The Promise of Sustainable Transportation: An Environmental Investigation of Emerging Transportation Technology

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Outline

1. Motivation and Research Framework
2. Research Work
   - Autonomous Vehicle Adoption: Use Phase Environmental Implications
   - Electric Bike Sharing: The Case of Madison, Wisconsin
   - Insights into Pandemic Environmental Impacts
3. Research Needs & Conclusions

The Transportation Sector: Environmental Insights

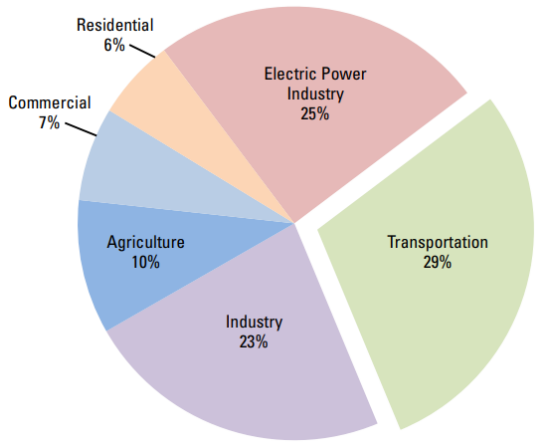


Figure 1: Share of U.S GHG Emissions by Sector, 2019 [1]

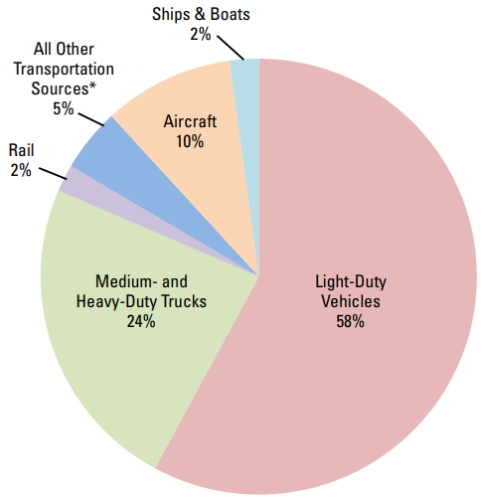


Figure 2: Share of U.S. Transportation Sector GHG Emissions by Source, 2019 [1]

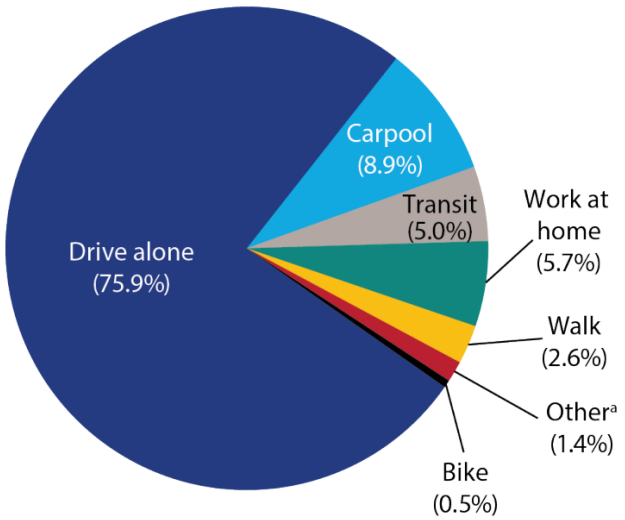


Figure 3: Commute share by Mode, 2019 [5]

- Most polluting sector in the US; overtaking the power sector
- On road vehicles and driving alone major are contributors to transport pollution

Road to Sustainable Transportation

Challenges

- Modal Shifts: Migrate users away from carbon-intensive modes of transportation into sustainable ones
- Emerging Modes: Decrease reliance on fuel-based mobility

Trends in Transportation Sector

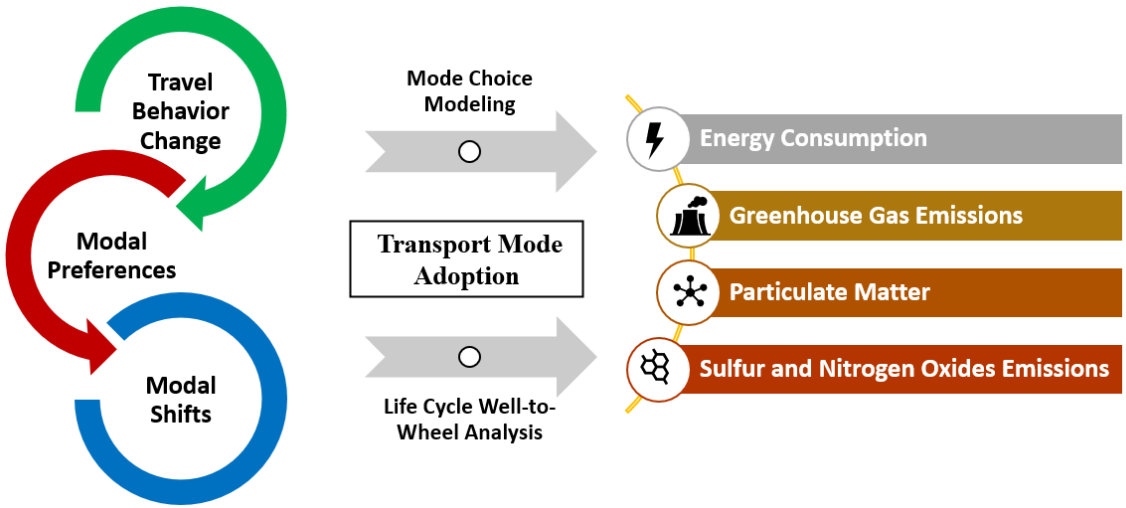
1. Optimistic commercial deployment of Autonomous vehicle (AVs)
2. Electric vehicle sales grew by **85%** from 2020 to 2021 [4]
3. Trips in micro-mobility (shared bicycles, electric bicycles, electric scooters) increase **60%** between 2018-2019 [3]

Research Framework

Overarching Goal

To steer the development and deployment of emerging transportation technology in ways that match user preferences and are environmentally beneficial

- Identify users of different transportation modes
- Estimate and predict market share of different transportation modes
- Identify potential modal shifts from one transportation to another
- Quantify the resultant environmental impacts

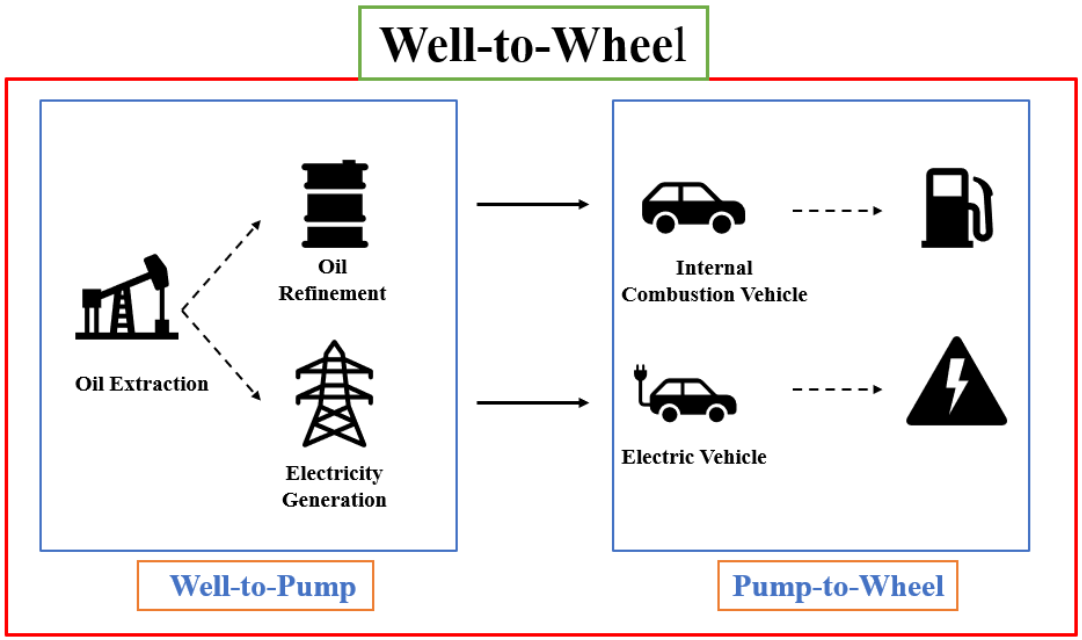


Research Methods

A. Mode Choice Modeling: Traveler's probability of choosing a mode of transportation in presence of other modes; informed through survey data

$$\mathcal{P}^n = \int_\beta \frac{e^{\beta_n \mathcal{X}_{ni}}}{\sum_j e^{\beta_n \mathcal{X}_{nj}}} f(\beta, \theta) d\beta \tag{1}$$

B. Use Phase LCA: Quantifying environmental emissions of modes of transportation on a per-mile basis



Part 1: Autonomous Vehicle Adoption [2]

Autonomous Vehicle Adoption

What are the environmental tradeoffs resulting from the adoption of autonomous vehicles (AVs) ?

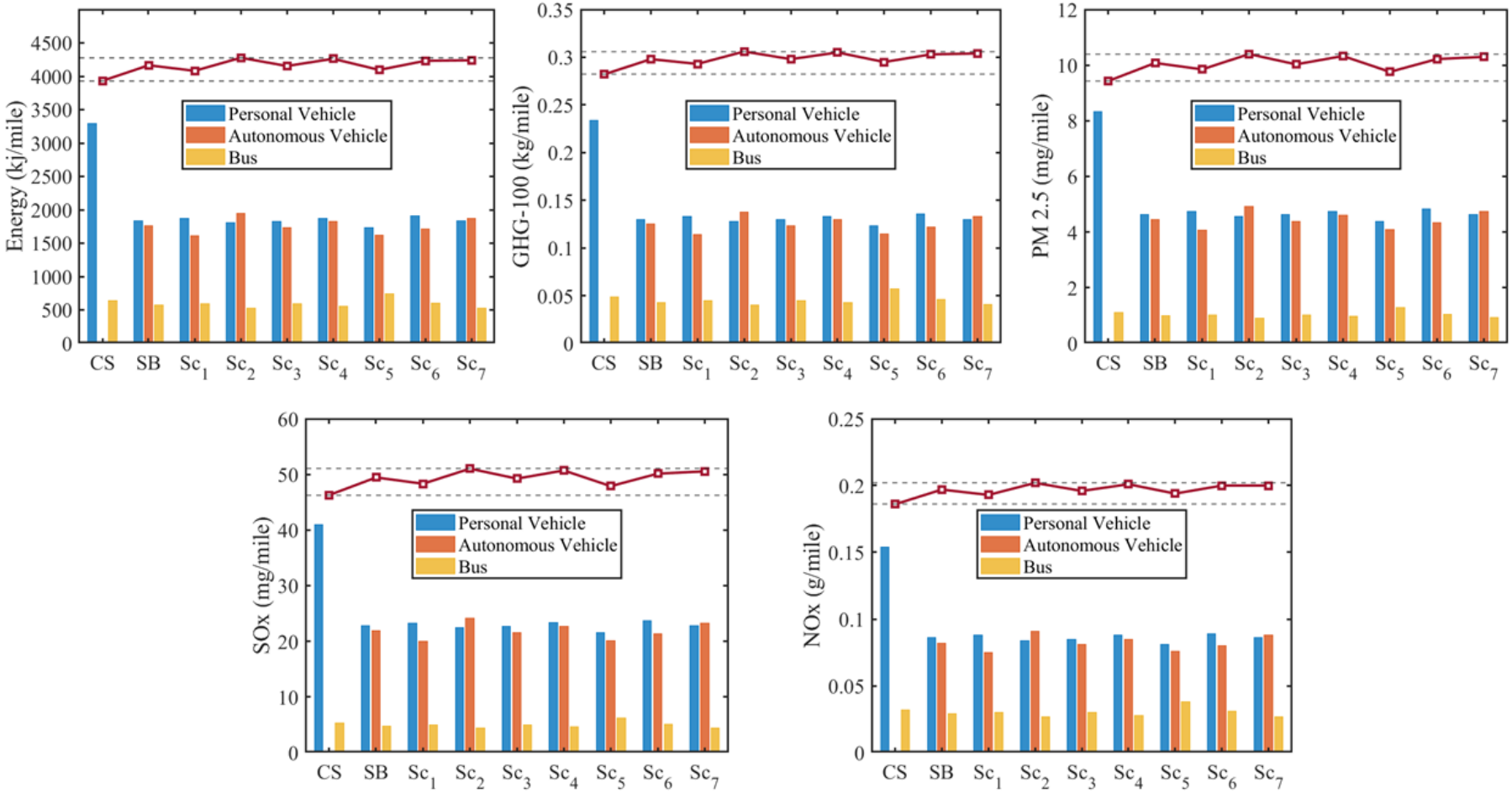
Autonomous Vehicle Adoption: Study Results

Major findings:

- Autonomous vehicles were a desirable mode of transportation by travelers: reducing ridership of public transport and bicycles (i.e., the bus in Madison)
- In our survey **31%** of the time respondents chose AV as their desired mode of transportation, **32%** for personal vehicles, **16%** for bus and **21%** for bicycle

Autonomous Vehicles: Study Results

Environmental Implications of AV's induced modal shifts: An overall increase in environmental emissions



Environmental Implications of AV's Induced Modal Shifts

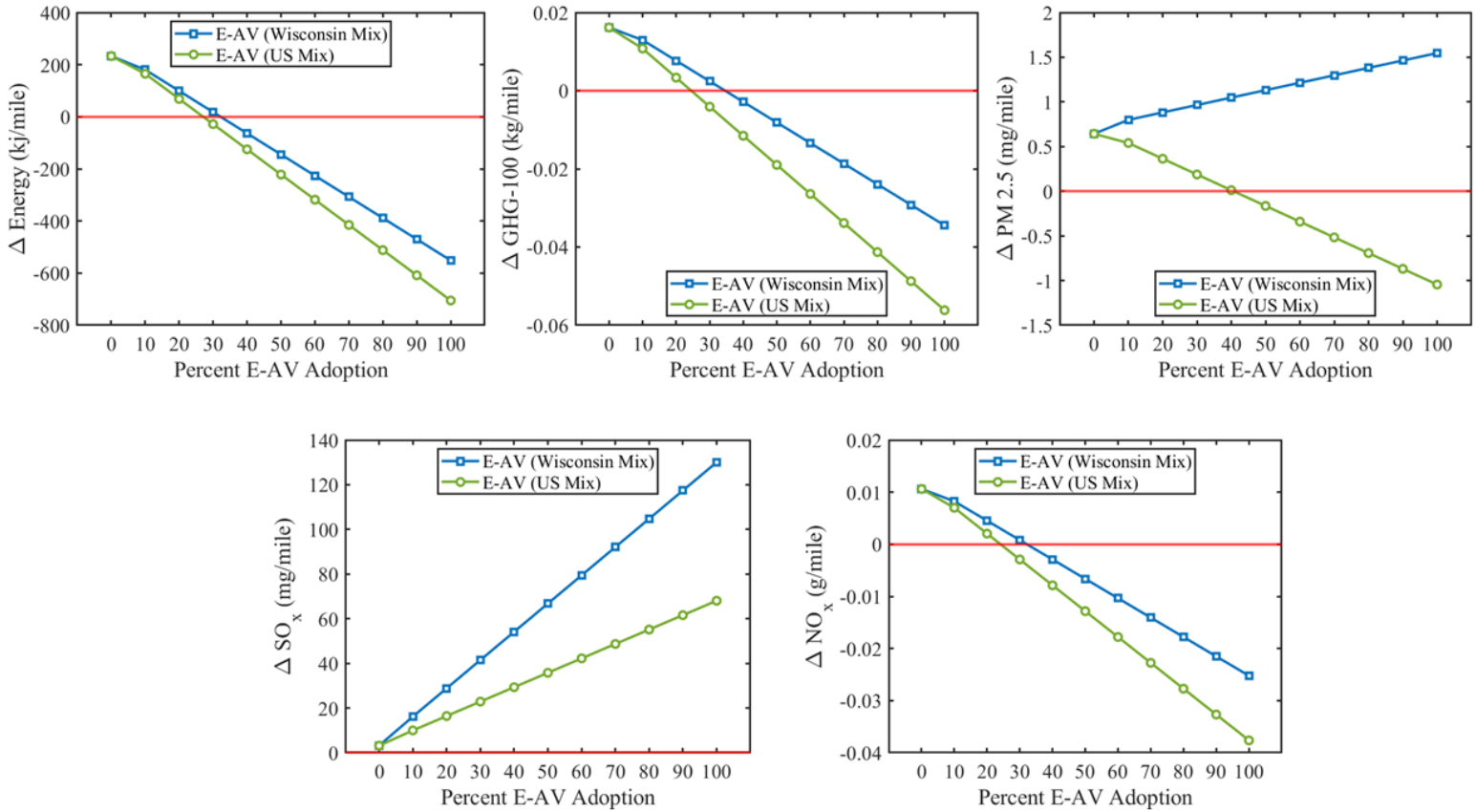
Scenario	Description
Sc1	20% increase in AV travel cost
Sc2	20% decrease in AV travel cost
Sc3	20% decrease in bus access time (walking and waiting)
Sc4	20% increase in personal vehicle travel cost
Sc5	20% decrease in bus travel time
Sc6	20% increase in personal vehicle and AV travel time
Sc7	10% increase in AV travel cost with 20% decrease in its travel time

Environmental impact	Survey (SB)	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7
Energy consumption (kJ mile^{-1})	+5.93%	+3.81%	+8.81%	+5.66%	+8.41%	+4.17%	+7.64%	+7.82%
GHG-100 (kg mile^{-1})	+5.72%	+3.68%	+8.47%	+5.48%	+8.14%	+4.30%	+7.47%	+7.51%
PM 2.5 (mg mile^{-1})	+6.80%	+4.39%	+10.20%	+6.36%	+9.52%	+3.51%	+8.31%	+9.14%
SO_x (mg mile^{-1})	+6.85%	+4.41%	+10.26%	+6.40%	+9.56%	+3.47%	+8.34%	+9.19%
NO_x (g mile^{-1})	+5.70%	+3.67%	+8.44%	+5.47%	+8.12%	+4.35%	+7.46%	+7.58%

Environmental Implications:

- Adoption of AV's could increase environmental emissions
- Policies to incentivize public transport usage can reduce impacts of AV adoption; but unable to offset it

Environmental Implications of AV's



Electric Autonomous Vehicles adoption

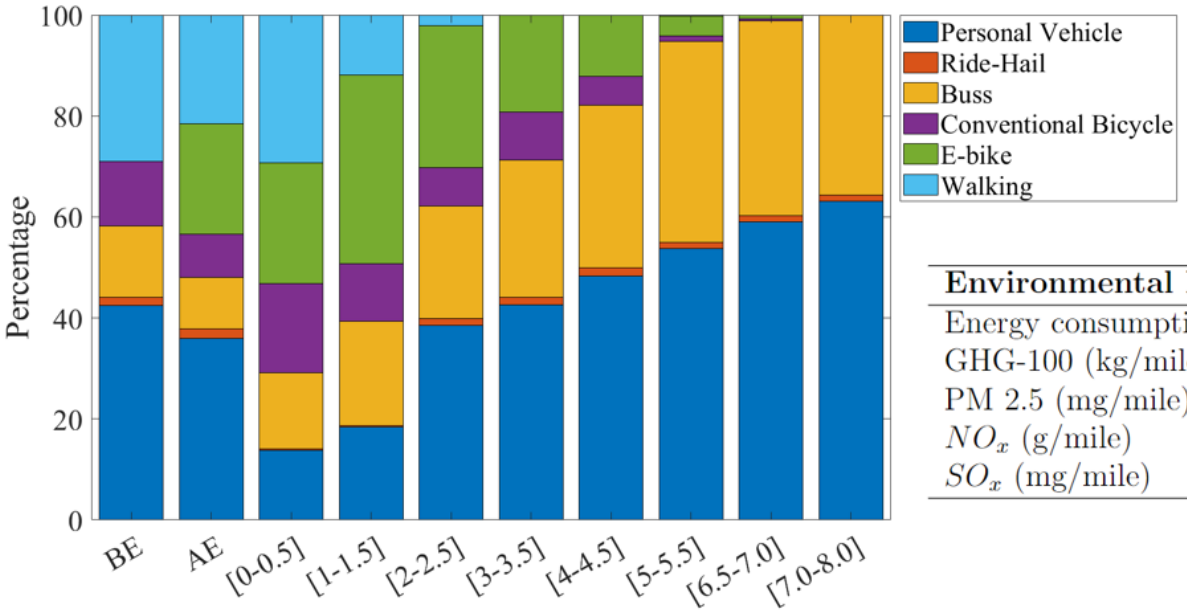
- Can offset the environmental impacts of AV adoption
- Benefits expected are dependent on adoption rates and electricity generation

Part 2: Electric Bicycles (E-Bikes)

E-Bikes Sharing Program (BCycle in Madison)

What are the environmental benefits of an E-Bike sharing program? and how effective it is inducing modal shifts away from carbon-intensive modes?

E-Bikes: Study Results



Environmental Impact	Change (%)
Energy consumption (kj/mile)	−15.78%
GHG-100 (kg/mile)	−15.92%
PM 2.5 (mg/mile)	−14.44%
NO_x (g/mile)	−15.89%
SO_x (mg/mile)	−12.61%

Findings

- E-bikes can compete for ridership against personal vehicles and busses: resulting in environmental benefits
- Some walking and conventional bicycle trips are substituted by E-bikes: resulting in environmental emissions
- E-bikes are most competitive at short distance trips (generally ≤ 2 miles)

Part 3: Pandemic Insights

Environmental implications of the pandemic

How did the pandemic influence usage of transportation modes? And what are resultant environmental implications?

Part 3: Pandemic Influence on Environmental Impacts

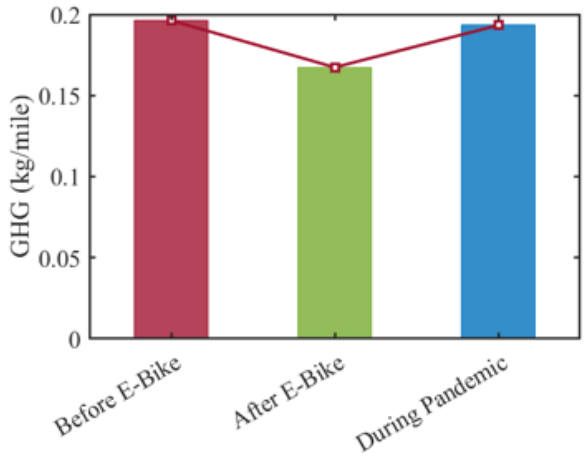


Figure 4: Emissions based on modal shifts (per-mile basis)

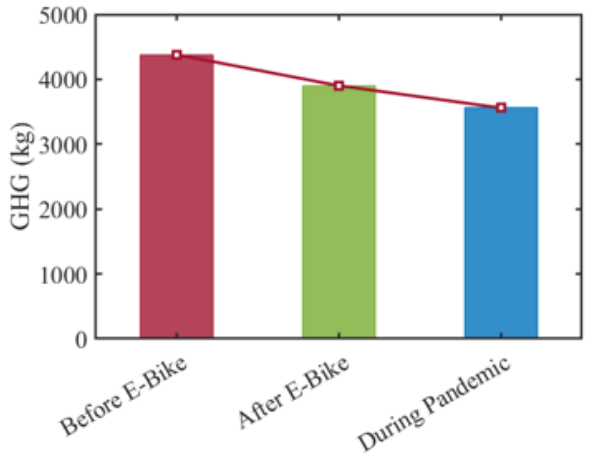


Figure 5: Emissions based on trip distances

Duality of impacts due to pandemic

- The pandemic shifted modal usage towards personal vehicles: Travelers ascertain a high risk in shared travel (bus, shared vehicles)
- Reduction in overall trips done by travelers resulted in no environmental impacts for modal shifts

Research Needs and Conclusion

The Move into Sustainable Transportation Technologies

- Transportation modes should match consumer travel behavior to warrant competitive usage
- Emerging modes trigger complex shifts in travel behavior all leading to cascading environmental impacts
- Electric bikes enjoy a level of attractiveness that could be utilized to decrease transportation emissions
- Electric mobility and the energy infrastructure (the way we generate our electricity) can be leveraged to limit transportation emissions

Questions ?

References I

[1] EPA (2021). Fast facts u.s. transportation sector greenhouse gas emissions 1990-2019.

[2] Kontar, W., Ahn, S., and Hicks, A. (2021). Autonomous vehicle adoption: use phase environmental implications. *Environmental Research Letters*, 16(6):064010.

[3] NACTO (2019). Shared micromobility in the u.s.:2019. *NACTO Bike Share and Shared Micromobility Inititative*.

[4] Saver, E. (2022). New plug-in electric vehicle sales in the united states nearly doubled from 2020 to 2021.

[5] USDOT (2021). Transportation statistics annual report, 2021. *Bureau of Transportation Statistics*.