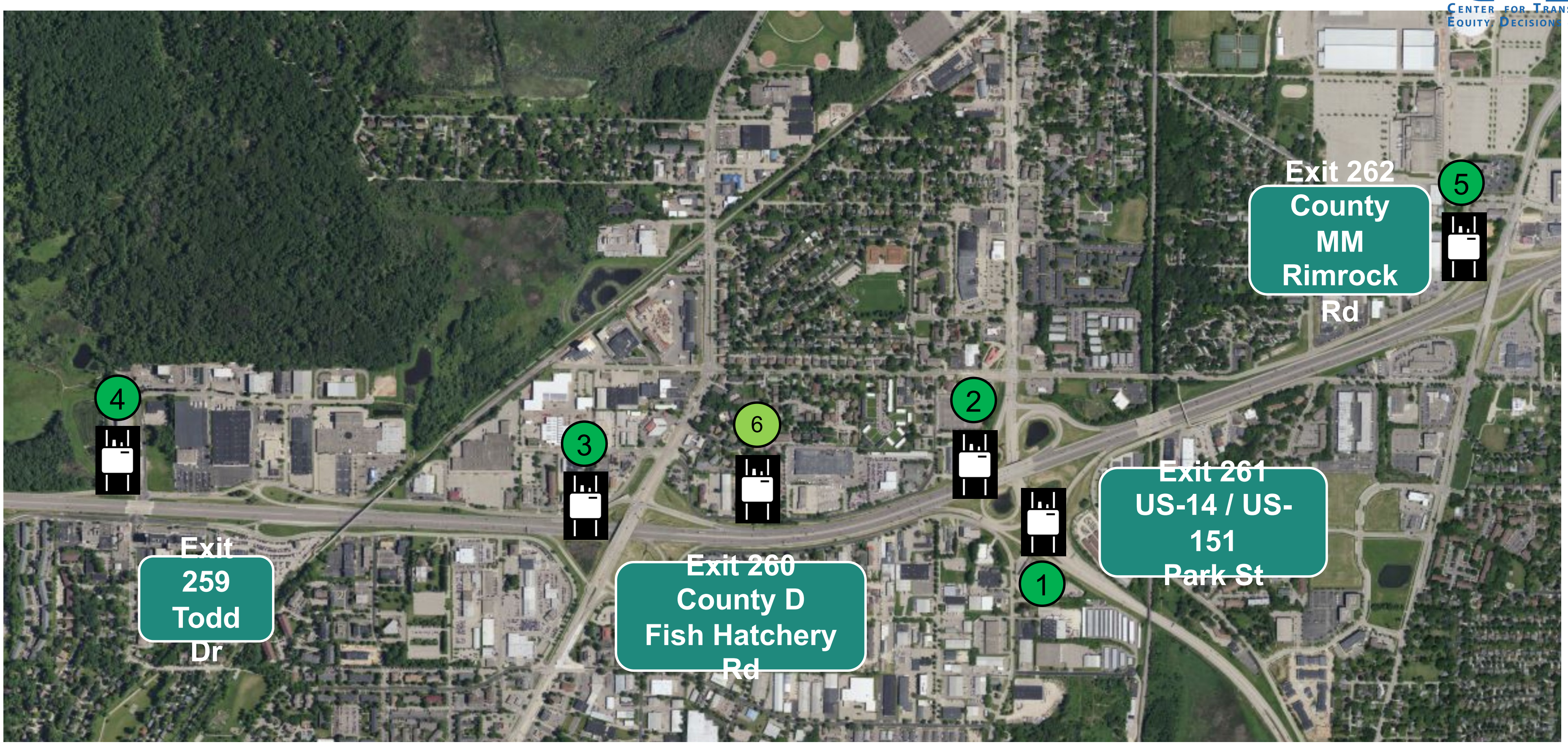
Park Street Connected Corridor



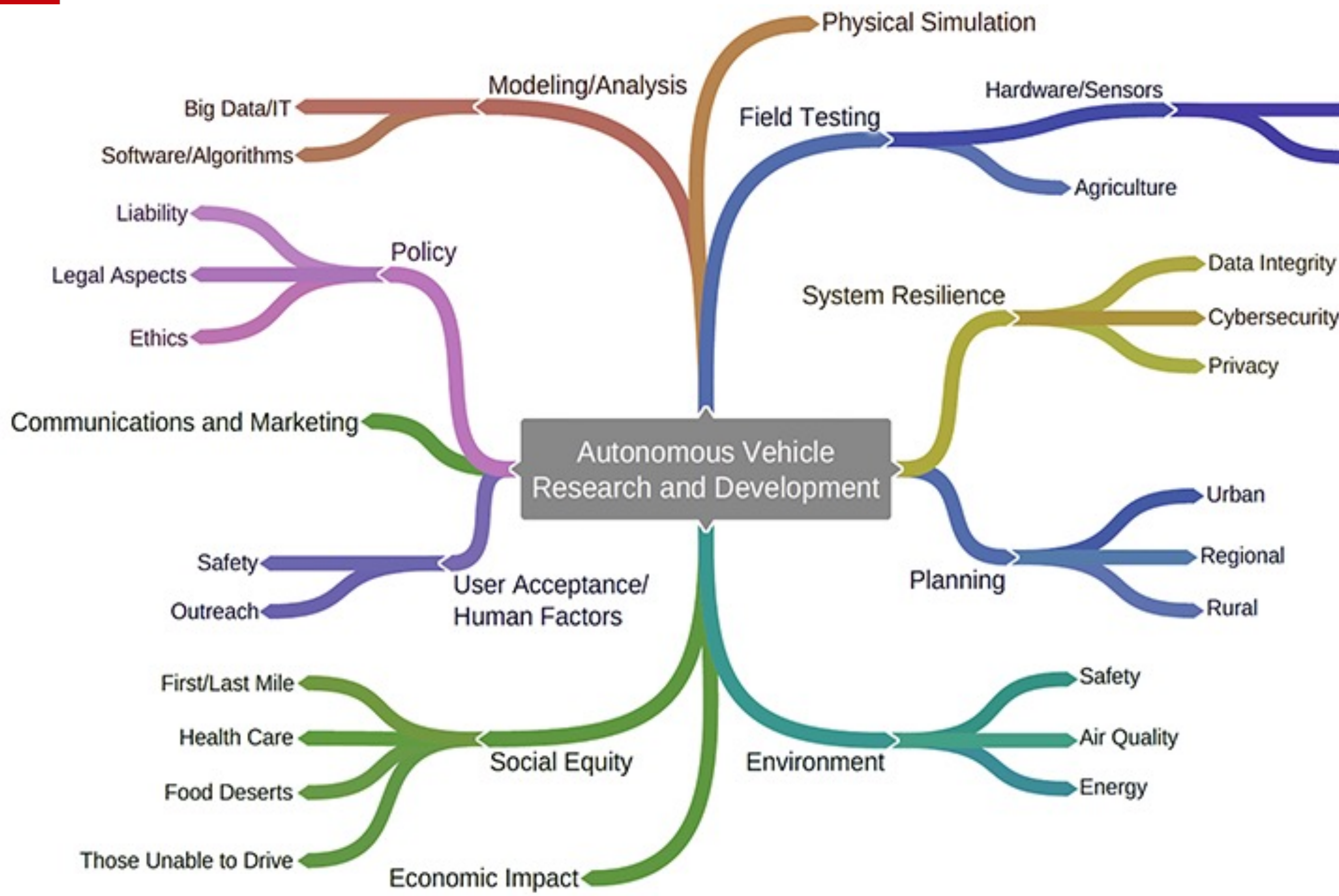
WisDOT CV Pilot Phase 3

- Steps
  1. Determine locations for ~6 RSUs
  2. Installation planning
  3. Field integration
  4. Network integration

Group staff will learn about best practices of this process


Exit 262
County MM Rimrock Rd
5
4
3
6
2
1
Exit 261
US-14 / US-151
Park St
Exit 259
Todd Dr
Exit 260
County D
Fish Hatchery Rd

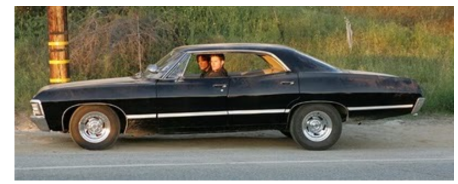
Breadth, Complexity, Edge Cases



Issues Surrounding AV/CV

- Vehicle Cybersecurity
- Information Privacy
- Vehicle Ethics
- Crashworthiness
- System Disengagements / Driver Re-Engagement
- Complex Driving Situations
- Deep Learning / Artificial Intelligence
- Vehicle Assertiveness
- Technology is coming – Will we shape it or let it shape us?

Rural Engagement on Automated and Connected Technologies



- Rural engagement workshops
- Aging community outreach
- Low-income community outreach
- Users with disabilities
- Vulnerable industry sector research
- Healthcare travel
- Trucking / truck platooning
- Interaction with classic cars / motorcycles / horse and buggy
- Rural applications of AV/CV

Example Deployment Process

- **Planning and Analysis**
  - Conducting feasibility studies, site assessments, and environmental impact analysis.
- **Design and Prototyping**
  - Developing detailed designs and creating prototypes for testing.
- **Testing and Validation**
  - Rigorous testing in controlled environments and real-world conditions.
- **Implementation**
  - Deploying infrastructure, installing hardware, and integrating software systems.
- **Monitoring and Maintenance**
  - Continuous monitoring and regular maintenance to ensure safety and performance.

Key Takeaways

- Regulatory
- Policy
- Coordination
- Benefits: Policy Development and Modeling
- Equity
- Financial
- Standardization
- Data Ownership, Access, Privacy, and Cybersecurity

Looking forward

- **Continued Learning**
  - Stay updated with industry advancements
- **Networking**
  - Engage with industry professionals
- **Innovation**
  - Be a part of sustainable solutions

Questions?

Appendix B: Technology Transfer

The main technology transfer in this project was the development and refinement of the course materials as well as the two course offerings to a wide range of professionals including law enforcement, municipal engineers, and public works professionals. The post-project T2 plans include further refinement and inclusion of this course content in InterPro course offering at UW-Madison.

CENTER FOR TRANSPORTATION EQUITY, DECISIONS & DOLLARS

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WISCONSIN UNIVERSITY OF WISCONSIN–MADISON

C-TEDD@UTA.EDU | CTEDD.UTA.EDU | @UTACTEDD | @C__TEDD | @ CENTER FOR TRANSPORTATION, EQUITY, DECISIONS AND DOLLARS | 817.272.5138