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Are Cities Prepared for Autonomous Vehicles?

Planning for Technological Change by U.S. Local Governments

Yonah Freemark Anne Hudson Jinhua Zhao

ABSTRACT

Problem, research strategy, and findings: Local government policies could affect how autonomous vehicle (AV) technology is deployed. In this study we examine how municipalities are planning for AVs, identify local characteristics that are associated with preparation, and describe what effects bureaucrats expect from the vehicles. We review existing plans of the 25 largest U.S. cities and survey transportation and planning officials from 120 cities, representative of all municipalities with populations larger than 100,000. First, we find that few local governments have begun planning for AVs. Second, cities with larger populations and higher population growth are more likely to be prepared. Third, although local officials are optimistic about the technology and its potential to increase safety while reducing congestion, costs, and pollution, more than a third of respondents worried about AVs increasing vehicle miles traveled and sprawl while reducing transit ridership and local revenues. Those concerns are associated with greater willingness to implement AV regulations, but there is variation among responses depending on political ideology, per capita government expenditures, and population density.

Takeaway for practice: Municipal governments' future approaches to AV preparation will likely depend on the characteristics of city residents and local resources. Planners can maximize policy advancement if they work with officials in other cities to develop best practices and articulate strategies that overlap with existing priorities, such as reducing pollution and single-occupancy commuting.

Keywords: autonomous vehicles, municipalities, transportation planning

Autonomous vehicles (AVs)—combined with other recent transformations in urban mobility, such as electrification and shared use—have the potential to alter urban living by shocking the "system of automobility" (Urry, 2004, pp. 31, 33) out of its reliance on single-occupancy vehicles and, in so doing, achieve "huge energy, environmental, and social benefits" (Sperling, 2018, p. x). Cities are essential players in determining the direction of that shock, holding key regulatory powers such as managing most of the public right-of-way and articulating land use policy. In this study, we explore how AV technology is affecting city officials' thinking, aiming to answer three questions: Are cities preparing for AVs? What concerns do officials have about the technology, and do different types of cities have different concerns? What municipal characteristics are associated with cities that are beginning planning?

In this study, we offer the first scholarly insight into how officials working in municipal governments throughout the United States are conducting AV-related policymaking. We review plans and undertake a large-scale, representative survey. We document that cities have made limited preparations, even as many bureaucrats are concerned about potential risks related to the vehicles, including increased vehicle miles traveled (VMT) and sprawl, as well as decreased transit ridership. We use a series of ordered probit regression models to analyze survey results to understand how cities of varying characteristics are approaching the new technology and how responsibility for the technology is distributed within city governments. In the process, we further Mohr's (1969) argument that policy development requires a combination of governmental motivation, limited obstacles, and adequate resources. We conclude by recommending that cities tie their AV regulations[1] to their broader goals for surface transportation, taking advantage of their existing capacities in the process.

Understanding the Potential Impacts of Autonomous Vehicles

Although the unique feature of AVs is the replacement of human drivers with automated driving systems,[2] their

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impacts may be more widespread. AVs may be treated as a rupture in the transportation system that provokes an opportunity to advance other transformations, including electrification and shared use (Sperling, 2018). Yet skepticism of AVs is warranted; without adequate preparation, they may worsen many of the problems that already plague metropolitan mobility (Bahamonde-Birke, Kickhöfer, Heinrichs, & Kuhnimhof, 2018; Wolmar, 2018). City policies will influence how these vehicles are linked to these changes, determining whether AVs are "innovations [that] serve the public interest" or not (Sperling, 2018, p. xiii).

But scholars have not yet examined cities' AV-related preparations, nor have they identified the ways in which bureaucrats believe that this technology will affect their cities. Despite frequent media discussion, we do not know whether cities are prioritizing AV planning or whether they consider planning for AVs to be a waste of resources given limited knowledge about how such vehicles will shape the built environment and the transportation system. In this study, we fill a portion of this gap by offering a better understanding of municipal officials' attitudes as well as segment cities by their characteristics and resultant preparation for the technology. We argue that a failure of municipalities to plan for AVs is an oversight given the relationship between AVs, mobility, and urban form.

The literature has explored automation's impacts in combination with other transportation transformations.[3] When operated through ride-hailing services, AVs could ease point-to-point travel, a particular convenience for people underserved by traditional automobiles, such as the young, elderly, and disabled. The lack of a driver could eventually mean lower travel costs, safer navigation, and more efficient use of road capacity (Fagnant & Kockelman, 2015). These costs could decline further if AVs are shared, which could lower the number of cars on the road (Frazzoli, 2015; Martinez, 2015). At the same time, depending on ownership, propulsion, and regulations, AVs could be associated with negative outcomes. Lower costs and the ability of former drivers to reorient travel time to productive uses (reading, working, etc.) could increase VMT (Duranton & Turner, 2011; Metz, 2018), thus increasing congestion, such as in contexts where vehicles circle the block rather than pay for parking (Chase, 2014). Cheaper trips could encourage a mode shift away from transit (Levinson, 2015), a problem if the result is higher pollution, more traffic, and less accessibility for low-income people. Finally, governments reliant on parking tickets, speeding fines, vehicle registration, and fuel taxes could lose revenues, challenging cities to find alternative funding sources.

AVs also promise to influence the design of cities and vice versa (Duarte & Ratti, 2018). The willingness of some commuters to travel further, for example, could encourage sprawl (Ewing, Pendall, & Chen, 2003) and, in the process, increase energy consumption and income-based segregation (Johnson, 2001). Design choices that planners make about the allocation of street space, meanwhile, will ultimately govern interactions between different modes (Heinrichs, 2015). AVs also have the potential to reduce the need for parking as a result of a shared travel–induced reduction in car trips and a redistribution of vehicles elsewhere to park themselves. This would liberate land currently occupied by parking lots and structures for alternative uses. But these outcomes—positive and negative—remain conjectural.

Paradoxically, the uncertainty regarding AVs plays out in the context of extensive AV experimentation. Companies are testing on public roads in cities from Boston (MA) to Singapore, though the timeline for full rollout remains unclear (Adams, 2017). In the short term, given continued use of human-driven cars, AVs may alter the transportation system little; a longer term equilibrium with a fully automated system will be different.

The future of governmental policy, especially in the period before a fully automated system, is similarly uncertain. Can we expect AV-specific regulations, or will they be rolled into a broader ground transportation legal framework? How will regulations affect this technology's form? Given the changes associated with "smart mobility" (Docherty, Marsden, & Anable, 2018) and growing interest in redesigning urban streets (von Schönfeld & Bertolini, 2017), we can speculate that AVs will motivate governmental actors to rethink policies. Some technological disruptions have catalyzed change for urban transportation systems in the past (Kent, Dowling, & Maalsen, 2017; Marsden & Docherty, 2013); thus, AVs could serve as an opportunity for municipalities to reconsider policies widely recognized as effective in achieving key goals shared by cities but with significant hurdles in the current political climate, such as congestion pricing. As Kingdon (1986) notes, long-anticipated policies often wait for the appropriate opportunity to be deployed.

Higher-level governments in the United States have begun introducing AV-related policies, indicating that automation is sparking a conversation about transport regulations. As of 2018, 35 states have passed legislation or had governors issue executive orders related to AVs. In 2016 and 2017, the federal government provided AV guidance, and Congress is considering legislation that would allow experimentation nationwide (National Conference of State Legislatures, 2018). These guidelines address issues such as vehicle safety and registration.

To fully understand the reach of public policy responses to AVs, we focus on the role of local governments. In the United States, municipalities are limited by their status as "creatures of the state," which restricts their abilities to intervene. But cities are primary actors with regards to how streets and the urban environment function, often exerting entry controls on taxis using medallions while establishing fare and coverage policies (Schaller, 2007); similarly, cities such as Chicago (IL) and New York (NY) tax ride-hailing services.[4] Cities often manage transit (through subsidiary authorities), the allocation of public space (Lang et al., 2016), parking and speed limits (Glancy, 2015), land use (Williams, 2013), data (Batty et al., 2012), street police powers, and, to some degree, tax bases (Barron, 2003).

Hypotheses

Despite the limited scholarship on municipal AV preparations, related research indicates what we might expect. In reviewing U.S. metropolitan planning organizations, Guerra (2016) finds that few have planned for AVs. Though officials are aware of the existence of the technology, the nebulous nature of the final product dissuades them from putting their ideas on paper, let alone acting. As such, we hypothesize that cities in the United States are similarly unprepared for AVs:

> Hypothesis 1: As a whole, cities have conducted little planning for AVs.

The policy innovations literature offers insight into how governments address certain issues and what causes individual policies to advance (Berry & Berry, 1990). Mohr (1969) suggests that new policy is developed when officials have the motivation to innovate, when obstacles are limited, and when there are adequate resources. Scholars show that governments with greater resources are more likely to plan and regulate, as are cities whose residents have more liberal political ideologies, linked to support for a stronger governmental role (Hajnal & Trounstine, 2010; Shi, Chu, & Debats, 2015). Organizational size is positively associated with policy adoption (Bingham, 1978). Finally, cities with larger populations are more likely to innovate (Krause, 2011). We cluster these potential explanations for why city governments act as they do, using multiple regression models that we describe below to test the relative influence of each. We therefore hypothesize the following:

> Hypothesis 2: Cities with more financial resources, liberal political ideologies, staff, and population have engaged in a higher level of preparation for AVs.

Disruptions in the status quo can induce governments to promote new policies (Kent et al., 2017; Kingdon, 1986). Yet these disruptions, such as new technology deployment, are not alone adequate to spur change. We expect variations among cities based on their respective concerns about the consequences of AVs. Officials must recognize the link between policies and goals to advance new regulations (Johansson, Gustafsson, Falkemark, Gärling, & Johansson-Stenman, 2003); thus, a sense of avoiding perceived negative outcomes—particularly in the context of a supportive public and political environment—can be a motivator for bureaucrats. We hypothesize the following:

> Hypothesis 3: Officials with greater concern for the negative impacts of AVs and with a sense of a supportive public and political environment are more motivated to engage in AV regulations.

Measuring Municipal Planning for Autonomous Vehicles

Planning Documents

To determine how municipalities are planning for AVs, we collected long-term comprehensive (land use and transportation) or transportation plans as of January 2019. Due to the technical capacity required to create such plans, smaller cities are less likely to have them or they are likely to be less developed; thus, we concentrate this review on the 25 largest U.S. cities. Comprehensive plans generally offer policy guidance but do not prescribe legally enforceable rules for governmental agencies or private entities (this applies to AV and non-AV contexts). We identify whether the documents address AVs and whether these cities have produced other "new mobility" plans.[5]

Web-Based Survey

The overview offered by these plans is not representative of conditions in U.S. cities generally, applying only to the largest cities. As such, we also conducted an online survey of planning and transportation officials that was much more comprehensive in scope.[6] It consisted of questions on preparations for the arrival of AVs, the time officials have devoted to developing AV-related policies, and perceived AV impacts. We allowed open-entry submission for certain questions, such as, "What is unique about the way in which your city is approaching AVs?" We include select quotations from officials throughout this study to contextualize quantitative findings. The survey (questions are found in the

Table 1

Characteristics of surveyed officials.

Group	Contacted an official	Responded to all questions	Responded at least partly
All cities in sample	307	120 (39.1%)	146 (47.6%)
Transportation/public works	304	69 (22.7%)	78 (25.7%)
Planning/community development	306	71 (23.2%)	89 (29.1%)
Other	0	8	8
Total respondents		148	175

Technical Appendix online) was field tested among select officials during the 2018 Transportation Research Board Annual Meeting; students and faculty in our department provided further feedback.

We created a database of all 307 non-county, general-purpose local governments (primarily cities, all categorized as "places" by the U.S. Census) with at least 100,000 residents in 2016. Although a large range of governments in the United States make transportation policy—federal, state, metropolitan, county, and city officials are all often involved, to different degrees depending on the place—our focus on cities allows us to investigate this level of government in depth. We selected the top officials working in planning or community development and transportation or public works in each city, performed searches to identify appropriate email addresses, and then contacted them. We instructed interviewees that responses were anonymous and that they could delegate the survey to another official to complete on their behalf. Responses were recorded from April to June 2018.

We intentionally focused on top officials: directors of planning or transportation. Although we acknowledge that policy promotion is a shared activity, with policy entrepreneurs—the people who push change—often working in think tanks, private business, and government (Mintrom, 1997; Mintrom & Norman, 2009), the officials we targeted are leaders in policy identification and promulgation. If cities make changes related to AVs, these officials will play an important role, particularly during the agenda-setting and formulation stages of the policy cycle (Marsden & Reardon, 2017), when formative decisions are made.

Officials from all 307 cities were contacted and at least one representative from 120 cities (39%) responded in full, summarized in Table 1. About half the respondents represent planning departments and the other half represent transportation departments (several hailed from mayor's offices, etc.). Our survey had an overall response rate of about 23%. Of respondents, 66.1% identified as civil service staff and 25.3% were appointed. In the results, we include multiple responses from some cities and account for differences between planners versus other types of officials. In addition, we include results from 27 partially completed surveys from an additional 26 cities. We believe this is the first such survey conducted related to AVs, offering extensive insights into how officials are approaching the subject area.

We assembled a set of variables representing city characteristics, including demographics (level and change), employment, density, budgets, and wealth, as described in Table 2; these are primarily sourced from the U.S. Census (U.S. Census Bureau, 2000, 2010, 2015, 2016). We also include data on municipal-level ideology developed by Tausanovitch and Warshaw (2014) to represent residents' liberal and conservative views based on polling. Finally, we collected mayoral partisanship information from web-based sources; in cities with nonpartisan races, we noted how mayors self-identified. To ensure the sample is representative of conditions in the population of cities, we conducted *t*-tests of means to compare qualities of cities with respondents who completed surveys and the full group. Sample cities are not significantly different from the population across all covariates.

Table 2

Comparison of covariates for responding cities versus full group of cities.

Description	Source	Mean (*SD*)		
		Fully completed surveys ($n = 120$)	All cities ($N = 307$)	*P* value of *t*-test of means
Number of jobs in city	ACS (2010)	199,120 (442,182)	161,138 (309,665)	.39
Number of residents in city	ACS (2016)	380,416 (883,888)	303,109 (596,518)	.38
Jobs per capita	Jobs/pop	0.52 (0.2)	0.51 (0.2)	.65
Residents per square mile	ACS (2016)	4,581 (3,854)	4,213 (3,340)	.36
Change in residents from 2000	ACS (2016), Census (2000)	0.29 (0.55)	0.42 (2.37)	.39
−1 (liberal) to +1 (conservative) ideology score for city	Tausanovitch and Warshaw (2014)	−0.17 (0.29)	−0.12 (0.29)	.13
Ideology score for state		−0.01 (0.16)	−0.01 (0.17)	.95
Total local expenditures per capita (000s)	Census state and local 2015, city websites	2.529 (1.81)	2.46 (1.88)	.51
Share of population that is non-Hispanic White	ACS (2016)	0.48 (0.19)	0.47 (0.2)	.92
Share of population that is non-Hispanic Black		0.17 (0.16)	0.16 (0.16)	.75
Share of commuters who travel by walking, biking, or public transit to work		0.10 (0.10)	0.09 (0.10)	.29
Share of commuters with work trips more than 45 min		0.15 (0.09)	0.14 (0.08)	.38
Share of people 25 years and older with at least a bachelor's degree		0.34 (0.13)	0.32 (0.13)	.22

(*Continued*)

Table 2 (*Continued*).

Description	Source	Mean (*SD*)		
		Fully completed surveys ($n = 120$)	All cities ($N = 307$)	*P* value of *t*-test of means
Median household income		56,303 (19,058)	55,560 (17,076)	.71
Share of households who rent		0.48 (0.11)	0.47 (0.11)	.29
Share of households with no vehicle		0.1 (0.08)	0.1 (0.07)	.42
Share of renters paying at least 30% of income to rent		0.53 (0.07)	0.53 (0.07)	.83
Median housing value		264,280 (171,626)	247,598 (159,654)	.36
Share of residents in poverty		0.14 (0.07)	0.14 (0.06)	.91
Gini index of inequality		0.46 (0.05)	0.46 (0.04)	.57
Dummy for whether the mayor is a Democrat	Web sources	0.58 (0.5)	0.53 (0.5)	.31

Note: ACS indicates American Community Survey.
Sources: U.S. Census Bureau, 2000, 2010, 2015, 2016.

We developed a series of ordered probit regressions to assess responses using the variables assembled in Table 2, as well as dummy variables for whether the respondent was a member of the planning department. We used ordered probit models because of the Likert scale used to record responses. The Likert scale provides respondents with five choices from *strongly disagree* to *strongly agree* or from *decrease a lot* to *increase a lot*, depending on the question. Each model shows standardized coefficients to allow for comparisons between the relative influence of the variables, which are on different scales, as well as average marginal probability effects to determine the net effect of each variable, and uses robust standard errors (see the Technical Appendix). We chose to undertake these methods because they are key tools in evaluating how cities are planning and are likely to plan in the future. Specifically, they provide the power to differentiate the influence of various city characteristics, a task for which descriptive statistics alone are inadequate.

To test for response rate variation from planners versus transportation officials, we conducted *t*-tests, comparing cities from which planners responded and those from which transportation officials responded (we tested this twice, both with all cities—thus with an overlap between the two groups—and just with cities where only planners *or* transportation officials responded). We find no significant differences across city characteristics for respondents from different departments for any variables; as such, it is appropriate to include them within the same sample, but it is worth noting that the cities from which transportation officials

hailed are marginally ($p < .1$) Whiter in population and have fewer renters.

Municipal Planning Is Limited, but City Officials Have Clear Views About How Autonomous Vehicles Will Alter Their Cities

In this section, we review planning documents and survey results. We examine cities' AV preparations, consider in what ways officials believe AVs will alter urban transportation, and evaluate which municipal characteristics are associated with an interest in developing new policy.

In General, Municipal Planning for AVs Has Been Minimal, With Few Specific Strategies and Policies Enumerated for AVs

An examination of citywide plans approved by the 25 largest U.S. municipalities demonstrates limited planning thus far, supporting Hypothesis 1. Most cities (64%) have not mentioned AV-related policies in their comprehensive or transportation plans, illustrated in Table 3. Nevertheless, of the 13 plans passed since 2016, 7 reference AVs and several other cities are currently undertaking efforts to address them. As cities update plans, which typically are released only every decade or so, AVs will likely be integrated. One official surveyed noted, for example, that her city's upcoming plan "include[s] language about what to do as right-of-way becomes available thanks to AVs."

The plans that mention AVs mostly do not pinpoint appropriate planning actions. Most use language that prioritizes "innovation" and "flexibility" rather than concrete regulatory strategies. *Go Boston 2030*, for example, recommends that AV policy "initial[ly] focus on the testing of new technology," leading to "generating best practices" but little specificity (City of Boston, 2017, p. 192). San Antonio's *SA Tomorrow Plan* recommends incorporating AVs into municipal goals, identifies potential benefits of the vehicles, and recommends that "city staff should follow driverless vehicle developments." It suggests the city "has the opportunity to proactively establish regulations, policies, and plans" but does not identify the policies to be pursued (City of San Antonio, 2016, pp. 6-32, 6-33).

Six of the cities profiled have separate plans specific to AVs or "new mobility," such as ride-hailing. Los Angeles' *Urban Mobility in a Digital Age* recommends increased data sharing and developing a business plan for a municipal AV fleet and suggests a network of AV lanes, but it does not point to what regulations would be enforced for private operators and how city streets would be reconfigured (City of Los Angeles, 2016). Seattle's *New Mobility Playbook* is more specific, reviewing pros and cons of new technologies and then identifying several dozen strategies that would allow the city to shape AV rollout (Seattle Department of Transportation, 2017). Several other cities developed plans in response to the U.S. Department of Transportation's Smart Cities Challenge (other than the winner, Columbus [OH], these are not noted in the table because we found no evidence they have been pursued further).

On the right side of Table 3, we document the goals that cities identify for AV implementation in either their comprehensive or new mobility plans. These goals are typically stated in general terms, not specifics, yet they suggest what planners consider important related to AVs. Plans with such goals most frequently mention increasing street safety, supporting the transit system, and improving the environmental effects of transportation. Less important to the average city in our sample, in decreasing order, is using AVs to mitigate congestion, expand equity, provide last-mile connections, redesign streets, and improve quality of life.

The plans described above are only for the largest cities. Responses to the far more broadly representative web survey, however, support a similar conclusion: Minimal planning for AVs has been undertaken thus far at the municipal level. As shown in Figure 1, a clear majority of officials disagreed that their respective cities were prepared for AVs, had a clear sense of who was responsible for them, or had developed plans or policies related to them. Of respondents, 80.9% noted that there had been little or no staff time yet committed to AVs, and 89.8% indicated that elected officials had committed little to no time preparing for AVs. Only 5.7% of respondents agreed that staff had spent considerable time examining the issue. One respondent wrote, "Unfortunately, our city is not doing anything proactive regarding AVs."

Despite the fact that 52% of respondents agreed that their cities prioritized technological innovation, the same share agreed that they were waiting for federal or state-level legislation before moving forward. Indeed, several officials wrote statements to the effect of "I don't believe that local governments will have much leverage in regulating AVs" because, according to another, "We anticipate state laws that will explicitly prohibit our ability to regulate these services." In other words, a cohort of the leaders we surveyed believes that their efforts will be preempted by higher levels of government, so why pursue policy now?

Table 3

Municipal planning documents, 25 largest U.S. cities.

	Comprehensive land use or transportation plan		"New mobility" plan	Goals for AV implementation in one or both plans							
City (by population size)	Year	Does it promote AV-related goals?	Year	Increase street safety	Support transit	Expand equity	Mitigate congestion	Improve sustainability	Link last mile	Improve quality of life	Redesign streets
New York (NY)	2015	No	2016	X			X	X	X	X	
Los Angeles (CA)	2016	No	2016	X	X	X	X	X	X	X	
Chicago (IL)	2012[a]	No									
Houston (TX)	2015	No									
Phoenix (AZ)	2015	No									
Philadelphia (PA)	2018	Yes			X						X
San Antonio (TX)	2016	Yes		X	X			X	X		X
San Diego (CA)	2008	No									
Dallas (TX)	2006[a]	No									
San Jose (CA)	2011	No									
Austin (TX)	2012	No	2017	X	X	X	X	X	X	X	

Jacksonville (FL)	2010[a]	No									
San Francisco (CA)	2017	Yes	2018	X	X	X	X	X	X		
Columbus (OH)	2016	No	2017		X				X		
Indianapolis (IN)	2018[b]	Yes			X	X	X				X
Fort Worth (TX)	2017	No									
Charlotte (NC)	2017	No									
Seattle (WA)	2016	No	2017	X	X	X	X	X		X	X
Denver (CO)	2017	No									
El Paso (TX)	2012	No									
Washington (DC)	2014	Yes		X			X	X			
Boston (MA)	2017	Yes		X		X	X	X			X
Detroit (MI)	2018	Yes		X	X						
Nashville (TN)	2015	Yes		X							
Memphis (TN)	2018[b]	Yes			X			X			
Share of total		36%	24%	40%	40%	24%	32%	36%	24%	16%	20%

Notes: As of January 2019.
a. These cities are currently developing new general transportation plans.
b. Document in draft form.

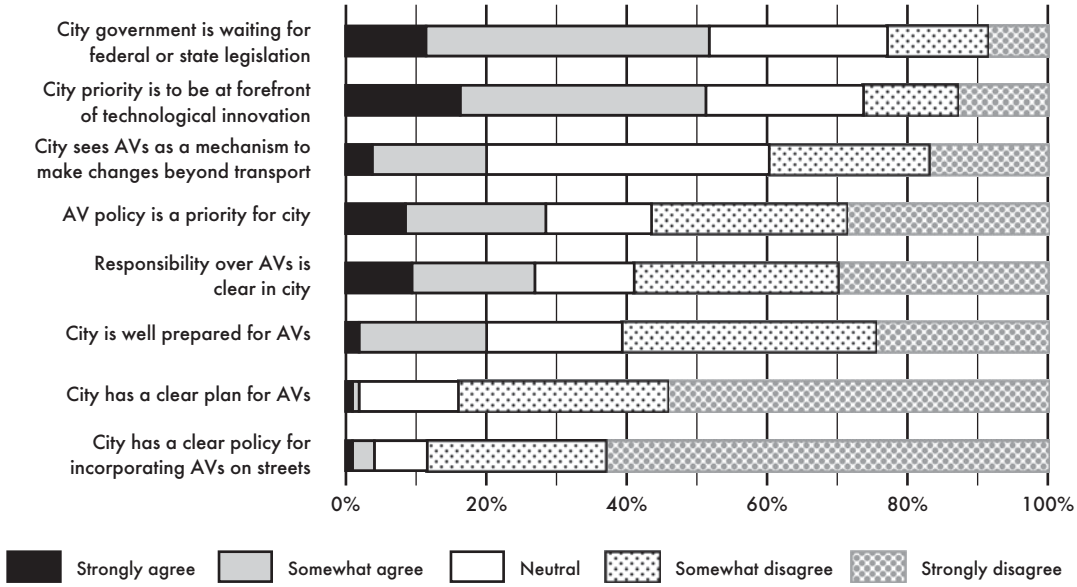

Figure 1. Respondents' sense of preparations for autonomous vehicles.

In the survey, we asked officials how responsibility for AV policy had been delegated in the municipal government. Here, preparations are stronger: Just 9.9% said that their cities had yet to assign policy to a particular department. On the other hand, 9.9% had assigned it to planning departments, 32.2% had assigned it to transportation departments, and 7.2% had assigned it to other departments. This still leaves 40.8% of cities with assignments to multiple departments. This provides some evidence backing officials' views that responsibility over matters related to AVs has not yet been clearly delegated because direct lines of accountability may be missing in contexts where oversight is performed by several departments.

Overall, these results confirm Hypothesis 1 that local governments have conducted little planning for AVs. This lack of preparation is concerning because officials are convinced AVs will be available for nonexperimental passenger use soon. Most respondents (76.6%) believe such services will be available within 10 years and 35.4% believe they will be ready within 5 years. Only 2.5% of officials believe it will take more than 15 years for such services to be offered in their respective cities. There is thus strong consensus across the country about upcoming changes in urban transportation, at least from the perspective of AV *availability*.

As we show below, many officials believe AV-related regulations are needed, but a large cohort of them is concerned about intervening before understanding the vehicles' parameters. About a third of respondents noted their uncertainty in open-ended comments. One official said, "I think it is awfully early to tell"; another wrote, "We have a bit of a wait-and-see attitude." Others pointed out that impacts depend on where the vehicles are deployed. "I find those that are deeply immersed in this field to be far too optimistic about how fast this technology will change the way the public uses transportation," one noted, "especially outside of extremely dense urban areas." Another emphasized that "the vast majority of vehicles on the road will remain traditional once AVs become available."

City Preparations Vary Depending on Local Characteristics

To test for variation among cities and examine Hypothesis 2, we investigated whether more local resources, more liberal political ideologies, a larger staff (based on the self-reported number of employees in the department of the respondent[7]), and higher population growth affected municipal preparation (Tables A-1 and A-2 in the Technical Appendix).

We identify partial evidence in support of Hypothesis 2 (Tables A-1 and A-2). We find no link between local political ideology or departmental employment and higher levels of preparation, yet we find a significant and strong link between per capita expenditures and officials' sense that their cities are well prepared for AVs (model 2, adjusted for controls). Indeed, several officials (presumably from less-resourced cities) noted that "funding capacity is an issue." "We're a

Table 4

Expected impacts of autonomous vehicles on city life and local politics.

AVs …	Strongly disagree (%)	Somewhat disagree (%)	Neutral (%)	Somewhat agree (%)	Strongly agree (%)
Will improve quality of life	2.9	5.7	28.7	44.8	17.8
Will face local public opposition	1.1	17.7	18.9	51.4	10.9
Will improve the city	1.7	9.2	30.5	42.0	16.7
Should be regulated by municipality	18.9	23.4	15.4	27.4	14.9
Could pose a serious risk	15.6	32.9	19.7	26.6	5.2
Will face local political opposition	6.3	28.6	34.3	22.3	8.6
Will face local bureaucratic opposition	6.9	29.1	33.1	23.4	7.4

poor city," another respondent wrote. "Introduction of AVs would appear to need substantial funding, which we don't have." These issues are of greater concern to planners, who are far less likely to believe that AV policy is a priority or responsibility for AVs is clear (models 4 and 6).

As expected, population size plays a significant and strong role once we adjust for other municipal-level characteristics; officials from larger cities are more likely to see AV policy as a priority (model 4), though they do not see their cities as well prepared. Larger and denser cities are much less likely to be waiting for legislation from higher-level governments (model 8).

Unexpectedly, we find that recent municipal population growth has the strongest influence (the largest coefficients in these standardized coefficient results) on officials' views of their cities as prepared, having AV policy as a priority, and having clear responsibility over AVs assigned (models 2, 4, and 6). It is possible that increasing population acts as a sort of local resource we did not anticipate; in a context of a resident base (and therefore tax revenue) growing more quickly than service needs, cities may be able to devote more time and money to preparing for new technology.

Officials Are Optimistic About AVs, but Those With Greater Concern for Negative Impacts Are More Motivated to Engage in Related Regulations

Despite limited planning thus far and uncertainty about AV effects, officials articulated strong views about their consequences. To examine these feelings and the degree to which they motivate officials to make policy, and to test Hypothesis 3, we explore whether those with more concerns about AVs are more likely to want to regulate them. Most surveyed officials hold a sanguine view about autonomous vehicles, with one even writing in a comment, "AVs: the sooner the better." Tables 4 and 5 document responses to questions where officials were asked to agree or disagree on questions of AV impacts on city life and local politics and to evaluate the net impact (decrease to increase) of AVs on specific aspects of the urban environment and transportation system. These show that most agreed that AVs would improve the city in general (58.7%) and improve quality of life specifically (62.6%). Respondents largely agreed that AVs would reduce congestion (38.6%; a significant share expected no change or were not sure), transportation costs (50.3%), energy use (44.2%), and pollution (51.3%), and increase safety (58%).

Table 5

Expected impacts of autonomous vehicles on aspects of the urban environment and transportation system.

How do you think AVs are likely to change …	Decrease a lot (%)	Decrease a bit (%)	No change (%)	Increase a bit (%)	Increase a lot (%)	Not sure (%)
Safety	3.2	12.1	17.8	28.7	29.3	8.9
VMT	1.3	21.7	28.0	28.7	13.4	7.0
Equity (mobility)	2.6	21.8	28.2	32.7	7.1	7.7
Sprawl	0.6	12.9	45.8	22.6	11.0	7.1
Cars on the road	3.2	32.3	25.9	22.8	9.5	6.3
Energy use	3.2	41.0	16.7	28.2	3.2	7.7
Employment (overall)	0.6	6.4	52.9	26.8	1.3	12.1
Walking and biking	0.0	14.6	53.5	26.8	0.6	4.5
Congestion	4.4	34.2	27.2	19.0	7.6	7.6
Equity (overall)	1.9	18.6	44.9	23.7	2.6	8.3
Employment (transportation)	7.1	29.5	30.1	24.4	0.6	8.3
Segregation	0.6	12.8	53.2	17.3	4.5	11.5
Transportation costs	8.9	41.4	17.2	15.9	4.5	12.1
Transit ridership	5.1	35.7	27.4	18.5	1.9	11.5
Pollution	5.8	45.5	26.9	14.7	1.9	5.1
Municipal revenues	4.5	19.1	43.9	14.0	1.3	17.2

Nevertheless, officials expressed concerns about certain potential AV impacts. Though few respondents disagreed that AVs would increase quality of life (just 8.6%), 31.8% agreed AVs could pose a serious risk to their respective cities, as shown in Table 4.

Table 5 indicates some reasons, spanning mobility and land use issues, why they might feel that way. Many respondents agreed that AVs would likely increase VMT (42.1%), reduce transit ridership (40.8%), reduce local government revenues (23.6%), reduce employment in transportation (36.6%), and increase sprawl (33.6%). Some officials also agreed that AVs would increase the number of cars on the road (32.3%), increase congestion (26.6%), reduce social equity (26.3%), and increase segregation levels (21.8%). These concerns suggest that although officials are generally optimistic about the benefits of AVs, many simultaneously harbor significant fears about them.

Most respondents (62.3%) also agreed the rollout of AVs would face public opposition, as noted in Table 4, suggesting they believe residents may be skeptical of their value. A smaller but still large share of officials expected AVs would face bureaucratic (30.8%) and political (30.9%) opposition. Concerns about AVs from officials themselves, then, are matched by their sense that the public and other members of the government are worried about the technology.

These findings paint a portrait of municipal officials with divergent views. Many agree the vehicles will produce normatively positive outcomes, such as reduced congestion, increased safety, and reduced pollution. Yet many respondents also believe AVs could increase the number of cars on the road, reduce municipal revenues, and increase sprawl. Officials appear to be optimistic about AVs even though they are fearful of some of their consequences. One factor worth considering: When we asked what issue they prioritized most in terms of transportation, they ranked safety highest and the environment, equity, and efficiency lowest. Given that order, officials may be satisfied with the safety benefits that they expect from AVs and thus be less worried about potential increases in energy use, sprawl, segregation, and VMT.

The divergence in views among officials is also a reflection of varying local characteristics. Table 6 shows differences in responses across a variety of AV-related outcomes between the top and bottom quartiles, as well as the middle two quartiles, of cities in terms of population size, median household income, ideology, population growth, per capita expenditures, and population density. Several results stand out: Officials from cities with higher populations, with higher per capita expenditures, and with residents holding more liberal ideologies are more likely to expect AVs to increase VMT and reduce transportation employment, whereas the opposite is true of cities with high population growth. Officials from more conservative cities are less likely to be concerned about AVs reducing transit ridership, increasing sprawl, or reducing social equity. Bureaucrats from cities with low population growth are far more likely to be concerned about AVs reducing city revenues than peers from fast-growing places. Finally, those from the densest cities are more likely to be concerned about reduced social equity.

Just as interesting are responses where there was little variation among officials based on local characteristics. Population size and population growth had little influence on officials' views about the vehicles' potential to induce sprawl or reduce transit ridership. And the wealth of local residents was unrelated to concerns about AVs increasing VMT.

We also compare views on whether AVs should be municipally regulated (rightmost column in Table 6). Here, we show that officials from the largest, most liberal, densest, and highest spending cities are much more willing to regulate than their counterparts in cities with different characteristics. On the other hand, the cities with the highest population growth are less likely to support regulations. This may seem at odds with the fact that officials from such cities consider themselves more prepared, as discussed above. Nonetheless, there is coherence in a philosophy of governance that asserts direct public interference is not needed in the face of private investment driving change. In such cases, AV policy can be prioritized even as regulation is eschewed; this is the approach many fast-growing cities pursue today. The opposite is the case for slow-growth municipalities.

To examine Hypothesis 3 in more detail, we examine whether respondents concerned about negative repercussions from AVs, and with fewer concerns about resistance to AV rollout, are more likely to believe that their cities have made AV policy a priority and are more motivated to engage in future regulations (Tables A-3 and A-4 in the Technical Appendix). We identify a significant and strong connection between a respondent's expectations of political opposition to AV deployment and views that AV policy is *not* a municipal priority (models 1, 2, and 5; it is the variable with the highest magnitude in these models, which show standardized coefficients). At the same time, there is no such connection with the respondents' answers regarding whether or not AVs should be municipally regulated (models 6, 7, and 10). This partially confirms our expectation in Hypothesis 3 that political opposition plays a role in determining whether new policies are developed, though this does not extend to the issue of whether or not AVs should be locally regulated. It may be that city

Table 6

Cross-tabulations, expected impacts of autonomous vehicles.

	Share of municipal officials who agree that AVs …						
	Will increase VMT (%)	Will reduce transit ridership (%)	Will reduce city revenues (%)	Will reduce transport employment (%)	Will increase sprawl (%)	Will reduce social equity (%)	Should be regulated by municipality (%)
Population size							
Top quartile	50.0	37.5	25.0	52.5	35.0	32.5	61.4
Middle quartiles	43.8	44.3	22.8	33.3	30.8	14.1	37.9
Bottom quartile	29.7	36.8	23.7	26.3	37.8	21.1	31.8
Median household income							
Top quartile	39.0	48.8	22.0	35.0	27.5	22.0	40.0
Middle quartiles	45.3	38.2	21.1	31.6	32.0	21.3	45.3
Bottom quartile	39.0	37.5	30.0	47.5	42.5	17.5	38.6
Ideology							
Top quartile (most liberal)	58.5	52.4	26.2	45.2	43.9	33.3	61.4
Middle quartiles	40.7	40.0	26.3	36.3	31.3	18.8	33.7
Bottom quartile (most conservative)	26.5	29.4	14.7	27.3	24.2	9.1	41.9
Population growth							
Top quartile	40.5	35.1	13.5	22.2	27.8	13.5	29.5
Middle quartiles	40.8	46.8	24.7	33.8	35.5	21.1	47.1
Bottom quartile	46.5	35.7	31.0	54.8	33.3	26.2	46.5

(*Continued*)

Table 6 (*Continued*).

	Share of municipal officials who agree that AVs …						
	Will increase VMT (%)	Will reduce transit ridership (%)	Will reduce city revenues (%)	Will reduce transport employment (%)	Will increase sprawl (%)	Will reduce social equity (%)	Should be regulated by municipality (%)
Per capita expenditures							
Top quartile	39.0	48.8	26.8	46.3	40.0	26.8	54.8
Middle quartiles	52.6	37.2	23.1	35.1	33.8	22.1	40.9
Bottom quartile	23.7	39.5	21.1	28.9	26.3	10.5	33.3
Population density							
Top quartile	46.3	36.6	17.1	46.3	31.7	34.1	59.1
Middle quartiles	44.7	46.8	28.6	32.9	34.7	18.4	34.5
Bottom quartile	32.5	33.3	20.5	33.3	33.3	10.3	40.9
Overall	42.1	40.8	23.6	36.6	33.6	20.5	42.3

governments with limited political opposition to AVs envision their relationship with the vehicles as one based on consensual planning (or letting the market decide), not regulation, but we were unable to parse out the difference based on answers. These results also suggest that expectations of public and bureaucratic opposition to AVs are not considered, on the whole, important enough to influence whether regulation occurs.

We find the perception that AVs pose a risk is associated with respondents' sense that AVs should be municipally regulated across multiple models, even when incorporating controls (models 8, 9, and 10). Nevertheless, this perception is not linked with making AV policy a priority. We find only one correlation with potential sources of risk assessed using the variables with respect to traffic, equity, and environment: A fear that AVs will increase traffic is positively associated with officials seeing AVs as a priority (this effect disappears in the full model 5). Concerns about negative impacts of AVs may motivate officials, but we could not find any effects of specific *types* of fears on municipal priorities or need for regulation.[8]

Differences in Approaches by Planners and Transportation Officials

Because of our sample's composition—primarily of representatives of transportation and planning departments—we examine whether the two types of officials responded differently. If their approaches and opinions varied dramatically, the choice of which department to lead planning for AVs could be consequential. For example, if transportation officials were empowered, perhaps they would prioritize the mobility-related effects of AVs as a matter of concern over the land use effects.

In the models presented above, planners were far less likely to believe that AV policy is a municipal priority. To test this question more directly, we conducted *t*-tests for answers to all of the questions that we asked, comparing officials from the two groups.[9] This comparison

shows no significant contrast between expectations of officials from the two groups of departments regarding AVs on issues such as segregation and sprawl (land use related) or VMT and congestion (mobility related). We find significant variation ($p < .05$) between planners' and transportation officials' answers to just 3 of the 30 questions posed to them. These results show that planners were about half as likely as transportation officials to believe that AVs will improve the city; they were less likely to believe that AVs would reduce pollution; and they were less likely to believe that responsibility over AV policy had been clearly defined.

A Fleeting Opportunity for Municipalities to Link Existing Planning Goals With Autonomous Vehicles

In this study we bring new insight into how U.S. local governments are preparing for the rollout of AVs. By examining local plans and conducting a nationwide survey, we show that cities have only dipped their toes into the water when it comes to regulating this technology. Most officials feel unprepared to respond, and municipal governments have not clearly designated responsibility over the matter. At the same time, most of the officials who responded to our survey believe AVs will be available for the public within the decade.

There is great uncertainty regarding what features AVs will include and how they will interface with other changes in urban transportation, such as electrification and shared use. Perhaps it is unreasonable for cities to be planning for a technology whose boundaries have not yet been fully defined. Although our results suggest that top-level municipal officials are optimistic about many of the benefits AVs will bring, a significant share is also concerned about their negative effects. It is worth noting, in particular, the relatively large number of officials who worry about AVs increasing VMT and sprawl while reducing transit ridership and employment. If those fears come to fruition, many cities will be acting in direct opposition to their stated policy goals. Despite the nebulousness surrounding AVs, this finding indicates a need for creating policies specifically targeted at preventing these potentially deleterious effects. Moreover, although caution is merited in creating policies for a technology that is in its early stage of development, a large share of officials told us they *wanted* to develop regulations on the topic but felt they lacked the resources to do so.

We find clear differences in responses regarding officials' views on how AVs will change their cities. Cities with higher per capita government expenditures, more residents, and more liberal local political ideologies are much more likely to be concerned that AVs will increase VMT, reduce employment in transportation, and reduce social equity. Meanwhile, cities with higher population growth are less likely to be concerned about AVs. This variation suggests American cities will respond to AVs with contrasting approaches.

Cities have an opportunity to engage by guiding AV rollout to ensure that their forms and use patterns match municipal officials' goals as expressed in their local plans. Cities retain major policy powers, particularly with regards to street and land use management, that could allow them to influence how the vehicles work within jurisdictional boundaries. The shock represented by a major advancement in transportation technology might spur new thinking about previously unimplemented policy changes (Kingdon, 1986). However, the timing of such public interventions matters; if not engaged at the right moment, policy change may have limited effect on transportation use (Acharya & Morichi, 2007). Several cities expressed concern about the role of higher levels of government. The specter of preemption may limit or delay local AV policymaking; a clearer division of responsibilities among different levels of government combined with state authorization for using municipal powers to help shape the arrival of AVs might help to alleviate such hesitation.

Mohr (1969) argues that the development of new policies depends on officials having the motivation to innovate, limited obstacles standing in the way, and the availability of adequate resources; our study largely confirms this theory. We find that cities with higher population where officials expect less political opposition to the rollout of AVs are more likely to prioritize developing related policies. We also find that officials with major concerns about the vehicles are much more likely to think they should be regulated by the municipality. Officials hold these views even though the characteristics of AVs have not been fully defined.

To advance planning, cities need to devote appropriate funding to do so while being offered the freedom to develop policies by higher-level governments. Planners can identify what problems they foresee with AVs and use the advent of the technology to argue for strategies to address them, specifically concentrating on the many policies that will likely also relate to human-driven automobiles. Connecting current problems with plans for AVs may resolve the dilemma that many cities face in the context of inadequate resources and knowledge; it would allow planners to think about the future while focusing on today. In addition, given shared concerns among many officials, they may be able to work together across cities to develop best practices.

Because cities evincing differing characteristics also expressed differing levels of willingness to engage in

policymaking and regulations, a one-size-fits-all approach is likely inappropriate. Rather, future research is necessary to propose concrete policies and actions for different groups of cities based on their characteristics, their level of resources, and their political predispositions. Scholars such as Sperling, van der Meer, and Pike (2018) have identified promising policies designed to promote the effective rollout of AVs, including incentives for shared fleets and zero-emissions vehicles, through mechanisms such as tolled roadways, emissions regulations, new types of curbside management, and making it difficult to drive single-occupancy cars into dense neighborhoods. We share enthusiasm for these ideas, especially because they would improve quality of life and transportation effectiveness in cities today, with or without automation, while doubling as key regulations for shaping an AV future. Indeed, these policies would also address many of the goals articulated by existing plans laid out in Table 3, including increasing street safety, supporting transit, and improving sustainability. From this perspective, planning for AVs can be considered an extension of planning for transportation in general.

Additional research is necessary to identify how officials think about policies related to AVs, such as whether they are even considering the recommendations put forward by Sperling (2018) and others. Does the uncertainty related to the vehicles, on the other hand, stand in the way of making regulatory progress, even in fast-growing megacities in the developing world? Moreover, we need to better understand what role the officials whom we surveyed play in the broader transportation policymaking ecosystem. Will their assessments today affect the thinking of elected officials, who ultimately make final decisions, and does the assignment of AV policy to transportation versus planning departments matter in terms of outcomes?

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SUPPLEMENTAL MATERIAL

Supplemental data for this article can be found on the publisher's website.

NOTES

1. For the purposes of this study, we do not distinguish between policies and regulations because we focus on the *impetus* for municipal action on AV technology.

2. "Highly" automated vehicles are levels 3 to 5 on the Society of Automotive Engineers' classification; this includes system control of steering, acceleration, and monitoring of the driving environment. Levels 4 to 5 also involve no fallback to human drivers in the case of dynamic driving tasks, and level 5 extends automation to all driving modes (Li, Sui, Xiao, & Chahine, 2018).

3. See, for example, the 3 Revolutions: Shared, Automated, Electric project of the University of California at Davis, Institute of Transportation Studies (2017) (http://3rev.ucdavis.edu).

4. In some states, such as Pennsylvania, taxi service is regulated at the state level by a special commission as opposed to by cities themselves (Schaller, 2007).

5. We also conducted a search of ordinances or mayoral executive orders related to AVs beyond requirements for testing. Though Portland (OR) developed a draft policy in 2017, in no city did we identify legal documents directly associating city planning issues with AVs.

6. In the survey documented here, we did not define what we meant by "AV," leaving this question open ended. Based on text responses, most interpreted it as meaning a passenger car–sized vehicle operating on city streets, as it has been described commonly in the U.S. press; we did not receive any indication that there was confusion on this matter. Nevertheless, to clarify, there are other forms of automated transportation, such as trains and buses.

7. We also tested number of departmental employees per capita, adjusted for local population levels. This produced similar results.

8. We find little significant correlation between more liberal political ideology and increasing support for municipal regulations (see Technical Appendix Table A-3; in fact, in model 7, we find the opposite, though these effects disappear with additional controls in models 9 and 10), despite the

correspondence in Table 6 between the two. It is true that when we run a single-variable probit regression, we find a significant ($p < .05$) and strong relationship; however, this relationship disappears once we control for local population size.

9. To do this, we transformed Likert responses into a −2 to +2 scale.

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