Some Reflections on Resilient Integrated Infrastructures for Electricity and Mobility

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NSF workshop on "Towards Carbon-neutral Electricity and Mobility"

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- This short talk will muse on how our consideration on global warming has led to development of carbon-neutral solutions and technologies, in particular, on mobility and electricity.
- This results in challenging issues in the **design and operations** of complex integrated power and mobility infrastructures.
- Claims and disclaimers: I have extensive background in transportation and mobility (many PhDs and collaborations), while only limited experience in power and electricity (with some published research in power planning and distribution, and power reliability, and 2 PhD students).





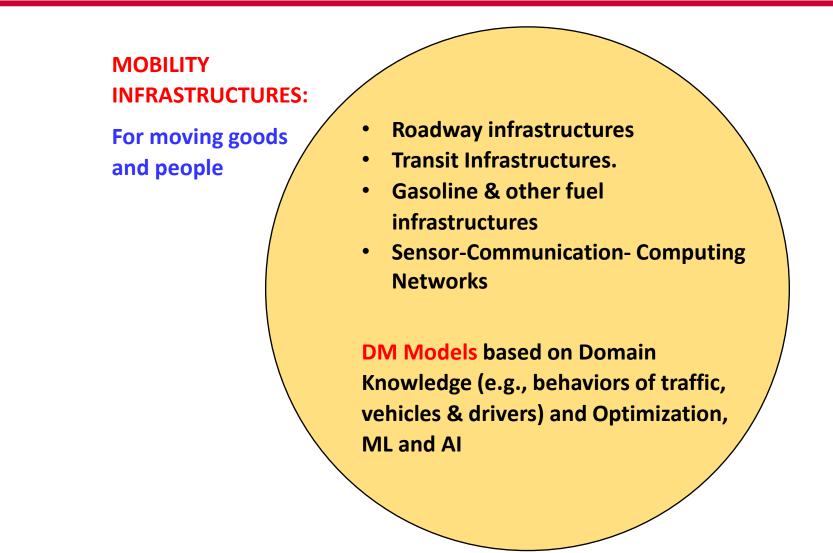
- 1. Big Pictures: Summarize current interconnected infrastructures
- Some details on Mobility Infrastructures for Traffic and EVs (based on my research)
- 3. Some issues on developing Integrated Electricity-Mobility Infrastructure

– includes decision-making on the design of physical architecture as well as its efficient and reliable operations





The Big Pictures : Mobility Infrastructures



The Big Pictures : Electricity Infrastructures



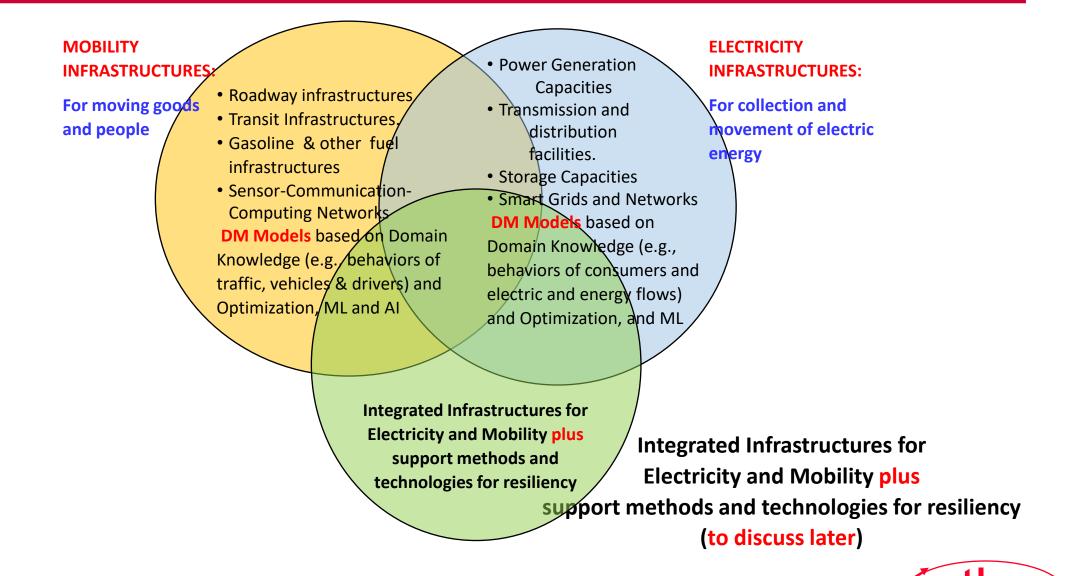
- Transmission and distribution facilities.
- Storage Capacities
- Smart Grids and Networks

DM Models based on Domain Knowledge (e.g., behaviors of consumers and electric and energy flows) and Optimization, and ML

ELECTRICITY INFRASTRUCTURE:

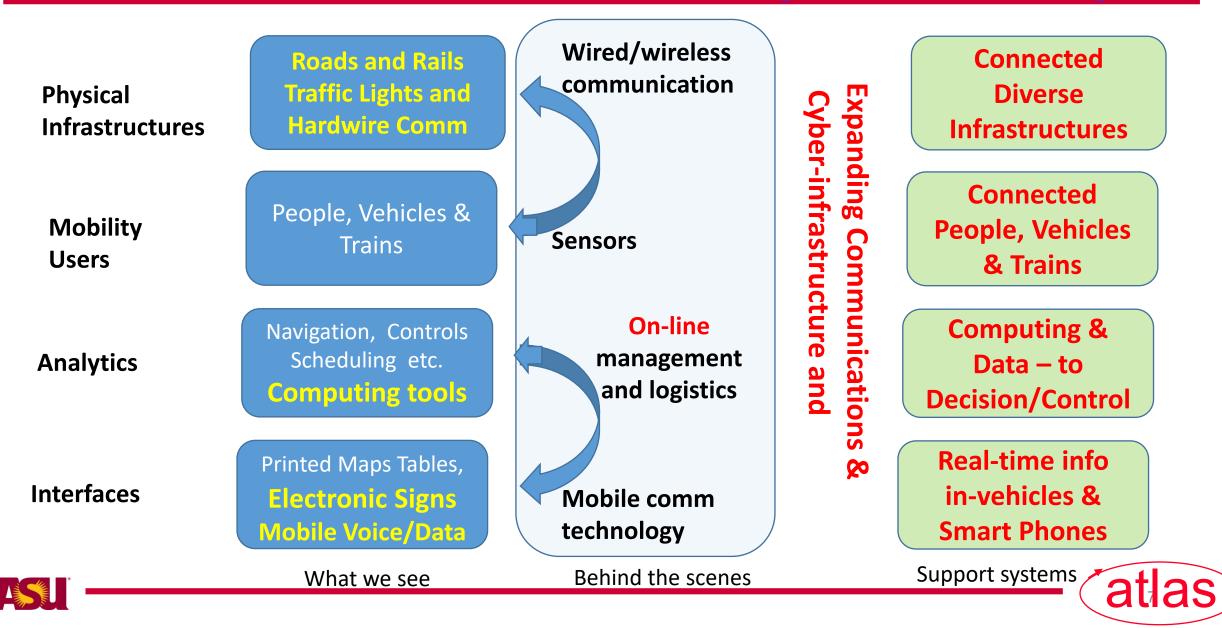
For collection and movement of electric energy

The Big Pictures



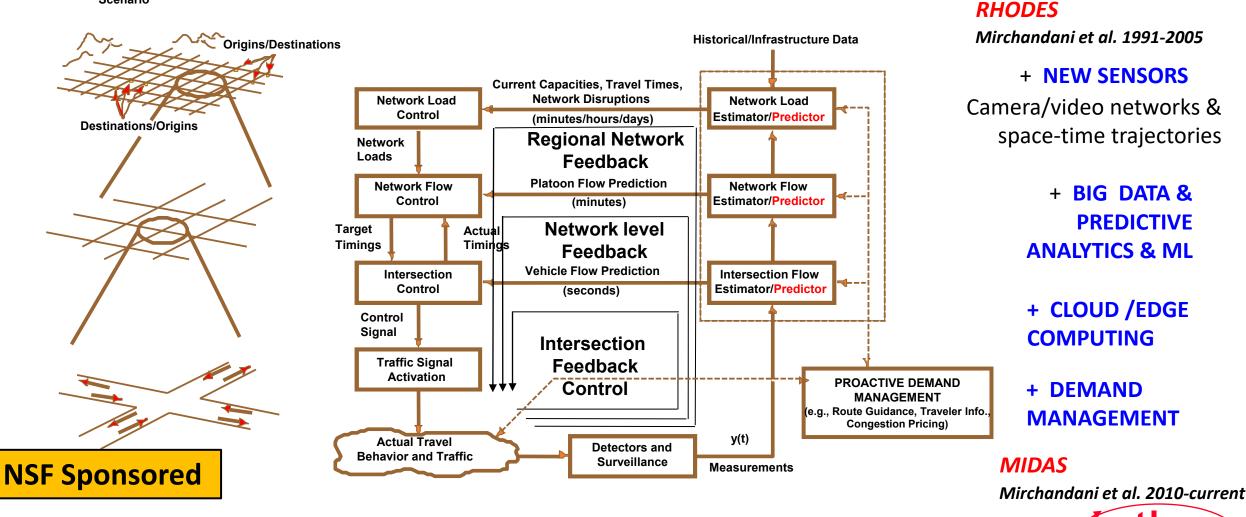


Current Infrastructures Driven by User Mobility



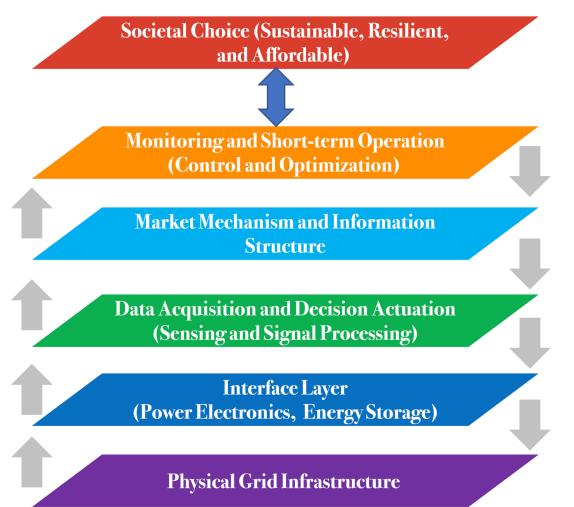
Support: Cyber-Phy. Architecture for Traffic Flow Management





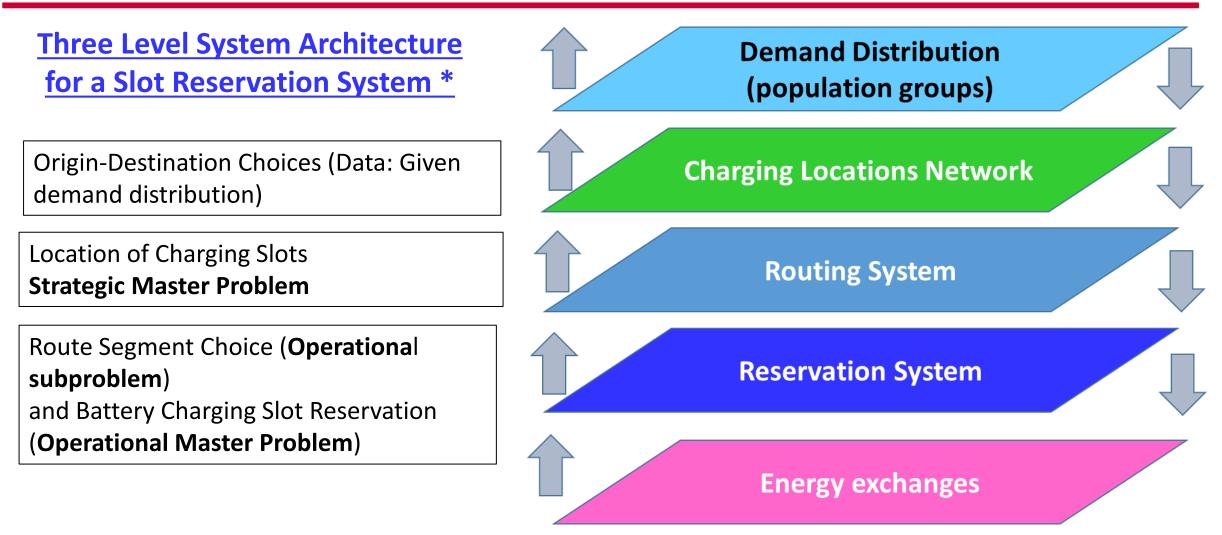


A possible architecture of the future electricity grid*



* Source: Le Xie, Chanan Singh, Sanjoy K. Mitter, Munther A. Dahleh, and Shmuel S. Oren. "Toward carbon-neutral electricity and mobility: Is the grid infrastructure ready?" Joule (2021)

Support: An infrastructure for an EV Charging System



* Supported by NSF Grant 1234584 "Design, Analysis and Evaluation of Battery-Changing Infrastructure for Electric Vehicles

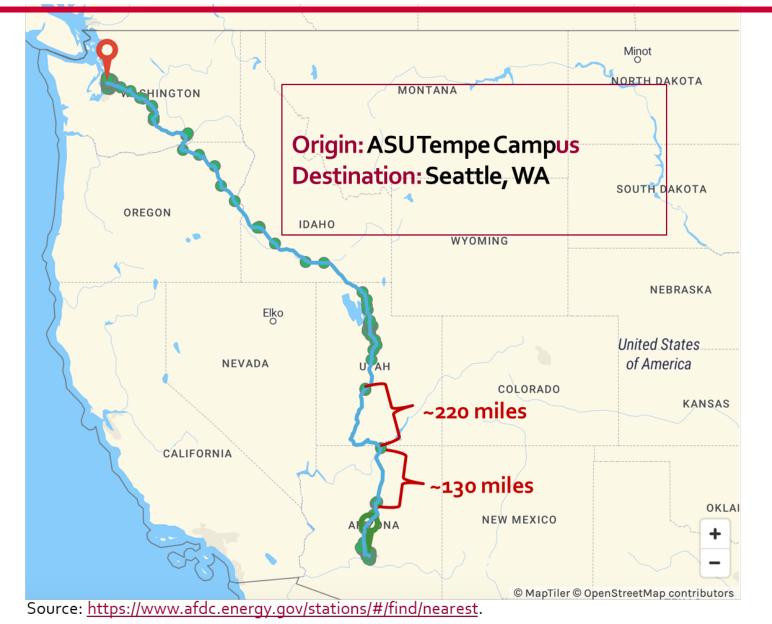
An EV Charging Infrastructure with Reservation given EV Charging Slots

Motivation

Considering purchasing an electric car?



- Infeasibility of a trip
- Fear of running out of charge – range anxiety
- Long charging times



Subproblem: Routing from an O to D

Electric vehicle shortest walk problem

- Suppose we wanted to find the route an electric vehicle should take from an origin (O) to a destination (D)
- The route must include where to stop to recharge the battery
- Not necessarily a "path" since may have to traverse edges multiple times and hence we may end up with a "walk" in a graph
- We may want to limit the number of stops to a certain number because they are frustrating
- How do we find this shortest walk? Can it be done solved efficiently? (Ans: Yes)

Master problem: Online Slot Reservations (OSR)

Dynamic Real-Time Operations with Realtime OD Generations Developed an "Online routing and battery reservations" for electric vehicles in a network with battery charging slots

The whole OSR system can be modeled as a Large Markov Decision Process solvable **by Al's Reinforcement Learning***

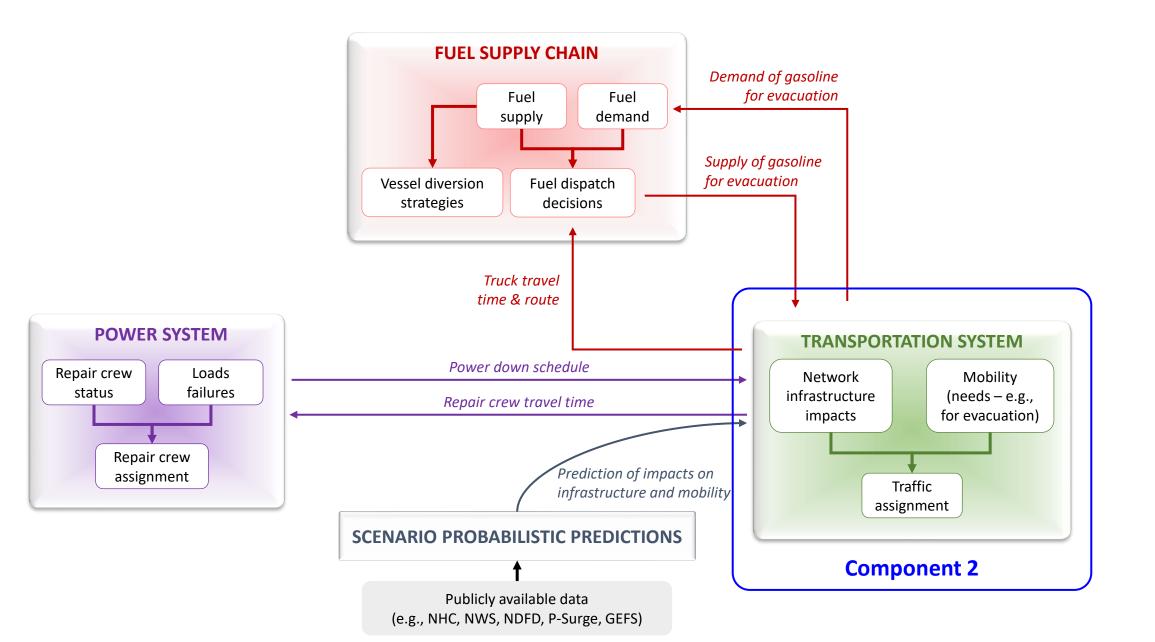
* Source: Jonathan D Adler, Pitu B Mirchandani "Online routing and battery reservations for electric vehicles with swappable batteries" Transportation Research Part B: Methodological, 70, (2014).

Issues on interconnected Infrastructures

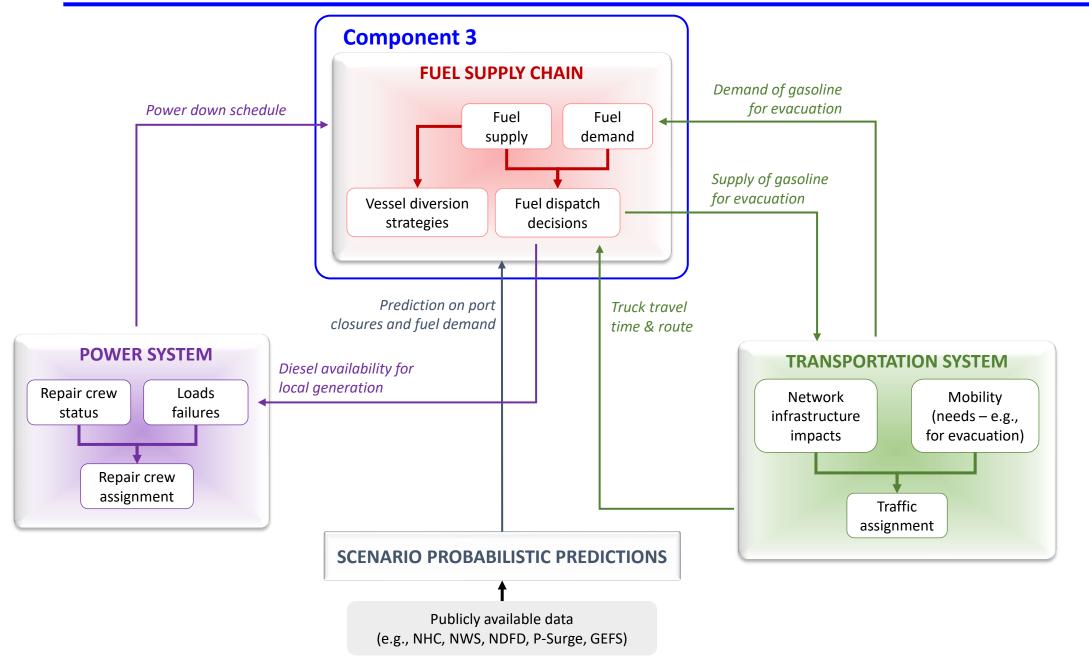
- Recently studied Proactive Response to Hurricane Disasters *
- Developed a comprehensive simulation, and data-driven decision supports systems
- Next three slides quickly summarize the complex interconnectedness of three infrastructures: transportation, power, and liquid fuel supply chain **

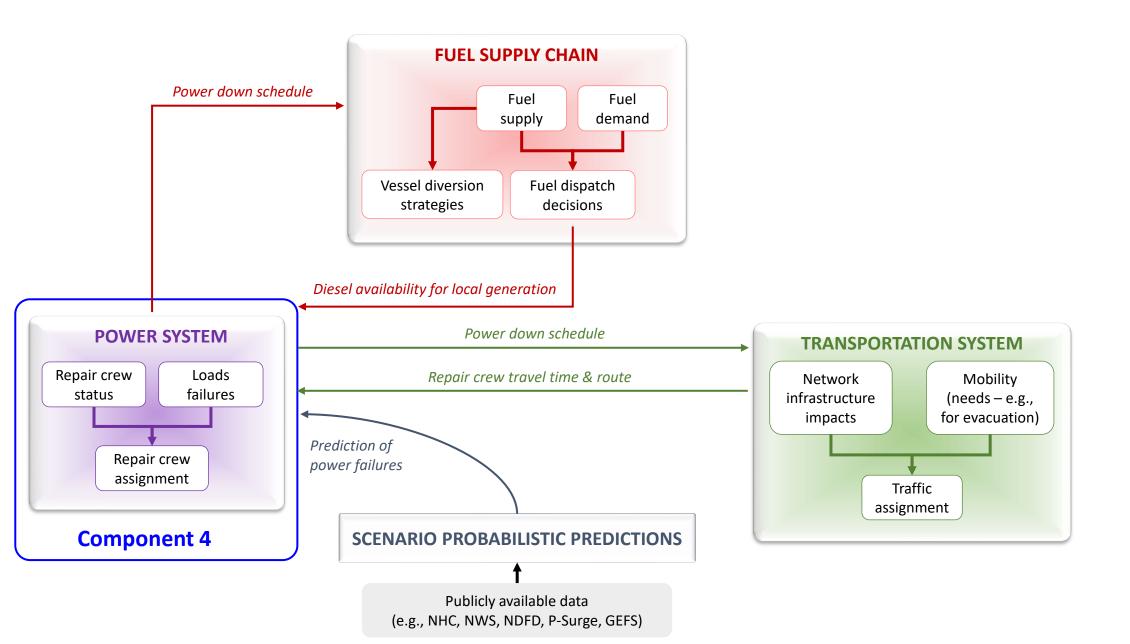
* Pitu Mirchandani, Lauren Davis, Ross Maciejewski, David Morton, Giulia Pedrielli, **Proactive Decisions & Response Under Uncertain Cascading Emergencies**, Final Report for DHS Center for Accelerating Operational Efficiency (CAOE), Arizona State University, Feb 2020.

** Ketut Gita, Modeling Cascading Network Disruptions under Uncertainty For Managing Hurricane Evacuation, PhD Dissertation, August 2020

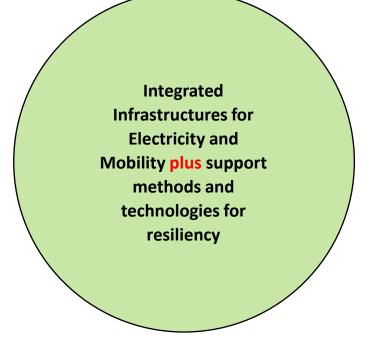


Proactive Decisions & Response under Uncertain Cascading Emergencies





Integrated Electricity-Mobility Infrastructure



*Michael Dumiak, "A Road Test for Vehicle-to-Grid Tech" IEEE Spectrum, August 2022

Integrated Electricity-Mobility Infrastructure (IEMI) Issues

- Range Anxiety well designed IEMI will decease this and improve market penetration for EVs
- **Power Outages**: Revisit Plug-in Hybrid (PHEW)
- **Disaster Resiliency**: Consider multifuel vehicles
- **Bidirectional Charging**: Powering Grid by EVs*
- Harvesting Energy while driving and selling to Grid: A new vehicle design?
- Role of Incentives and Subsides?
- Charging & gasoline pricing: An Independent Exchange System? A new Market Design?
- **Overall Design**: High-level costs and pricing considering market oil prices, electric pricing, reserves, etc.: New federal organization like FAA?



Thank you!