The Impacts and Adoption of Connected and Automated Vehicles in Tennessee

TennSMART Webinar, August 27th 2020

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Contents

- Background & introduction
- Survey findings
- Modeling framework
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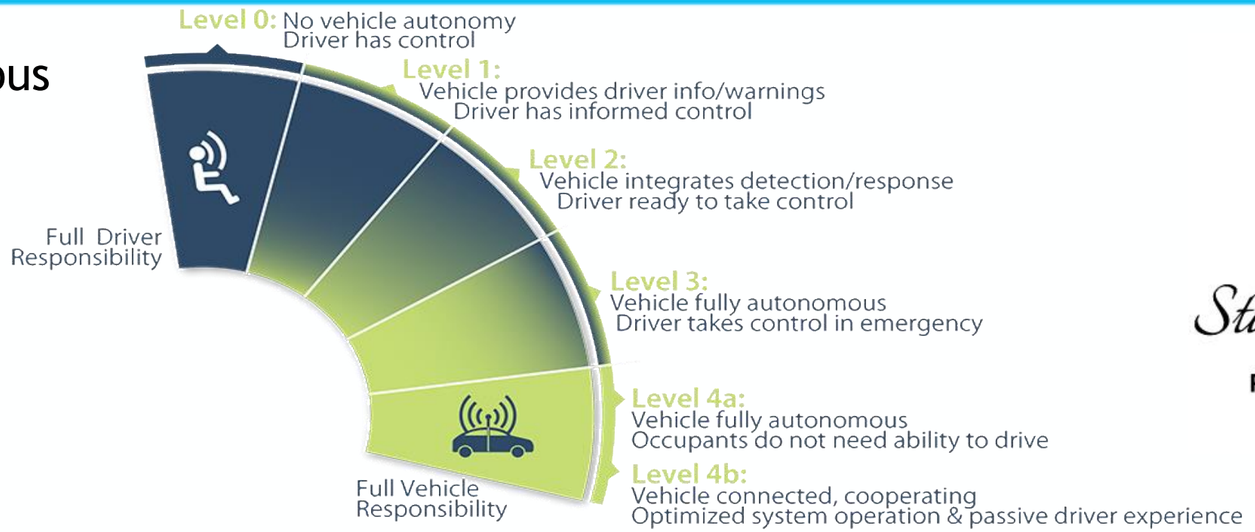
Background / Motivation

- We realize Connected and Autonomous Vehicles (CAVs) will provide benefits
- But mixed opinions on adoption
- How to identify demand?
- Majority of studies revolve around modeling:
  - Results in imprecise forecasts
  - Fail to capture the effects of an individual adopting CAV/HAT based on his/her social network.
- TN welcomes CAV, how do we model demand?



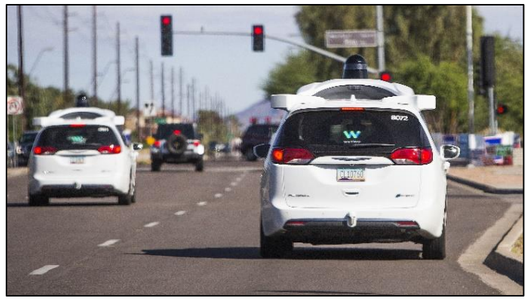
State of Tennessee

PUBLIC CHAPTER NO. 474

SENATE BILL NO. 151

Tesla Autopilot (Level 2): Operational on public roads

Audi A8L dashboard (Level 3 in European conditions): available for European consumers



Google Waymo (Level 4): CAV based TNC, operational in Phoenix, AZ

Images' sources: https://www.dropbox.com/s/d6wzvph3khy1whl/image%20sources.docx?dl=0

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Objectives

- To understand the perception of Tennessee residents towards CAVs.
- Intention to adopt/own/use different CAV based mobility services
  - Personal CAVs and carpooling
  - CAV based ride hailing & sharing services
  - CAV based public transport.
- Adoption forecasts at ZIPCODE level

Statewide CAV survey (April 2020 – June 2020)

- Survey
  - Hosted in Qualtrics
  - Survey distributed through multiple online channels:
    - Amazon Mechanical Turk
      - » Crowdsourcing website
      - » Survey posted as a Human Intelligent Task (HIT)
    - Social media: Facebook and Instagram
      - » Survey promotion through advertisement
    - Higher education institutes in Tennessee
    - Survey panel:
      - » Dynata - data analytic company
- Received 4,602 complete responses from all channels

Survey Components	Questionnaire Elements
Survey Part A: Person level information	Age, gender, employment, income, work schedule
Survey Part B: Household level information	Household size, composition, vehicle ownership
Survey Part C: Social Networks	Communication type, work/social ties,
Survey Part D: Preferences towards CAVs	Importance towards CAV, purchase power, risks, CAV features and perceptions

dynata

amazon mechanical turk beta

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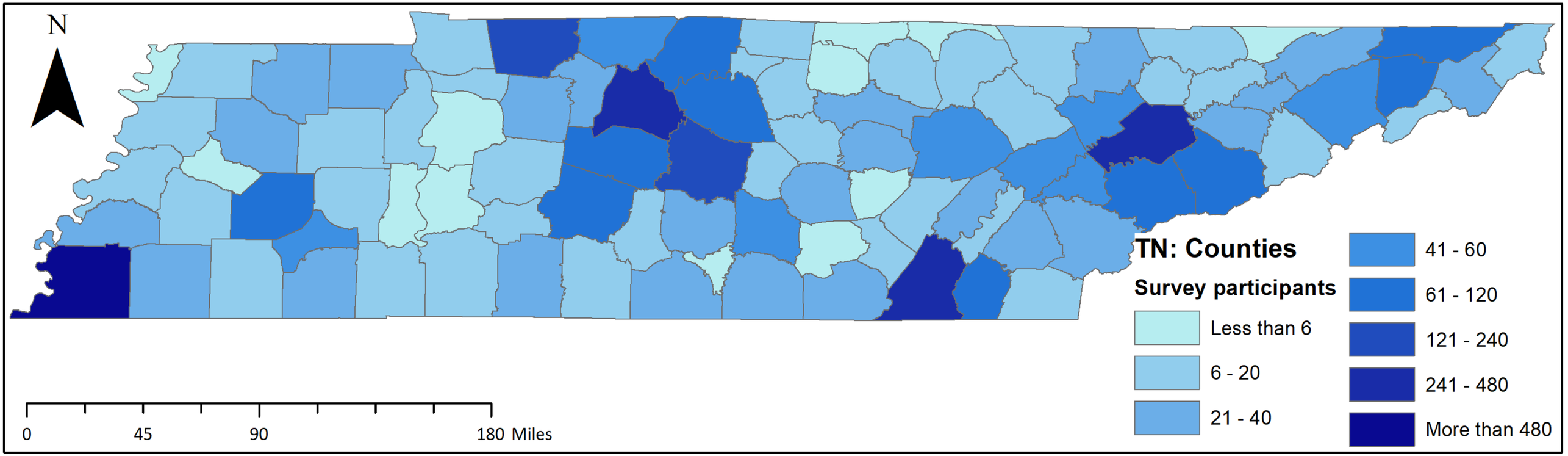
Statewide CAV survey: County wise responses

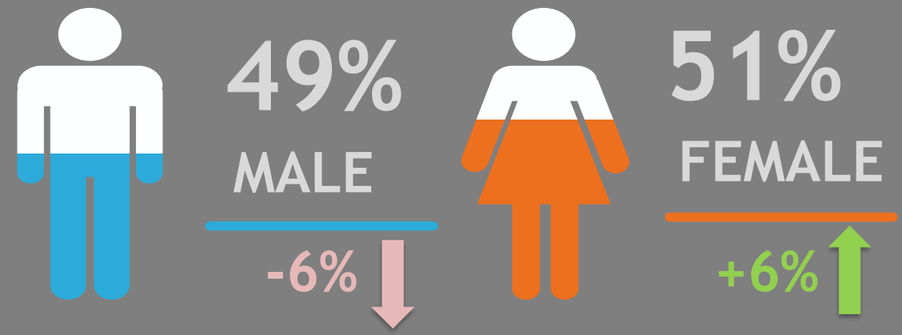


- 456 distinct ZIPCODEs
- As expected, Majority of responses are from four major cities

Statewide CAV survey: Survey demographics

Socioeconomic Characteristic		Tennessee	Sample	Difference
Population		6,597,381	4,602	--
Gender	Male	48.80%	42.44%	-6.36%
	Female	51.20%	57.56%	6.36%
Age	18 to 24 years	6.90%	14.19%	+7.29%
	25 to 34 years	13.30%	21.36%	+8.06%
	35 to 44 years	12.70%	17.23%	+4.53%
	45 to 54 years	13.60%	13.43%	-0.17%
	55 to 59 years	6.80%	10.13%	+3.33%
	60 to 64 years	6.20%	8.69%	+2.49%
	65 to 74 years	9.20%	12.21%	+3.01%
	75 years and over	6.20%	2.76%	-3.44%
Race	White	74.26%	77.25%	+2.99%
	Black or African American	16.66%	14.84%	-1.82%
	American Indian and Alaska Native	0.23%	0.87%	+0.64%
	Asian	1.66%	2.28%	+0.62%
	Native Hawaiian and Other Pacific Islander	0.05%	0.24%	+0.19%
	Some other race	5.28%	2.78%	-2.50%
	Two or more races	1.86%	1.74%	-0.12%

Sample vs Population (TN)

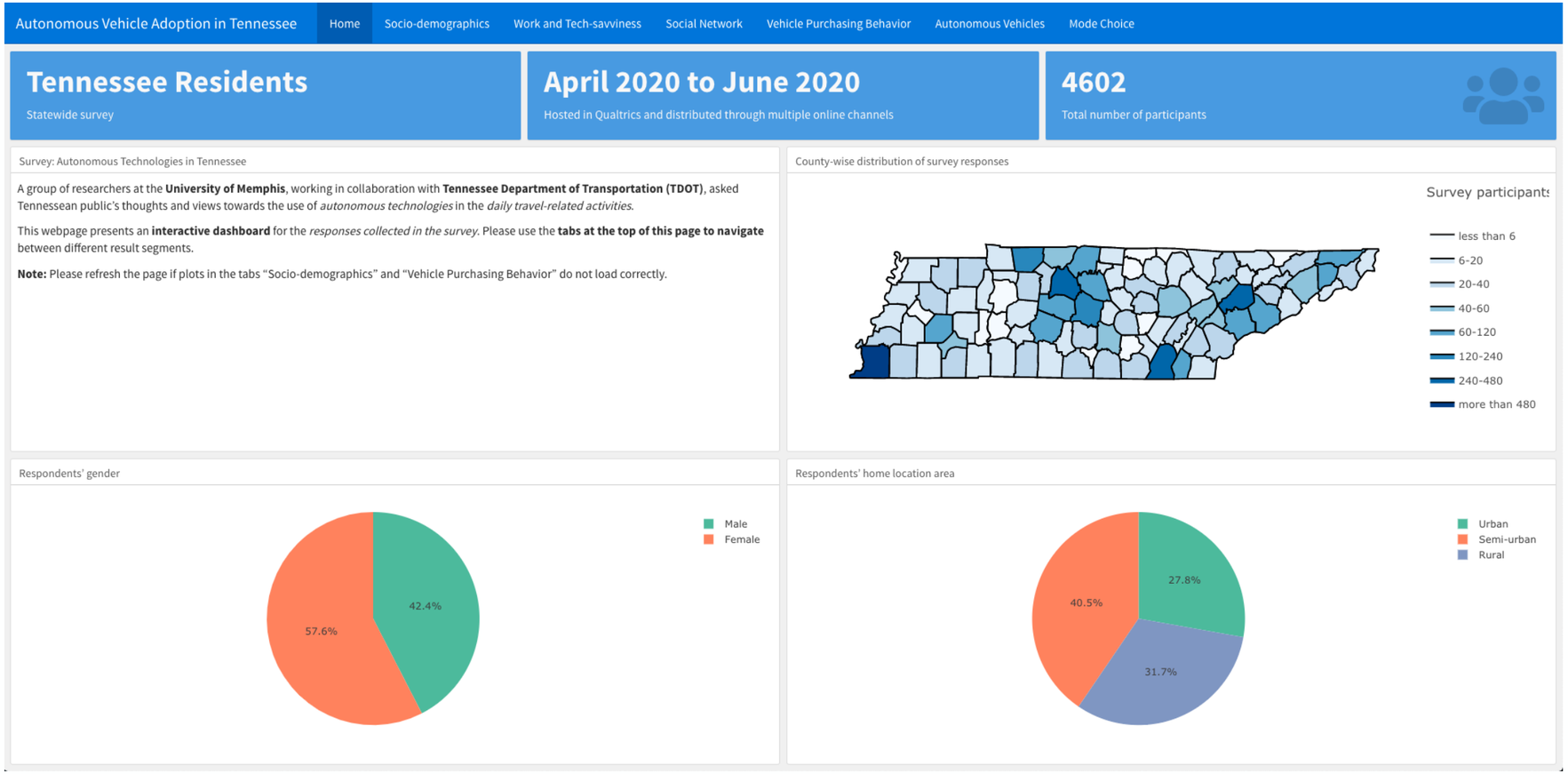


Strong presence of young individuals (Aged 18-34)

Strong presence of White Americans

Statewide CAV survey: Results (1)

- Real-time web dashboard
  - Survey results
  - Synthetic population
  - survey webpage: link



Statewide CAV survey: Results (2)

Respondent Profile

32%
Living in Rural Areas

95%
Owned a Smartphone

58%
Planning to Buy or Sell A Car in Next 3 Years

78%
Familiar with CAVs

23
Average number of peers in the social network

68%
Communicated Regularly with Peers in Workplace

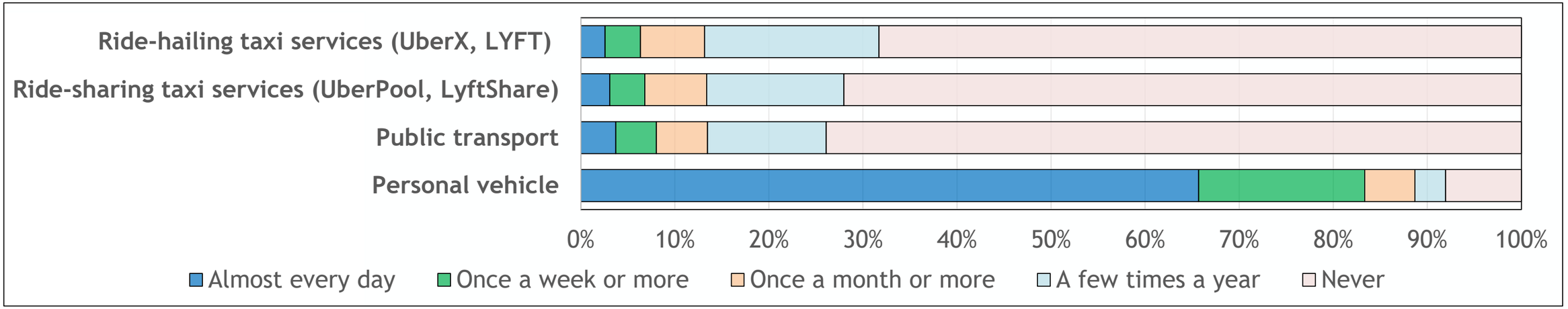
Perceptions towards CAVs

High level of concern towards negative impacts of CAVs

- System failure due to virus attack, operating system crash and poor internet connection
- Data privacy and confidentiality
- Reduced maneuverability & agility compared to regular cars

Statewide CAV survey: Results (3)

- Perceptions towards CAVs
  - High level of interest towards positive impacts of CAVs
    - Multitasking while traveling
    - Cost savings: insurance premium and parking fee
    - Travel time savings at traffic intersections (V2V, V2X)
- Majority of respondents used personal vehicles for their daily commute.

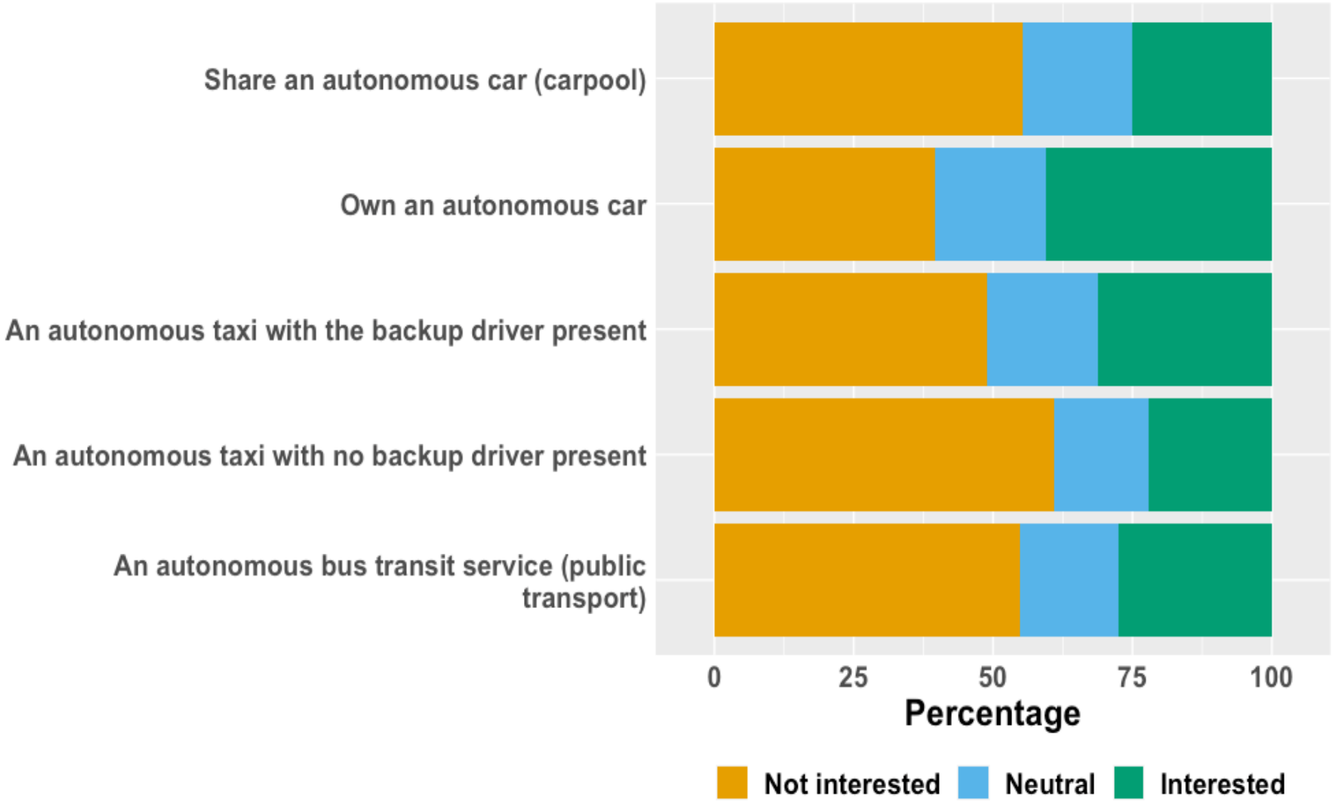


Synthetic Population

- A person-level synthetic population
  - a synthetic reconstruction approach.
    - uses the Iterative Proportional Updating (IPU) algorithm,
      - reallocates and adjusts weights among a particular type of household until household- and person-level attributes are both matched with the marginal distributions
- We used socioeconomic characteristics age, gender and race and five-digit ZIP code of respondents' home location.
- Inflated the sample of 4,602 individuals to entire population of Tennessee, 6,321,882 (Census 2010).

Modeling framework: Choice Models

- Interest to use different level-4 CAV based travel modes:
  - Ride hailing: Option of backup driver
  - Personally owned
  - Carpooling
  - Public transport
- Three levels of interest:
  - 1: Not interested
  - 2: Neutral
  - 3: Interested.
- Modeled ordinal logit choice model for each travel mode
  - Dataset split as 70:30
    - model training and testing



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Modeling framework: Choice Models

- Random utility theory:
  - Assumes an individual as a rational decision maker
  - Based on Utility maximization theory
    - Individuals select the choice with maximum utility
    - Easier to interpret as backed by behavioral reasoning.
    - Limitations
      - Individual is presented with hypothetical utility, not the the actual one.
  - Outcome: provides probability of choosing an alternative

Results: Sociodemographic

- Significant variables: age, gender and ethnicity
  - Increase in age has negative impact on interest to use CAVs.
  - Females are more likely to adopt ride hailing CAVs with no backup driver present
  - Whites are more likely to own a CAV.

Variable		Coefficients significance level				
		Ride Hailing CAV with backup driver present	Ride Hailing CAV with no backup driver present	Own a CAV	Share a CAV (Carpooling)	CAV based public transport
Age (base: less than 35)	35 to 54	0.026***	0.167***	-0.084***	-0.203***	-0.091***
	more than 54 years	-0.403***	-0.476***	-0.531***	-0.707***	-0.586***
Gender: Male (base: Female)		0.194***	-0.115***	0.469***	0.408***	0.569***
Ethnicity (base: others)	White	-0.206***	0.067***	0.201***	0.253***	-0.109***
	African American	-0.147***	-0.048***	-0.104***	0.069***	-0.221***

Note: *p<0.1; **p<0.05; ***p<0.01

Findings and Results: **Owning a CAV**

– Interested

- **Married**
- **Higher educational** attainment
- **Tech savviness**: smart home and navigation
- **Urban** area residents
- **Infrequent users of ride hailing** services
- Increased number of **peers**
- **Familiar** with CAVs

Willing to pay more if CAV would drive themselves to service stations

– Not Interested

- Households owning **more than 1 car**
- **Purchased a car in last 10 years**
- Annual mileage **> 5,000 miles**
- **Frequent users of ride sharing** services and **public transport**
- **Physically disabled**

Findings and Results: **CAV-based Ride Hailing Services**

– Interested

- **College graduates**
- Frequent users of **smart home devices like Amazon Alexa**
- **Urban residents**
- **Flexible work schedule**
- Frequent users of **ride sharing services**
- Infrequent users of **public transport**
- **Smartphone ownership**
- **Physically disabled** (if backup driver is present)

– Not Interested

- **Infrequent teleworkers**
- Annual **vehicle mileage more than 5,000 miles**
- Frequently use **private cars for daily commute**
- **Past experience in vehicle crashes (if backup driver is present)**

Findings and Results: **Share a CAV (Carpooling)**

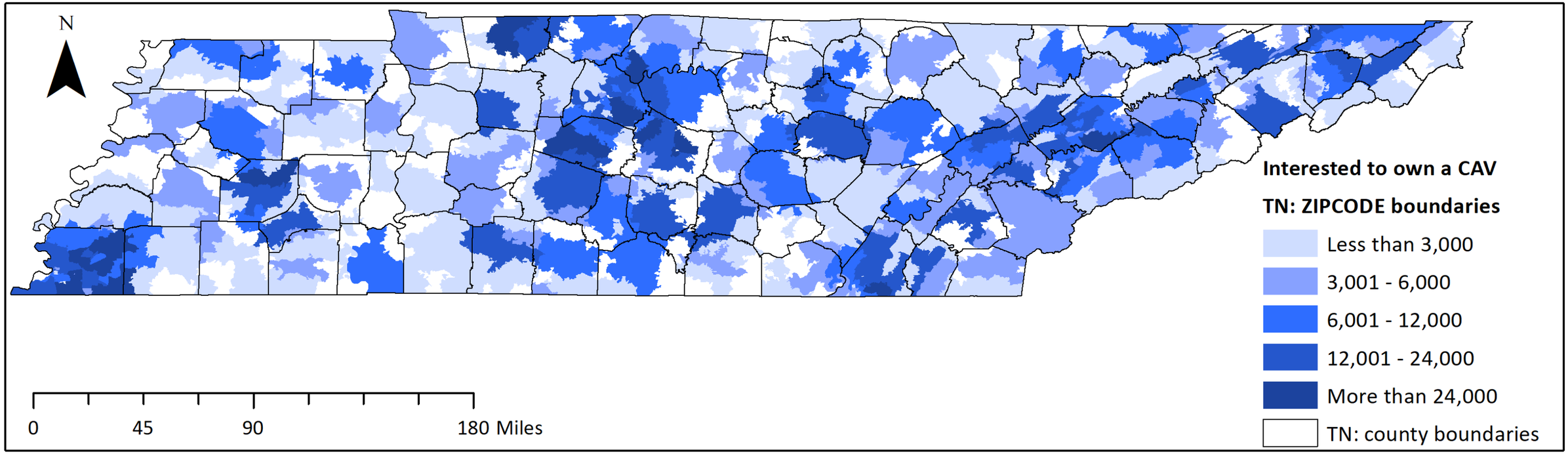
- **Interested**
  - Regularly listen to **Radio and watch TV**
  - **Urban** residents
  - Three or more household members (**Household size**)
  - **Frequent teleworkers**
  - **Flexible work schedule**
  - Regular users of **ridesharing and public transport**
  - Communicate frequently with **peers**
  - **Physically disabled**
- **Not Interested**
  - Annual Household **income more than $100,000**
  - **Vehicle ownership**
    - Own more than one car in household
    - Frequent car buyers
    - Annual vehicle mileage > 5,000 miles
    - Experience in vehicle crashes
    - Planning to buy car in next 3 years

Findings and Results: **CAV-based public transport**

- **Interested**
  - **Urban residents**
  - **Flexible work schedule**
  - **Frequent users of**
    - Public transport
    - Ride sharing services
    - Ride hailing services
  - **Social network**
    - Number of peers
    - Communicate frequently with peers
  - **Owns a smartphone**

- **Not Interested**
  - **Higher annual income** (Personal and household)
  - **Three or more household members**
  - **Vehicle ownership**
    - Own more than one car in household
    - Frequent car buyers
    - Willing to pay more than $30,000 for buying a car
    - Planning to buy or sell a car in 3 years
  - **Use GPS navigation services**

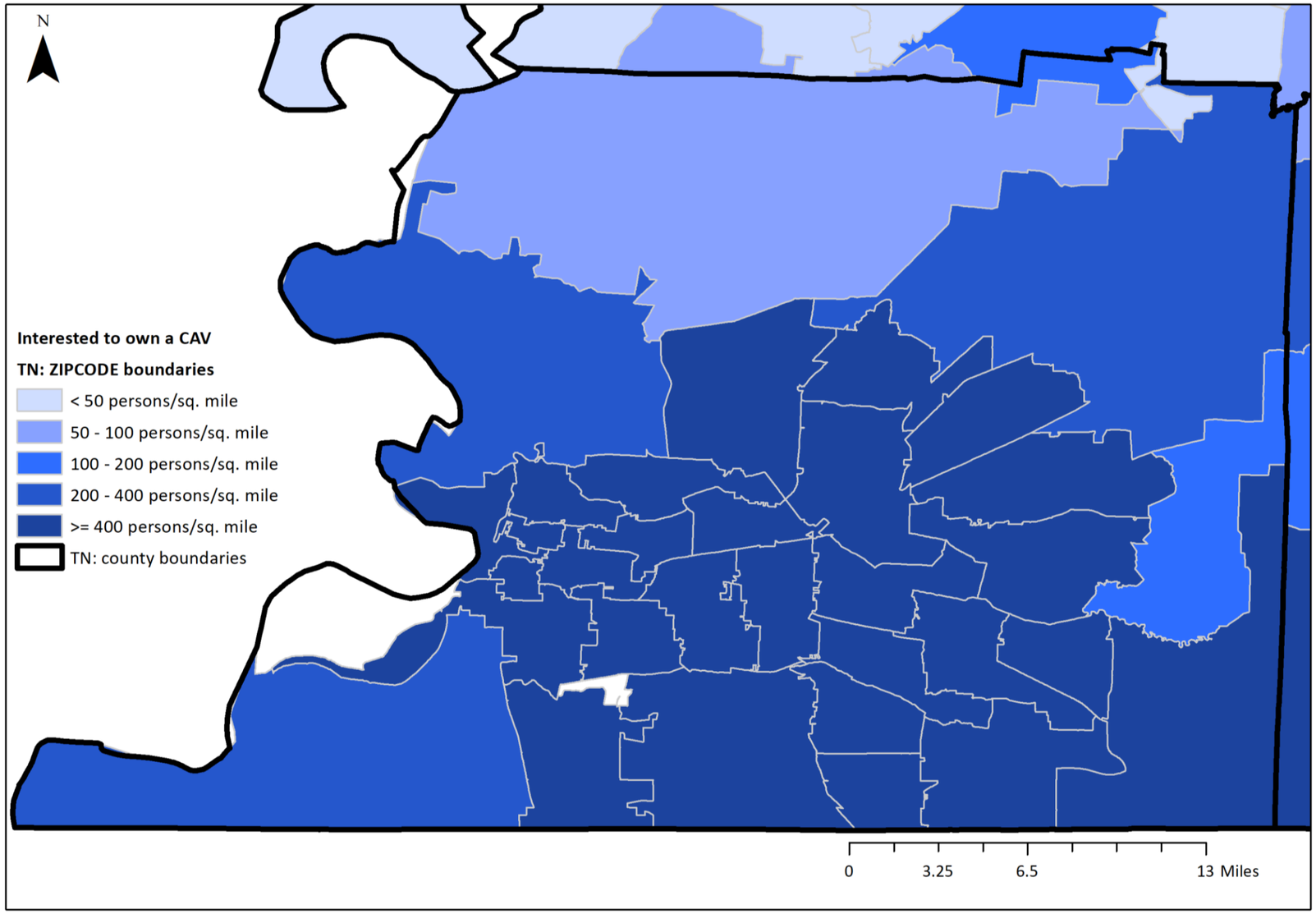
State level adoption: Owning a CAV



- Interested to own CAV: persons

- Person level plot does not tell anything about the adoption rates in different counties.

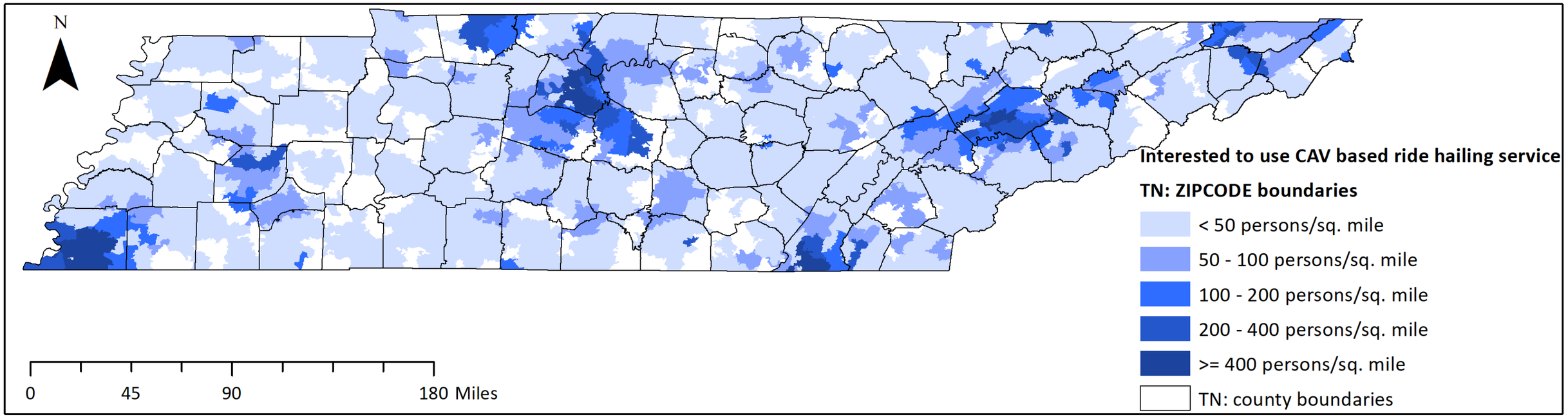
State level adoption: Owning a CAV



Shelby county:

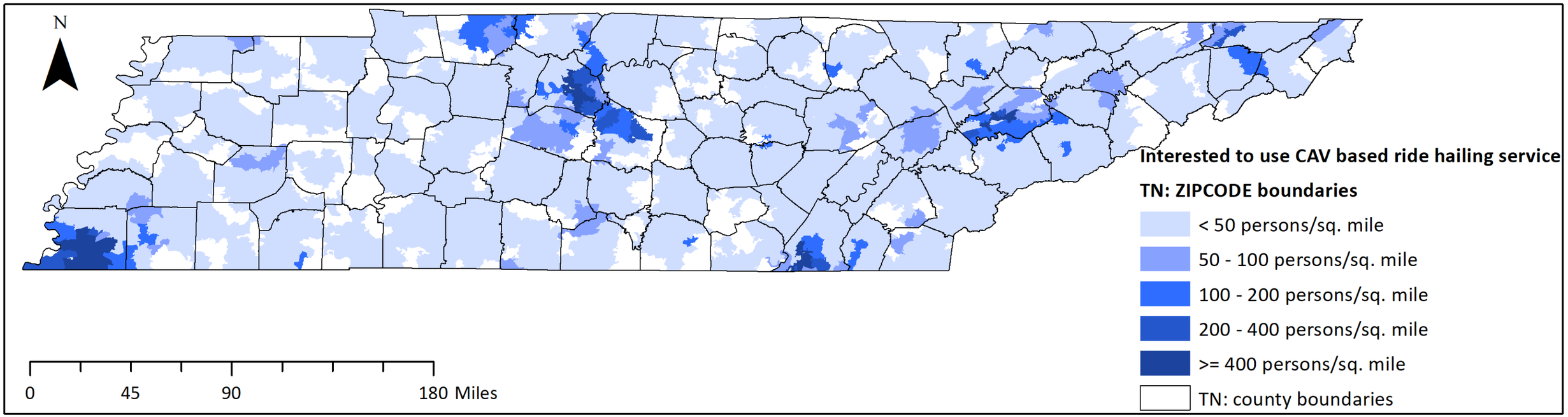
- Interested to own CAV: persons per square mile
- High adoption rate for suburban zip codes
- Higher income

State level adoption: CAV-based ride hailing service. (with backup driver)

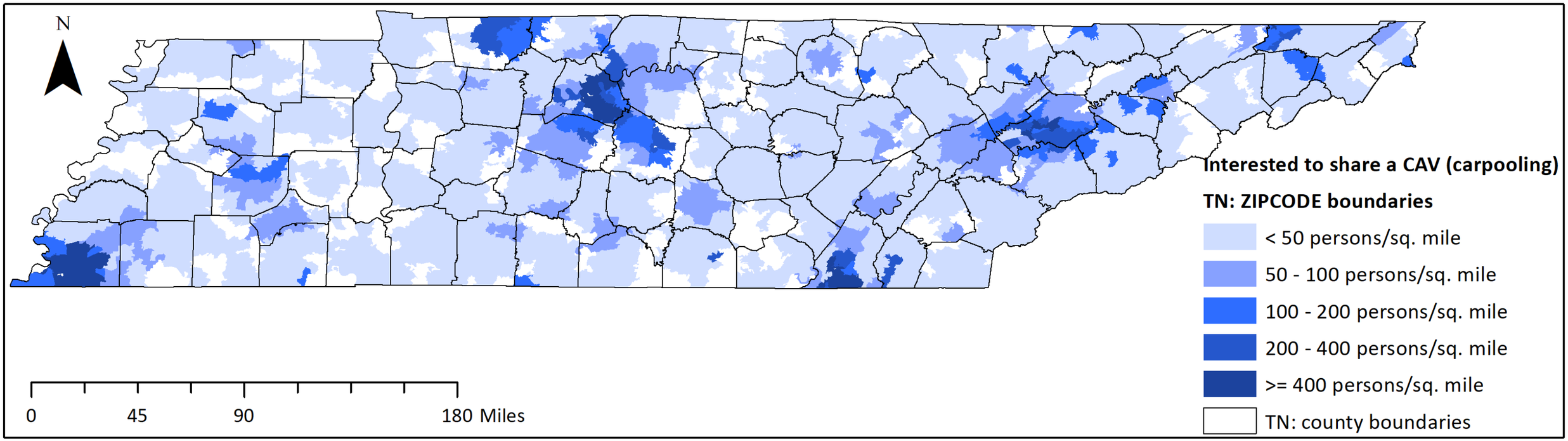


- Presence of backup driver increases the interest in CAV based ride hailing services.

State level adoption: CAV-based ride hailing service (without backup driver)

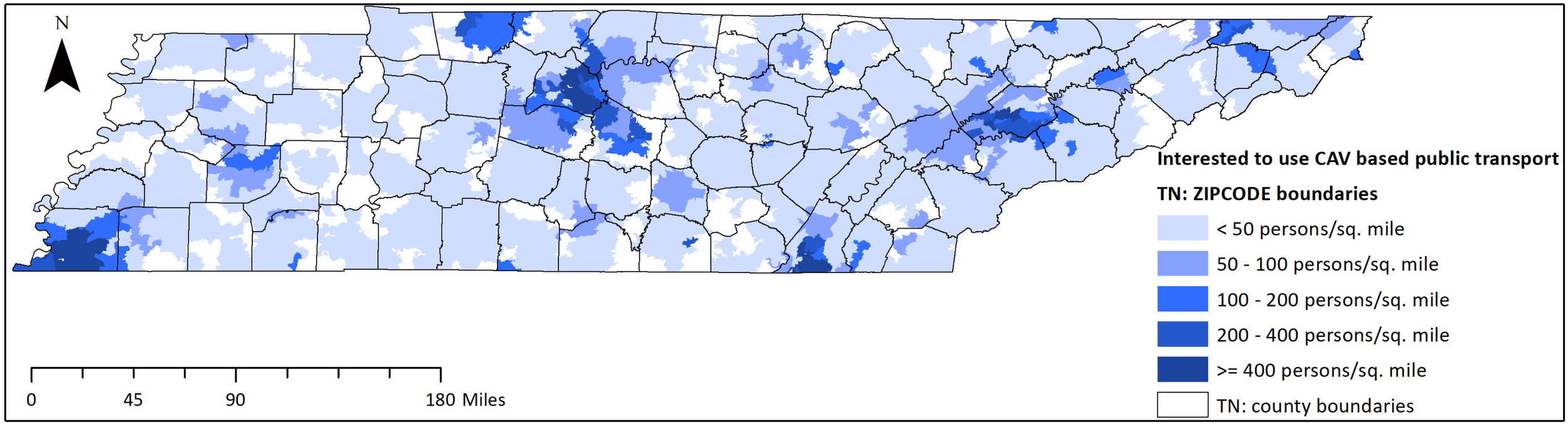


State level adoption: sharing a CAV (carpooling)



- Less willingness to opt for carpooling compared to owning

State level adoption: CAV-based public transport



Interested in locations where public transit is currently available

Policy implications

- **Major challenges Identified for CAV adoption:**
  - High costs associated with vehicle automation technology
  - Public's concern towards barriers of CAVs (especially in initial stages)
- **Policy interventions for promoting CAV adoption**
  - Policies gaining public's trust in automation technologies
  - Advertising cybersecurity and privacy related legal information to the public
  - Target tech-savvy persons in the initial phases
  - Advertising CAVs via highlighting:
    - Attractive features like increased productivity, travel time savings
    - Technological features enhancing safety and increased mobility access.
  - Offer incentives to cater for initial costs associated with automation technology.

Future work

01

Forecast the CAV adoption levels until 2050

- Agent-based modeling Framework
- Synthetic social network

02

Quantify the rank choice behavior among all four modes of CAVs

- Include attitudes and perceptions towards benefits and barriers associated with CAVs

Preliminary work

Transportation Research Part C 95 (2018) 363–380

Contents lists available at ScienceDirect

Transportation Research Part C

journal homepage: www.elsevier.com/locate/trc

Predicting the adoption of connected autonomous vehicles: A new approach based on the theory of diffusion of innovations

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ARTICLE INFO

Keywords:
Connected autonomous vehicles
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Diffusion of innovations
Agent-based modeling
Simulation
Adoption

ABSTRACT

On the grounds that individuals heavily rely on the information that they receive from their peers when evaluating adoption of a radical innovation, this paper proposes a new approach to forecast long-term adoption of connected autonomous vehicles (CAVs). The concept of resistance is employed to explain why individuals typically tend to defer the adoption of an innovation. We assume that there exists a social network among individuals through which they communicate based on certain frequencies. In addition, individuals can be subject to media advertisement based on certain frequencies. An individual's perceptions are dynamic and change over time as the individual is exposed to advertisement and communicates with satisfied and dissatisfied adopters. We also explicitly allow willingness-to-pay (WTP) to change as a result of peer-to-peer communication. An individual decides to adopt when (i) there is a need for a new vehicles; (ii) his/her WTP is greater than CAV price; and (iii) his/her overall impression about CAVs reaches a cutoff value. Applicability of the proposed approach is shown using a survey of employees of the University of Memphis. Our results show that the automobile fleet will be near homogenous in about 2050 only if CAV prices decrease at an annual rate of 15% or 20%. We find that a 6-month pre-introduction marketing campaign may have no significant impact on adoption trend. Marketing is shown to ignite CAV diffusion but its effect is capped. CAV market share will be close to 100% only if all adopters are satisfied with their purchases; therefore, the probability that an individual becomes a satisfied adopter plays an important role in the trend of adoption. The effect of the latter probability is more pronounced as time goes by and is also more prominent when CAV price reduces at greater rates. Some caveats may be inserted when considering the study results as the findings are subject to sample bias and data limitations.

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Modeling consumers' likelihood to adopt autonomous vehicles based on their peer network

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ARTICLE INFO

Keywords:
Integrated choice and latent variable model
Latent attitudes
Exploratory factor analysis
Ordinal logit
Structural equation modeling

ABSTRACT

Adoption of connected and autonomous vehicles (CAVs) is viewed as one of the vital factors by public and private agencies as benefits are slowly getting quantified with further advancement in technology. From a wide variety of CAV perception and demand estimation studies, the literature lacks the impact of adoption based on an individual's social network and values. In this paper, we utilize an integrated choice and latent variable model to capture individuals' likelihood to adopt level 4 CAVs based on their social values in their peer network using an institutional survey dataset. The model results suggest that households with high income and frequent car buyers are more likely to adopt CAVs. CAV adoption will have a positive influence on an individual's social values among his peers. The proposed framework can be used to provide useful insights for policymakers to quantify consumers' preferences about CAV adoption based on their social values.

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