

TRANSPORT FINDINGS

Spatial Distributions of Attitudes and Preferences towards Autonomous Vehicles

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Transport Findings

Prior research on attitudes towards autonomous vehicles (AVs) shows variation across a set of demographic and socio-economic factors, but few consider spatial patterns. We investigate the spatial distributions of attitudes and preferences towards AVs from a U.S. nationally representative on-line panel. We examine 1) four attitudinal dimensions established by an exploratory factor analysis – technology acceptance, driving enjoyment, risk-taking, and traffic regulation – and their spatial variations; and 2) public viewpoints and preferences in purchasing, sharing, and using privately-owned and shared AVs. Findings suggest that the northeastern US is more receptive to AVs, compared to other parts of the country.

1. RESEARCH QUESTIONS AND HYPOTHESES

A growing body of scholarship examines public perceptions and attitudes towards AVs in order to understand future AV adoption rates and their potential impact. This prior research shows variation across a set of demographics and socio-economic factors, but does not consider spatial patterns (Bansal, Kockelman, and Singh 2016; Menon et al. 2019; Wang et al. 2020). One exception is Nodjomian and Kockelman (2019) who found that access to jobs, the mix of land uses, and home location choice are associated with levels of interest in AVs and anticipated use of AV's. Our investigation is further motivated by the observation that the heterogeneity in acceptance of AVs exists across regions and countries (Schoettle and Sivak 2014; Haboucha, Ishaq, and Shiftan 2017). Specifically, we hypothesize that attitudes and preferences towards AVs may also be shaped by regional location in the United States. We focus on the following research questions:

- What are both the expressed and latent attitudes towards AVs, and do they vary geographically?
- If these vary geographically, do preferences for purchasing, sharing, and using privately-owned and shared AVs co-vary with demographic, travel and accessibility factors?

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2. METHODS AND DATA

Using an on-line panel from Qualtrics, a survey was conducted in September 2018 and is demographically representative of the adult US population (see Wang et al. 2020). After removing invalid and incomplete responses for demographic information, we had 782 respondents (from 834 in total). We collected information on attitudes, socio-demographics, location (postal code), and travel behavior (commuting mode, commuting time, daily travel mode, and car ownership). The main limitation of on-line panels is that survey-takers are paid and may be more tech-savvy. We also examined how representative our data is at the regional level. While less so than nationally, we found slightly more survey respondents from the northeast, and fewer from the west, but most demographic variation differed by only a few percent compared to census data for the region. The one exception was more male respondents in the northeast. Our questions and responses on views towards privately-owned and shared AVs are in Table 1.

Table 1: Questions and responses on views of autonomous vehicles in survey

Category	Attitudinal questions	Response statistics					
Privately-owned AVs	Q1. Do you have a positive or negative view of self-driving cars?	Positive		Neutral		Negative	N
		304 (36.7%)		343 (41.5%)		180 (21.8%)	827
	Q2. Would you be likely to purchase a fully self-driving car when these are available?	Yes		Uncertain		No	N
		277 (33.4%)		243 (39.4%)		308 (37.2%)	828
Shared AV services	Q3. Would you use a taxi service that was self-driving?	Yes		Maybe		No	N
		189 (24.2%)		289 (37.1%)		302 (38.7%)	780
	Q4. Would you use a self-driving taxi that is shared with someone you do not know?	Yes		Maybe		No	N
		163 (21.1%)		217 (28.1%)		392 (50.8%)	772
	Q5. How many minutes would you be willing to wait to/ from work when using ridesourcing services?	Min	Median	Mean	Max	SD	N
		0/0	10/10	11.8/11.9	60/60	10.0/10.3	638
	Q6. How many minutes would you be willing to wait to/ from a grocery store when using ridesourcing services?	Min	Median	Mean	Max	SD	N
		0/0	10/10	12.4/11.8	90/80	10.3/10	637
	Q7. How many minutes would you be willing to wait to/ from a restaurant when using ridesourcing services?	Min	Median	Mean	Max	SD	N
		0/0	10/10	13.5/12.7	120/60	11.6/10	638

Table 2: Factor loadings for attitudinal variables.

	Factor 1 Pro- Technology	Factor 2 Driving enjoyment	Factor 3 Risk Avoiders	Factor 4 Regulating traffic
How often do you use Uber, Lyft, or another ridesharing service?	0.89	0.15	0.14	0.12
When did you first use a smartphone app-based ridesharing service?	0.89	0.15	0.10	0.08
I believe that the government should develop regulations for self-driving cars.	0.11	0.15	0.41	0.08
I believe that the technology companies developing self-driving cars should have the freedom to test their vehicles on city streets.	0.45	0.14	0.06	0.22
When I am driven by someone I do not know (such as a cab driver, limo driver, or Uber or Lyft driver) I am not concerned about my safety.	0.45	0.10	0.08	0.26
I think speed limits are too high	0.27	0.08	0.16	0.81
Fines for speeding should be higher.	0.21	0.11	0.33	0.51
I prefer to avoid risky activities.	-0.01	-0.01	0.72	0.18
I really dislike not knowing what is going to happen.	0.11	0.15	0.45	0.06
I chose my vehicle because it fits my personality and represents who I am as a person.	0.29	0.37	0.18	0.17
I prefer to drive when I am in a motor vehicle.	0.12	0.68	0.18	0.07
I love to drive and driving seems fun.	0.15	0.80	0.09	0.05

Note: The number of valid responses in our factor analysis is 715 (less than the 782 responses with valid demographic information).

About 37% of our sample has a positive view of AVs, with one-third likely to purchase their own. Only 24% of our sample would use a self-driving taxi and only 21% would share a self-driving taxi with a stranger. Respondents report marginally more willingness to wait when using ridesourcing services for travel to/from destinations such as restaurants compared to work or shopping.

Additionally, we surveyed attitudes towards new technologies using a 5-point Likert scale from “strongly disagree” to “strongly agree.” These questions are shown in Table 2 including the results of a factor analysis that decomposed these into four factors defined as “pro-technology”, “driving enjoyment”, “risk avoiders”, and “regulating traffic”. The shaded areas in Table 2 show the largest loadings for each variable.

We used Getis-Ord G_i^* (Anselin and Getis 1992), a distance-based statistical method to identify statistically significant clusters of values across a spatial distribution. The method assesses each value within the context of its neighboring values. Using region-scaled (250 to 325 miles) distance bands, we examined spatial distributions of: (1) the four attitudinal factors; (2) preferences for AVs; and, (3) willingness to wait when using ridesourcing services.

3. FINDINGS

The results of our Getis-Ord G_i^* analysis for these four factors is shown in Figure 1. *Pro-Technology* shows significant clustering of high values in the Mid-Atlantic and Northeast regions, and clustering of low values ranging from parts

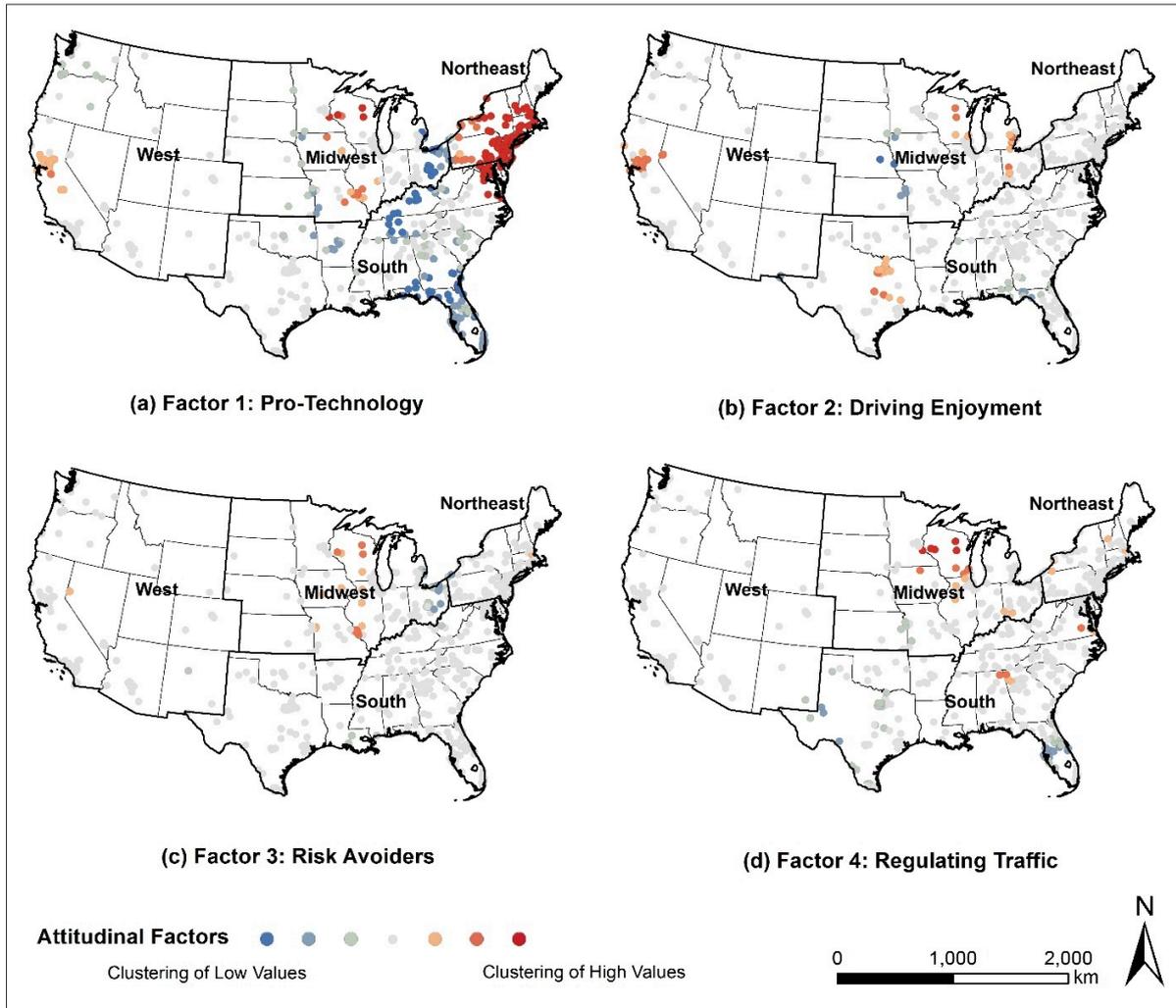


Figure 1: Spatial hotspot analysis of four attitudinal factors.

of Ohio to Mid-South and Central Florida regions. The other three factors show less significant clustering patterns compared to *Pro-Technology* with a notable positive value of clusters for all the other factors in the upper Midwest.

A hotspot analysis for preferences towards AVs is shown in Figure 2. In general, “Positive” (or “Yes”) responses are spatially clustered around large, dense urban regions such as New York City or the Bay Area in California (home of Silicon Valley), while “Non-positive” (or “Uncertain” / “No”) responses are significantly clustered in the South. For the attitudes towards AVs, as shown in Figure 2 (a), positive attitudes are significantly more likely in the Bay Area, Arizona, New England, and the Washington DC metro. Figure 2 (b) to (d) represent the positive responses of the willingness to buy an AV, the willingness to use an AV taxicab and the willingness to share an AV taxi with a stranger; positive responses are significantly clustered in the Mid-Atlantic and New England regions.

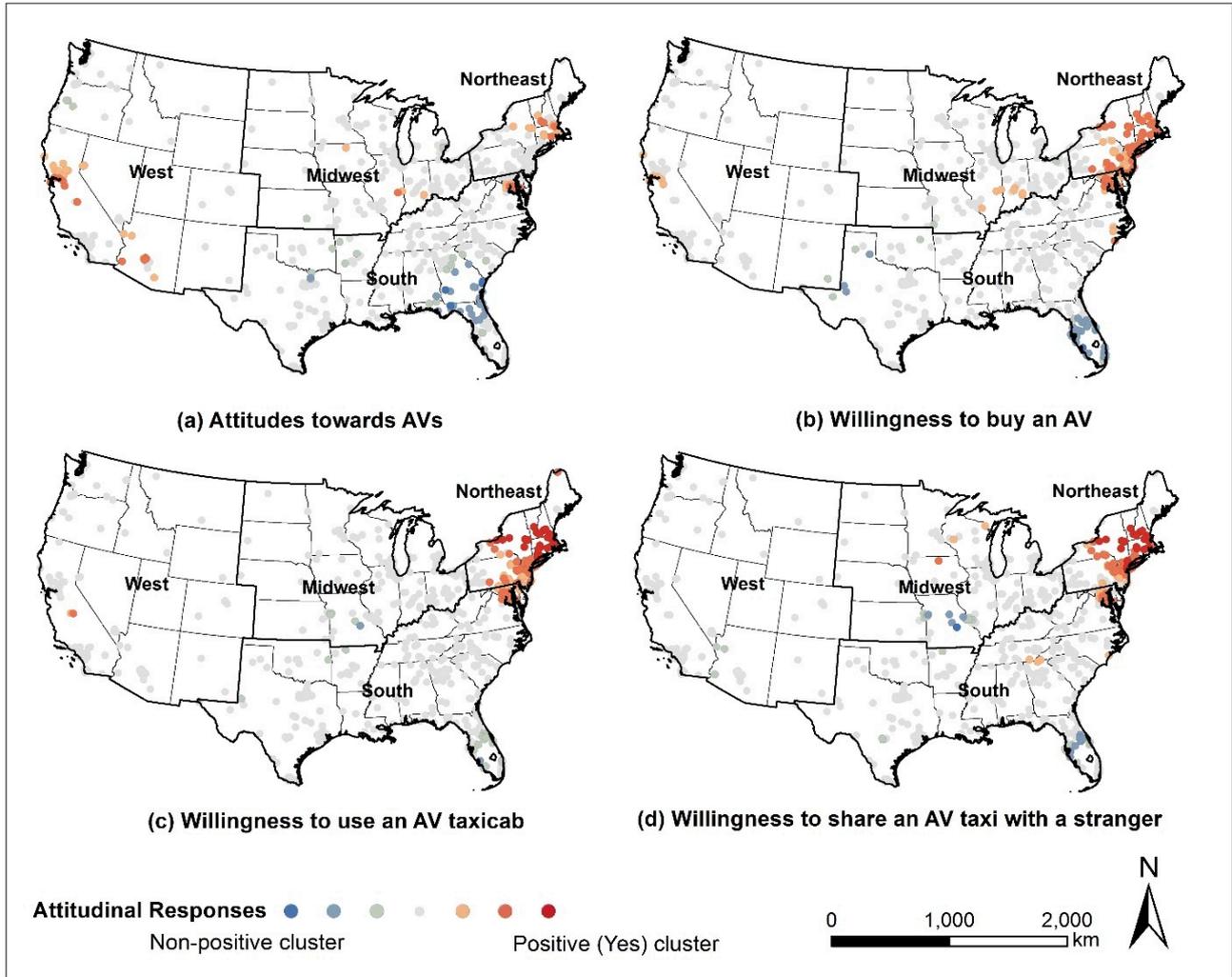


Figure 2: Spatial hotspot analysis of attitudinal responses.

Spatial variation in willingness to wait is shown in Figure 3. The results show that the duration respondents are willing to wait for trips to/from grocery stores and restaurants is significantly higher in parts of the South and Midwest. Despite no significant reported interest in sharing AV taxis, respondents in these areas may be more amenable to sharing because of their increased willingness to wait.

While we observe significant regional clustering, demographic factors may covary across regions in a way that explains the spatial variability. We therefore summarize a range of variables by US census-designated region including an ANOVA or Chi-Square test in Table 3 using weighted data to represent the regional population. Weights were calculated for gender, age, income, and region based on a statistical raking algorithm using the “survey” package in R (Lumley 2020). As displayed in Table 3, respondents from the Northeast region do have substantially more positive attitudes toward AVs overall and they are more “pro-technology”, but the demographics of the Northeast also deviate from other regions. The Northeast has higher average and median

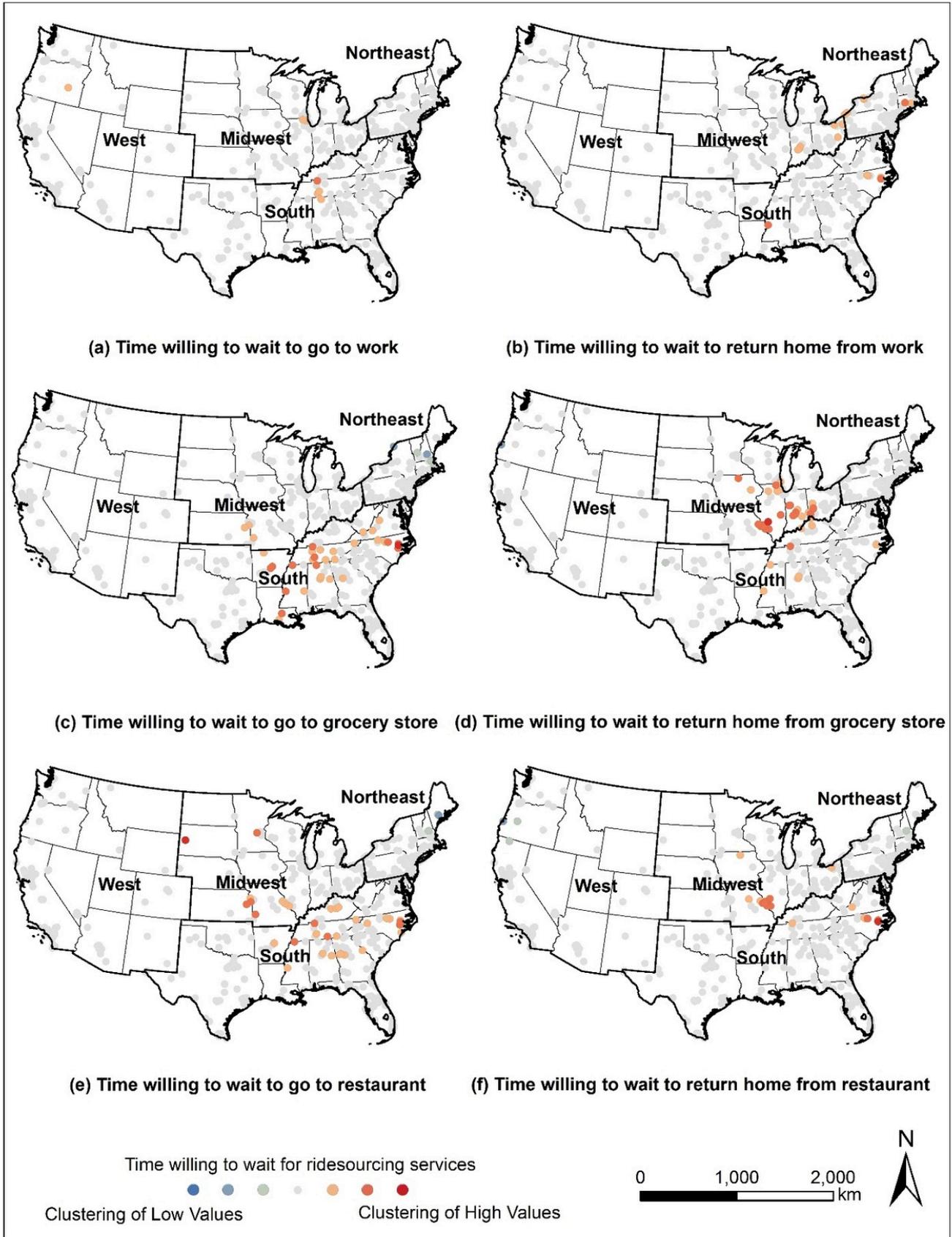


Figure 3: Spatial hotspot analysis of waiting time for ridesourcing services.

automobile accessibility than other regions. When we look at the automobility accessibility of each city, we find that New York City and other large, older cities of the Northeast have greater access to jobs within 45 minutes. Moreover, the Northeast and West regions have, on average, higher traffic congestion levels and road density levels than the South and Midwest regions. Demographically, respondents from the Northeast live in more urbanized locations, are wealthier, and more familiar with AVs overall.

Our investigation shows that attitudes toward technology and AV preferences are spatially clustered, however the reasons remain undetermined.

Table 3: Weighted summary statistics by Census region

	Midwest	Northeast	South	West	F-value / x2
Number of participants	167	169	315	131	-
Mean automobile accessibility ¹ index	0.06	0.23	0.05	0.12	26.5***
Median automobile accessibility ¹ index	0.03	0.07	0.03	0.07	
Mean workers per job index ²	0.38	0.47	0.41	0.44	10.5***
Mean TTI index ³ (averaged across respondents)	0.41	0.57	0.45	0.64	23.1***
Mean age	47.68	47.73	46.35	44.18	1.4
Mean commuting time (min)	18.67	19.67	17.39	19.57	0.8
Mean number of children in a household	0.93	0.66	0.62	0.64	3.1*
Income ⁴ >= \$200,000 %	5%	10%	3%	8%	3.1*
Income \$150,000 - \$200,000 %	6%	8%	4%	5%	1.0
Income \$100,000 - \$150,000 %	14%	16%	11%	12%	0.8
Income \$50,000 - \$100,000 %	31%	28%	30%	38%	1.4
Income \$25,000 - \$50,000 %	23%	19%	30%	18%	3.5*
Income Under \$25,000 %	20%	19%	22%	20%	0.2
Urban ⁵ %	72%	92%	80%	80%	5.5**
Female %	51%	51%	51%	51%	0.02
Own/be interested in smart devices %	71%	74%	77%	75%	2.23
Be familiar with AVs %	49%	56%	50%	48%	2.22
Positive attitude towards AVs%	37%	40%	32%	38%	3.18
Willing to purchase AVs%	34%	38%	29%	32%	3.61
Willing to use AV taxicab service%	25%	31%	19%	26%	8.22*
Willing to share AV taxi with a stranger%	20%	26%	20%	17%	3.60
Mean of Factor 1: Pro-Technology	-0.07	0.13	-0.06	-0.03	1.32*
Mean of Factor 2: Driving enjoyment	0.01	0.05	-0.01	0.03	0.16
Mean of Factor 3: Risk Avoiders	-0.01	0.02	0.00	0.04	0.15
Mean of Factor 4: Regulating traffic	0.01	0.12	-0.09	0.04	1.89
Mean of time willing to wait to work	12.8	11.0	11.5	10.8	1.19
Mean of time willing to wait from work	12.2	12.7	12.0	9.5	3.5*
Mean of time willing to wait to a grocery store	13.0	12.1	12.7	11.5	0.71
Mean of time willing to wait from a grocery store	12.7	11.8	12.0	10.3	1.81
Mean of time willing to wait to a restaurant	14.5	12.7	13.7	12.0	1.56
Mean of time willing to wait from a restaurant	13.0	12.8	13.3	10.8	2.50

Significance codes: $p < 0.000$ '***', $p < 0.001$ '**', $p < 0.01$ '*'.

¹Automobile accessibility is a normalized value showing the number of jobs within 45 minutes auto travel time at zip code level. Data source: United States Environmental Protection Agency. (2014). Smart Location Database.

²Workers per job index is the household workers per job equilibrium index from the 2014 US EPA Smart Location Database. As the index approaches one, the more balanced are resident workers and jobs in a zip code.

³TTI index is the urban mobility scorecard travel time index (TTI) index at zip code level. Data source: Texas Transportation Institute (2015).

⁴Income is a categorical variable that reflects the respondent's total household income in 2017.

⁵Urban indicates whether the respondent lives in an urban area or not. Our questionnaire queried respondents for their home Zip code. Based on the Zip code, we classified respondents living in urban areas using the National Center for Education Statistics (NCES) location code.



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