Urban Robotics: Achieving Autonomy in Design and Regulation of Robots and Cities

Jesse Woo, Jan Whittington, Ronald Arkin

Abstract

This paper argues that cities are the optimal sites of experimentation for emerging technologies such as robotics, and that they should be empowered to regulate these technologies in order to facilitate that function. The paper introduces the nature and current state of robotics technologies being tested in cities, and the institutional economics and potential hazards for cities that open their public rights of way to experimentation with new technologies. The paper pays particular attention to the privacy impacts of robots for cities, and local government's role in reshaping concepts of privacy in public space. It also clarifies the legal authority of cities to regulate urban robots within the complicated schema of federal and state laws that touch this technology. Finally, it critiques proposed and existing legislation that would preempt local governments and deprive them of their ability to shape urban infrastructure to suit the needs of both cities and robots.

This paper brings a unique interdisciplinary approach, with three authors who are experts in law, institutional economics, and robotics design, respectively. It was presented at the 2018 We Robot conference at Stanford Law School, the premier academic robotics law and policy conference, with an acceptance rate of less than 10%. It will also be the focus of a plenary session panel presentation at the Institute of Electrical and Electronics Engineers' (IEEE's) flagship smart cities conference on the policy track.

This is the first paper to systematically address the role of cities in robotics regulation and merge the literatures on two cutting edge topics: smart cities and robotics. It develops arguments in favor of local government authority at a time when cities increasingly contend with preemption by state and federal governments.It therefore contributes new insights to debates over federalism and local power. It also provides a more unified framework to understand robotics technology in cities and the myriad issues that attend their deployment such as privacy, equity, and use of public space.

The core legal argument of the paper is that preemption of cities by state and federal authorities interferes with the design process, whereby cities and technologists engage in an iterative, evidence-based policy making process to develop technology that serves the public. This is especially prevalent in robotics because the task environment encompasses the urban built environment. Cities therefore need some authority over this task environment, which is threatened by proposed legislation.

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Part I: Introduction

Are cities ready for self-driving, artificially intelligent, vehicles and robotics? The urban marketplace is increasingly filled with products emblematic of "smart" cities, from widely discussed autonomous vehicles (AVs) to smaller variations on the theme, such as robotics for delivery, security, and entertainment.[1] Altogether, such urban robotics represent a new wave of technology in which digital sensors, networked devices, and their associated data stores are given the algorithmic, physical, and legal means to move in public space.[2] As time goes on, the public is increasingly likely to encounter self-driving vehicles, robots, and drones on city streets, sidewalks, and in urban airspace. How should cities respond to these new and impending technologies?

Firms have technological, market, and financial interest in testing and deploying their products in public space, but the implications for cities span a broad array of intended and unintended consequences. Cities are natural sites of experimentation for firms interested in bringing these products to market, and the perception of economic opportunity associated with tech firms is leading city representatives to reclaim public spaces, transforming them into testbeds for product development.[3] It is worth noting, however, that experimentation involves trial and error, and there are limitations to the ability of artificial intelligence to navigate the wide range of conditions and events that comprise the urban environment.[4] Ultimately, the design of the

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[1] Jeffrey Mervis, *Are we going too fast on driverless cars?*, Sci., Dec. 14, 2017, http://www.sciencemag.org/news/2017/12/are-we-going-too-fast-driverless-cars, "Transportation experts have developed six levels that describe autonomous vehicles. In general, a higher number means a more independent vehicle, with less for the human driver to do, thanks to more sophisticated sensors, cameras, and algorithms. …[a] level-four car … will operate autonomously only under certain conditions, say in good weather during the day, or on a road with controlled access. The technology for that capability already exists"; Olivia Solon, *Robots are invading malls (and sidewalks) near you*, MIT Technology Review, (June 8, 2016) https://www.technologyreview.com/s/601635/robots-are-invading-malls-and-sidewalks-near-you/, "a small but growing number of human-scale mobile robots … are finding employment outside the confines of industrial settings like factories. They're invading consumer spaces including retail stores, hotels, and sidewalks in a quest to deliver services"; Paul Miller, *Taking a ride on Segway's Loomo robot*, The Verge (Jan. 11, 2018) (https://www.theverge.com/2018/1/11/16874220/segway-loomo-robot-hands-on-ces-2018).

[2] On the theory of the combinatorial evolution of technology, including artificial intelligence, see W. Brian Arthur, *The Nature of Technology,* NY: The Free Press, (2009).

[3] A natural site of experimentation is any site that is one and the same as the intended market for the device, analogous to the natural habitat for a species. On the topic of city representatives accommodating firms, see Emily Badger "Pave over the subway? Cities face tough bets on driverless cars" The New York Times, July 20, 2018, https://www.nytimes.com/2018/07/20/upshot/driverless-cars-vs-transit-spending-cities.html;, Regarding a partnership with Ford in which Miami becomes a testbed, Mayor Carlos A. Giménez of Miami-Dade, Florida said, "We want to learn from Ford what it is we need to do to get ready for these vehicles, so that when AVs become a reality, fully, we'll be one of the first communities to get them,... We want to let the world know that Miami is ready to be a testbed." Laura Bliss, "Self-driving pizza just hit Miami" CityLab, February 27, 2018, https://www.citylab.com/transportation/2018/02/self-driving-pizza-just-hit-miami/554138/.

[4] Veronica Richa, "Crime-fighting robot hits, rolls over child at Silicon Valley Mall" Los Angeles Times, July 14, 2016, http://www.latimes.com/local/lanow/la-me-ln-crimefighting-robot-hurts-child-bay-area-20160713-snap-story.html; On the safety of self-driving cars, Jeremy Kahn, "An idea for making self-driving cars safer: Reprogram humans" Los Angeles Times, August 17, 2018, http://www.latimes.com/business/autos/la-fi-hy-driverless-car-safety-20180817-story.html; on the extent to

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environment may be as important to the success of urban robotics as the design of the hardware and software in these products.[5] These are matters that city officials care about; the design, function, and finance of urban built environments is generally the purview of local government. Significant new questions in law, such as legal liability for the performance of artificially intelligent devices, are being addressed as autonomous vehicles and devices enter public rights-of-way.[6] Additionally, artificial intelligence imbues devices with the purpose of replacing as well as augmenting the roles and responsibilities of persons, and this tension exists at the local level.[7] Lastly, these products generate rich data stores about the public, bringing

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which roboticists depend on the design of the environment, Futuris, "Urban robots: a new generation of robots" YouTube, www.euronews.net, UPC, May 10, 2012 (https://www.youtube.com/watch?v=t8cstaDhjjI), describing one of the many challenges of designing robots to operate among people in an urban environment, "for example, autonomous navigation, that's to say [the robots would] be able to move around and find out where they are, those are things that to us seem very routine and very simple, but for the robots they are very complex".

[5] As the National Association of City Transportation Officials says, "Automated vehicle technology holds many promises for cities, but the potential benefits of automation are not guaranteed. City policies must proactively guide the technology to prioritize people-centric design." NACTO *Blueprint for Autonomous Urbanism*, Module 1, Fall 2017, Designing Cities Edition, https://nacto.org/publication/bau/blueprint-for-autonomous-urbanism/; US Department of Transportation, "FHWA Announces Vehicle to Infrastructure Guidance" Transportation.gov, January 19, 2017 (https://www.transportation.gov/briefing-room/fhwa0317), U.S. Transportation Secretary Anthony Foxx notes that vehicle-to-infrastructure communication is a, "critical component of a connected vehicle environment—a system of hardware, software, firmware and wireless communication that enables the dynamic transfer of data between vehicles as well as between vehicles and elements of the roadway infrastructure"; Futuris, "Urban robots: a new generation of robots" YouTube, www.euronews.net, UPC, May 10, 2012 (https://www.youtube.com/watch?v=t8cstaDhjjI), describing one method to overcome the challenge of designing a robot to navigate the urban environment, "this campus is equipped with wifi internet and twenty cameras to allow the robots to navigate around; the same setup would be needed in any city for [the robots] to be able to work autonomously".

[6] The death of a pedestrian by an autonomous vehicle test driven by Uber in Arizona highlights the import of these issues. Larry Greenemeier, "Uber self-driving car fatality reveals the technology's blind spots" Scientific American, March 21, 2018, https://www.scientificamerican.com/article/uber-self-driving-car-fatality-reveals-the-technologys-blind-spots1/ quotes experts in the field on the inevitability the crash, saying "it was only a matter of time," as the technology "is not mature enough to be completely driverless" and "it is unlikely that a person would be able to prevent a crash by taking over a self-driving system at the last minute"; https://www.npr.org/sections/thetwo-way/2018/03/19/594950197/uber-suspends-self-driving-tests-after-pedestrian-is-killed-in-arizona?sc=tw; describes the firm's decision to suspend tests of self-driving vehicles in the wake of the fatal crash; Timothy Lee, "NTSB: Uber's sensors worked; its software utterly failed in fatal crash" Ars Technica, May 24, 2018, https://arstechnica.com/cars/2018/05/emergency-brakes-were-disabled-by-ubers-self-driving-software-ntsb-says/; summarizes findings from an investigation by the National Transportation Safety Board; Mike Isaac, "Uber's vision of self-driving cars begins to blur" New York Times, August 19, 2018, https://www.nytimes.com/2018/08/19/technology/uber-self-driving-cars.html, describes the firm's choice between continuing or abandoning investment in it's autonomous vehicle unit.

[7] Olivia Solon, "Robots are invading malls (and sidewalks) near you" MIT Technology Review, June 8, 2016 (https://www.technologyreview.com/s/601635/robots-are-invading-malls-and-sidewalks-near-you/), Urban robots and the firms that deploy them are "in a quest to deliver services alongside human staff members for a fraction of the price of employing people to do a variety of typically unexciting tasks."; Jeffrey Mervis, "Are we going to fast on driverless cars?" Science, December 14, 2017 (http://www.sciencemag.org/news/2017/12/are-we-going-too-fast-driverless-cars), "Technologists see AVs as the next step in what's called "mobility as a service." That is what taxi fleets and ride-sharing

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market potential along with the coupled moral hazard of data monetization and loss of privacy, including surveillance.[8] Which parties are positioned to benefit from this experimentation, and which will absorb the costs? In the face of these potentially widespread and enduring industrial and technological changes, how might cities act in the public interest?

The answers to these questions lie as much in the institutional arrangements designed to govern this new wave of technologies as it does in the intrinsic capabilities of these products. Anyone evaluating the existing policy environment for artificially intelligent devices today would find technological optimism, conflicting perspectives of the public interest, and preemptive acts at the state and federal levels.[9] In particular, preemption in current policy-making raises issues, because the consequences and cost of product design, including safety and surveillance as well as convenience and expense, play out at the local level.[10] As city officials ask their residents to co-exist with robots and negotiate with firms over the transaction costs that accompany these

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services such as Uber and Lyft now offer. What is attracting AV investors is the huge payoff from removing the biggest cost of that service, namely, the person behind the wheel."

[8] E.g., Kayla Matthews, "How anonymous cars will make big data even bigger" *DATAFLOQ*, January 7, 2018 (https://datafloq.com/read/how-autonomous-cars-will-make-big-data-even-bigger/1795), "autonomous vehicles, or "smart" cars of the future, are nothing more than a cog in a much larger data-collection system"; Matt McFarland, "Your car's data may be more valuable than the car itself" *CNN Tech*, February 7, 2017 (http://money.cnn.com/2017/02/07/technology/car-data-value/index.html), "A self-driving car can generate 1 gigabyte of data per second … More data means more potential money. All sorts of creative business opportunities will arise." and "By collecting data from vehicles, you effectively digitize the public space, unlocking potential safety, security, municipal and commercial benefits,"; S. Somesegar and Daniel Li, "Business models will drive the future of autonomous vehicles" *TechCrunch*, August 25, 2017 (https://techcrunch.com/2017/08/25/business-models-will-drive-the-future-of-autonomous-vehicles/), "The issues of who owns data, who can access data and who will process the data will be a critical question for companies and regulators over the next several years. As vehicles generate and consume more and more data, it will be critical to watch who controls the data and how they decide to monetize the data."; McKinsey & Company, *Monetizing Car Data,* September, 2016 (https://www.mckinsey.com/~/media/McKinsey/Industries/Automotive%20and%20Assembly/Our%20Insights/Monetizing%20car%20data/Monetizing-car-data.ashx) outlining the business opportunity created by the generation of data from autonomous vehicles;

[9] Ralph Nader, *Driverless-car legislation is unsafe at this speed*, The Wall Street Journal, August 23, 2018, https://www.wsj.com/articles/driverless-car-legislation-is-unsafe-at-this-speed-1534973755, "Mr. Thune's bill [AV Start Act (S. 1885)] would eviscerate vehicle regulations by allowing companies to sell potentially limitless numbers of driverless cars that would be exempt from established federal safety standards. This bill would also pre-empt states from exercising their own safety duties."; Noah Seigel, *Will the feds handcuff cities on automated vehicles?*, Public Square: A CNU Journal (Nov. 9, 2017) https://www.cnu.org/publicsquare/2017/11/09/will-feds-handcuff-cities-automated-vehicles, "[AV START] includes an insidious clause that ...preempts states and cities from providing any oversight, public information, or policy direction when AVs hit their streets."

[10] Susan Crawford, Autonomous vehicles might drive cities to financial ruin, Wired, June 20, 2018, https://www.wired.com/story/autonomous-vehicles-might-drive-cities-to-financial-ruin/, "many cities balance their budgets using money brought in by cars: gas taxes, vehicle registration fees, traffic tickets, and billions of dollars in parking revenue [charges that autonomous vehicles can avoid]… [cities are] beginning to look at fees that could be charged [to autonomous vehicles] But many states, urged on by auto manufacturers, won't let cities take these steps."; also Noah Seigel, *Will the feds handcuff cities on automated vehicles?*, Public Square (Nov. 9, 2017) https://www.cnu.org/publicsquare/2017/11/09/will-feds-handcuff-cities-automated-vehicles and Lisa Nisenson & Brad Davis, *Ten steps toward autonomous urbanism*, Public Square (Dec. 11, 2017) https://www.cnu.org/publicsquare/2017/12/11/ten-steps-toward-autonomous-urbanism

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products, they need the flexibility and funding necessary to adapt to market conditions and the authority to act as market makers.[11] In the best of circumstances, federal agencies provide guidance and domain expertise, while states provide a supportive framework for cities to operate in, with a backstop against the expansive possibility of harm. In the most egregious cases, preemption threatens to revoke the rights of the persons who, at the local level, are asked to bear the risk and cost of residing with robots, and to prevent the resolution of conflicts through local levels of government.[12] Preemption debates in technology law have already arisen around the regulation of air carriers,[13] the taxation of e-commerce,[14] net neutrality,[15] sharing

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[11] On the potential for autonomous vehicles to impact local public finance, see: Susan Crawford, Autonomous vehicles might drive cities to financial ruin, Wired, June 20, 2018, https://www.wired.com/story/autonomous-vehicles-might-drive-cities-to-financial-ruin/, and Benjamin Y. Clark, Nico Larco & Roberta F Mann, "The Impacts of Autonomous Vehicles and E-commerce on Local Government Budgeting and Finance" Oregon Next (Aug. 2017) https://cpb-us-east-1-juc1ugur1qwqqqo4.stackpathdns.com/blogs.uoregon.edu/dist/f/13615/files/2017/07/Impacts-of-AV-Ecommerce-on-Local-Govt-Budget-and-Finance-SCI-08-2017-2n8wgfg.pdf; Jan Whittington, Ryan Calo, Mike Simon, and Jesse Woo, Push, Pull, and Spill: A Transdisciplinary Case Study In Municipal Open Government, 30 Berkeley Tech. L.J. 1967 (2015) page 1964,http://btlj.org/data/articles2015/vol30/30_3/1899-1966%20Whittington.pdf, on the standardization of public contracts with private technology firms, "Mid to large-size cities such as Seattle with big information needs and access to considerable resources have the potential to be market-makers, i.e., to drive the market toward best practices".

[12] Noah Seigel, *Will the feds handcuff cities on automated vehicles?*, Public Square: A CNU Journal (Nov. 9, 2017) https://www.cnu.org/publicsquare/2017/11/09/will-feds-handcuff-cities-automated-vehicles, "It is a not a radical idea to allow cities and local governments to lead on transportation policy and technological disruption. Before the advent of the automobile, roads were generally financed by local property taxes. When cars became ubiquitous, state and local governments adopted vehicle registration fees, fuel and weight mile taxes, and parking meters to help pay for and regulate automobiles and their externalities. All of this predated the federal gas tax and the interstate highway system. It is likely that local governments will need to foster a similar kind of innovation to cope with (and pay for) AVs. These are the kinds of conversations about the public (and private) good that are in danger of being preempted by the current version of the AV START bill."; Susan Crawford, Autonomous vehicles might drive cities to financial ruin, Wired, June 20, 2018, https://www.wired.com/story/autonomous-vehicles-might-drive-cities-to-financial-ruin/, "Cities serve as the front lines of every pressing social problem the country is battling: homelessness, illiteracy, inadequate health care, you name it. They don't have any resources to lose. The rise of autonomous vehicles will put struggling sections of cities at a particular disadvantage.";

[13] Noah Seigel, *Will the feds handcuff cities on automated vehicles?*, Public Square: A CNU Journal (Nov. 9, 2017) https://www.cnu.org/publicsquare/2017/11/09/will-feds-handcuff-cities-automated-vehicles

[14] ibid.

[15] Jon Brodkin, FCC will also order states to scrap plans for their own net neutrality laws, Ars Technica (Nov. 21, 2017) https://arstechnica.com/tech-policy/2017/11/fcc-will-also-order-states-to-scrap-plans-for-their-own-net-neutrality-laws/ ; https://www.citylab.com/equity/2018/03/net-neutrality-executive-orders-fcc-mayors-bill-de-blasio/555344/; Noah Seigel, *Will the feds handcuff cities on automated vehicles?*, Public Square: A CNU Journal (Nov. 9, 2017) https://www.cnu.org/publicsquare/2017/11/09/will-feds-handcuff-cities-automated-vehicles, as Siegel explains, preemption clauses in the 1994 FAA Authorization Act were short-sighted in preventing local governments from enacting law or policy that would effect the "price, route, or service" of any air carrier "transporting property by air or by motor vehicle", which was then reinforced in the 1998 Internet Tax Freedom Act, as together, these acts have prevented local governments from taxing the firms that depend on the public provision of local road infrastructure, and thus have disrupted the long-standing ability of cities and states to ask those who benefit to pay for public improvements.

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economy platforms,[16] and municipal broadband,[17] with important consequences. Some proposed federal and state laws and existing state statutes already preempt cities on robotics in ways that could impede local governments' autonomy with regard to the design, management, operation, and finance of public rights-of-way. Laws that preempt cities based on broad or poorly defined definitions of performance could limit local control of the infrastructure that constitutes the operational domain of urban robots, irrespective of the public interest.

The purpose of this article is to provide a framework for public decision-makers to engage effectively with the firms that are bringing artificially intelligent robotics to market in public space. With an institutional economic perspective, this article suggests a means for evidence-based policymaking by breaking down design and its evaluation into constituent sequential components, recognizing the private and social costs of experimentation in cities, and recommending a limited scope for state and federal intervention. Part II begins by defining the characteristics of the current wave of robotics entering public space, placing public-facing robotics within the theory of the nature of technology, and elaborating on the process of product design with algorithmic feedback for machine learning in complex urban environments. Part III explores the opportunities and hazards that await cities as sites of experimentation, and introduces a comparative approach to policy-making to forestall negative social externalities while permitting technological change. Part IV explores the role of cities in the evolving policy environment for data privacy regulation in the face of advanced sensing technologies like robotics that undermine existing legal protections. Part V analyzes laws governing urban robots at the local, state, and federal level, and the impact of preemption on cities' ability to serve as sites of experimentation. It recommends against broad express preemption or field preemption at the state and federal level, particularly the broad language in proposed federal autonomous vehicle legislation. Part VI addresses possible counter arguments. Part VII presents concluding thoughts.

Part II: Urban Robotics and the Quest for Intelligent Design

This part provides an overview of the emerging field of autonomous machines in public space, including a section that situates these products in the evolution of technology, and brings the process of design to the forefront of discussion about the benefits and pitfalls of this new wave of technology for cities and local residents.

A. Robots are Coming to a City Near You

Companies that make robots are sending their products out into the cities of the world. Not to be confused with the spectacular humanoid devices of science fiction, the robots entering our city roadways, sidewalks, parking lots, and airspace include any machine that can sense, process,

[16] Nicole DuPois, City Rights in an Era of Preemption: A State-by-State Analysis 2018 Update, National League of Cities (2018)

[17] Jon Brodkin, States win the right to limit municipal broadband, beating FCC in court, Ars Technica Aug. 8, 2016 https://arstechnica.com/tech-policy/2016/08/in-blow-to-muni-broadband-fcc-loses-bid-to-overturn-state-laws/.

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and act upon the physical world.[18] The robots being deployed, tested, and marketed in urban public rights of way could be said to fall into several broad categories: automated vehicles for transporting persons and cargo, delivery robots, security robots, and entertainment or companion robots.[19]

The automation of vehicles currently allows drivers to turn their attention away from the road for periods of time, but the purpose of this technology is to eventually transform human-driven fleets of vehicles into services provided with self-driving fleets of vehicles. Several tech companies and numerous automobile manufacturers are experimenting with these capabilities.[20] Though most are working on automobiles, recent market entrants and hopefuls include automated buses, automated semi-trucks for cargo delivery, and personal drones for air travel.[21] At the time of this writing, 46 cities in the US reportedly have active pilot programs for automated vehicles, with several more in the planning stage.[22] In 2016, for example, the city of Pittsburgh established a test center and became an early test site for Uber's self-driving taxis.[23] Google's Waymo website identifies 25 US cities in its map of test locations, most of which are in the San Francisco Bay Area of California, or in proximity to its early test site of Chandler, in

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[18] People working in the field are quick to separate artificial general intelligence, such as the development of a sentient being, from today's forms artificial intelligence: "Artificial intelligence is not about building a mind; it's about the improvement of tools to solve problems." Gideon Lewis-Kraus, "The great A.I. awakening" New York Times Magazine, December 14, 2016, https://www.nytimes.com/2016/12/14/magazine/the-great-ai-awakening.html; Ryan Calo, Robotics and the Lessons of Cyberlaw, 103 Calif. L. Rev. 513 (2015), defines robots.

[19] Technologists are also working on robots that can maintain or repair infrastructure such as roads or light posts is underway, but we are not aware of these systems currently in use in any cities. Jane Wakefield, Tomorrow's Cities: Dubai and China roll out urban robots, BBC Jun. 10, 2018 https://www.bbc.com/news/technology-41268996. Cities aside, technologies may be found that increasingly include the characteristics of robots with human operators who monitor and occasionally intervene in large scale infrastructure systems and their development, such as instrumented rail inspection systems, automated trucks and yard cranes for container port operations, and tunnel construction excavating systems. This is similar to the use of robotics in manufacturing, "China's robot workforce" MIT Technology Review, YouTube, April 26, 2016, https://www.youtube.com/watch?v=wUAM-7jbhIw.

[20] Danielle Muoio, Ranked: The 18 companies most likely to get self-driving cars on the road first, Bus. Insider (Sep. 27, 2017).

[21] Adele Peters, "Automated buses are here, now we have to decide how they are going to reshape our cities" Fast Company, July 17, 2017, https://www.fastcompany.com/40444021/automated-buses-are-here-now-we-have-to-decide-how-they-will-reshape-our-cities; Alex Davies, "Self-driving trucks are now delivering refridgerators" Wired, November 13, 2017, https://www.wired.com/story/embark-self-driving-truck-deliveries/; David Katzmaier, "In the future we'll all fly personal drones like this" CNET, September 28, 2017, https://www.cnet.com/news/in-the-future-fly-personal-drones-like-this/.

[22] Bloomberg Philanthropies and The Aspen Institute, "Initiative on cities and autonomous vehicles" Accessed September 7, 2018, https://avsincities.bloomberg.org/. Cities may be granted or denied this authority by the state. At the time of this writing, 22 states have enacted legislation authorizing the operation of autonomous vehicles, and the Governors of another 10 states have signed executive orders for this purpose, ""Autonomous vehicles / self-driving vehicles enacted legislation" National Conference of State Legislatures, August 27, 2018, http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx#Enacted%20Autonomous%20Vehicle%20Legislation.

[23] Cecilija Kang, "No driver? Bring it on. How Pittsburgh became Uber's testing ground" The New York Times, September 10, 2016, https://www.nytimes.com/2016/09/11/technology/no-driver-bring-it-on-how-pittsburgh-became-ubers-testing-ground.html.

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Arizona.[24] Other noteworthy cities with automated vehicle pilot programs include Denver, Boston, Detroit, Las Vegas, Reno, San Antonio, Tampa, and Washington, DC.[25] Testing in cities should be distinguished from test centers, as the former refers to partial or complete spatial access to the city while the latter refers to sites designed for testing purposes with limited public access.[26] With or without test sites, the number of participating cities is growing rapidly. It is still important to note, however, that these programs are in flux. The dedication of an area for testing does not necessarily imply permanence for the technologies or the firms; following the recent death of a pedestrian in Chandler Arizona, Uber suspended testing and operations of automated vehicles in all locations.[27]

Delivery robots are intended to complete last mile logistics -- the most complex and expensive portion of the shipping system -- where products move to and from distribution centers and homes or offices.[28] The wide variation in the characteristics of these devices has them destined for all manner of public spaces, including sidewalks, roadways, parking spaces, and airspace. For example, Starship Technologies' short, electric, six-wheeled robots operate autonomously to deliver items up to 40 pounds in weight within a 2-mile radius, with the possibility of intervention by remote operators.[29] They have partnered with firms to offer delivery services in Redwood City, California and Washington, DC.[30] Robots from Marble, Dispatch, Robby, Eliport, and Kiwi, strike a similar profile and occupy a similar market niche.[31] Robots like these operate

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[24] Waymo, "On the road", Accessed September 7, 2018, https://waymo.com/ontheroad/. Note that state governments are playing roles as well: State of California Department of Motor Vehicles "Driverless testing and public use rules for autonomous vehicles approved" February 26, 2018, https://www.dmv.ca.gov/portal/dmv/detail/pubs/newsrel/2018/2018_17; See i.e.,National Conference of State Legislatures "Autonomous vehicles state bill tracking database" Accessed August 21, 2018, http://www.ncsl.org/research/transportation/autonomous-vehicles-legislative-database.aspx.

[25] Bloomberg Philanthropies and The Aspen Institute, "Initiative on cities and autonomous vehicles" Accessed March 4, 2018, https://avsincities.bloomberg.org/.

[26] For examples of test sites, "U.S. Department of Transportation Designates 10 Automated Vehicle Proving Grounds to Encourage Testing of New Technologies" US Department of Transportation, Transportation.gov, January 19, 2017, https://www.transportation.gov/briefing-room/dot1717.

[27] Ian Wren, Uber Suspends Self-Driving Tests After Pedestrian is Killed in Arizona, Mar. 19, 2018, https://www.npr.org/sections/thetwo-way/2018/03/19/594950197/uber-suspends-self-driving-tests-after-pedestrian-is-killed-in-arizona?sc=tw.

[28] Elle Hunt, "'It's like a robot playground': the cities welcoming self-driving delivery droids" The Guardian, May 1, 2018, https://www.theguardian.com/cities/2018/may/01/what-the-hell-is-that-self-driving-delivery-robots-hit-london; Lora Kolodny, Postmates and DoorDash are testing delivery by robot with Starship Technologies, TechCrunch (Jan. 18, 2017); Erica E. Phillips, *When Robots Take to City Sidewalks*, Wall Street Journal (Apr. 12, 2017) https://www.wsj.com/articles/when-robots-take-to-city-sidewalks-1491970141.

[29] Elle Hunt, "'It's like a robot playground': the cities welcoming self-driving delivery droids" The Guardian, May 1, 2018, https://www.theguardian.com/cities/2018/may/01/what-the-hell-is-that-self-driving-delivery-robots-hit-london; Lora Kolodny, "Postmates and DoorDash are testing delivery by robot with Starship Technologies" TechCrunch, January 18, 2017, https://techcrunch.com/2017/01/18/postmates-and-doordash-are-testing-delivery-by-robot-with-starship-technologies/.

[30] Lora Kolodny, "Postmates and DoorDash are testing delivery by robot with Starship Technologies" TechCrunch, January 18, 2017, https://techcrunch.com/2017/01/18/postmates-and-doordash-are-testing-delivery-by-robot-with-starship-technologies/.

[31] "8 delivery robot startups for last mile delivery" Nanalyze, April 27, 2018, https://www.nanalyze.com/2018/04/8-delivery-robot-startups-last-mile-delivery/; Marble's delivery robot

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under a patchwork of legal rules, sometimes requiring a permit, but sometimes enabled to operate without, either because of a lack of regulation or permissive state laws. Starship representatives have suggested that relaxed rules allow their use in Virginia, Florida, Wisconsin, and Idaho, as well as Washington, DC.[32] There are also firms competing in this space with larger vehicles, which may be subject to many of the same regulations as autonomous vehicles for passengers. Nuro's delivery vehicles are about half of the size of an automobile, suggesting larger payloads, travel on roadways, and the need to occupy a parking space while loading, unloading, or perhaps charging up.[33] Reports suggest that Teletretail's prototype, similar in size, can operate within a 50 mile radius.[34] Udelv, whose vehicles may include a driver, recently announced a plan to begin operation in Oklahoma City.[35] Notably, automakers envision a role for themselves in this market.[36] Ford has announced that it will test its full-sized automated vehicles for package delivery services, and Toyota has unveiled a prototype.[37] In addition, at least two firms offer delivery services via aerial drones: Flirtey and Matternet.[38] Flirtey garnered attention in 2016, with its first delivery sanctioned by the Federal Aviation Administration of a

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rolls through SF, TechCrunch, (Apr. 12, 2017) https://www.youtube.com/watch?v=pNpH4G-hoIY; Brian Heater, "Kiwi's robots deliver food to hungry Berkeley students" TechCrunch, May 26, 2018, https://techcrunch.com/video/kiwis-robots-deliver-food-to-hungry-berkeley-students/; "Eliport: Delivering an Autonomous Future" Start Engine, 2017, https://www.startengine.com/eliport. In addition, there are models from Savioke and Aetheon, that are being marketed for use indoors, in hotels and hospitals, respectively. Paul Miller, "The Relay hotel delivery robot will soon spot Wi-Fi dead zones and mingle with guests" The Verge, January 11, 2018, https://www.theverge.com/2018/1/11/16879432/savioke-relay-hotel-delivery-robot-wi-fi-dead-zones-mingle-ces-2018; "Welcome to the one-of-a-kind world of TUG" Aetheon, 2018, https://aethon.com/.

[32] Javier Espinosa, "Delivery robots hit the streets, but some cities opt out" The Financial Times, January 30, 2018, https://www.ft.com/content/0a2a5a76-e0ea-11e7-a0d4-0944c5f49e46.

[33] Alan Ohnsman, "Ex-Google Engineers Raise $92 Million To Roll Out Robot Delivery Vehicles This Year" Forbes, January 30, 2018, https://www.forbes.com/sites/alanohnsman/2018/01/30/ex-google-engineers-raise-92-million-to-deploy-robot-delivery-vehicles-this-year/#3c7c739875d1.

[34] Lara Kolodny "Teleretail built a delivery robot to make on-demand delivery easy for small businesses" TechCrunch, May 15, 2017, https://techcrunch.com/2017/05/15/teleretail-built-a-delivery-robot-to-make-on-demand-logistics-easy-for-small-businesses/;

[35] David Dishman, "Autonomous vehicles to bring groceries to Oklahoma City residents" Transport Topics, September 14, 2018, https://www.ttnews.com/articles/autonomous-vehicles-bring-groceries-oklahoma-city-residents;

[36] Daimler has invested in both Starship Technologies and Matternet, and Ford's recent agreement suggest the interest of automakers in automated delivery services. CB Insights, "Automating The Last Mile: Startups Chasing Robot Delivery By Land And Air" Research Briefs, March 30, 2017, https://www.cbinsights.com/research/autonomous-drone-delivery-startups/; Laura Bliss, Self-Driving Pizza Just Hit Miami, CityLab Feb. 27, 2018 https://www.citylab.com/transportation/2018/02/self-driving-pizza-just-hit-miami/554138/; Elle Hunt, "'It's like a robot playground': the cities welcoming self-driving delivery droids" The Guardian, May 1, 2018, https://www.theguardian.com/cities/2018/may/01/what-the-hell-is-that-self-driving-delivery-robots-hit-london.

[37] Laura Bliss, Self-Driving Pizza Just Hit Miami, CityLab Feb. 27, 2018 https://www.citylab.com/transportation/2018/02/self-driving-pizza-just-hit-miami/554138/. Margi Murphy, " CES 2018: Driverless Pizza Hut delivery van draws Black Mirror comparisons" The Telegraph, January 9, 2018, https://www.telegraph.co.uk/technology/2018/01/09/ces-2018-driverless-pizza-hut-delivery-van-draws-black-mirror/.

[38] CB Insights, "Automating The Last Mile: Startups Chasing Robot Delivery By Land And Air" Research Briefs, March 30, 2017, https://www.cbinsights.com/research/autonomous-drone-delivery-startups/.

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product from a 7-Eleven to a home via drone.[39] Amazon Prime Air delivery by drone has been undergoing tests in the UK, but not in the US.[40] Reports suggest that Boeing is also entering the market, with a drone for payloads of up to 500 pounds.[41]

Security robots, which could be said to operate like mobile closed circuit television with the capacity to automatically call authorities, are intended to reduce the need for human security guards.[42] Although such products are privately owned and operated, some scholars have conceptualized them as a form of automated law enforcement.[43] For the most part, security robots have been deployed without ex ante permission from cities.[44] The company most prevalent in searches for security robots is called Knightscope, although there are others.[45] Robots from Knightscope can be programmed to patrol a predefined area, and are currently being used or contemplated for use in parking lots, residential neighborhoods, and quasi-public areas such as corporate campuses, shopping malls, museums, and airports.[46] The K5 units for outdoor use weigh over 300 pounds, are over five feet tall, and come with an electrical pad for charging.[47] They are outfitted for 360 degree video recording, storage, and streaming, including

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[39] CB Insights, "Automating The Last Mile: Startups Chasing Robot Delivery By Land And Air" Research Briefs, March 30, 2017, https://www.cbinsights.com/research/autonomous-drone-delivery-startups/.

[40] Kyle Bailey, "Amazon Prime Air delivery by drone has been undergoing tests in the UK, but not in the US." Observer, November 20, 2017, https://observer.com/2017/11/amazon-prime-air-drone-delivery-service-might-never-happen-in-united-statesr/; Jeff Desjardins, "Amazon and UPS are betting big on drone delivery" Business Insider, March 11, 2018, https://www.businessinsider.com/amazon-and-ups-are-betting-big-on-drone-delivery-2018-3.

[41] Stephen Trimble, "Unmanned cargo lifter deepens Boeing's push on autonomy", FlightGlobal, January 10, 2018, https://www.flightglobal.com/news/articles/unmanned-cargo-lifter-deepens-boeings-push-on-auton-444788/.

[42] "Knightscope wants to keep humans in the loop with its robots, but it's not hard to imagine a day when someone else gets the bright idea to give other security machines a lot more autonomy" Matt Simon, "The tricky ethics of Knightscope's crime-fighting robots" Wired, December 21, 2017, https://www.wired.com/story/the-tricky-ethics-of-knightscopes-crime-fighting-robots/; "Already, Knightscope robots are edging into the private security industry, patrolling parking lots, a shopping center and corporate campuses in California." Shan Li, Robots are becoming security guards. 'Once it gets arms...it'll replace all of us', Los Angeles Times Sep. 2, 2016 http://www.latimes.com/business/la-fi-robots-retail-20160823-snap-story.html; Knightscope, "K5" 2018, https://www.knightscope.com/knightscope-k5/, Accessed March 4, 2018, "If a marked law enforcement vehicle were placed in front of your facility, criminal behavior would dramatically change. ADMs [autonomous data machines] have the same impact."

[43] Hartzog et al., *Inefficiently Automated Law Enforcement*, 2015 Mich. St. L. Rev. 1763 (2015). See Elizabeth Joh, Private Security Robots, Artificial Intelligence, and Deadly Force, 51 UC Davis L. Rev. 569 (2017) https://lawreview.law.ucdavis.edu/issues/51/2/Symposium/51-2_Joh.pdf

[44] Michael Hamiliton, Cities Should Not Design for Autonomous Vehicles, Market Urbanism, Nov. 13, 2017 http://marketurbanism.com/2017/11/13/cities-should-not-design-for-autonomous-vehicles/. But see SF's ban on Knightscope robot.

[45] Robbie Gonzalez, I Spent the Night With Yelp's Robot Security Guard, Cobalt, Wired (Aug. 4, 2017). https://www.wired.com/story/i-spent-the-night-with-yelps-robot-security-guard-cobalt/

[46] Shan Li, Robots are becoming security guards. 'Once it gets arms...it'll replace all of us', Los Angeles Times Sep. 2, 2016 http://www.latimes.com/business/la-fi-robots-retail-20160823-snap-story.html; Tim Johnson, Coming soon: Security roots that patrol streets -- or guard your home, McClatchy Oct. 30, 2017 http://www.mcclatchydc.com/news/nation-world/national/article181343981.html.

[47] Tim Johnson, Coming soon: Security roots that patrol streets -- or guard your home, McClatchy Oct. 30, 2017 http://www.mcclatchydc.com/news/nation-world/national/article181343981.html.

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thermal imaging, reading license plates, tracking parked cars, playing pre-recorded messages, and a two-way intercom between a remote operator and people who encounter the device.[48] Also known as "automated data machines," the devices stream data to the company's "security operations center," and the firm advertises the ability to stream the same to recipients' online web portals.[49] A report in October, 2017, noted that the firm had already deployed 47 of these devices for clients in 10 states, including venues in Boston, Atlanta, Dallas, Sacramento, Washington DC, and Tampa.[50] Security in markets for technology can take many forms, however. In a curious twist, Boston Dynamics suggests that security is an appropriate use for their doglike robot, SpotMini.[51] Drones are also in use in numerous police departments, though the extent to which police use automated devices as opposed to remote control is not clear.[52] The world's largest drone manufacturer and the largest police body-camera manufacturer recently partnered to sell drones to police departments, and critics fear that this partnership will put drones with powerful artificial intelligence capabilities, such as facial recognition, in the hands of police with little oversight.[53]

Entertainment or companion robots represent another wave of autonomous devices entering urban space.[54] For entertainment, synchronized drones, for example, are in use by Disney, and were featured in the opening and closing ceremonies of the 2018 Winter Olympics.[55] The film

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[48] Shan Li, Robots are becoming security guards. 'Once it gets arms...it'll replace all of us', Los Angeles Times Sep. 2, 2016 http://www.latimes.com/business/la-fi-robots-retail-20160823-snap-story.html

[49] Knightscope, https://www.youtube.com/watch?v=UtuLB2duq2E

[50] Tim Johnson, Can Robots Replace Human Security Guards?, Gov Tech. Oct. 31, 2017 http://www.govtech.com/public-safety/can-robots-replace-human-security-guards.html; Tim Johnson, Coming soon: Security roots that patrol streets -- or guard your home, McClatchy Oct. 30, 2017 http://www.mcclatchydc.com/news/nation-world/national/article181343981.html

[51] Holley, Peter, "This company is building a massive pack of robot dogs for purchase in 2019" Washington Post, July 24, 2018. https://www.washingtonpost.com/technology/2018/07/24/this-company-is-building-massive-pack-robot-dogs-purchase-starting/?utm_campaign=d3930868f3-UW_Today_Thursday_July_26_2018&utm_medium=email&utm_source=UW%20News%20Subscribers&utm_term=.52cf5207b7b8

[52] Citing Bureau of Justice Statistics, a report from the National Institute of Justice in 2016 suggested that "350 law enforcement agencies in the U.S. had aviation programs in active use" https://www.nij.gov/topics/law-enforcement/operations/aviation/Pages/harnass-benefits-of-unmanned-aircraft-systems.aspx

[53] Dave Gershgorn, This is the week that the drone surveillance state became real, Jun. 8, 2018 https://qz.com/1299947/this-is-the-week-that-the-drone-surveillance-state-became-real/; The recent case of IBM's undisclosed use of data from the New York Police Department's closed circuit television systems reads like a precursor for the proprietizatioin of surveillance data from security robots, including drones, James Vincent, "IBM secretly used New York's CCTV cameras to train its surveillance software" The Verge, September 8, 2018, https://www.theverge.com/2018/9/6/17826446/ibm-video-surveillance-nypd-cctv-cameras-search-skin-tone.

[54] William Grimes "Drones kill, yes, but they also rescue, research and entertain" New York Times, May 11, 2017, https://www.nytimes.com/2017/05/11/arts/design/drones-kill-yes-but-they-also-rescue-research-and-entertain.html

[55] "The Making of Walt Disney World's First Drones Show | Disney Springs" Disney Parks, YouTube, December 1, 2016, https://www.youtube.com/watch?v=dHHMrvaXgyA; Ron Dicker, "The Olympics Opening Ceremony Drone Show Is Just So Damn Impressive" Huffington Post, February 9, 2018, https://www.huffingtonpost.com/entry/opening-ceremony-drone-show-is-just-so-damn-impressive_us_5a7db877e4b08dfc930363ae

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industry is using drones to replace expensive rigging with aerial cinematography.[56] And, perhaps more importantly for public space, anyone can now purchase an aerial drone that follows and video records any specified person, animal, or moving object, wherever it goes, for an elaborate form of "selfie".[57] Though they appear to be no different from remote controlled commercial drones, these devices may be set to automatically track a signal or follow an individual, and may also be equipped with the software necessary to detect and avoid other objects.[58] The same "follow me" features are also emerging in devices on roadways and sidewalks. At the 2018 Consumer Electronics Show, the Segway company unveiled Loomo, which is marketed as a robot that can follow its user, take pictures, and display simple social computing characteristics (smiley faces).[59] It is a hoverboard that users can ride or load with up to 200 kilograms of packages, capable of traveling up to 11 miles per hour and a range of 22 miles on a single charge, with sensors and software that includes voice command and facial recognition.[60] Segway promises that Loomo will be on the streets in 2018.[61] Similarly, the company responsible for Vespa Scooters is working on Gita, a small cargo "droid" designed to free the user's hands as they traverse dense urban environments.[62] Another company recently unveiled a robotic suitcase.[63] While not strictly meant as entertainment (although one writer described Gita as "more like having a pet than an artificial intelligence"), these machines are designed to delight users while contributing to leisure experiences.[64]

B. Urban Robots and the Evolution of Technology

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[56] Richard Verrier, "Drones are providing film and TV viewers a new perspective on the action" Los Angeles Times, October 8, 2015, http://www.latimes.com/entertainment/envelope/cotown/la-et-ct-drones-hollywood-20151008-story.html

[57] Antonio Villas-Boas and Rachel Sandler, "This $2,500 'self-flying camera' can follow you around and snap photos without anyone controlling it — here's how it works" Business Insider, February 15, 2018; Fintan Corrigan, "12 best follow me drones and follow you technology reviewed" Dronzon, February 16, 2018, https://www.dronezon.com/drone-reviews/best-follow-me-gps-mode-drone-technology-reviewed/

[58] Fintan Corrigan, "12 best follow me drones and follow you technology reviewed" Dronzon, February 16, 2018, https://www.dronezon.com/drone-reviews/best-follow-me-gps-mode-drone-technology-reviewed/, "It is good to remember that the vast majority of Follow Me mode drones do not have object avoidance".

[59] Paul Miller, Taking a ride on Segway's Loomo robot, The Verge (Jan. 11, 2018) https://www.theverge.com/2018/1/11/16874220/segway-loomo-robot-hands-on-ces-2018.

[60] Andrew Tarantola, "Segway's Loomo is the robotic hoverboard nobody asked for" Engadget, March 6, 2018, https://www.engadget.com/2018/03/06/segways-loomo-robotic-hoverboard-hands-on/

[61] IndieGoGo, Loomo: MiniTransporter Meets Robot Sidekick (last visited Aug. 28, 2018) https://www.indiegogo.com/projects/loomo-mini-transporter-meets-robot-sidekick-mobile?gclid=Cj0KCQjw1q3VBRCFARIsAPHJXrH8cDkDj3X-2WZ08UUh6heo3V5X542nzwuo0N7Cs23ouXreJ6LOaulaArpVEALw_wcB#/

[62] Ian Bogost, *The Cute Robot That Follows You Around the City*, The Atlantic, Feb 28, 2018, https://www.theatlantic.com/technology/archive/2018/02/piaggio-gita-jeffrey-schnapp/554222/

[63] Dean Takahashi, *Travelmate Robotics' robot suitcase will follow you to CES 2018*, Venture Beat, Jan. 3, 2018, https://venturebeat.com/2018/01/03/travelmate-robotics-robot-suitcase-will-follow-you-to-ces-2018/

[64] Ian Bogost, *The Cute Robot That Follows You Around the City*, The Atlantic, Feb 28, 2018, https://www.theatlantic.com/technology/archive/2018/02/piaggio-gita-jeffrey-schnapp/554222/. Entertainment robots like Gita or the robotic suitcase could conceivably constitute a separate "personal service robot" category, but until such use cases actually develop we will use the current classification scheme.

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To understand the magnitude and endurance of urban robotics, it may be helpful to place these products within the evolutionary theory of technology.[65]

According to theory, technologies are designed to apply scientific knowledge for a purpose, they are in and of themselves assemblies of technologies, and their evolution occurs through the recombination of newly incorporated phenomena with existing components.[66] Technology is commonly developed to augment the forces of nature and, as it relies on basic science about how the world works, modern technology is understood to advance along with discoveries in basic science.[67] As products, however, technologies are recursive, in that they are made of assemblies of components which are themselves technologies, each harnessing scientific knowledge about physical effects and other natural phenomena.[68] Given that all technologies rely on the understanding and application of natural or physical effects, the combinatorial evolution of technology accelerates when a new family of phenomena are discovered and incorporated into components for further recombination.[69]

Urban robotics combine the newfound capacity for autonomous controls, brought about by machine learning and artificial intelligence, with a multitude of existing sensor, robotic, compute, communication, energy, and transportation technologies.[70] Given that machines can now be programmed to use algorithms that process richly expansive data collected from the environment and, flipping the process, modify or develop new algorithms based on feedback from the environment, people can and should expect products to come to market that attempt to

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[65] W. Brian Arthur, *The Nature of Technology: What it is and How it Evolves*, New York: Free Press, 2009, presents a theory of evolution for technology, a theory constructed from a "coherent group of general propositions" that can be used to "explain technology's behavior" (page 23).

[66] W. Brian Arthur, p.23, building an argument about the essence and evolution of technology from "three fundamental principles," first that "all technologies are combinations… constructed or put together--combined--from components or assemblies or subsystems at hand," second, that "each component of technology is itself in miniature a technology," and third, that "all technologies harness and exploit some effect of phenomenon, usually several".

[67] W. Brian Arthur, p.46 "A technology is always based on some phenomenon or truism in nature that can be exploited and used to a purpose." p.60 "Science is necessary for the unearthing of modern phenomena, the more deeply hidden clusters of effects, and for forming technologies from these", and p.59, distinguishing natural phenomena from technology, "Not every phenomenon of course is harnessable for use, but when a family of phenomena is uncovered, a train of technologies follows."

[68] W. Brian Arthur, p. 39 "any technology...consists of component building blocks that are also technologies, and these consist of subparts that are also technologies, in a repeating (or recurring) pattern" combined for a human purpose, p.43 "Combination must work not just by bringing a purpose with a concept or principle that matches it. It must provide a main set of assemblies or modules to execute this central idea. It must support this with further assemblies, and these again with further assemblies to support these. And all these parts and assemblies must be orchestrated to perform together harmoniously."

[69] W. Brian Arthur, see above, cite from page 59, and p. 172 commenting on William Ogburn's suggestion that the growth of technologies resembles a "compound interest curve, growing "exponentially", Arthur says, "as the number of technologies increases, the possibilities for combination also increase." p. 174 "if new technologies lead to further new technologies, then once the numbers of elements in the collective pass through some threshold, the possibilities of combination begin to explode."

[70] Ryan Calo, Robotics and the Lessons of Cyberlaw, 103 Calif. L. Rev. 513 (2015), defines robots. Nagenborg, M. Ethics Inf Technol (2018). https://doi.org/10.1007/s10676-018-9446-8, defines "urban robots" as a term by which to address robots as urban technologies.

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navigate the physical environment autonomously.[71] In the language of the evolutionary theory of technology, nascent human scientific understanding of how the brain works is accelerating evolution by providing the opportunity to combine a whole new family of artificially intelligent controls with existing technologies.

With this perspective, today's autonomous urban robotics and vehicles can be understood to represent the beginning of a long arc of technological exploration, development, and proliferation, which may stretch at least as long as one can imagine it will take to learn about intelligence.[72] If markets and institutions permit, people should be able to see the development and emergence of more intelligent designs over time, each competing for survival. At the moment, entrepreneurship is giving rise to a diversity of devices; the presumed standard sizes and uses for vehicles, robotics, and drones, are being blurred as devices appear to fill in gaps in continua of size, shape, and purpose. As technology progresses, new applications should open up and individual robotics platforms should be able to operate in multiple task domains. In other words, the technology will converge, as devices are created to serve multiple or perhaps open-ended purposes across the variety of public and private spaces.[73] This convergence could lead to the creation of open robotics platforms, which could drive further innovation.[74]

The evolution of technology is an endogenous source of economic development, evidenced as new products emerge and flourish in urban markets.[75] In economics, the notion that technology

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[71] Machine learning algorithms allow computers to recognize patterns and make connections that are not pre-program, but instead "learned" based on associations in large data sets. As such, they require large amounts of data to be effective. Will Knight, "The dark secret at the heart of AI" MIT Technology Review, April 11, 2017, https://www.technologyreview.com/s/604087/the-dark-secret-at-the-heart-of-ai/, "From the outset, there were two schools of thought regarding how understandable, or explainable, AI ought to be. Many thought it made the most sense to build machines that reasoned according to rules and logic, making their inner workings transparent to anyone who cared to examine some code. Others felt that intelligence would more easily emerge if machines took inspiration from biology, and learned by observing and experiencing. This meant turning computer programming on its head. Instead of a programmer writing the commands to solve a problem, the program generates its own algorithm based on example data and a desired output. The machine-learning techniques that would later evolve into today's most powerful AI systems followed the latter path: the machine essentially programs itself." A noted early example,, A. L. Samuel, "Some Studies in Machine Learning Using the Game of Checkers," in IBM Journal of Research and Development, vol. 3, no. 3, pp. 210-229, July 1959. doi: 10.1147/rd.33.0210, http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5392560&isnumber=5392559.

[72] E.g., M. Mitchell Waldrop, "Inside the moonshot effort to finally figure out the brain" MIT Technology Review, October 12, 2017, https://www.technologyreview.com/s/609070/inside-the-moonshot-effort-to-finally-figure-out-the-brain/.

[73] *See* Siddhartha Menon, Policy Initiative Dilemmas Surrounding Media Convergence: A Cross National Perspective, 24 Prometheus: Critical Studies in Innovation 59 (2007). Loomo is an example of a robotics platforms where multiple capabilities converge in a single platform.

[74] Ryan Calo, Open Robotics, Maryland L. Rev. 101 (2011) https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1706293.

[75] Joseph Schumpeter, *The Theory of Economic Development*, 1912, Reprint, Harvard University Press, Cambridge, MA, 1934; Quoting Schumpeter, W. Brian Arthur p.19 explains, "Schumpeter was asking whether an economy could change itself without external factors -- purely from within -- and if so how" and p.20 "realized that there was 'a source of energy within the economic system which would of itself

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contributes to growth dates back to Adam Smith, with the idea that trade in surplus products may be reinvested in technology and shift the division of labor to result in more surplus for trade, in a virtuous cycle of economic growth.[76] Technology is appealing to city officials because of the promise of economic growth that it may bring. The function of economic development for local government is practically synonymous with attracting businesses with new or established technologies to develop or relocate facilities in the government's jurisdiction. Competitions to attract tech firms demonstrate that cities and states will gamble with significant amounts of tax dollars in the hope that jobs and technological advancement will expand opportunities for local residents.[77]

Artificial intelligence assigns, however, a new purpose to technology, because it allows technology to replace as well as augment the forces of nature.[78] While technological change is a source of endogenous economic development, it brings with it the force in economic theory characterized as creative destruction, in which new products disrupt existing markets.[79] When technology attempts to replicate the functions of the brain, as in the autonomous control of an automobile, mobile robot, or drone, this technology can be designed for the purpose of replacing

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disrupt any [economic market] equilibrium that might be attained.'...The economy continually created the new by combining the old, and in doing so it disrupted itself constantly from within."

[76] Adam Smith, AN INQUIRY INTO THE NATURE AND CAUSES OF THE WEALTH OF NATIONS (Edwin Cannan ed., The Modern Library 1937) (1776), p.11, "It is the great multiplication of the productions of all the different arts, in consequence of the division of labor, which occasions, in a well-governed society, that universal opulence which extends itself to the lowest ranks of the people. Every workman has a great quantity of his own work to dispose of beyond what he himself has occasion for; and every other workman being exactly in the same situation, he is enabled to exchange a great quantity of his own goods for a great quantity, or, what comes to the same thing, for the price of a great quantity of theirs." and with regard to the role of technology p.7, "The great increase of the quantity of work, which, in consequence of the division of labour, the same number of people are capable of performing, is owing to three different circumstances", one of which is "the invention of a great number of machines which facilitate and abridge labour, and enable one man to do the work of many."

[77] Cecilia Kang, "No driver? Bring it on. How Pittsburgh became Uber's testing ground" The New York Times, September 10, 2016, https://www.nytimes.com/2016/09/11/technology/no-driver-bring-it-on-how-pittsburgh-became-ubers-testing-ground.html; Cecilia Kang, "Pittsburgh welcomed Uber's driverless car experiment. Not anymore" The New York Times, May 21, 2017, https://www.nytimes.com/2017/05/21/technology/pittsburgh-ubers-driverless-car-experiment.html.

[78] W. Brian Arthur, p.215 "If we merely used nature's phenomena in raw form, to power water wheels or propel sailing ships, we would feel more at home with technology,... But now, with the coming of genetic engineering, machine intelligence, bionics, climate engineering, we are beginning to use technology--use nature--to intervene directly within nature."

[79] Joseph Schumpeter, *Capitalism, Socialism and Democracy*, George Allen and Unwin, Ltd, London, England, 1943, Eighth impression, 1959, p. 82 "The opening up of new markets, foreign or domestic, and the organizational development from the craft shop and factory to such concerns as U.S. Steel illustrate the same process of industrial mutation -- if I may use that biological term -- that incessantly revolutionizes the economic structure *from within*, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism. It is what capitalism consists in and what every capitalist concern has got to live in." (italics in original)…p. 82-83 "Every piece of business strategy acquires its true significance only against the background of that process and within the situation created by it. It must be seen in its role in the perennial gale of creative destruction; it cannot be understood irrespective of it"

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people.[80] Thus the creation of new technology can result in the development of new markets, but also the destruction of existing ones, disrupting current pathways for the creation of wealth in the economy. As the scale of autonomous technology expands, as it is likely to do, such disruptions have the potential to change the structure of the economy for whole industries.

Borrowing from Darwin's theory of evolution by natural selection, technologies may be said to compete for survival, but there are limits to this analogy.[81] What theories of natural and technological evolution share is attention to design over time. Their differences, curiously, are based on whether one can credibly say that evolution is due to intelligent design. Evolution in nature occurs by the process of natural selection, in which design consists of the traits of individuals, passed down to or emergent in offspring, as may happen over time within the resources and constraints of the environment.[82] Though people have advocated for a theory of evolution that attributes the origin and abundance of variety in nature to design by an intelligent being, this concept is not applicable to the natural world.[83] Natural selection is a process which begets design, but has no designer.[84] It has resulted in intelligence, but it is not intelligent.

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[80] M. Mitchell Waldrop, "Inside the Moonshot Effort to Finally Figure Out the Brain", MIT Technology Review, October 12, 2017, "AI is only loosely modeled on the brain. So what if you wanted to do it right? You'd need to do what has been impossible until now: map what actually happens in neurons and nerve fibers." https://www.technologyreview.com/s/609070/inside-the-moonshot-effort-to-finally-figure-out-the-brain/

[81] W. Brian Arthur, p.103 "The process of problem solving in engineering brings forth novel solutions--novel combinations--in an abrupt way that does not match Darwin's slow cumulation of changes. Then from these, the better ones are selected, and then propagate through engineering practice, a la Darwin… [this] does not mean that in technology the best--or fittest--solutions always survive…[by] [s]mall chance events" technologies gain prevalence and "technologies (or solutions) that gain prevalence tend to gain further advantage and to lock in, so there is a positive feedback process at work in the 'selection' of technologies."

[82] Charles Darwin, *On The Origin of Species*, LONDON: JOHN MURRAY, ALBEMARLE STREET, 1859, In summary (quote from chapter 14), "this whole volume is one long argument…[advancing] the theory of descent with modification through natural selection", and defining natural selection, (quote from chapter 4) "if variations useful to any organic being do occur, assuredly individuals thus characterised will have the best chance of being preserved in the struggle for life; and from the strong principle of inheritance they will tend to produce offspring similarly characterised. This principle of preservation, I have called, for the sake of brevity, Natural Selection".

[83] Daniel Dennett, *Darwin's Dangerous Idea*, Touchstone, Simon & Schuster, New York, NY: 1995. P. 75-76 "For over a century, skeptics have been trying to find a proof that Darwin's idea just can't work, at least not *all the way*. They have been hoping for, hunting for, praying for ...a 'mind first' force or power or process, an exception to the principle that al design, and apparent design, is ultimately the result of a mindless, motiveless mechanicity." p. 46 "[A]lthough Darwin depended on his idea of the mechanism of natural selection to inspire and guide his research on evolution, the end result reversed the order of dependence: he showed so convincingly that species had to have evolved that he could then turn around and use this fact to support his more radical idea, natural selection."; for a current account of empirical evidence of evolution by natural selection, Jonathan Weiner, *The Beak of the Finch: A Story of Evolution in our Time*, Alfred A. Knopf, New York, NY, 1994.

[84] Darwin; Daniel Dennett, p. 59 "Darwin's dangerous idea: the algorithmic level *is* the level that best accounts for the speed of the antelope, the wing of the eagle, the shape of the orchid, the diversity of species, and all the other occasions for wonder in the world of nature… Can [the actual biosphere] be the outcome of nothing but a cascade of algorithmic processes feeding on chance? And if so, who designed that cascade? Nobody. It is itself the product of a blind, algorithmic process." p. 65 Characterizing evolution by natural selection as an algorithm, "Darwin suggests...Give me Order, he says, and time, and

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Intelligent design is, however, a useful concept for understanding the theory of the evolution of technology.[85] Technology requires designers, and intelligent design, while in the eye of the beholder, is a description that becomes apt as a product competes in an economic market and survives.

C. The Intelligent Design of Urban Robotics

The following paragraphs provide an overview of the factors that lead firms to seek out testbeds within cities and the basic stages of design. If cities are to be urban testbeds for robots, city officials and their residents should become familiar with the process of design because, whether they realize it or not, they are participating in it.

The design of an autonomous system is a complex process, and one that cannot be optimized in the abstract. Designing an autonomous system requires an understanding of the task for the device and the environment in which it must reside. Design is a process of making trade-offs: between mobility, sensing, intelligence, cost, and much more. A roboticist must first understand the design specifications and parameters in which the system will operate. Further, robots operate within an ecology; a complex system where changes to one part may impact the whole in unintended ways.

Cities are not the easiest of environments for roboticists to contemplate in design. The simplest environments for robots are factory floors, which are typically engineered in ways that reduce the scope of the task the robot must undertake. The most complex environment for an autonomous system to operate in is the natural environment, which is characterized by uncertainty and lack of structure. The urban environment falls somewhere in between, where considerable structure has been put in place already for humans to navigate. Urban roadways in the US are already highly engineered for human use, with design standards for pavement, curb cuts, sidewalks, crosswalks, auto lanes, parking, bike lanes, street signs, and so on, which have either shaped or been shaped by existing cultural conventions of behavior in public space, such as passing on the right or the left, and signaling a turn.[86] To follow in the path already established by existing modes of transport in public rights-of-way is a fairly obvious economical approach to urban robotic design.

I will give you Design. Let me start with regularity--the mere purposeless, mindless, pointless regularity of physics--and I will show you a process that eventually will yield products that exhibit not just regularity but purposive design"

[85] W. Brian Arthur, p. 129, considering the role of the designer in answering "the key question [in evolution] of how novel technologies arise,...The mechanism is certainly not Darwinian; novel species do not arise from the accumulation of small changes. They arise from a process, a human and often lengthy one, of linking a need with a principle (some generic use of an effect) that will satisfy it." p. 132 "developers borrow freely from that many available solutions and select some for their designs. This is where Darwinian variation and selection really come in, in technology. The many versions of a technology improve in small steps by the selection of better solutions to their internal design problems.", p. 188 "In technology, combinatorial evolution is foremost, and routine. Darwinian variation and selection are by no means absent, but they follow behind, working on structures already formed."

[86] See standards published for transportation design by the American Association of State Highway and Transportation Officials, "AASHTO", https://www.transportation.org/, accessed September 18, 2018.

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The notion of robots operating in an ecology manifests in an inverse relationship between the intelligence of the robot and investments made in the environment to assist the robot in carrying out its intended tasks. As autonomous systems perceive the world quite differently than humans do, forcing robots to rely entirely on cues that are embedded in the environment for people makes the task for the designer more difficult. Cities simplify the design process when they create controlled spaces or stable task environments where autonomous systems can operate freely and safely. In some domains, such as supermarkets, barcodes, RFID tags and the like have been embedded in the environment to simplify navigation and identification tasks for autonomous agents. Ultimately, though, these products are not operating in their intended markets until they are active in public space. Thus, one pressing question autonomous system designers have for city decision-makers is how much information will be embedded in the urban infrastructure, and not simply the autonomous agent.[87]

As a practical matter, this means that efforts to embed signals for use by robots in urban infrastructure or modify the allocation or design of urban space to accommodate autonomous systems will simplify the effort required by the roboticist.[88] Some policy commentators, mainly stakeholders in automated vehicles, have advocated that cities update or change their infrastructure to speed the adoption and testing of robots. The installation of advanced sensors to create smart streets or smart intersections, characterized as vehicle-to-infrastructure communication, is one idea.[89] The idea is that city infrastructure can be updated to communicate with automated vehicles to collect and send the data that helps them drive safely.[90] The city of Atlanta has already begun to implement this, touting the sensors on its "smart corridor" for their ability to promote automated vehicles.[91] Similarly, engineering firm Eng proposed a dedicated lane for automated vehicles in New York that would allow a fleet of automated vehicles to move quickly around the city.[92] Graduate students at UC Berkeley have

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[87] Driverless Seattle, UW Tech Policy Lab (2017) http://techpolicylab.org/wp-content/uploads/2017/02/TPL_Driverless-Seattle_2017.pdf

[88] Michael Nagenborg, Urban robotics and responsible urban innovation, Ethics Information and Technology (2018) https://ris.utwente.nl/ws/portalfiles/portal/22918386 "Humanoid robots with a similar size and weight to human beings may have the advantage of being able to use structures designed for humans. However, any deviation from the culturally and materially embedded body norms may result in a disabling environment for such machines in much the same way that similar differences would be disabling for humans. Thus, a question arises whether we should build cities for robots or robots for cities. The answer to this question is likely to be found in a mixed approach, where the built environment will be adopted to enable new robotic applications while safeguarding the quality of city life."

[89] Adam Theier and Ryan Hagemann, Removing Roadblocks to Intelligent Vehicles and Driverless Cars, Mercatus Center, Sep. 2014 at 29. https://www.mercatus.org/system/files/Thierer-Intelligent-Vehicles.pdf.

[90] Michael Hamiliton, Cities Should Not Design for Autonomous Vehicles, Market Urbanism, Nov. 13, 2017 http://marketurbanism.com/2017/11/13/cities-should-not-design-for-autonomous-vehicles/. Holly Beilin, Atlanta is betting on a smart corridor to reduce traffic jams, Venture Beat, Oct. 11, 2017,

[91] Holly Beilin, Atlanta is betting on a smart corridor to reduce traffic jams, Venture Beat, Oct. 11, 2017 https://venturebeat.com/2017/10/11/atlanta-is-betting-on-a-smart-corridor-to-reduce-traffic-jams/.

[92] Benjamin Schneider, Do Driverless Cars Need Their Own Roads Around Manhattan?, Citylab, Jul. 26, 2017, https://www.citylab.com/transportation/2017/07/will-autonomous-vehicles-lead-to-a-resurgence-of-auto-centric-infrastructure/534804/.

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designed a similar system for automated vehicles dubbed a Hyperlane.[93] From the point of view of the roboticist, such investments raise concomitant tradeoffs in mobility and sensing, which have impacts on cost and energy efficiency for the robot.

The inverse relationship between the design of an autonomous system and its environment suggests that simple environments and smart infrastructure for designers will not bring about the safest or most viable outcomes for urban robots or automated vehicles, because the greater the complexity of the task environment in which the robot can navigate unassisted, the greater the likelihood that the same robotic design will perform successfully in the variety of conditions that occur in urban settings. In other words, unaltered, chaotic urban environments can give rise to smarter autonomous systems. Also, any reliance on embedded technology in urban infrastructure will limit the extent of the market for that robot and its associated firm. In truth, firms may seek out cities regardless of embedded technology in infrastructure. Cities provide unique conditions, which firms and their roboticists take up as challenges in the process of design.[94] New York City is considered a particularly attractive automated vehicle testing location because of its narrow streets and dense pedestrian population.[95] This density also means more interactions between robots and humans, and these interactions generate more data with which to train the algorithms that control the robots. The population density in cities also provides a greater marketplace for services like autonomous vehicle taxis or food delivery, and the ability to earn revenue while testing is appealing to firms.

In order to effectively proceed in the design of an urban robot, users, corporate developers and city managers should all be engaged to better understand and characterize the available trade space prior to design.[96] Trade space may be described as "the range of possible implementation options," and early evaluation involves brainstorming to identify the full range of options.[97] The expertise involved includes those with knowledge of the various subsystems and

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[93] Benjamin Preston, Berkeley duo's plan to solve traffic jams: hyper-fast lanes for self-driving cars, Jun.3, 2017, https://www.theguardian.com/technology/2017/jun/03/self-driving-cars-high-speed-lane-berkeley-california

[94] John Markoff, A Guide To Challenges Facing Self-Driving Car Technologists, Jun. 7, 2017, https://www.nytimes.com/2017/06/07/technology/autonomous-car-technology-challenges.html

[95] Andrew J. Hawkins, GM will be the first company to test self-driving cars in New York City, The Verge (Oct. 17, 2017) https://www.theverge.com/2017/10/17/16488330/gm-cruise-nyc-self-driving-car-test-cuomo.

[96] The idea that the design of urban technologies should involve societal actors and innovators working together, is captured in the general idea of "value-sensitive design", Batya Friedman (1996). Value-sensitive design. Interactions, 3(6), 16–23. https://doi.org/10.1145/242485.242493, and incorporated by reference to urban robotics by Michael Nagenborg, "Urban robotics and responsible urban innovation" Ethics and Information Technology, published online 30 January 2018, https://doi.org/10.1007/s10676-018-9446-8.

[97] Contemporary Planetary Robotics: An Approach Toward Autonomous Systems, edited by Yang Gao, NY: Wiley, section 2.5.2.4 SLR Design Evaluation. Explanations of the concept of trade space are perhaps easier to find for areas of robotics supported by public funds, such as robotics for space exploration. Zachary James Bailey, A trade space model for robotic lunar exploration, Massachusetts Institute of Technology (2010) https://dspace.mit.edu/handle/1721.1/59552; Jessica Knizhnik, Mark Austin, Craig Carignan, Robotic Satellite Servicing Trade Space Down-Selection, INCOSE International Symposium Aug. 30, 2017 http://onlinelibrary.wiley.com/doi/10.1002/j.2334-5837.2017.00442.x/full.

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existing technological concepts relevant to the design of the new autonomous system, plus those with knowledge of the environment and the intended users of the system. Just identifying the trade space in the fast-paced industry of urban robotics poses challenges, because the technology is itself a moving target. Designing for today may mean you are superseded by those designing for tomorrow, so there is inherent risk in the overall enterprise. At this early stage, the purpose of gathering information is to understand the risks that the various options bring in terms of cost, the need for new development of software or hardware, the ability of the system to reliably perform its intended tasks, and the time it may take to move to market. This information becomes valuable to designers, who then must down-select, or reduce the pool of available options and make trade-offs across the subsystems of robotic design, and result in a prototype.

To ease the integration of users and city managers with robotic designers, it may be helpful to borrow vocabulary from the video game industry, which is known for its reliance on participants from outside the firm as designs are given shape, tested, and prepared for commercial release. In video game development, the first meaningful milestone for bringing a product to market is "alpha." Alpha is reached when designers have completed one of each of the objects, features, and environments to be developed in the game with basic functionality (a.k.a. "vertical slice"), and can thus demonstrate the game to others, begin testing the play of the game with a few trusted people outside the firm, and continue making modifications, adding features, and building out the remaining copies or versions of objects and environments. For urban robots, alpha could be the milestone that is reached when a prototype that is designed to carry out pre-determined tasks is ready for testing in one or more closed or controlled environments of the physical world (as opposed to simulated, virtual tests, which may also be productive).[98]

Once a prototype is developed, the next major milestone is reached when all of the features and environmental interactions have been completed and are ready for large scale user feedback, but contain bugs or glitches that have to be discovered and fixed. Testing at this phase, known as "closed beta," is often by invitation to a wider audience of persons interested in playing the game, but progress for these players in the game is reset or discarded prior to commercial release. Until recently, firms did not charge players for closed-beta invitations, but market interest sometimes allows them to do so. During closed beta, milestones are set up as hurdles to meet before the game can proceed to "open beta," a form of commercial release in which anyone can play and all of the features of monetization are activated. For urban robotics, closed beta milestones could involve increasing the complexity of the task environments, and user testing amongst a wide array of groups, in a wide variety of settings. For city managers, closed beta could be a useful period in development for gradual expansions of geofenced areas for testing, for neighborhoods to opt-in to requests to join the testing environment for a given product, and for heightened calls for feedback from residents. Commercial release, or launch, finishes the process and allows marketing to begin.

[98] Selected individuals for alpha game testing may be asked to sign non-disclosure agreements to protect the interest of the firm, and waivers of liability may also be appropriate for tests in a physical environment.

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Roboticists have an interest in communicating with governmental decision-makers during the testing phase because legislation passed after a system has been designed can invalidate the initial design assumptions.[99] Participation also creates opportunities for public agencies to research the potential effects of rules to govern robots in the public interest. For example, should there be a speed limit for robots operating on the sidewalk? Should robots or autonomous vehicles ever legally be allowed to bump into people? When technology progresses faster than regulatory systems, designers build systems for the unknown, which can have the effect of raising costs and risks for both the firm and the communities in which their products operate.

Still, many robotic system designers have assumed that they know what people want, and have moved through the design process without prior consultation. This historically has led to the bankruptcy (e.g., Denning Mobile Robotics[100], Lily Robotics[101]) or abandonment of product by numerous companies who have created security robots, entertainment (iRobot's My Real Baby[102]), research platforms, and the like. This is also what happens when firms adopt strategies that involve asking forgiveness rather than permission, and purposefully move to market before legal issues are settled. This aggressive stance is risky, because it may result in harm to consumers and local action to ban the product.[103] Yet the prospect of being a first-mover in a new market, or competing for market share in the early years of development has been known to motivate firms to take this risk.[104] Perhaps it is for this reason that machine learning pioneer Andrew Ng has suggested that "[r]ather than building AI to solve the pogo stick problem [of unknown edge cases causing problems for AI], we should partner with the government to ask people to be lawful and considerate…. Safety isn't just about the quality of the AI technology."[105]

Part III: Cities as Testbeds for Autonomous Vehicles and Robotics

This part of the article explores the enthusiasm that city decision-makers and managers have for autonomous vehicles and robotics, and the hazards that await cities as sites of experimentation. This section begins with the arguments city officials make in favor of automated systems, followed by an overview of the hazards for cities that pertain to the uses and physicality of autonomous products, and a section on hazards involved in the collection and

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[99] One noteworthy example of this is the FAA restriction on drones that limits their operation to the area within the line of sight of the operator, and the limits this places on air package delivery for firms such as Amazon.

[100] Hans Moravec, Re: The company status of Denning Mobile Robotics, Inc. https://www.frc.ri.cmu.edu/~hpm/project.archive/robot.papers/2000/Denning.Mobile.Robotics.bankruptcy

[101] Jessica Pishko, The Drone Company that Fell to Earth, Wired, Jul. 26, 2017, https://www.wired.com/story/the-drone-company-that-fell-to-earth/

[102] Danny Allen, Creepy: iRobot's "My Real Baby", Gizmodo, Aug. 8, 2009 https://www.gizmodo.com.au/2009/08/creepy-irobots-my-real-baby/

[103] Julia Carrii Wong, San Francisco sours on rampent delivery robots: 'Not every innovation is great', The Guardian, Dec. 10, 2017, https://www.theguardian.com/us-news/2017/dec/10/san-francisco-delivery-robots-laws

[104] Matt Simon, "SAN FRANCISCO JUST PUT THE BRAKES ON DELIVERY ROBOTS", Wired, December 6, 2017, https://www.wired.com/story/san-francisco-just-put-the-brakes-on-delivery-robots/.

[105] Russell Brandom, Self-Driving Cars are Headed Toward an AI Roadblock, The Verge, Jul. 3, 2018, https://www.theverge.com/2018/7/3/17530232/self-driving-ai-winter-full-autonomy-waymo-tesla-uber

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use of data from these systems. Lastly, an evidence-based, comparative institutional economic approach to policy-making is recommended, to forestall negative externalities while permitting technological change.

A. The Interest of Cities in Firms and their Autonomous Products

City decision-makers that welcome autonomous vehicles and devices perceive their efforts through the lens of economic development, job creation, the need to position for a wave of economically beneficial technological change, and as part and parcel of visionary plans for the future in the transportation sector. Through the formation of partnerships, the adoption of tech-friendly policy, and changes to city information systems and physical environments, city decision-makers are extending invitations to firms and their products. As the intended markets for these products, cities and their decision-makers will be vital to any effort to shape these products and their uses in the public interest.

As cities have formed partnerships with the firms that want to mobilize autonomous products, their decision-makers have raised the hope or expectation of reciprocal efforts on the part of firms to deliver civic benefits. Public reports of Alphabet's Waymo use in Austin highlight the ability of a blind person to achieve mobility by hailing a driverless automobile.[106] Pittsburgh assisted Uber in acquiring a large plot of land and the Mayor and Governor fended off state legislation that would have banned autonomous vehicles with the expectation that the firm would provide jobs, free rides, and further commitments in an application for a high-profile US DOT "smart city challenge" grant.[107] Boston's approach, which currently includes testing by nuTonomy, Optimus Ride, and Aptiv, is framed by the city's action plan for transportation, with goals for equity, economic opportunity, and climate responsiveness.[108] The recipient of the US DOT challenge grant, Columbus, Ohio, set the target of reducing infant mortality by 40 percent by 2020, through the automation of transit in low-income neighborhoods.[109]

While some benefits can be expected from investments in transportation services, the scale of claims associated with autonomous systems is beyond the imaginable. Cities of the US have under-invested in transit and related transportation infrastructure for decades, with noticeable

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[106] See e.g., Ashley Halsey III and Michael Laris, Blind man sets out alone in Google's driverless car, Washington Post, Dec. 13, 2016,

[107] Cecilia Kang, No Driver? Bring It On. How Pittsburgh Became Uber's Testing Ground, NY Times, Sep. 10, 2016, https://www.nytimes.com/2016/09/11/technology/no-driver-bring-it-on-how-pittsburgh-became-ubers-testing-ground.html; Cecilia Kang, Pittsburgh Welcomed Uber's Driverless Car Experiment. Not Anymore, May 21, 2017, https://www.nytimes.com/2017/05/21/technology/pittsburgh-ubers-driverless-car-experiment.html; Ashley Gold, How Uber lost its way in the Steel City, Politico, May, 1, 2017, https://www.politico.com/story/2017/05/01/uber-pittsburgh-city-mayors-237772.

[108] Vision Framework, City of Boston, https://www.boston.gov/sites/default/files/document-file-03-2017/go_boston_2030_-_plan_highlights_to_download.pdf; Go Boston 2030, City of Boston (last visited Aug. 28,2018) https://www.boston.gov/departments/transportation/go-boston-2030; Autonomous Vehicles: Boston's Approach, City of Boston https://www.boston.gov/departments/new-urban-mechanics/autonomous-vehicles-bostons-approach

[109] Laura Bliss, Who Wins When a City Gets Smart?, Citylab, Nov. 1, 2017, https://www.citylab.com/transportation/2017/11/when-a-smart-city-doesnt-have-all-the-answers/542976/

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impacts to equity.[110] The fact that the transportation sector is responsible for about one third of US greenhouse gas emissions, provides the US government with the added burden of investing in or overseeing the electrification of the system, with concurrent investments in carbon neutral energy sources.[111] The widely touted notion, however, that artificially intelligent vehicles and devices can eliminate traffic congestion, death, injury, disparity, and emissions, while freeing up the vast acreage of asphalt and concrete currently devoted to parking, is ludicrous. The simple math of public space allocation, single occupancy vehicles, and the basics of machine learning do not add up in favor of these claims.[112]

In the face of unrealistic claims of benefits from autonomous vehicles and robotics, cities must be recognized as critical forces in the effort to shape these products and their uses for public good. The public good and current designs, composition, or envisioned uses of these products are not necessarily aligned, and the effects of these products, for better or worse, are going to be experienced locally. For example, the choice of whether to allow and financially support changes to urban physical infrastructure to accommodate autonomous systems are almost entirely local, in that state departments of transportation tend to have responsibility only for state and national highways. Even for drones, the Federal Aviation Administration regulates airspace, but changes to the local urban infrastructure to accommodate delivery or "follow me" drones will be almost entirely up to local governments and the physical environments that they own or regulate. This means that city managers and decision-makers are likely to experience pressure from firms to modify the allocation of public space, environmental design, and associated local public revenues and expenditures, regardless of state and federal legislation. For example, online magazine Quartz reported that in negotiations with the city of Pittsburgh, Uber wanted the city to grant non-exclusive access to bus lanes and municipal parking lots to use as staging areas.[113] These demands contributed to the breakdown in the working relationship between Uber and the city.[114] Relatedly, other groups have advocated that cities reduce parking space to promote automated vehicles, though the economics of the situation simply look like increased demand for curbside use, and parking is often an important source of municipal revenue.[115] As

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[110] Junfeng Jiao and Chris Bischak, People are stranded in 'transit deserts' in dozens of U.S. cities, Mar. 13, 2018, http://theconversation.com/people-are-stranded-in-transit-deserts-in-dozens-of-us-cities-92722

[111] "In 2015, greenhouse gas emissions from transportation accounted for about 27 percent of total U.S. greenhouse gas emissions, making it the second largest contributor of U.S. greenhouse gas emissions after the Electricity sector." https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

[112] Bloomberg Philanthropies and the Aspen Institute, Taming the Autonomous Vehicle, file:///C:/Users/janwhit/Desktop/TamingtheAutonomousVehicleSpreadsPDFreleaseMay3rev2.pdf; NACTO, Blueprint for Autonomous Urbanism, Module 1, Fall 2017, Designing Cities Edition; The Boston Consulting Group, "Quantifying the impact of autonomous vehicles on city traffic" https://www.youtube.com/watch?v=zMZIEBoR49U; Allison Arieff, "Automated vehicles can't save cities" The New York Times, https://www.nytimes.com/interactive/2018/02/27/opinion/automated-vehicles-cant-save-cities.html

[113] Alison Griswold, Uber asked a lot of Pittsburgh for its self-driving cars, and offered back very little, Quartz, Dec. 26, 2016, https://qz.com/874548/uber-asked-a-lot-of-pittsburgh-for-its-self-driving-cars-and-offered-back-very-little/.

[114] *Id.*

[115] "Transportation and land use planning and policies should minimize the street and parking space used per person and maximize the use of each vehicle. We discourage overbuilding and oversized vehicles and infrastructure, as well as the oversupply of parking." Shared Mobility Principles for Livable Cities, https://www.sharedmobilityprinciples.org/

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enthusiastic as city decision-makers and managers may be for firms with autonomous products, they still need to represent the interest of local residents and taxpayers, and this places them in a position to negotiate with firms on behalf of the general public.

As stewards of the public good, city managers and decision-makers care about efficiency, effectiveness, and equity in the provision of essential goods and services, as well as the effects of the choices they make on jobs and the economy. Publications from the National Association of City Transportation Officials (with membership from 52 cities across the US), and the Regional Plan Association (serving the New York metropolitan area), urge city managers to brace against the potentially disruptive effects of automated vehicles, for example, by engaging in proactive policymaking to ensure that "public benefit guides private action," to "shape how [automated vehicles] interact with transit," and to "prioritize street space for public transit, pedestrians, bikes, and freight."[116] Several of these choices are exhibited today in the attempts of ride-sharing firms to partner with local governments and transit agencies, for example, for subsidized first and last mile passenger delivery to remote transit stations.[117] Guidelines for city officials break down the components and possible effects of autonomous vehicles into modules and provide schema for the gradual, sequential alteration of the design and allocation of public space.[118] Highlighting the disruptive effects of artificially intelligent transportation, the Regional Plan Association also suggests that plans get underway to determine how to transition the 220,000 or so persons in vulnerable positions in the region to new forms of employment.[119]

For the public good, cities are also interested in the information that firms collect through these technologies. City officials have a general need to govern the flow of information for accountability, transparency, and privacy; a need which may be heightened by local or state regulations regarding privacy and surveillance.[120] At the same time, city managers see value in gaining access to this data for direct use in balancing demand and supply of services and built environments. Historically, transportation agencies have had to rely on relatively expensive and time-consuming methods to collect data on travel behavior and the use of transport facilities, because of the lack of integration of information technology in vehicles and the fact that autos and trucks are predominantly owned and operated by individuals.[121] The information technology

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[116] National Association of City Transportation Officials, Blueprint for Autonomous Urbanism, New York, 2017, pages 13-14, lists "public benefit guides private action" as one of six principles for autonomous urbanism; Regional Plan Association, New Mobility: Autonomous Vehicles and the Region, October 2017, page 3.

[117] US Federal Transit Administration, "Mobility on Demand (MOD) Sandbox Program" https://www.transit.dot.gov/research-innovation/mobility-demand-mod-sandbox-program.html, accessed September 18, 2018.

[118] National Association of City Transportation Officials, 2017, modules on page 9; RPA, 2017, "A Prospective Timeline in Four Phases", pages 16-17.

[119] Regional Plan Association, New Mobility: Autonomous Vehicles and the Region, page 5.

[120] E.g., see the California Consumer Privacy Act, and "About the Surveillance Ordinance" Seattle Information Technology, Seattle.gov, https://www.seattle.gov/tech/initiatives/privacy/surveillance-technologies/about-surveillance-ordinance, accessed September 18, 2018.

[121] The World Bank, "The World Bank Launches New Open Transport Partnership to Improve Transportation through Open Data" December 19, 2016, http://www.worldbank.org/en/news/press-release/2016/12/19/the-world-bank-launches-new-open-transport-partnership-to-improve-transportation-through-

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of transport is already undergoing dramatic changes: rideshare, car-share, and bike-share services concentrate travel information into the hands of comparatively small number of firms.[122] With the adoption of autonomous systems, the industrial organization of the entire transport sector is headed for upheaval: autonomous controls are likely to result in the concentration of the ownership of vehicles as well as information about their uses and users.[123] The ability of public agencies to make smart decisions about the allocation and governance of public space will depend on their ability to access and merge this information with data on public services and investments.[124] If disputes between the firms of the sharing economy and cities over access to data are indicators of what is to come, there will have to be neutral third parties to operate trusted data platforms and broker these exchanges.[125] Travel patterns are remarkably unique and sensitive for what they reveal about individuals and the actions of the firm, making the data valuable to firms inside and outside of the transport market, and of great concern to officials tasked with protecting the privacy of city residents.[126] At the same time, government agencies need to use the same data sources to hold firms accountable, and the public deserves transparency in the actions of government agencies for the same.[127]

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open-data, "traditional methods for collecting traffic data needed to address congestion are costly and rely either on labor-intensive field work or capital-intensive sensor data networks that far exceed available resources"; In US cities, labor-intensive traffic counts and travel diary surveys as information sources for transportation system decisions have recently been augmented by license plate readers, cell phone tracking data, data feeds from bluetooth and wifi sniffers, as cities have contracted with private vendors and university researchers to serve this need.

[122] Prominent firms in US markets include Uber and Lyft in rideshare, Reachnow and Car2Go in car-share, and Lime, ofo, Spin, and Mobike in dockless bike-share markets, all of which collect information on travellers from a combination of their mobile apps and the GPS and related technologies installed in the cars and bikes.

[123] "Self-driving cars will require new business models:Selling rides, not carrs" The Economist, May 1, 2018, https://www.economist.com/special-report/2018/03/01/self-driving-cars-will-require-new-business-models.

[124] NACTO, 2017, page 20, "Billions of detailed street-level data points are collected in real time daily on everything from traffic speeds and volumes to travel patterns and transit use. This data is vital to the operations and management of streets, regardless of the entity generating them."

[125] Cite legal contests between Uber, Lyft, and cities over the public release of data; e.g., University of Washington Transportation Data Collaborative, https://www.uwtdc.org/, "The Transportation Data Collaborative (TDC) is an initiative at the UW to create a protected and linked data repository of sensitive information from public and private transportation providers… The TDC allows partnering agencies to create data-driven policy, support research uses, and provide individuals with authenticated access to their own transportation records."; NACTO, 2017, page 21, "In order to protect user data, an independent third-party company can sort and anonymize data collected before it is used for analysis, ensuring individual users are not identified. Once analyzed, this data can be used to direct city policy and prioritize projects."

[126] Yves-Alexandre de Montjoye, César A. Hidalgo, Michel Verleysen & Vincent D. Blondel, "Unique in the Crowd: The privacy bounds of human mobility", *Scientific Reports*, volume 3, Article number: 1376 (2013) doi:10.1038/srep01376, https://www.nature.com/articles/srep01376, "We study fifteen months of human mobility data for one and a half million individuals and find that human mobility traces are highly unique. In fact, in a dataset where the location of an individual is specified hourly, and with a spatial resolution equal to that given by the carrier's antennas, four spatio-temporal points are enough to uniquely identify 95% of the individuals."; NACTO, 2017, page 20 "intricate information on people movement is laden with personally identifiable information that neither government nor private companies should have access to."

[127] Cites on accountability and transparency

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Cities are critical to the rollout of autonomous systems because, in contrast to Federal and State government, the diversity of approaches taken by city decision-makers in the adoption of new technologies makes them laboratories for policy, governance, and the implementation of enforcement mechanisms. Governments are in the business of institutional change; institutions are "the formal rules, informal norms, and enforcement characteristics" developed and used by the polity and judiciary to govern in the public interest.[128] The public interest is, in and of itself, complex phenomena, and institutional change has historically been led by cities and related local and state governments for their diversity of policies and evaluations of related outcomes in the formation of lasting regulations for the public good. In the face of rapid change in technology, it is remarkably difficult to determine ex ante the structure and content of policies most beneficial to the public. At the local level, pilot programs, sunset clauses with requirements for audit and program evaluation, and geofencing are mainstays of governance when testing new concepts, technologies, and environmental designs in public space, that have the practical purpose of supporting evidence-based changes to policy over time. Irrespective of technology, the authority city decision-makers have to draw boundaries that limit the spatial extent of the market, afix rules to public and private space that limit allowed activities, determine required and allowed uses and flows of information, develop and enforce pricing schemes, issue or revoke operating permits, and to tax, audit, charge fees, levy fines, and ban goods, constitute critical leverage in the negotiations between firms and city governments for the public good.

In sum, as enthusiastic as they may be, city decision-makers should be strategic in their evaluation, adoption, and regulation of autonomous vehicle and robotic technologies.[129] The benefits of utilizing cities as laboratories for policy-making depends on the ability of city managers and decision-makers to shape these new markets for the public good and to enter these relationships with eyes wide open, on the lookout for unintended as well as intended consequences.

B. The Hazards in Store for Cities as Testbeds of Autonomous Systems

Cities are appropriate centers of autonomous robotic innovation, but they should proceed carefully to avoid treating the associated risks of these technologies and partnerships as afterthoughts. The problems that accompany autonomous systems in cities could be understood in the same terms as the promises associated with these technologies, for safety, convenience, equity, emissions, and the economy.

Safety is the risk that has risen to the forefront of governmental offices as they have witnessed the early adoption of autonomous vehicles and robotics. The bulk of activities at the Federal, State, and local level, from reports and model legislation to the development of testbeds outside as well as within public rights-of-way, highlight the importance of safety in the design and use of

[128] Cite Douglass North; Oliver Williamson, "NIE taking stock, looking ahead" Journal of Economic Perspectives

[129] Regional Plan Association, New Mobility: Autonomous Vehicles and the Region, October 9, 2017, http://www.rpa.org/publication/new-mobility-autonomous-vehicles-and-region; University of Washington Tech Policy Lab, Driverless Seattle, n.d. http://techpolicylab.org/wp-content/uploads/2017/02/TPL_Driverless-Seattle_2017.pdf

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these products.[130] Similarly, accounts of accidents in the news have raised public and private concern over the continuing role of the human behind the wheel or with hands on the controls, and the impacts to people and property from collisions with autonomous vehicles, robots and drones.[131] News that a pedestrian was killed by an automated vehicle in Chandler, Arizona, struck many advocates of the technology as shocking.[132] Such anecdotes appear to have temporarily pierced the popular notion that autonomous systems will eliminate death and injury. The idea that autonomous controls will eliminate injury is unrealistic because, like all complex technological systems, artificially intelligent autonomous controls are never completely understood, even by those that design the system.[133] The complexity and processing power of autonomous controls can be expected to increase over time as the systems are trained to operate within complex environments.[134] But, because of the tendency designers have to add responsibilities to these systems as fast as possible, there are some in the field who caution that it may be impossible to create a truly safe autonomous system.[135]

Public pronouncements that autonomous systems will usher in an unprecedented era of convenience contrast with early evaluations of autonomous vehicles that show, in the context of the holistic use of urban public space, that they are not as cost-effective as existing alternatives. Most of the firms engaged in trials of autonomous vehicles are using cars that would carry three or fewer occupants.[136] Recent studies of the impact of autonomous vehicles on traffic in downtown Boston, with associated simulations to model preferences for mode choice, show a 15 percent reduction of vehicles on the road, coupled with a 16 percent increase in vehicle miles traveled, resulting in only a 4 percent improvement in travel time in general and a 5 percent increase in travel time and associated congestion in the downtown area.[137] As improvements, these impacts fall short of traditional investments in bus and rail transit services, and underscore the importance of transitioning from single occupancy vehicles to pooled ridership and renewed investment in transit.[138] Otherwise, the influx of autonomous services in the form of vehicles and robots would be predicted to increase congestion, and cause more of a nuisance than a convenience.

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[130] CITE reports

[131] Swapna Krishna, San Francisco restricts the use of delivery robots on its sidewalks, Dec. 7, 2017, https://www.engadget.com/2017/12/07/san-francisco-restricts-delivery-robots/; Will Knight, The Dark Secret at the Heart of AI, MIT Tech. Rev. Apr. 11, 2017, https://www.technologyreview.com/s/604087/the-dark-secret-at-the-heart-of-ai/; Megan Geus, Drone crashes in Arizona National Forest, starts a wildfire, ars technica, Mar, 9, 2018, https://arstechnica.com/tech-policy/2018/03/drone-crashes-in-arizona-national-forest-starts-a-wildfire/

[132] Ian Wren, Uber Suspends Self-Driving Tests After Pedestrian is Killed in Arizona, Mar. 19, 2018, https://www.npr.org/sections/thetwo-way/2018/03/19/594950197/uber-suspends-self-driving-tests-after-pedestrian-is-killed-in-arizona?sc=tw

[133] Arend Hintze, I Am an AI Researcher. This is What Keeps Me Up at Night, Popular Mechanics, Jan. 3, 2018, https://www.popularmechanics.com/technology/security/a14537028/i-am-an-ai-researcher-this-is-what-keeps-me-up-at-night/

[134] CITE with note on processing and deep learning

[135] CITE Arend Hintze

[136] Check firms and CITE

[137] Boston Consulting Group, Quantifying the Impact of Autonomous Vehicles on City Traffic, Youtube, Jan. 25, 2018, https://www.youtube.com/watch?v=zMZIEBoR49U

[138] Cite from transit/transportation lit

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Autonomous vehicles and robotics can only be expected to make cities more equitable if they are accessible to all at affordable rates. The firms participating in these markets are like any other firms in that they will reach a point in time when the profitability of autonomous services matters.[139] As they strive for profitability, firms can be expected to care about pricing, market share, participation in two-sided markets, their ability to influence the adoption of rules and regulations that stave off competition, and to generally safeguard their financial self-interest. The moves of firms in these areas can also be expected to be regressive, having a disproportionate impact on those who have relatively little ability to pay for transportation services and those who are in vulnerable, low-wage jobs.[140] These economic conditions are not going to change with autonomous systems. Reading the media today, it would be easy to assume that the free or low-priced services that accompany the initial rollout of products to market would continue into the future, because it is tempting to think that firms will pass on the cost savings that come from automated fleet services to customers.[141] To assume so would be naive. The need for free and reduced price services and requirements of service-area coverage enforced today by transit and transportation agencies will not disappear with new technologies.[142] The equitable pricing and access to transportation services will continue to be of critical importance for policy-makers in the era of autonomous systems.

Emissions will only be reduced by autonomous vehicles and robotic systems if the sources of energy used to power them are less carbon intensive than the current fuel mix. Environmental and political pressure to convert from fossil fuel sources to electricity are transforming the auto industry at the same time that automakers are partnering en masse with information technology firms to adopt autonomous control systems.[143] The conversion to electric energy is also leading automakers to expand into areas of the transportation market in search of opportunities to lock-in new sources of revenue, such as long term concession agreements that would place firms in the position of controlling access to and the price of public parking spaces in exchange for capital investment in electric charging stations.[144] Altogether, the combined forces of automation and electrification may upend the industrial organization of the transportation industry, transforming what has been a highly disaggregated ownership structure based on private personally-held assets, into highly concentrated ownership of fleets, and firms with ownership in search of preferential or exclusive rights to currently public rights-of-way.

Of these concerns, perhaps the most complex is the question of whether or not autonomous vehicles and robots will bring about economic and associated financial improvements in the public interest, for the cities responsible for the infrastructure that these systems rely on. Early

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[139] Tech firms benefit in early development and market expansion from venture capital and other types of investment for revenue.

[140] Cite recent study of increasing cost of rideshare v. existing transportation options; cite recent study of impact focused on low-wage jobs

[141] CITE

[142] CITE examples of free and reduced transit pricing

[143] Recent announcements from France, China, and other nations to ban the sale of vehicles that rely on fossil fuels; Recent announcements from automakers converting market offerings to all electric. Recent announcements of GM, Fiat Chrysler, Ford, and so on in partnership with various AV firms.

[144] BMW and others in this area

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reports already suggest that public parking, which is one of the most important sources of revenue for cities in the transportation sector, may be under threat by autonomous systems. Results from last year's simulation of the effect of autonomous vehicles on Boston's parking system show a reduction in demand for parking by 48 percent. At the same time, cities can expect to experience pressure from firms to invest more in public rights-of-way, by either embedding technologies in infrastructure or re-designing and constructing built environments to favor their products, and to provide preferential or exclusive allocations of public space for their private use.[145] In general, such efforts should be recognized as attempts to pass on the private cost of adopting these technologies to the public taxpayer, and with that to society.

C. Privacy and Surveillance Risks of Urban Robots

In addition to hazards related to safety, the environment, municipal finances, and other public goods discussed above, urban robots present an acute risk of loss of privacy and increased surveillance. A robot that operates in a city has sensing and computing capabilities that enable it to collect and process information in public spaces on a potentially massive scale, challenging existing information privacy governance frameworks.[146] The privacy hazard presented by urban robots has three components: the technological trend of Internet-connected devices and other digital technologies collecting "big data," changing concepts of privacy in public spaces, and a growing role for city officials in protecting privacy.

Robots fit into a larger trend of widespread digital technologies that threaten to erode privacy. A robot or autonomous system is essentially a mobile computing platform that senses and operates in the physical world, and can therefore be conceptualized as a type of Internet of Things (IoT) application.[147] IoT devices can be deployed to surveil locations and situations with untiring and near perfect recall. For example, many cities have or plan to install cameras on street lights that can observe and record the public space under its purview.[148] Unlike a human observer, it will never tire, and can record for as long as it has storage capacity and a power source. These recording capabilities can be combined with facial recognition and other AI-powered processing tools that could, for instance, query police databases in real time.[149] They may be employed by a governments or private companies, often in cooperation with one another. Further, with IoT devices traditional privacy controls like notice and choice become more difficult to execute because devices often lack an interface with which to communicate

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[145] Ashley Gold, How Uber lost its way in the Steel City, Politico, May, 1, 2017, https://www.politico.com/story/2017/05/01/uber-pittsburgh-city-mayors-237772.

[146] Ryan Calo, Robots and Privacy, *in* Robot Ethics: The Ethical and Social Implications of Robotics, 187 (Patrick Lin, George Bekey, and Keith Abney, eds.,).

[147] Pieter Simoens et al, *The Internet of Robotic Things: A review of concept, added value, and applications*, Int'l. J. of Advanced Robotic Systems, Feb. 26, 2018

[148] Sarah Holder, *The Shadowy Side of LED Street Lights*, Citylab, Mar. 8, 2018, https://www.citylab.com/equity/2018/03/their-lights-were-watching-odd/554696/.

[149] Clare Garvie, Alvaro M. Bedoya, & Jonathan Frankle, The Perpetual Lineup: Unregulated Police Face Recognition in America, Georgetown Law Center on Privacy & Tech. (2016) http://www.perpetuallineup.org/.

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information about privacy practices to the subjects of data collection.[150] Even where devices or their operators can provide notice to data subjects, those individuals may lack meaningful choice about being recorded.[151] A person can choose not to use Facebook if they do not agree with the company's data practices, but opting out of recording of IoT devices on city streets would effectively mean retreating from public life.[152]

The collection and recording of big data in public challenges the notion that individuals are not entitled to their privacy in public spaces. In an analog world, an individual moving in public space may be observed and might even be recorded as a one-off event, but generally one's presence could have been characterized as a fleeting event, without definitive purpose or identifiability beyond existing social circles or persistent investigation on the part of law enforcement. Urban robotics are, however, often being marketed for characteristics that include the ability to identify individuals, and to follow those individuals. If this behavior is desired, it is a feature, but if it is unwanted, it can be seen as a pernicious form of surveillance. Separately from these features, it is important to note that the ability of a robot to navigate in urban space requires the collection and constant use of immense data stores about the urban environment, including the observation of persons -- if for no other reason than to avoid collisions with humans. Another perspective on data collection and privacy is emerging from the point of view of the consumer. In the transition from personally-owned vehicles to fleets of automated vehicles owned by firms, people appear to be losing the right to privacy that they have historically been afforded through ownership of the vehicle. As firms recognize liability for the performance of automated vehicles, they can be expected to argue in favor of increased surveillance of persons inside of vehicles, irrespective of public desires for personal privacy. Lastly, it is important to note mention information asymmetry between consumers and firms in urban robotics and similar areas of technology. Cell phones could be thought of as precursors to urban robotics, and demonstrations show that people are unaware of the personally identifiable and invasive nature of the information that accumulates on such devices. People are especially identifiable with regard to their place of residence and employment, or locations frequented in any routine way. These routines tend to be local for the vast majority of persons, and this means that the persons in authority who may be most likely to identify with the problems created by technologies that surveil or otherwise amass local data, are local government representatives.

D. How Cities Can Prepare to be Sites of Experimentation

This paper argues that cities should be given the authority and flexibility to experiment with autonomous vehicles and robotics, and that city managers and decision-makers should prepare

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[150] Peter Swire and Jesse Woo, Privacy and Cybersecurity Lessons at the Intersection of the Internet of Things and Police Body-Worn Cameras, 96 N. Carolina L. Rev. 101, 134 (2018) https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3168089.

[151] Kelsey Finch & Omer Tene, Welcome to the Metropticon: Protecting Privacy in a Hyperconnected Town, 41 Fordham Urban LJ 1581 (2016).

[152] Some have argued that large social media companies like Facebook have become the "digital public square" and should therefore be treated like public spaces or regulated like utilities. For a discussion of such proposals, see Peter Swire, Should the Leading Online Tech Companies Be Regulated as Public Utilities?, Lawfare, Aug. 2, 2017 https://www.lawfareblog.com/should-leading-online-tech-companies-be-regulated-public-utilities.

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to participate in the testing process with the designers of artificially intelligent systems. This section provides an overview of the task ahead for cities, highlighting perspectives and methods useful for evaluating the effects of policy choices in the public interest.

From an institutional economic perspective, cities as sites of experimentation need to recognize and harness their ability to act as market makers. Governments create the rules of the game for private firms. In times of institutional change, governments can act in the public interest by orienting policy-making toward the purposes of minimizing social harm, internalizing externalities, and preventing the transfer of private costs to society. When considering the many facets of change accompanying autonomous vehicles and technologies, focus should build on the collection of metrics such as those emerging from Boston, and move to evidence-based policy and evaluations that compare the costs to firms and the public of existing and new technologies as they occur under various institutional arrangements.

City managers and decision-makers will need support for sophisticated negotiations in the domain of automated vehicles and robotics. Policies, procedures, regulations, and enforcement implicated in governing these technologies span the boundaries of the transportation and information technology sectors as we understand them today. It is perhaps for these reasons that several cities have formed interdisciplinary working groups on the topic of testbeds for autonomous vehicles, including partnerships with outside organizations, some of which appear to be unique in the history of the sector. One of these is Boston's multi-year partnership with Boston Consulting Group and the World Economic Forum which, in the first of several reports affirms that cities should work cooperatively with state and federal agencies, but that cities should really be in "the lead in establishing a governance structure and testing policy and parameters to foster innovative solutions to their most pressing transportation challenges."[153]

Advice and support can be especially helpful if it can be interdisciplinary, providing a clear picture of the implications of the various policy options ahead. At times like this -- when the adoption of policy can actually reshape the entire industrial organization of a sector of critical infrastructure -- it pays to place policy debates in economic and social terms. When political arguments have economic motivations, it is particularly important to know the economic implications of their adoption in law and policy. Arguments for the freedom to innovate may have ideological merit, but the practical implications for policy change are usually about the reallocation of property rights across the public and private sector for economic or financial gain. These reallocations have the effect of determining, inter alia, the factors and associated costs that will be internal to markets and therefore borne by firms and established in the pricing of goods and services on the market, and the factors and associated costs that will be externalized, and thus borne by public agencies, the taxpayers that fund them, and society in general.

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[153] Boston Consulting Group, Boston Test of Self-Driving Cars Reveals Five Key Lessons for Cities Worldwide, Oct. 17, 2017, https://globenewswire.com/news-release/2017/10/17/1148405/0/en/Boston-Test-of-Self-Driving-Cars-Reveals-Five-Key-Lessons-for-Cities-Worldwide.html; Nikolaus Lang et al, Making Autonomous Vehicles a Reality: Lessons from Boston and Beyond, Boston Consulting Group Oct. 17, 2017, https://www.bcg.com/publications/2017/automotive-making-autonomous-vehicles-a-reality.aspx.

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Furthermore, the methodologies used to reveal these relationships matter. Simple cost-benefit analyses, commonly recommended in the analysis of public expenditures, are not appropriate when the alternatives to be evaluated serve differing policy goals. More promising analyses are possible if, borrowing somewhat from research methodologies in institutional and transaction cost economics, the economic effects of policy options are examined holistically for the trade-offs experienced by the various public and private parties involved in delivering and receiving services, with current and potential future industrial organizations of the sector in mind.[154] In all cases, it is important to understand the comparative effects of current and proposed policy options with respect to the distribution of production and transaction costs across the parties involved in delivering, governing, and consuming the products and services. The methodologies for examining comparative institutional arrangements from transaction cost economics, which break down the delivery of services by task, noting which party bears costs and which receives benefits, and in what amounts, may be adapted to this purpose.[155]

It is also important that research consider the effects that policies may have on competition, and the impacts that would occur if competition in the transport sector were to be replaced by concentrated ownership of assets. Competition is still the most important force in delivering economic benefits from markets, but the extent to which society reaps these benefits and maintains competition depends also on the institutions that govern the sector. Historically the private ownership of mobile assets and public investment in network -- operated as a non-excludable asset -- has assisted this sector in avoiding several market failures that are more visibly acute in, for example, the communication sector's struggle over net neutrality or rent-seeking behavior on the part of organizations that own the transmission systems needed to wheel water from one community to another. Policies that preserve equal access to essential infrastructure such as the underlying network of roads, parking, conduit, utility poles, curb, and gutter, and resist the urge to privatize public space on transportation and related communication networks, have the economic effect of keeping this space in play for all parties, and keeping barriers low for competitors seeking entry to the market with mobile assets. Privatization of public space and policies that offer preferred or exclusive access have the opposite effect, locking public entities into monopoly or oligopoly relations in the provision of services and thus the potential for multiple downstream hazards, such as disputes over pricing, quality of service, and a host of opportunity costs that accompany the privatization of public assets.[156]

Guidance from National Association of City Transportation Officials and the Regional Plan Association of New York suggests that cities create public-facing, proactive strategies for

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[154] Cite Whittington, Journal of the American Planning Association, on a transaction cost methodology for comparing costs and trade-offs, shown as the amount of funding allocated to and from the parties involved in the various tasks involved in delivering infrastructure projects, according to alternative policies. Cite Whittington and Hoofnagle, UNC Law Review, on the consequences of small numbers of competitors for consumers in information-intensive industries, such as social network services, with demand and supply side economies of scale.

[155] E.g., Whittington, Journal of American Planning Association, 2012

[156] Cite Elliot Sclar, You Don't Always Get What You Paid For, ; Ellen Dannin 2011 law article on hidden costs of privatization; and Siemiatycki probably 2009

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exploring, testing, permitting, and supporting autonomous vehicles, and the same guidance should be extended to include urban robotics and drones. City strategies should be designed to assist decision-makers in understanding the strengths and limitations of artificially intelligent products, and the prevailing business models that firms are relying on as they enter the market. It would be important to know, for example, the interests of firms as they seek access to the public rights-of-way, the models for pricing of goods and services, plans for market and service-area expansion, and the disposition of the data the firm collects about the public. These factors are central to the operation of firms and happen to coincide with the interests that cities have in crafting policies in the public interest. Each city should be prepared to evaluate these products and their providers on the merits and the costs to city government and city residents. Existing guidance attempts to summarize the values that city decision-makers and managers consider important and, as noted above, these considerations are not necessarily aligned with the interests of the firms. Firms may seek to externalize costs and use data about local residents on secondary markets, and cities should avoid this trap. The capacity to evaluate policy will matter, as noted in this section, and so will the capacity to evaluate the various forms of agreements and contracts that will be instrumental in preserving public values while adopting these new technologies.

In their efforts, city managers should perhaps make a point of explaining to the various parties in these new industries that environmental design is local, expensive, and extremely consequential. Guidance from National Association of City Transportation Officials and the Regional Plan Association makes this point in subtle ways, by emphasizing efficient options for intersection design, for example, and laying out a timeline for the gradual redesign of urban arterials that surely appears to be slow in comparison to the business plans of firms and their investors. From the point of view of city management, this slow pace of environmental design is what may be realistic, under the most ambitious of timeframes, given how changes to the built environment actually proceed. Earthwork, concrete, utility posts, the relocation of utilities -- these are the types of modifications that people take for granted, but are highly significant for their expense and opportunity cost in the budget cycle of public agencies. One new sensor or communication device on a utility pole will not cost very much, but when contemplated at the scale of the transportation system the cost quickly becomes prohibitive for all but the most wealthy of jurisdictions. The consequences of alterations to the built environment are of course physical, but they are also financial, they are dependent in their financial impact on the contractual arrangements that made them possible, and they matter for the extent to which they give rise to new flows of information, impacts to privacy, and monetization of data about local residents. Lastly, many legal requirements extend from local environmental design, from local speed limits, to liabilities for safety, nuisance, security, and privacy.

Part IV: The Evolving Legal Frameworks for Privacy and Urban Robots

As discussed above, the potential for urban robots to serve as data gathering and surveillance tools will challenge existing societal expectations of what is “private,” as well as the laws that protect privacy. Urban robots will contribute to a trend, already underway, of digital technologies forcing changes to legal frames governing personal data. Currently, the law gives individuals very little control over their data once it has been disclosed to a third party. Once an individual’s

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information has disclosed to a company, for instance on a social media platform like Facebook, the company can analyze, aggregate, and sell that data with very few restrictions as long as they gave notice and obtained consent. The idea is that information that has been made public, that is no longer secret, is not private and therefore not protected. The same reasoning has applied to government and law enforcement access to data. The third-party doctrine means that information shared with a third party is not protected by the Fourth Amendment because it is no longer private. This is why there is no warrant requirement for law enforcement to access the telephone numbers a person dials; when people share those numbers with the phone company they "assume the risk that the information will divulged to the police," even though many people might consider that information sensitive.[157] These legal rules become problematic however when the mere act of existing in an urban public space means that the individual will be subject to extensive recording by robotic sensors. If recording in public spaces is ubiquitous, as it will be with urban robotics, there will be no meaningful way to opt-out of recording without withdrawing from public spaces altogether. The same is true of the third party doctrine. If robots record everything that happens in public, the very act of moving in public spaces will expose personal information to collection by third parties.

There is no federal regulation that addresses this problem, in fact there is no single comprehensive federal privacy law at all.[158] State laws have also struggled to fill this gap. However, some regulators and lawmakers have been innovating, which has led to some noteworthy legal developments.[159] There are at least four approaches to coping with the erosion of privacy in public spaces by ubiquitous computing: 1) adapting existing doctrine and US law, 2) regulating the design and deployment of information systems with limits on collection and use of data, 3) allowing data collection but giving consumers more control over their data, 4) and rethinking the third party doctrine. Privacy law is in a state of flux, and it's future shape of the is unknown. However, as policy makers at all levels experiment with new regulatory approaches, cities will feel the impacts and serve as the test beds for new rules.

Adapting existing laws

The Federal Trade Commission's (FTC) efforts at regulating IoT are emblematic of the first approach: adapting existing laws to cover the uses of new technologies in public spaces. The FTC is the principle privacy regulator in the U.S. Absent an industry-specific law, most private company's privacy practices fall under the FTC's authority to regulate "unfair and deceptive acts and practices in or affecting commerce."[160] The scope of this authority means that the FTC targets companies that break public promises about their privacy practices, for instance through their publicly available privacy policies, but imposes few substantive requirements beyond what

[157] Smith v. Maryland 442 U.S. 735, 45 (1979).
[158] The U.S. takes a sectoral approach to privacy, regulating specific industries or sectors like banking or health. The Federal Privacy Act governs how federal agencies keep a "system of records," but these rules are not relevant to the privacy issues cities will face with robotics. 5 U.S.C. Sec. 552a (5).
[159] Margot Kaminski, *Toward defining privacy expectations in an age of oversharing*, The Economist Aug. 16, 2018 https://www.economist.com/open-future/2018/08/16/toward-defining-privacy-expectations-in-an-age-of-oversharing
[160] 15 U.S.C. Sec. 45(a)(1)

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companies themselves promise. The Commission has not yet brought enforcement action against any commercial robotics company for privacy violations, but its work with IoT device makers suggests how it might handle similar technology.[161]

The Commission is aware of the privacy challenges posed by IoT, and its approach is best captured by the Nomi consent decree.[162] Nomi is a company that partners with retailers to track shopper's locations within stores using sensors that track cell phone mac addresses. This information can tell retailers who visits their stores, how long they spend inside, and even what they want to buy.[163] The FTC enforcement action alleged that the company promised in its privacy policy to inform individuals when they were being tracked and offer an opt-out mechanism, but did neither.[164] Because it broke these promises, the FTC was able to bring a complaint against Nomi for deceptive acts.

The Nomi action highlights the FTC's willingness to enforce privacy rules even in public spaces, but also the limits of its authority. Had Nomi simply tracked individuals without making promises about notice and choice and thereby committing no deceptive act, the FTC would have been largely powerless to stop it.[165] This is the big gap in federal privacy law: absent a sector specific law or regulation, companies can largely do as they please so long as they do not commit a deceptive act.[166] While the FTC has worked hard to adapt to new technologies, it can only do so much with its existing legal tools. Robotics companies operate under this same regime. They can and do deploy sophisticated sensors in public spaces, gathering personal data (such as video footage of people) governed only by the public promises of the company. There is no law stopping companies from reselling this data or using it for a secondary purpose.

The SELF DRIVE Act follows this adaptive approach, requiring AV companies develop a privacy plan that addresses data collection, use, sharing, encryption, and other common privacy practices.[167] The law does not mandate any particular privacy practices or create a minimum level of protections however. For this reason, the SELF DRIVE Act's requirement for AV companies to have a privacy policy may not be adequate to protect privacy. Without more substantive rules to set a floor of protection in company data practices, companies will largely get to set their own rules.

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[161] The FTC has enforced against makers of connected toys for having poor cyber security, but such toys are outside the scope of our discussion.
[162] In the Matter of Nomi Technologies, Inc., no. 132 3251, Federal Trade Commission https://www.ftc.gov/enforcement/cases-proceedings/132-3251/nomi-technologies-inc-matter.
[163] Stephanie Clifford and Quentin Hardy, Attention Shoppers: Store Is Tracking Your Cell, NY Times Jul. 14, 2013 https://www.nytimes.com/2013/07/15/business/attention-shopper-stores-are-tracking-your-cell.html?mtrref=www.google.com
[164] *Id.*
[165] It is theoretically possible that the Commission could have relied on its unfairness authority in such a situation, but highly unlikely.
[166] The Commission has relied on its unfairness authority to enforce against poor cybersecurity practices, however even that authority is in doubt with a recent 11th Circuit ruling. LabMD Inc. v. Federal Trade Commission, No. 16-16270 (2018).
[167] SELF DRIVE Act, H.R. 3388, 115th Cong. Sec 12(a) (2017).

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Regulating the Design and Deployment of Technology

The General Data Protection Regulation (GDPR) is a comprehensive overhaul of European privacy law that, among other things , requires that organizations only collect information when they have a legal basis to do so, and only as much as necessary. The legal bases to collect data are narrowly defined categories like consent or a "legitimate interest" (where the company's interests are carefully weighed against the individual's privacy rights).[168] This requirement applies even where data is collected in public spaces, such as by a CCTV camera. Organizations must conduct a data privacy impact assessment when handling large volumes of sensitive data, and have data retention limits, meaning they can only keep the data as long as they need to. These provisions are much more privacy protective than laws in the U.S.

The GDPR seeks to constrain companies by creating guidelines on how they design and deploy technology. Stiff penalties of up to 4% of global revenue create strong incentives for firms to comply.[169] Firms must now justify the data they collect and apply strict safeguards. They must respect principles of fairness and transparency in their data processing activities. The effect of the law is that firms have afforded new rights to users and revamped their privacy practices to comply with the law. Many have lauded the strong privacy protections, though some worry that the law will stifle the development of AI.

Strengthening Consumer Control

The recently passed California Consumer Privacy Act places fewer restrictions on data collection and minimization and instead seeks to offer consumers more control over the data they share with companies. It creates several rights for individuals, such as the right to request deletion of data and the right to opt out of sharing with third parties. However, the law exempts "publicly available information" from its definition of personal information. This definition will likely limit its protections in public spaces. For example, whether a video recording of a public space captures "publicly available information" is an open question. Though the law seeks to offer consumers more control over their data with strong opt-out and consent requirements, it does not strictly limit what information companies collect or what they can do with it. It remains to be seen whether this approach addresses problems of ubiquitous recording in public. The law is also likely to change, given the unique circumstances under which it was passed.[170] With an effective date of January 1, 2020, there will be much time before the impacts of the law are felt or fully understood.

Doctrinal Reassessment of Privacy in Public

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[168] Regulation 2016/679 of the European Parliament and of the Council [hereinafter GDPR], Chapter II Article 6 Sec. 1.
[169] GDPR Chapter VIII Article 83 Sec 5.
[170] Issie Lapowsky, The Fight Over California's Privacy Bill Has Only Just Begun, Aug. 29, 2018, https://www.wired.com/story/california-privacy-bill-tech-lobbying/

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The Supreme Court has been at the forefront of reshaping privacy doctrine that had previously offered very few protections in public spaces. Recent Supreme Court cases have begun to reconsider the Third Party Doctrine in light of large amounts of personal data that is subject to recording by modern digital technology. The first hint of change came with *U.S. v. Jones*, a case about whether the police needed a warrant to surreptitiously track a suspect's vehicle by attaching a GPS device to the undercarriage.[171] Justice Scalia's majority opinion held that the use of the GPS tracker without a warrant constituted a search because by attaching the device to the defendant's car, police had trespassed against his property.[172] Justices Sotomayor and Alito wrote separate concurrences, with Justices Ginsburg, Breyer, and Kagan joining Alito, supporting a different rationale than Justice Scalia's property-based trespass theory. They reasoned that even though the GPS tracked information that could be observed in public and not normally considered private (the location of the defendant's vehicle on public roads), using technology to collect large amounts of this information could trigger the privacy protections of the Fourth Amendment.[173] Thus, in *Jones* five justices on the Court expressed support for the "Mosaic Theory," that recording and compiling large amounts of public information could violate a person's privacy even if the individual data points were not especially revealing on their own.[174]

The Court again recognized the sensitive nature of digital stores of information in *Riley v. California*, when it held unanimously that examining the digital contents of a cell phone was a Fourth Amendment search requiring a warrant.[175] Chief Justice Roberts reasoned that a cell phones is not simply another piece of property to be searched incident to arrest, but rather a modern tool to store large quantities of potentially sensitive data.[176] He reasoned that the breadth of different types of data, collected in large amounts in one place, could be especially revealing.[177] He concluded by writing that: "Modern cell phones are not just another technological convenience. With all they contain and all they may reveal, they hold for many Americans "the privacies of life."'"[178] Thus, in *Riley* the Court recognizes that the cell phones contain personal information that requires protection by the Fourth Amendment, and that digital technologies that collect large amounts of revealing data can present an acute threat to privacy.

Chief Justice Roberts built on the foundation laid in the previous two cases to reshape the Third-Party Doctrine for the digital age in *Carpenter v. United States*.[179] In *Carpenter*, the Court decided whether the Fourth Amendment required a warrant for an individual's history cell phone

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[171] United States v. Jones, 565 U.S. 400 (2012).
[172] *Id.* at 403-10.
[173] *Id.* at 413-25.
[174] For a discussion of mosaic theory and *Jones*, see Christopher Slobogin Making the Most of *United States v. Jones* in a Surveillance: A Statutory Implementation of Mosaic Theory, 8 Duke J. Const. L. & Pub. Pol'y. 1 (2012); David Gray and Danielle Citron, The Right to Quantitative Privacy, 62 Minn. L. Rev. 98 (2013).
[175] Riley v. California, 134 S. Ct. 2473 (2014).
[176] *Id.* slip op., at 17-8.
[177] *Id.* at 18.
[178] *Id.* at 28.
[179] Carpenter v. United States, No. 16-402, 585 U.S. ___ (2018).

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location records. Investigators in the *Carpenter* case used the Stored Communications Act to request the history of which cell phone towers the defendant' phone had connected with around the same time as a string of robberies in Detroit. The phone's connections to the cell towers revealed the defendant's location around the time of the robberies, which prosecutors used to convict him. Law enforcement was able to acquire the information using the Stored Communications Act (which has a lower standard) instead of a warrant because of the Court's ruling in *Smith v. Maryland* that the individuals have no privacy rights in information they share with third parties like telephone companies.[180]

However, Roberts' opinion declined to extend *Smith v. Maryland* and *United States v. Miller*, and held that the Fourth Amendment required a warrant to access a suspect's cell tower location history.[181] Although it did not overturn *Smith* or *Miller*, by declining to extend those cases to cell tower location history, *Carpenter* marks a significant reversal of the Third-Party Doctrine. Roberts' reasoning relied heavily on the impact of digital technology. Americans share digital data with third parties in quantities and kinds that would have been unfathomable to the framers, and so the new digital reality warrants a change in legal doctrine. Roberts also noted that in the time between Carpenter's conviction and when the Court heard the case, the number of cell towers had greatly increased, which made cell tower location information much more precise and revealing.[182] The proliferation of cell phone towers is analogous to advances in IoT generally and robotics specifically, sensors become more capable and more numerous, and gather even more personal information in public. Professor Orin Kerr sees *Carpenter* as a form of "equilibrium adjustment," where the court adjusts privacy protections to preserve privacy in light of encroachments from new technologies.[183] Roberts' opinion was controversial however, with four Justices dissenting.

Justice Gorsuch's dissent was perhaps the most intriguing, as it proposed an alternate, property-based theory to protect private information shared with third parties. In his lone dissent, he reasoned that positive law may have indicated an intent to treat cell phone location data as private by enacting protections against unauthorized dissemination.[184] Therefore the information about Carpenter's location could be considered his property for Fourth Amendment purposes.[185] If the information was Carpenter's property, then investigators seized it without a warrant in violation of the Fourth Amendment. Gorsuch argued that the property-based theory of the Fourth Amendment was in line with other property-based decisions such as *Jones*, *Jardines*,[186] and *Collins*.[187] He would have preferred to overturn *Katz* and do away with the reasonable

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[180] Smith v. Maryland 442 U.S. 735, 45 (1979).
[181] Carpenter slip op., at 11.
[182] *Id.* at 2.
[183] Orin Kerr, First Thoughts on Carpenter v. United States, Reason Jun. 22, 2018 https://reason.com/volokh/2018/06/22/first-thoughts-on-carpenter-v-united-sta
[184] Carpenter slip op., at 115 (Justice Gorsuch dissenting) https://www.supremecourt.gov/opinions/17pdf/16-402_h315.pdf.
[185] Carpenter slip op., at 118-19.
[186] Florida v. Jardines, 569 US 1 (2013)
[187] Collins v. Virginia, No. 16-1027, 584 US ___ (2018).

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expectation of privacy test in favor of this theory, but lamented that the property theory of the Fourth Amendment had not been briefed or developed by the parties.

The Court is in the middle of a debate about the theoretical underpinnings of Fourth Amendment privacy that will have significant implications for the relationship between technology and privacy in public spaces. More cases addressing new technologies will come before the Court in time, and this debate is likely to intensify as robots are increasingly deployed in public spaces.

Cities as Test Beds of Data Privacy

It is difficult to predict precisely what impact these changes in privacy law will have on cities, but it is almost certain that they will be felt strongly there. Cities are the places where robots, and their accompanying sensors, will be tested and deployed. The physical infrastructure of cities is also likely to be embedded with sensors and computers to allow the robots to interact more smoothly with the built environment. Further, the density of people in cities means that the scale of data collection will be at its greatest in urban areas. Cities have an interest in using the data robotics companies collect and also in protecting the privacy rights of their residents. Do comprehensive privacy protections prevent firms from developing cutting edge technologies? What balance of market power and control between firms and individuals allows for innovation and privacy protection? Will a change in the third party doctrine impact policing practices at the local level? These questions will play out at the local level.[188] As privacy law continues to evolve, cities can serve as test beds for governance not just of the robots but the data those robots collect.

Ira Rubinstein has begun an important exploration of the role of cities in privacy policy-making through "privacy localism."[189] He documents the rise of local privacy laws and surveillance oversight bodies in the cities of Seattle and New York. He argues the federal and state privacy laws leave significant gaps by failing to protect against surveillance in public spaces (the public surveillance gap) and failing to protect local government records (the Fair Information Practices gap).[190] Because privacy localism fills these gaps and fulfills the democratic values inherent in federalism, cities should be allowed to develop their own privacy localist programs within the framework of federalism.[191]

Cities will continue to fill the privacy gap for urban robotics because federal legislative attempts to address privacy issues with robotics are inadequate. As discussed, the SELF DRIVE Act's privacy rules are based on existing, inadequate privacy frameworks that rely on self-regulation through corporate privacy policies. The AV Start Act establishes an AV "Data Access Advisory

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[188] In addition, aldermen in the city of Chicago have introduced a local ordinance that would create opt-in consent and disclosure requirements similar to California's law. City of Chicago Ordinance No. 02018-3240 https://chicago.legistar.com/LegislationDetail.aspx?ID=3480452&GUID=241F981B-94D6-43E8-AC73-D122DBECD413&Options=Advanced&Search=.

[189] Ira Rubinstein, Privacy Localism, New York University School of Law Working Paper Series 18-18

[190] *Id.* at 13-18.

[191] *Id.* at 59-60.

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Committee" to consider the issue of privacy and AVs and issue a report to Congress within 180 days.[192] However, federal regulators are prohibited from issuing new rules on AV privacy until the committee submits its report.[193] So the SELF DRIVE Act establishes no baseline protections for this highly sensitive technology, and the public will not even know what privacy protections result from AV Start for 180 days. Federal rules for drone privacy have also been lacking. The FAA has explicitly declined to issue rules on drone privacy. Meanwhile these technologies are being deployed and tested in urban public spaces and collecting large amounts of data. It is up to cities to set their own rules of the road as the sites of this experimentation.

We agree that cities should be empowered to develop local privacy regimes. Not only does privacy localism comport with the values of federalism, it reflects the fact that impacts of privacy regulations will be felt at most keenly at the local level. Further work is required to explore the implications of robotics on privacy localism, and the role of privacy localism to shape privacy policy-making more broadly.

Part V: Preemption, Cities, and the Governance of Autonomous Systems

This Part is an account of the law of urban robotics. It begins with an overview of federal and state preemption and city police powers, noting that federal and state governments can greatly restrict local authority, although there are some spheres where cities typically exercise their authority. Next, it surveys existing or proposed federal and state robotics laws, with particular attention to preemption issues. We then provide an account of how cities are regulating urban robots and serving as test beds for innovation.

A. Federal Preemption and Home Rule

Two types of preemption are important for this account of urban robotics: federal preemption of states and localities, and state preemption of localities. Federal preemption is where federal law supersedes and invalidates a state or local government law. It is is based on the Supremacy Clause of the US Constitution, which provides that federal law and Constitution are "the supreme Law of the Land; and the Judges in every State shall be bound thereby, any Thing in the Constitution or Laws of any State to the Contrary notwithstanding."[194] The dispositive question for a court in finding federal preemption is whether Congress intended to preempt the states on the matter.[195] If Congress expresses its preemptive intent in the text of the law, it has created express preemption.[196] If a court finds express preemption, it must then determine "the substance and scope of Congress' displacement of state law..."[197] The Supreme Court has said that when statutory preemption language has more than one plausible reading, courts should "accept the reading that disfavors pre-emption."[198]

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[192] AV START Act, S. 1885 115th Cong. Sec 15 (d)(1) (2018). https://www.congress.gov/bill/115th-congress/senate-bill/1885/text#id3A5BBC81EA0B4BF88DA9C458CFC987BC.

[193] AV START Act, Sec 15 (c)(1)

[194] U.S. Const. art. VI, cl. 2.; see also McCulloch v. Maryland, 17 U.S. (4 Wheat.) 316 (1819).

[195] Altria Group v. Good, 555 U.S. 70, 75 (2008).

[196] *Id.*

[197] *Id.* at 76

[198] Bates v. Dow Agrosciences LLC, 544 U. S. 431, 47 (2005)

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If a court finds no language that expressly preempts state law, it may still find implied preemption in the legislation's structure and purpose.[199] Implied preemption takes two forms: conflict preemption and field preemption. With conflict preemption, state or local laws either conflict with federal law or present an obstacle to the Congressional purpose.[200] With field preemption, the Congress has expressed an intent to "occupy the field" on that issue, leaving no room for states to supplement the law or otherwise regulate.[201] For example the Supreme Court has held Illinois licensing and training requirements for hazardous waste handling to be invalided by the Occupational Safety and Health Administration's regulations.[202]

While federal law may be supreme, the constitutional system of federalism provides only certain enumerated powers to the federal government, while reserving all others to the states.[203] The 10th Amendment prevents the federal government from "commandeering" state governments by imposing affirmative duties to do things that they would not otherwise do.[204] For example, Congress may not force states to assume liability for radioactive waste, or use state police resources to conduct federal background checks for firearm purchases.[205] Congress may condition federal grant money on certain state actions, such as raising the drinking age to 21.[206] However the conditions of the grant may not be so onerous that they coerce the states into action.[207]

State preemption of local governments does not operate under the same constitutional framework as federal preemption. While the U.S. Constitution reserves broad power for states in the 10th Amendment,[208] cities are not even mentioned in the document. Broadly speaking there are two views of local power in relation to states: Dillon's rule and Home rule. Under the traditional view described in Dillon's Rule, cities are simply administratively convenient organizations that derive their power from states, so they only have the limited powers granted by the state.[209] They are not themselves sovereign. Discontent with Dillon's rule eventually led states to grant more powers to cities, first on matters of "local concern," and later broader

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[199] Altria Group at 75.
[200] Altria Group.
[201] Gade v. National Solid Wastes Mgmt. Ass'n, 505 U.S. 88, 98 (1992).
[202] *Id.*
[203] U.S. Const. 10th Am.
[204] New York v. United States, 505 U.S. 144 (1992); Printz v. United States, 521 U.S. 898 (1997).
[205] *Id.*
[206] South Dakota v. Dole, 483 U.S. 203 (1987)
[207] National Federation of Independent Business v. Sebelius, 567 U.S. 519 (2012).
[208] U.S. Const. 10th Am. https://www.law.cornell.edu/constitution/tenth_amendment
[209] "Municipal corporations are political subdivisions of the state, created as convenient agencies for exercising such of the governmental powers of the state as may be entrusted to them....The number, nature, and duration of the powers conferred upon these corporations and the territory over which they shall be exercised rests in the absolute discretion of the state." Hunter v. Pittsburgh, 207 U.S. 161, 178 (1907)

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"police powers."[210] Police powers encompass the public's health, safety, welfare, and morals.[211] However, they are still "subject to denial of power in a particular substantive field by specific act of the state legislature."[212] That is, local governments typically do not have unfettered police powers even under home rule. States enact home rule either in their constitutions or legislatively.[213] Home rule powers come in two forms: empowerment/initiative, the ability to enact substantive policy; and immunity, the ability to "resist encroachment from another governmental entity or from a private party."[214]

Despite existing under a different constitutional framework than federal preemption, state preemption of cities often operates in similar ways. As with the federal level, state preemption can be either express or implied.[215] Implied preemption in turn can be either field or conflict, although most states do not use these exact terms.[216] However, the nuances of Home rule versus Dillon's rule and the exact wording of state grants of authority to cities can impact the outcome of state preemption cases[217] For example, Oregon's state constitution has been read to create a presumption *for* preemption in criminal law matters but *against* it in civil matters.[218]

A group of legal experts convened by the American Constitution Society identifies five categories of municipal power. *Structural* authority is the power to choose or modify the form of city government.[219] *Personnel* authority is the power to set employment policies, compensation, and collective bargaining.[220] *Fiscal* authority is the power to "raise revenue, borrow money, and spend."[221] *Proprietary* authority is the power to set policy through the procurement and contracting process, what we call market making.[222] *Regulatory* or functional authority encompasses the "police power" to set substantive policy and regulate health, safety, welfare, and morals.[223] Cities often rely on regulatory power when setting rules for firms, so it is often at issue in state preemption fights.[224]

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[210] Paul Diller, Intrastate Preemption, 87 B.U.L. REV. 1113, 1122-25 (2007)
[211] Richard Briffault et al, *The Troubling Turn in State Preemption: The Assault on Progressive Cities and How Cities can Respond*, American Constitutional Society 4 (2017) https://www.acslaw.org/wp-content/uploads/2017/09/ACS_Issue_Brief_-_Preemption_0.pdf.
[212] Diller at 1125.
[213] Briffault et al at 4.
[214] Nestor M. Davidson, Cooperative Localism: Federal-Local Collaboration in an Era of State Sovereignty, 93 Va. L. Rev. 959, 967 (2007)
[215] Lauren E. Phillips, *Impeding Innovation: State Preemption of Progressive Local Regulations*, 117 Columbia L. Rev. 2225 (2017) https://columbialawreview.org/content/impeding-innovation-state-preemption-of-progressive-local-regulations/
[216] *Id.*
[217] *Id.*
[218] *Id.*
[219] Briffault et al at 3.
[220] Briffault et al at 4.
[221] *Id.*
[222] *Id.*
[223] *Id.*
[224] *Id.*

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Home rule schemes vary a great deal from state to state. In states where the home rule grant is purely legislative, the state can preempt any city action and cities have no immunity.[225] However some state constitutions expressly protect local authority.[226]

Cities and states legislatures have engaged in high profile preemption conflicts on a variety of issues. These issues run the gamut from anti-discrimination rules for transgender individuals, to sanctuary city and minimum wage laws, to municipal broadband and ride-sharing apps.[227] Cities feel that they have an interest in the impact of technological change on the health or safety of their residents, or the provision of city services. Where firms operate new technological platforms in cities, namely ride and room sharing, several states have preempted city regulation.[228] Cities have also sought to impose regulation or alter street design to keep traffic algorithms like Waze from redirecting freeway traffic onto urban and suburban side streets.[229] These recurring debates highlight the fact that cities occupy a legally difficult space when it comes to the source and scope of their power to regulate.

Even with the variety that exists among states, cities tend to have a great deal of authority in certain areas related to environmental design. They typically have broad powers in zoning to determine the nature and character of city neighborhoods.[230] Cities usually control the maintenance of public streets within their territory, although the lines of which government body is responsible for which street can blur.[231] They also regulate the design of public and private spaces by placing restrictions on building height or space between the building and the street (called the "setback").[232] Cities exercise broad taxing authority to raise funds for improvements to public space, manage those improvements, and maintain the condition of the space, either in house or in contract with the private sector. Many utility services, such as parking, electricity, water, communications, wastewater, stormwater, and solid waste, occupy the same rights-of-way and may be publicly owned.

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[225] *Id.*

[226] E.g., COLO. CONST . art. XX, § 6 (declaring that local charters and ordinances involving "local and municipal matters...shall supersede . . . any law of the state in conflict therewith"). [Need other examples]

[227] Nicole DuPois, City Rights in an Era of Preeption: A State-by-State Analysis 2018 Update, National League of Cities (2018) http://www.nlc.org/sites/default/files/2017-03/NLC-SML%20Preemption%20Report%202017-pages.pdf

[228] *Id.*

[229] Lisa W. Foderaro, As apps like Waze reroute commuter traffic, towns fight back, Boston Globe Dec. 24, 2017 https://www.bostonglobe.com/business/2017/12/24/apps-like-waze-reroute-commuter-traffic-towns-fight-back/WqzeqfiikCc9yPtBFkgvbO/story.html

[230] Richard Briffault, Our Localism: Part I--The Structure of Local Government Law 90 Colum. L. Rev. 1, 39-59 (1990).

[231] See e.g. Amanda Gray, Who is responsible for sidewalks: The city, the state, or you?, Goshen News Aug. 3, 2018 http://www.goshennews.com/news/who-is-responsible-for-sidewalks-the-city-the-state-or/article_3a89622d-f811-56ea-853e-734fa7b317a8.html; Maintenance Questions, City of Sacramento (last accessed Aug. 29 2018) https://www.cityofsacramento.org/Public-Works/Questions/Maintenance; Street Maintenance, Richmond, Virginia (last accessed Aug. 29, 2018) http://www.richmondgov.com/PublicWorks/StreetMaintenance.aspx.

[232] E.g. Davis Municipal Code 40.26.010(c) http://qcode.us/codes/davis/?view=desktop&topic=40-40_26-40_26_010. Building Setbacks: What is a setback?, City of Bellevue (last visited Aug. 29, 2018) https://development.bellevuewa.gov/zoning-and-land-use/zoning-requirements/building-setbacks/.

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The preemption debate is already beginning to play out with urban robots. Proposed federal autonomous vehicle legislation has quite broad preemption language. One libertarian think tank has raised the alarm that ride sharing firms will lobby cities to ban individual ownership of autonomous vehicles and urged states to preempt cities on that issue.[233] Several state laws currently preempt city regulation of autonomous vehicles. On the other hand, the states with delivery robot laws on the books explicitly allow cities to regulate such machines.

B. Federal and State Robotics Laws

The following section reviews local, state, and federal laws and policies pertaining to autonomously controlled vehicles, delivery robots, security and entertainment robots, and drones.[234] For each category of robot we examine the interaction between different levels of government and the likely sources of conflict or preemption. We also discuss the impact that preemption might have on the urban built environment or the design of the robots themselves.

AVs

AV regulation in many cities is in danger of preemption by both state and federal laws. Cities have been at the forefront of AV testing and employed sundry regulatory approaches based on local needs and political realities. However some state laws already preempt city regulation of AVs, and proposed federal legislation.

The diversity of local AV regulations reflect the varied needs of cities to control their public rights of way as well current experimental state of this technology. Many cities have pilot programs to implement automated vehicles into their own transportation systems, for example with autonomous buses.[235] For instance, the city of Atlanta has created a "smart corridor" that pairs a

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[233] Marc Scribner, Uber Wants to Make it Illegal to Operate Self-Driving Car in Cities, Competitive Enterprise Institute Feb. 1, 2018 https://cei.org/blog/uber-wants-make-it-illegal-operate-your-own-self-driving-car-cities

[234] Autonomous *flying* cars present a separate set of challenges and do not fit neatly into these categories. Although the flying taxi company Kitty Hawk recently announced an agreement with the government of New Zealand to test its autonomous flying personal vehicles, the Federal Aviation Administration has been less active on the topic of flying cars. The agency has issued exemptions to some of its regulations on general aviation aircraft to come company, but the process is reported to be quite complicated and time consuming. This process could, for example, complicate Uber's promise to deliver flying car service by 2020. See Andrew Ross Sorkin, Larry Page's Flying Taxis, Now Exiting Stealth Mode, NY Times (Mar. 12, 2018) https://www.nytimes.com/2018/03/12/business/dealbook/flying-taxis-larry-page.html; Joe Stumpe, FAA excites nascent flying-car industry, Aerospace America Jan. 3, 2017 https://aerospaceamerica.aiaa.org/faa-excite-nascent-flying-car-industry/; Jacob Bogage, *Flying cars just took a big step closer to being legal*, Wash. Post Jun. 20, 2016 https://www.washingtonpost.com/news/the-switch/wp/2016/06/20/flying-cars-just-took-a-big-step-closer-to-being-legal/?utm_term=.a42f4cdc9a84; Jim Moore, *Uber Promises Flying Cars by 2020*, AOPA Apr. 27, 2017 https://www.aopa.org/news-and-media/all-news/2017/april/27/uber-promises-flying-cars-by-2020.

[235] Advanced Transportation and Congestion Management Technologies Deployment Initiative, San Francisco Municipal Transportation Agency https://www.sfmta.com/sites/default/files/projects/2017/ATCMTD%20Grant%20Application.pdf; Skip Descant, Atlanta's Second Smart Transportation Corridor Takes Shape, Govtech Jun. 22, 2018; Andrew

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driverless bus with smart infrastructure like traffic lights that will communicate with the AV. Cities experimenting with autonomous busses have made infrastructure upgrades that incorporate computers that can communicate with the AVs.[236] In many cases these pilot programs appear to be implemented through public-private partnerships between cities and firms.[237] With the exception of Boston, we have not been able to find publicly available copies of these agreements however.[238] Boston requires compliance with federal AV safety guidelines and strictly controls the driving conditions under which companies can test their AVs.[239] This includes weather conditions, time of day, and presence of safety drivers who can take control of the vehicle in an emergency. Cities such as Ann Arbor and San Jose have also created dedicated physical spaces for automated vehicle testing.[240] They have already begun planning the necessary infrastructure upgrades to accommodate and prepare for widespread automated vehicle deployment.[241] Chandler, AZ has become the first city to modify its zoning laws to accomodate AV passenger pick-up and drop-off.[242] Private companies have proposed dedicated lanes of traffic for AVs both on highways and city streets, although to our knowledge no city has taken steps to implement such lanes yet.[243] And consultants and firms are promoting the necessity of infrastructure upgrades to promote AVs.[244]

In sum, in regulating automated vehicles most cities have relied on their proprietary authority to form public-private partnerships with firms, or their regulatory authority to shape the physical

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J. Hawkins, Las Vegas is expanding its self-driving shuttle experiment, Verge Nov. 6, 2017 https://www.theverge.com/2017/11/6/16614388/las-vegas-self-driving-shuttle-navya-keolis-aaa

[236] Andrew J. Hawkins, Las Vegas is expanding its self-driving shuttle experiment, Verge Nov. 6, 2017 https://www.theverge.com/2017/11/6/16614388/las-vegas-self-driving-shuttle-navya-keolis-aaa; Skip Descant, Atlanta's Second Smart Transportation Corridor Takes Shape, Govtech Jun. 22, 2018.

[237] Global Atlus, Initiative on Cities and Autonomous Vehicles, Bloomberg Philanthropies and the Aspen Institute https://avsincities.bloomberg.org/global-atlas.

[238] Memorandum of Understanding, City of Boston https://www.boston.gov/sites/default/files/document-file-01-2017/template-mou-for-av-testing.pdf

[239] *Id.*

[240] Mcity Test Facility (last visited Aug. 29, 2018) https://mcity.umich.edu/our-work/mcity-test-facility/; Transportation Innovation Zone, City of San Jose (updated Mar. 7, 2017) https://www.arcgis.com/home/item.html?id=68b10f2c69ff42ba97cc2c0efe93edc6.

[241] Advanced Transportation and Congestion Management Technologies Deployment Initiative, San Francisco Municipal Transportation Agency https://www.sfmta.com/sites/default/files/projects/2017/ATCMTD%20Grant%20Application.pdf; Smart Mobility Roadmap, City of Austin at 33 (2017) http://austintexas.gov/sites/default/files/files/Smart_Mobility_Roadmap_-_Final.pdf.

[242] Chandler, AZ, Ordinance No. 4811 Sec 2 https://www.chandleraz.gov/sites/default/files/CC_Ord4811.pdf

[243] Loop NYC, Edg (last visited Aug. 29, 2018) https://vimeo.com/225302665; Benjamin Preston, Berkeley duo's plan to solve traffic jams: hyper-fast lanes for self-driving cars, The Guardian Jun. 3, 2017 https://www.theguardian.com/technology/2017/jun/03/self-driving-cars-high-speed-lane-berkeley-california; Tom Alberg, Daniel Li, and Craig Mundie, Autonomous Vehicle Corridor, Madrona Venture Group http://www.madrona.com/wp-content/uploads/2017/09/MVG-I5-Proposal-Digital.pdf.

[244] Saber Fallah, Driverless cars are forcing cities to become smart, The Conversation Apr. 24, 2018 https://theconversation.com/driverless-cars-are-forcing-cities-to-become-smart-94707; Omri Barzilay, The Road To The Autonomous Age Will Be Paved By Smart Cities, Forbes Jan. 24, 2018 https://www.forbes.com/sites/omribarzilay/2018/01/24/the-road-to-the-autonomous-age-will-be-paved-by-smart-cities/#c1bee4668c3e

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space in which the technologies operate. A notable exception is the ordinance proposed in the City of Chicago, which would limit automated vehicles to permitted firms for test purposes.[245] The law's sponsors cited cybersecurity concerns and potential job losses to automation as motivations.[246] They had considered an outright ban but withdrew that proposal in light of Illinois' preemption of local AV regulations.[247]

As with cities, state lawmakers differ significantly in their approach to AVs. Although Professor Bryant Walker Smith has argued that AVs are generally legal on public roads,[248] many states have passed legislation or issued executive orders regulating them in some way. According to the National Conference of State Legislatures, at the time of writing 21 states have enacted some form of autonomous vehicle legislation, and six more have relevant executive orders.[249] A large majority of states (41) have considered legislation since 2012.[250]

Five of these states, Illinois, Nevada, North Carolina, Tennessee, and Texas, have preempted municipal regulation of autonomous vehicles in their legislation.[251] Illinois' law is the most circumspect. It states that a city may not "enact an ordinance prohibiting the use of Automated Driving System equipped vehicles on its roadways."[252] However cities may still regulate AVs for "traffic control purposes."[253] Nevada prohibits cities from singling out AVs for taxes, permits, or other requirements, but preserves their ability to collect a generally applicable business license fee.[254] Presumably other generally applicable laws are permitted as well. North Carolina, Tennessee, and Texas have much broader preemption, prohibiting any "regulation" of AVs by cities altogether.[255] In addition, cities in Dillon's rule states would not have the authority to

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[245] John Byrne, Aldermen consider tough regulations for self-driving cars, Chicago Tribune Aug. 22, 2017 http://www.chicagotribune.com/news/local/politics/ct-chicago-driverless-cars-regulations-met-20170821-story.html; it appears that the proposal was tabled for further discussion without being officially introduced Brendan Bakala, Alderman Ed Burke argued in favor of a ban on driverless cars with a movie clip from "Back to the Future", Illinois Policy Aug. 23, 2017 https://www.illinoispolicy.org/burke-to-the-future-chicago-alderman-wants-to-ban-self-driving-cars/.

[246] *Id.*

[247] *Id.*

[248] *See* Bryant Walker Smith, Automated Vehicles Are Probably Legal in the United States, 1 Tex A&M L. Rev. 411 (2014).

[249] Autonomous Vehicles | Self-Driving Vehicles Enacted Legislation, National Conference of State Legislatures (last updated Aug. 27, 2018) http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx

[250] *Id.*

[251] See *infra*. Michigan also prevents local governments from levying taxes on the networks used to summon AVs. Michigan Vehicle Code, Act 300 of 1949, Sec. 257.606b (2) http://www.legislature.mi.gov/(S(ysts2wibezgevhgg1cggsvni))/mileg.aspx?page=getObject&objectName=mcl-257-606b&highlight=michigan%20AND%20vehicle%20AND%20code.

[252] Illinois Vehicle Code, ILCS 5/Ch. 11 Art. II Section 11-208 (e) http://www.ilga.gov/legislation/ilcs/ilcs4.asp?DocName=062500050HCh%2E+11+Art%2E+II&ActID=1815&ChapterID=49&SeqStart=111800000&SeqEnd=114550000.

[253] *Id.*

[254] NRS 482A.110 https://www.leg.state.nv.us/NRS/NRS-482A.html#NRS482ASec080.

[255] North Carolina General Statutes Section 20-401(i) https://www.ncleg.net/EnactedLegislation/Statutes/PDF/BySection/Chapter_20/GS_20-401.pdf;

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regulate AVs unless state legislatures expressly grant it. However even Dillon's rule cities would likely have authority over certain local concerns that impact AVs such as zoning, lane placement, and other infrastructure management issues (such as whether to deploy smart infrastructure that can communicate with AVs).

Other state laws such as California have not expressly preempted cities but vested regulatory authority in an administrative agency such as the Department of Motor Vehicles (DMV).[256] This regulatory scheme could have the effect of creating implied preemption, with the DMV taking regulatory power out of the hands of cities. Mayors in San Francisco and Pittsburgh have expressed that this is likely the case, at least as far as being able to ban AVs completely.[257] However the scope of city authority in this regard has not been tested in court.

Massachusetts represents more collaborative model by creating partnerships with the Massachusetts Department of Transportation (MassDOT), companies, and local governments. Executive Order 572 requires companies to enter into a Memorandums of Understanding (MOU) with the agency and the cities where they will operate to operate.[258] MassDOT and participating cities in Massachusetts signed a separate MOU to establish a common application for AV companies, approve testing locations in the cities, and periodically review technical and policy advances in the AV space.[259] Now, in order to put AVs on the road in one of the urban testbeds in Massachusetts like Boston, a company must sign an MOU with the city and then complete a permit application with MassDOT.[260] This process involves numerous commitments from companies including standards for safety drivers, compliance with vehicle safety standards, data sharing, and more.[261] Although Massachusetts' approach is standardized across different cities, it appears to be the result of collaboration between the state and local level rather than dictated from the top. Further, at this stage cities with no wish to allow AV testing on their roads have no obligation to enter into the MOU.

Tennessee Code Annotated Sec. 55-30-105 ; Texas Code Sec 545.452 (b) https://statutes.capitol.texas.gov/Docs/TN/htm/TN.545.htm#545.452.

[256] Cal. Veh. Code Sec 38750 https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=VEH&division=16.6.&title=&part=&chapter=&article=.

[257] Joe Fitzgerald Rodriguez, Mayor calls on self-driving car companies to agree to voluntary SF safety test, San Francisco Examiner Mar. 7, 2018 http://www.sfexaminer.com/mayor-calls-self-driving-car-companies-agree-voluntary-sf-safety-tests/; Timothy B. Lee, *Uber wants to test driverless cars in Pittsburgh again -- the mayor is pissed*, Ars Technica May 24, 2018 https://arstechnica.com/cars/2018/05/uber-wants-to-test-driverless-cars-in-pittsburgh-again-the-mayor-is-pissed/.

[258] Executive Order No. 572, To Promote the Testing and Deployment of Highly Automated Driving Technologies https://www.mass.gov/files/documents/2016/11/pg/eo572.pdf.

[259] Memorandum of Understanding to Facilitate Testing of Autonomous Vehicles http://www.mapc.org/wp-content/uploads/2018/06/Final_AV-MOU.for_.Signing_6-21-18_.pdf

[260] Autonomous Vehicles: Boston's Approach, City of Boston https://www.boston.gov/departments/new-urban-mechanics/autonomous-vehicles-bostons-approach

[261] Memorandum of Understanding, City of Boston https://www.boston.gov/sites/default/files/document-file-01-2017/template-mou-for-av-testing.pdf

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Existing federal guidance and proposed laws envision a dominant and preemptive role for federal regulation of AVs. The National Highway Traffic Safety Administration's (NHTSA) guidance contemplates a dominant role for federal regulators as compared to states.[262] The US Department of Transportation has convened a series of meetings aimed at reducing regulatory barriers and promoting autonomous vehicle technology.[263] NHTSA has solicited comments from the public "to identify any regulatory barriers in the existing Federal Motor Vehicle Safety Standards (FMVSS) to the testing, compliance certification and compliance verification" of autonomous vehicles.[264] Fatal and non-fatal accidents involving AVs have spurred investigations by the National Transportation Safety Board (NTSB).[265]

In *Autonomous Driving Systems 2.0: A Vision for Safety*, the agency "strongly recommends States to allow [the US Department of Transportation] alone to regulate the safety design and performance aspects of [AV] technology. If a State does pursue [AV] performance-related regulations, that State should consult with NHTSA."[266] The agency lists state responsibilities as 1) "Licensing human drivers and registering motor vehicles in their jurisdictions," 2) "Enacting and enforcing traffic laws and regulations," 3) "Conducting safety inspections, where States choose to do so," and 4) "Regulating motor vehicle insurance and liability."[267]

Federal legislation that has passed in the House contains broad preemption language that would prevent states and cities from regulating autonomous vehicles. It contains the following preemption language: "No State or political subdivision of a State may maintain, enforce, prescribe, or continue in effect any law or regulation regarding the design, construction, or performance of highly automated vehicles, automated driving systems, or components of automated driving systems unless such law or regulation is *identical* to a standard prescribed under this chapter" (emphasis added).[268] A "political subdivision of a State" refers to cities and local governments, as cities typically derive their police power from the state. The bill allows cities and states to maintain laws related to "registration, licensing, driving education and training, insurance, law enforcement, crash investigations, safety and emissions inspections,

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[262] It was a federal agency that kickstarted the development of AVs. The Defense Advanced Research Projects Agency (DARPA) Grand Challenge is considered to have set off the current boom in AV research and development. Alex Davies, *Inside the Races that Jump-Started the Self-Driving Car*, Wired Nov. 10, 2017 https://www.wired.com/story/darpa-grand-urban-challenge-self-driving-car/.

[263] US Department of Transportation, Automated Vehicle Activities, https://www.transportation.gov/AV (last visited Feb. 26, 2018).

[264] National Highway Traffic Safety Administration, Department of Transportation; Removing Regulatory Barriers for Vehicles With Automated Driving Systems, 83 Fed. Reg. 2607 (Jan. 18, 2018) (49 CFR 571) https://www.federalregister.gov/documents/2018/01/18/2018-00671/removing-regulatory-barriers-for-vehicles-with-automated-driving-systems (last visited Feb. 26, 2018).

[265] Ryan Beene and Alan Levin, U.S. NTSB Opens Probe of Second Tesla Crash, Bloomberg Jan. 23 2018 https://www.bloomberg.com/news/articles/2018-01-23/u-s-safety-board-opens-probe-of-second-tesla-autopilot-crash; Megan Rose Dickey, *Uber's fatal self-driving car crash prompts NTSB investigation*, TechCrunch Mar 19, 2018 https://techcrunch.com/2018/03/19/ubers-fatal-self-driving-car-crash-prompts-ntsb-investigation/.

[266] DOT AV 2.0, at 20.

[267] DOT AV 2.0, at 20. (The relevant section in the 2016 guidance under Obama was functionally the same).

[268] SELF DRIVE Act, H.R. 3388, 115th Cong. Sec 3(b) (2017).

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congestion management on [State or city streets], or traffic unless the law or regulation is an unreasonable restriction on the design, construction, or performance" of autonomous vehicles.[269] Companies say that this preemption language is necessary to avoid a patchwork of regulation that will hinder innovation, but it has drawn criticism from safety and consumer advocacy groups and state governments.[270]

The Senate AV START Act, which is still pending, originally had the same language as the House version. However, it has been amended to read: "No State or political subdivision of a State may adopt, maintain, or enforce any law, rule, or standard regulating the design, construction, or performance of a highly automated vehicle or automated driving system with respect to any of the safety evaluation report subject areas described in section 30107(b)."[271] This language is less broad than the House bill and preserves some powers specifically for state and local governments: "Nothing in this paragraph may be construed to prohibit a State or political subdivision of a State from maintaining, enforcing, prescribing, or continuing in effect any law or regulation regarding the sale, distribution, repair, or service of highly automated vehicles, automated driving systems, or components of automated driving systems by a dealer, manufacturer, or distributor."[272] However one of the preempted subjected areas in section 30107(b) is the "expected operational design domain" of AVs.[273] This means that AV Start preempts cities and states with respect to "any roadway and infrastructure assets required for the operation of the highly automated vehicle or automated driving system, such as roadside equipment, pavement markings, signage, and traffic signals, and how it will respond if that operational design domain unexpectedly changes."[274] By extending the meaning of "design, construction, or performance" to the AV's operational domain, the ambit of AV Start's preemption is potentially very broad.

Both state and federal preemption of cities in the area of AV regulation are likely to be significant constraints of city authority. An exhaustive analysis of every state's constitutional scheme regarding Home rule versus Dillon's rule is beyond the scope of this paper, but state laws that expressly preempt city AV laws will face few if any limitations. As noted above, several states expressly prohibit cities from regulating AVs in any form. Even without express language, cities may still be limited by implied preemption by state AV statutes. California's approach is an example of implied preemption effectively limiting cities. Because California DMV regulations

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[269] *Id.*

[270] Andrew J. Hawkins, *Congress is about to hand over the keys to the big self-driving car companies -- and that's a problem*, The Verge Jul. 19, 2017 https://www.theverge.com/2017/7/19/15998356/self-driving-car-congress-legislation-lobbying-safety; Tina Bellon, *U.S. push for self-driving law exposes regulatory divide*, Reuters Sep. 15, 2017 https://www.reuters.com/article/us-autos-selfdriving-analysis/u-s-push-for-self-driving-law-exposes-regulatory-divide-idUSKCN1BQ24J; David Alpert, *Have senators? Ask them to let cities and states shape how autonomous vehicles affect us all*, Greater Greater Washington Oct. 3, 2017 https://ggwash.org/view/65027/have-senators-let-cities-and-states-shape-autonomous-vehicles-avs-affect-us-preemption-congress.

[271] AV Start Sec. 3 (a)(3)(A)

[272] AV Start Sec. 3 (a)(3)(C)

[273] AV Start Sec. 9 (a)

[274] *Id.*

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allow AVs on the state's public roads, cities there are powerless to ban AV access on their streets.[275] Such a ban would likely conflict with state law and therefore be preempted. However there are many forms of regulation that fall short of an outright ban. Suppose a city wanted to create certain AV-free zones near public parks, or impose lower AV speed limits. Or perhaps it wanted to pass a rule requiring AVs to always yield to pedestrians. If courts apply broad field preemption or its functional state law equivalent then cities will be foreclosed from doing so. If conflict preemption applies then cities will have more control over their public rights of way. Imagine if a legislature mandated the creation of AV hyperlanes, as some in Washington state have advocated. Such a mandate could take important local decisions about street and sidewalk allocation and design out of the hands of the hands of the places that are most impacted.

State preemption could also deprive of cities of important sources of revenue that may be lost as AVs transform the tax base of cities. If widespread AV fleets eliminate urban parking as some have predicted, then cities will lose a significant source of revenue. A city wishing to levy a tax on AVs to make up for this loss in Nevada, North Carolina, Tennessee, or Texas would be barred from doing so.

Proposed federal AV legislation would also create a great deal of uncertainty for cities. The SELF DRIVE Act's prohibition against "unreasonable" restrictions on AV "design, construction, or performance," could be read quite broadly, especially because it applies to congestion management and traffic laws.[276] If constantly roaming AV fleets lead to an increases in miles traveled, traffic congestion, and urban sprawl as some predict,[277] then cities would naturally want to enact policies to combat these problems. Is surge or congestion pricing aimed at AVs a "unreasonable restriction"? An AV company looking for a sword to wield against cities certainly might think so. As discussed above, the AV Start Act is narrower than SELF DRIVE, but the meaning of the term "performance" presents a possible problem for cities. Some AVs can communicate with smart infrastructure and may even rely on these vehicle-to-infrastructure (V2I) capabilities to some extent.[278] However, installing smart infrastructure can be expensive and time consuming. It is at least arguable that a city that refuses to install the "I" of V2I capabilities is hindering the performance of an AV. This interpretation is bolstered by the bill's definition of the "expected operational design domain," which includes infrastructure. Even "dumb" infrastructure impacts AV capabilities. For instance, many AVs have difficulty navigating

[275] California regulations do require firms to submit law enforcement interaction plans to cities, so there is some coordination built into the law. California Department of Motor Vehicles, Order to Adopt, 227.38 (e) https://www.dmv.ca.gov/portal/wcm/connect/a6ea01e0-072f-4f93-aa6c-e12b844443cc/DriverlessAV_Adopted_Regulatory_Text.pdf?MOD=AJPERES&CVID=

[276] SELF DRIVE Sec. 3 (1)

[277] Sarah J. Fox, *Planning for Density in a Driverless World*, 9 Ne. L. Rev. 151 (2017); Jacques Leslie, *Will Self-Driving Cars Usher in a Transportation Utopia or Dystopia*, Yale Environment 360 Jan. 8, 2018 https://e360.yale.edu/features/will-self-driving-cars-usher-in-a-transportation-utopia-or-dystopia.

[278] Conner Forest, *The X-factor in our driverless future: V2V and V2I*, ZDNet Feb. 1, 2018.

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traffic lanes are faded or signs obscured.[279] The local built environment can be a significant factor in AV safety and performance yet it is unclear whether and how AV Start would constrain cities in this regard. Both laws may encroach on the traditional sphere of authority of cities if they are construed too broadly.

It is also unclear how state privacy rules might fare under Federal preemption language in the AV START and SELF DRIVE Acts. The House bill currently requires companies to formulate a privacy policy for automated vehicles.[280] Having a policy will open companies to enforcement action by the FTC if they break the promises contained therein. State AGs may bring similar actions under state law. However, some states have substantively stricter privacy rules that may create an "unreasonable restriction" on automated vehicles. For example, Texas or Illinois' law against collection of biometric data could interfere with facial recognition capabilities in automated vehicles.[281]

Delivery robots

Cities have also been on the forefront of experimenting with delivery robots. Several cities including Washington DC; Austin, Texas; and a few cities in the San Francisco Bay Area, have created pilot programs either through partnerships with firms or by passing an ordinance to allow delivery robots.[282] The Austin ordinance is public, and Redwood City has published its partnership agreement along with reports on the pilot.[283] These laws and agreements tend to follow the same pattern. They define where the robots may operate (on sidewalks, not on highways), and create a permitting system for firms to gain permission to test the robots.[284] They also define certain parameters for the robot such as the maximum weight and speed, and impose certain safety requirements, such as not to interfere with pedestrians or bicycles.[285] Not every city is so welcoming however. San Francisco passed an ordinance that heavily regulates PDDs.[286] The law requires a permit for each robot being tested and limits the total number of

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[279] Alexandria Sage, *Where's the lane? Self-driving cars confused by shabby U.S. roadways*, Reuters Mar. 31, 2016 https://www.reuters.com/article/us-autos-autonomous-infrastructure-insig/wheres-the-lane-self-driving-cars-confused-by-shabby-u-s-roadways-idUSKCN0WX131.

[280] SELF DRIVE Sec. 12.

[281] These laws have already prevented a google facial recognition app from running in both states. Melissa Locker, Google's art selfie app not working in Texas or Illinois? Thank tricky biometric laws, Fast Company Jan. 18, 2018 https://www.fastcompany.com/40518224/googles-art-selfie-app-not-working-in-texas-or-illinois-thank-tricky-biometric-laws

[282] Kat Londorf, Hungry? Call Your Neighborhood Delivery Robot, National Public Radio Mar. 23, 2017 https://www.npr.org/sections/alltechconsidered/2017/03/23/520848983/hungry-call-your-neighborhood-delivery-robot; Conditions of Approval for Personal Delivery Device "PDD" Use Permit, Redwood City Nov. 13, 2017; Resolution 20170810-12, City of Austin http://austintexas.gov/edims/document.cfm?id=282589.

[283] Resolution 20170810-12, City of Austin http://austintexas.gov/edims/document.cfm?id=282589; Conditions of Approval for Personal Delivery Device "PDD" Use Permit, Redwood City Nov. 13, 2017.

[284] *Id.*

[285] *Id.*

[286] Autonomous Delivery Devices on Sidewalks - Permit Required, California Public Works Code, Sec. 794 https://sfpublicworks.org/sites/default/files/Autonomous%20Delivery%20Devices%20Legislation.pdf;

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permits to nine at any given time.[287] It also requires a human operator be present at all times and limits testing to industrially zoned areas away from high traffic.[288] The law was said to be motivated by safety concerns, although media reports say the legislator who introduced the ordinance considered an outright ban originally.[289]

State and federal regulation of delivery vehicles is more nascent than laws for autonomous vehicles and more permissive for cities. As of writing, six states have enacted laws to specifically allow and regulate delivery robots (called PDDs for "personal delivery devices"): Florida, Idaho, Ohio, Virginia, Wisconsin and Arizona.[290] Each state allows cities to pass their own PDD regulations or safety requirements, a marked difference from state AV laws.[291]

There is currently no federal law directly addressing PDDs. It is possible that the SELF DRIVE and AV Start Acts could apply to PDDs, though that is far from clear. Both laws refer to section 30102 of chapter 49 of the US code, which defines a motor vehicle as "a vehicle driven or drawn by mechanical power and manufactured primarily for use on public streets, roads, and highways, but does not include a vehicle operated only on a rail line."[292] While this definition arguably does not apply to PDDs that operate primarily on sidewalks, it could apply to larger delivery robots that operate on city streets.

At least for the moment cities can regulate PDDs as they wish, free from preemption at the state or federal level. One interesting phenomenon is that we have not found any active PDD pilot programs in cities where the state has passed a PDD enabling law, even though the laws in each state explicitly allow cities to regulate PDDs for safety, or in some cases ban them outright. It could be that pilot programs are simply not necessary where state law has already cleared the way for PDDs to operate on city streets. However, it is curious that no cities in states with PDD laws have created their own institutional arrangements for this technology on their streets. It is

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For a general discussion of the San Francisco permit system, see Autonomous Delivery Devices, San Francisco Public Works https://sfpublicworks.org/services/permits/autonomous-delivery-devices

[287] Autonomous Delivery Devices on Sidewalks - Permit Required, California Public Works Code, Sec. 794 https://sfpublicworks.org/sites/default/files/Autonomous%20Delivery%20Devices%20Legislation.pdf

[288] *Id.*

[289] See Adam Brinklow, San Francisco bans robots from most sidewalks, SF Curbed Dec. 6, 2017 https://sf.curbed.com/2017/12/6/16743326/san-francisco-delivery-robot-ban; Brian Heater, San Francisco made things much tougher for robotic delivery startups this week, TechCrunch Dec. 7, 2017 https://techcrunch.com/2017/12/07/san-francisco-made-things-much-tougher-for-robotic-delivery-startups-this-week/.

[290] Florida Legislature CS/HB 1027 (2017) https://www.flsenate.gov/Session/Bill/2017/1027/BillText/er/PDF; Idaho Legislature HB 204 (2017) https://legislature.idaho.gov/sessioninfo/2017/legislation/H0204/; Ohio Legislature HB 49 Gen. Assemb. 132 (2017) https://www.legislature.ohio.gov/legislation/legislation-summary?id=GA132-HB-49; Virginia Legislature S. 1207 2017 Sess. (2017) https://lis.virginia.gov/cgi-bin/legp604.exe?171+ful+CHAP0251; Wisconsin Legislature Act 13 SB148 (2017) http://docs.legis.wisconsin.gov/2017/related/acts/13; Arizona Legislature HB2422 53rd Sess. (2018) https://legiscan.com/AZ/text/HB2422/id/1688912.

[291] Arizona Revised Statutes 28-627 (A)(14) (Arizona permits cities to apply reasonable regulations, but not to ban PDDs outright); Wisconsin Statutes 349.236; Code of Virginia 46.2-904; Idaho Code 49-605; Florida Statutes 316.008 (7)(b)1; Ohio Revised Code 4511.513.

[292] 49 USC Section 30102 (a)(7). https://www.law.cornell.edu/uscode/text/49/30102.

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possible that state laws have inhibited independent regulation of PDDs by cities by signaling the priorities of state legislatures.

Security and entertainment

As with federal and state law, security robots have largely escaped regulatory attention at the city level. San Francisco is again a notable exception. In a widely publicized incident, residents complained about a Knightscope robot being used to chase off homeless people in the frontage space and parking area of a local SPCA animal shelter in the Tenderloin district.[293] The city's department of public works demanded the SPCA cease using the robot because it was traversing public sidewalks.[294] The source of the department's authority is unclear and has not been publicly disclosed.

There has also been local action that would impact police use of robots. A member of the board of supervisors of San Mateo County drafted a resolution calling on Congress and the United Nations to ban killer robots, although he later withdrew it and the board agreed to study the issue further.[295] More substantively, Santa Clara County and the Cities of Oakland, Berkeley, and Seattle have passed surveillance ordinances requiring citizen approval before police departments acquire new surveillance equipment.[296] Cities could easily use their proprietary power over municipal police departments to regulate vendor agreements with the makers of any future police robots, even in the absence of a surveillance ordinance.[297]

Entertainment robots are also largely unregulated, although that could change to the extent that they cross over into other, more regulated use cases. Recall the discussion of Loomo's use for package delivery and the possibility of a "follow me" suitcase.

Security robots have thus far escaped the attention of state and federal regulators. This is probably due to the fact that they mostly operate on private property, by private actors. Or perhaps they are simply less widespread, or seen as disrupting a less vital industry than transportation or last-mile delivery. Should they evolve into government controlled police robots, they will warrant greater regulation by state and federal actors. Professor Elizabeth Joh has

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[293] Sarah Buhr, Security robots are being used to ward off San Francisco's homeless population, TechCrunch Dec. 13, 2017 ttps://techcrunch.com/2017/12/13/security-robots-are-being-used-to-ward-off-san-franciscos-homeless-population/.

[294] Alisha Green, Security Robot that deterred homeless encampments in the Mission gets rebuke from the city, San Francisco Business Times Dec. 8, 2017 https://www.bizjournals.com/sanfrancisco/news/2017/12/08/security-robot-homeless-spca-mission-san-francisco.html.

[295] San Mateo County Board of Supervisor Meeting Minutes. Dec. 12, 2017.

[296] Santa Clara County, California Code of Ordinance, Title A, Div. A40; City of Oakland, California Code of Ordinance, 9.64; Berkeley Municipal Code 2.99; Seattle Municipal Code, 14.18.

[297] Richard Briffault et al, *The Troubling Turn in State Preemption: The Assault on Progressive Cities and How Cities can Respond*, American Constitutional Society 4 (2017) https://www.acslaw.org/wp-content/uploads/2017/09/ACS_Issue_Brief_-_Preemption_0.pdf; but see Elizabeth E. Joh, The Undue Influence of Surveillance Technology Companies on Policing, 92 NYU L. Rev. 101 (2017) http://www.nyulawreview.org/sites/default/files/Joh-FINAL_0.pdf.

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predicted such a development and called for "uniform national policies" for police robots, such as the use of conditions or strings attached to federal procurement grants to require police departments enact policies governing the use of robotic force.[298]

As with security robots, entertainment robots are currently unregulated at the state and federal levels. This may be just as well, as most have not even been deployed in commerce yet. In some cases the regulations for PDDs may apply, such as with Gita, the droid designed to "fit a case of wine."[299] Segway is also marketing package delivery as a possible use case for Loomo.[300] Loomo's ability to carry people may qualify it to operate on city sidewalks as a type of personal mobility devices under state law. Officials in the city of Austin speculated this would be true under Texas law.[301] It is possible that as these types of urban robots proliferate new laws may be proposed, but it is a little premature to speculate now.

Drones

Drones are a unique case for this paper because they fly, and are therefore regulated by the Federal Aviation Administration, and because they have applications that cut across the categories of urban robots we have explored thus far. Autonomous drones that are large enough to fit a person could serve as a type of flying robo taxi, while last-mile drone delivery has been a goal of companies (especially Amazon) for some time.[302] Startup companies are working on security drones to monitor property, an aerial version of Knightscope,[303] and the recreational drone was the "hot holiday gift" of the past few years.[304] One project even proposes to use drones to repair urban infrastructure.[305] Drone use cases extend to several other fields such as construction and surveying, agriculture, and the military, but the four categories of urban robotics are what interest us here.

Of all of these technologies, drones have seen the most local legislative action. This may be because domestic drones hit the market earlier than other forms of robotics, or because drones

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[298] See Elizabeth E. Joh, Policing Police Robots, 64 UCLA L. Rev. Disc. 516, 542 (2016) https://www.uclalawreview.org/policing-police-robots/.
[299] Ian Bogost, *The Cute Robot That Follows You Around the City*, The Atlantic, Feb 28, 2018, https://www.theatlantic.com/technology/archive/2018/02/piaggio-gita-jeffrey-schnapp/554222/
[300] Loomo Go, Segway Robotics (Mar. 9, 2018) available at https://web.archive.org/web/20180309082600/https://www.segwayrobotics.com/loomoGo.
[301] Robert Spillar, Staff Response to Council Resolution No. 20170504-039 -- Robotic Delivery Model, Austin Transportation Department, at 4 Jun. 8, 2017 http://www.austintexas.gov/edims/pio/document.cfm?id=278182
[302] Amazon Prime Air, Revising the Airspace Model for the Safe Integration of Unmanned Aircraft Systems (2015) https://s3.amazonaws.com/s3.documentcloud.org/documents/2182311/amazon-revising-the-airspace-model-for-the-safe.pdf.
[303] See e.g. Nightingale Security https://www.nightingalesecurity.com/ (last visited Aug. 30, 2018); Aptonomy Aerial Security http://www.aptonomy.com/ (last visited Aug. 30, 2018).
[304] John Cropley, Drones expected to be popular gift again in 2017, Daily Gazette Nov. 24, 2017 https://dailygazette.com/article/2017/11/24/drones-expected-to-be-popular-gift-again-in-2017.
[305] Linda Poon, *Drones Will do the Dirty Work in a 'Self-Reporting City'*, CityLab Oct. 20, 2015 https://www.citylab.com/life/2015/10/in-a-self-repairing-city-drones-do-the-dirty-work-of-infrastructure-maintenance/411526/.

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incited a more visceral reaction in the public (serving as a "privacy catalyst").[306] The National League of Cities cites Chicago's drone ordinance, passed in November 2015, as one of the first comprehensive drone law in a major city.[307] The ordinance places a number of prohibitions on drone flights, such as: flying directly over a person or private property without consent; flying over a school, hospital, place of worship, prison, or police station; flying outside visual line of sight, flying between dusk and dawn, and flying for the purpose of surveillance.[308] A 2017 study by the Center for the Study of the Drone found 133 local drone ordinances in 33 different states.[309] The author found the most common rules to be restrictions against flying over public property or private property without the owner's consent.[310]

Cities may also enforce general regulations already on the books that can be applied to drones. Simple criminal matters involving a drone are within the scope of city power to regulate. An assault committed with a drone is still an assault. For instance, the City of Seattle successfully prosecuted a reckless endangerment case against a man who lost control of his drone and crashed it into a woman during the 2015 Pride Parade.[311] Seattle has no law specific to drone endangerment, it simply prosecuted the man under Washington's reckless endangerment statute.[312]

Though there is a great deal of variety among state drone laws, many states have taken barred cities from regulating drones. According to the National Conference of State Legislatures, 41 states have enacted laws relating to drones in some form, and three more have adopted resolutions.[313] State drone laws range from anti-peeping Tom or voyeurism laws (California), to designations of "critical infrastructure that define the permissible airspace for drones (Nevada), to prohibitions on weaponizing drones (Oregon), to criminal sanctions on harming people or livestock (Utah).[314] Several states have some kind of express preemption for local drone

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[306] M. Ryan Calo, *The Drone as Privacy Catalyst*, 64 Stan. L. Rev. Online 29 (2011) http://www.stanfordlawreview.org/wp-content/uploads/sites/3/2011/12/64-SLRO-29_1.pdf.

[307] Cities and Drones: What Cities Need to Know About Unmanned Aerial Vehicles (UAVs), National League of Cities, 20 (2016) http://uavs.insct.org/wp-content/uploads/2016/09/NLC-Drone-Report.pdf.

[308] Chicago Municipal Code, Small Unmanned Aircraft, 10-36-400 http://library.amlegal.com/nxt/gateway.dll/Illinois/chicago_il/municipalcodeofchicago?f=templates$fn=default.htm$3.0$vid=amlegal:chicago_il.

[309] Arthur Holland Michel, *Drones at Home: Local State Drone Laws*, Center for the Study of the Drone at Bard College, 2 (2017) http://dronecenter.bard.edu/files/2017/03/CSD-Local-and-State-Drone-Laws-1.pdf.

[310] *Id.*

[311] John-Michael Seibler, *Seattle Case Shows Why Drone Regulation Should Be Local, Not Federal*, Daily Signal Mar. 9, 2017 http://dailysignal.com/2017/03/09/seattle-case-shows-why-drone-regulation-should-be-local-not-federal/

[312] *Id.* Seattle does have a proscription against flying motorized aircraft in public parks, but it was not at issues in that case. Seattle, Washington - Municipal Code, Motorized Models 18.12.265 https://library.municode.com/wa/seattle/codes/municipal_code?nodeId=TIT18PARE_CH18.12PACO_SUBCHAPTER_VIIUSRE_18.12.265MOMO.

[313] Current Unmanned Aircraft State Law Landscape, National Conference of State Legislatures (updated Feb. 1, 2018) http://www.ncsl.org/research/transportation/current-unmanned-aircraft-state-law-landscape.aspx.

[314] Cal. Civil Code Sec 1708.8 (2018); Nevada Rev. Statutes Sec 493.020 (2) (2018); Oregon Rev. Statutes Sec 837.365 (1) (2018); Utah Code Ann. 76-9-308 (2)(c) (2018). See also Current Unmanned

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regulation.[315] For instance, Florida prohibits a a city from regulating the "design, manufacture, testing, maintenance, licensing, registration, certification, or operation" of a UAV,[316] though cities may still enforce generally applicable laws that are not targeted at drones, such as nuisance, voyeurism, and reckless endangerment.[317] Connecticut enumerates similar categories where cities are forbidden to regulate.[318] By our count, ten other states preempt more broadly, prohibiting cities from enacting *any* regulation relating to drones except in very limited circumstances.[319] Wyoming however takes a more collaborative approach, establishing a commission to promulgate rules in cooperation with the the drone industry and local governments.[320]

Even with all the activity by cities and states, the federal government remains the principal regulator of drones, setting the rules that govern commercial drone operation. The Federal Aviation Administration (FAA) is the federal body charged by Congress to write rules to "safely accelerate the integration of civil unmanned aircraft systems into the national airspace

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Aircraft State Law Landscape, National Conference of State Legislatures (updated Feb. 1 2018) http://www.ncsl.org/research/transportation/current-unmanned-aircraft-state-law-landscape.aspx; Arthur Holland Michel, *Drones at Home: Local State Drone Laws*, Center for the Study of the Drone at Bard College, 2 (2017) http://dronecenter.bard.edu/files/2017/03/CSD-Local-and-State-Drone-Laws-1.pdf.

[315] Arthur Holland Michel, *Drones at Home: Local State Drone Laws*, Center for the Study of the Drone at Bard College, 2 (2017) http://dronecenter.bard.edu/files/2017/03/CSD-Local-and-State-Drone-Laws-1.pdf.

[316] Florida Statutes Sec 330.41 (3)(b) (2018)

[317] Florida Statutes Sec 330.41 (3)(c) (2018)

[318] General Statutes of Connecticut Sec 7-149b (b)

[319] Texas Statutes 423.009 © (2017) https://statutes.capitol.texas.gov/Docs/GV/htm/GV.423.htm; Code of Georgia Annotated Sec. 6-1-4 (b) (2018) https://advance.lexis.com/documentpage/?pdmfid=1000516&crid=be55ebc6-2f53-4aaa-98da-fbea630b35f1&nodeid=AAGAACAAE&nodepath=%2FROOT%2FAAG%2FAAGAAC%2FAAGAACAAE&level=3&haschildren=&populated=false&title=%C2%A7+6-1-4.+Unmanned+aircraft+system+defined%3B+preemption+for+unmanned+aircraft+systems%3B+operations&config=00JAA1MDBlYzczZi1lYjFlLTQxMTgtYWE3OS02YTgyOGM2NWJlMDYKAFBvZENhdGFsb2fed0oM9qoQOMCSJFX5qkd&pddocfullpath=%2Fshared%2Fdocument%2Fstatutes-legislation%2Furn%3AcontentItem%3A5STN-9BW0-004D-81BS-00008-00&ecomp=-Jxvkkk&prid=7746deca-fe70-4701-8c92-7ad2b5f092de; Luisiana Rev. Statutes Sec 2.2 A.(2) (2018) https://legis.la.gov/legis/Law.aspx?d=81828; New Jersey Rev. Statutes Sec 2C:40-29 (5) (2018) https://lis.njleg.state.nj.us/nxt/gateway.dll/statutes/1/2706/3281?f=templates$fn=document-frameset.htm$q=%5Brank,100%3A%5Bdomain%3A%5Band%3Aunmanned%20aircraft%5D%5D%20%5Bsum%3Aunmanned%20aircraft%5D%20%5D%20$x=server$3.0#LPHit1; Utah Code Ann. Sec 72-14-103 (1) (2018) https://le.utah.gov/xcode/Title72/Chapter14/72-14-S103.html?v=C72-14-S103_2017050920170509; Arizona Rev. Statute Sec 13-3729 C (2018) https://www.azleg.gov/legtext/52leg/2r/bills/sb1449h.pdf; Michgan Compiled Laws 259.305 Sec 5.(1) (2018) http://www.legislature.mi.gov/(S(xi0urzn0p3v1dfmjkap0wflb))/mileg.aspx?page=getobject&objectname=mcl-259-305&query=on&highlight=unmanned; Code of Virginia Sec 15.2-926.3 (2018) https://law.lis.virginia.gov/vacode/title15.2/chapter9/section15.2-926.3/; Delaware Code Sec 1334(e) (2018) http://delcode.delaware.gov/title11/c005/sc07/index.shtml; Maryland Code Sec 14-301(c) (2018) http://mgaleg.maryland.gov/2015RS/bills/sb/sb0370E.pdf. Montana only prohibits cities from regulating drones in relation to wildfires. Montana Code Annotated Sec 7-1-111 (19) (2018) https://leg.mt.gov/bills/mca/title_0070/chapter_0010/part_0010/section_0110/0070-0010-0010-0110.html.

[320] Wyoming Statutes Sec 10-3-201 (j) (2018) http://wyoleg.gov/NXT/gateway.dll?f=templates&fn=default.htm.

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system."[321] The result is the "small unmanned aircraft systems [UAS] rule" codified in 14 CFR 107.[322] Section 107 applies to drones under 55 pounds and requires that recreational and commercial drone (also called UAS) operators obtain a drone pilot certificate and register their drone with the FAA.[323] The rules for safe operation also prohibit flying over 400 feet, flying over people, and flying outside visual line of sight of the operator.[324] However, these safe operation rules can be waived with a "107 waiver" from the FAA.[325] Legislation introduced in the Senate in 2017 directs the FAA to create an "air carrier certificate" for companies to conduct package delivery via drone.[326] Congress' drone mandate made no mention of preemption, nor do the FAA regulations.

Proposed additional federal legislation seeks to clarify and preserve the authority of state and local governments to regulate drones. The Drone Federalism Act of 2017 directs the FAA to "ensure that the authority of a State, local, or tribal government to issue reasonable restrictions on the time, manner, and place of operation of a civil unmanned aircraft system that is operated below 200 feet above ground level or within 200 feet of a structure is not preempted."[327] It also requires the FAA to receive permission from property owners before authorizing "the operation of a civil unmanned aircraft in the immediate reaches of the airspace above property."[328] Congress has taken or at least considered a much more collaborative approach with states and cities for drones than for AVs.

Statements by the FAA and a recent federal district court case indicate that federal drone rules operate under conflict preemption, leaving room for states and cities to regulate so long as they do not conflict with federal law. In 2015 the FAA's Office of Chief Counsel issued a document that warned states and localities against creating a patchwork of rules that would hinder nationwide UAS safety, but listed examples of where states and localities would have authority to act.[329] Examples include warrant requirements for police use of drones, or peeping tom

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[321] FAA Modernization and Reform Act, Pub. L. No. 112-095, Section 332 (a)(1) 126 Stat. 111 (2012) https://www.congress.gov/bill/112th-congress/house-bill/658/text.
[322] 14 CFR 107 https://www.law.cornell.edu/cfr/text/14/part-107.
[323] 14 CFR 107.3-13 The registration requirement was struck down by a federal court in 2017 (Taylor v. Huerta (No. 15–1495; decided on May 19, 2017)), but later reinstituted by Congress National Defense Authorization Act of 2018 H.R. 2810, Section 1092 (d).
[324] 14 CFR 107.51
[325] 14 CFR 107.205
[326] S. 1405, 115th Cong. Sec 2136 "Small UAS Air Carrier Certificate" (2017-18) https://www.congress.gov/bill/115th-congress/senate-bill/1405/text#toc-id488e863d365a47cbbc1db9205799f44c.
[327] Drone Federalism Act of 2017, S. 1272 115th Cong. Sec 2 (b)(1) (2017) https://www.congress.gov/bill/115th-congress/senate-bill/1272/text
[328] *Id.* Sec. 3 (a)
[329] State and Local Regulation of Unmanned Aircraft Systems (UAS) Fact Sheet, Federal Aviation Administration (2015) https://www.faa.gov/uas/resources/uas_regulations_policy/media/uas_fact_sheet_final.pdf; see also Charles Raley, Local and State UAS Enforcement Authorities, FAA UAS Symposium (2017) https://www.faa.gov/uas/resources/event_archive/2017_uas_symposium/media/Workshop_7_Local_and_State_UAS_Enforcement_Authorities.pdf.

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laws.[330] The agency also recently instituted a program for states, cities, and tribal authorities to partner with companies to bypass existing regulations more easily and experiment with advanced UAS applications at the local level.[331]

A recent court case also concluded that the FAA rules operated under conflict preemption, not field preemption. *Singer v. Newton* related to a city ordinance that sought to impose certain regulations on drone flight within the city.[332] The city of Newton, Massachusetts passed a drone ordinance that applied to drone flights within the city limits. Michael Singer, an FAA-certified drone pilot who resides in Newton, challenged provisions that required drone operators register with the city, banned flights over private property without the property owner's permission, banned flights over Newton city property without permission, and required visual line of sight flight.[333] The ordinance also banned drone surveillance and interference with manned aircraft, but Singer only challenged the previous four provisions.[334] He argued that air safety is normally solely regulated by the FAA, so field preemption should apply.[335] However, Judge Young noted the FAA's statements about preserving some authority for state and local governments to regulate.[336] At the same time, he concluded that the FAA had not created "an express carve-out for states and localities to regulate," but rather hinted that "whether parallel regulations are enforceable depends on the principles of conflict preemption."[337]

The judge invalided each of the challenged provisions under conflict preemption. The FAA expressed its intent to be the "exclusive regulatory authority" for drones in the navigable airspace, and therefore the city's registration provision was invalid.[338] The judge concluded that Newton's requirement that drone flights over private and public property first obtain permission was effectively a ban on drone flights over the city, which frustrated the FAA and Congress' intent to integrate drones into the airspace.[339] Finally, the judge ruled that the line of sight rule impermissibly intervened "in the FAA's careful regulation of aircraft safety," because the FAA allows visual observers to augment line of sight flight or outright waivers of that requirement.[340] The Court's ruling makes sense given the FAA's policy statements about letting states and localities act in the drone space. However, it should stand as a warning against regulation that

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[330] State and Local Regulation of Unmanned Aircraft Systems (UAS) Fact Sheet, Federal Aviation Administration (2015) https://www.faa.gov/uas/resources/uas_regulations_policy/media/uas_fact_sheet_final.pdf.
[331] Program Overview, UAS Integration Pilot Program (last visited Aug. 31, 2018) https://www.faa.gov/uas/programs_partnerships/uas_integration_pilot_program/; Alan Boyle, FAA lays out process for advanced drone operations, giving a lift to Amazon's plans, GeekWire Nov. 2, 2017 https://www.geekwire.com/2017/faa-lays-process-advanced-drone-operations-giving-lift-amazons-plans/.
[332] Singer v. City of Newton, 284 F.Supp.3d 125 (D.Mass 2017).
[333] Singer at 127.
[334] *Id.* at 129.
[335] *Id.* at 130.
[336] *Id.*
[337] *Id.*
[338] *Id.* at 131.
[339] *Id.* at 131-3.
[340] *Id.* at 132-3.

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even seems like a ban on drones in the airspace. State or municipal attempts to regulate drone safety are especially suspect.[341]

Many city drone regulations would likely be preempted by either state or federal law, especially if they do not contain a savings provision. For instance, some of the Chicago provisions are similar to those overturned in *Newton*, namely the ban on flights over private property. However, the Chicago ordinance contains an exception for any flights authorized by federal or state law.[342] It is important to note that this ordinance passed in 2015, before the FAA promulgated its current regulations. The FAA currently allows waivers for flights outsight visual line of sight, at night, or over populated areas,[343] so without an exception allowing for such flights, the Chicago ordinance would almost certainly be preempted. The report by the Center for the Study of the Drone concluded that many of these city drone rules could conflict with federal or state laws.[344] The *Newton* case may inspire others to challenge local drone ordinances, although the FAA was not involved in that case and has not yet challenged any such laws itself. The federal scheme relying on conflict preemption still leaves room for cities to regulate however, as many local drone ordinances relate to privacy or trespass, which the FAA has deemed within the scope of local authority to act.[345]

States with blanket prohibitions on city drone laws will naturally be much more constraining for cities. Cities will only be able to pass generally applicable laws that happen to include conduct by drones, such as reckless endangerment. The bounds of this authority are unclear and may need to be tested in court. For instance, a city might pass an ordinance that does not mention drones but defines trespass as causing an object to hover up to 50 feet over private property. Is this a generally applicable law or a back door into a drone ban?

C. Impact of preemption on robotic and environmental design

The preceding sections have shown how cities are playing an active role as test beds of emerging robotics technologies and governance models. It has also shown that city authority in this area can be limited by both state and federal law, and that the interplay of different levels of regulation can be complex and unclear. This section argues that preemption at the state and federal level will impact design decisions made about autonomous systems and the local built environment, and may unintentionally foreclose some design choices.

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[341] *Id.* "The Ordinance seeks to regulate the method of operating of drones, necessarily implicating the safe operation of aircraft. Courts have recognized that aviation safety is an area of exclusive federal regulation."

[342] Chicago Municipal Code, Small Unmanned Aircraft, 10-36-400 © http://library.amlegal.com/nxt/gateway.dll/Illinois/chicago_il/municipalcodeofchicago?f=templates$fn=default.htm$3.0$vid=amlegal:chicago_il.

[343] 14 CFR 107.205(c).

[344] Arthur Holland Michel, *Drones at Home: Local State Drone Laws*, Center for the Study of the Drone at Bard College, 4 (2017) http://dronecenter.bard.edu/files/2017/03/CSD-Local-and-State-Drone-Laws-1.pdf.

[345] *Id.* There may be a tension between cities permissibly regulating trespass by drones and impermissibly banning flights over private property.

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The legal rules that govern urban robots will have consequences for autonomous systems and the urban built environment, and vice versa. For example, speed limits for automated vehicles or delivery robots will determine the machine's top speed. Or zoning laws will influence a neighborhood's use and character, including the design of public spaces and restrictions on the co-mingling of people with robotics. Laws that set a particular weight limit for machines enable some designs while foreclosing others. This very problem has occurred with some state delivery robot laws. Virginia's law defines a delivery robot as weighing under 50 pounds, but Marble, one of the main delivery robot startups, uses a machine that weighs over 80 pounds.[346] Some have accused Marble's competitor of writing the law to close off competition.[347] A law that requires a robot to yield to pedestrians,[348] effectively requires the design of sensing and processing capabilities to achieve this end. On the other hand, laws that require people yield to robots could dramatically reshape environmental design. Such was the case with the advent of the automobile and jaywalking laws.[349]

Urban robotics, environmental design, and legal rules will likely interact in more indirect or diffuse ways that are nonetheless impactful on the local level. The placement of any future restricted automated vehicle "hyperlanes," could have significant opportunity costs by influencing the distribution of travel modes onto other transportation infrastructure. One study has shown that ride sharing apps increase traffic and reduce public transit ridership.[350] This effect could get worse if the cost of automated vehicle ride sharing plummets, and further introduces the prospect, so evident today in cities with dockless car and bike share systems, of automated vehicles occupying streets and utilizing energy without passengers at all. In terms of long-term planning, it is important to consider that the provision of transportation infrastructure and services influences where people live in cities.[351] Transportation economists have long advocated for congestion pricing on roads to offset increases in miles traveled, and while this may be applied to automated vehicles, the need for increased density, specifically in public rights-of-way, highlights the need for other pricing structures, such as occupancy-based pricing for automated vehicles to promote shared vehicle and transit-scale systems.[352] In all there will likely be many unforeseen consequences to the proliferation of cheap, diffuse networks of last-

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[346] Code of Virginia Sec 46.2-100; April Glaser, *A robot-delivery startup helped write state laws that are locking out competition*, Recode Apr. 22, 2017 https://www.recode.net/2017/4/22/15273698/robot-delivery-startup-starship-state-laws-lock-out-competitors.

[347] April Glaser, *A robot-delivery startup helped write state laws that are locking out competition*, Recode Apr. 22, 2017 https://www.recode.net/2017/4/22/15273698/robot-delivery-startup-starship-state-laws-lock-out-competitors.

[348] Code of Virginia Sec 46.2-904.

[349] See Peter D. Norton, *Street Rivals: Jaywalking and the Invention of the Motor Age Street*, 48 Tech. & Culture 331 (2007).

[350] Regina R. Clewlow & Gouri Shankar Mishra, *Disruptive Transportation: The Adoption, Utilization, and Impacts of Ride-Hailing in the United States*, UC Davis Institute of Transportation Studies Report UCD-ITS-RR17-07, 27 (2017) https://itspubs.ucdavis.edu/wp-content/themes/ucdavis/pubs/download_pdf.php?id=2752.

[351] *Id.* at 28.

[352] Sarah J. Fox, Planning for Density in a Driverless World, 9 Northeastern University L. Rev. 151, 194 (2017).

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mile logistics and public safety machines in the form of delivery and security robots, as well as automated vehicles for passenger and cargo.

Changes brought about by new technology often have consequences for environmental design, and therefore need regulation that is sensitive to local context. Consider the impact of room sharing (Airbnb) on urban housing markets. While the anticipated death of the hotel business never came to pass, some research suggests that Airbnb contributes to housing shortages and drives up rents.[353] This effect has been attributed to property owners permanently shifting their homes from the rental market to "private accommodation," and Airbnb has worked with local governments to combat this practice.[354] This is just one example of technology's impact on local environmental design and legal rules, and more is in store as the industrial organization of the transport sector shifts from the concentrated ownership of information technologies in today's sharing economy, to more concentrated ownership of the mobile assets on the street.

State and federal laws that preempt cities on robotics may disrupt the natural interplay between the design of autonomous systems, urban environments, and local law, and so state and federal lawmakers should consider the local impacts of robotics laws and be wary of broad preemption. The controversy over the weight definition PDDs locking out some models of PDDs is one example.[355] Right now the regulation in this space is still developing, but the chances of future conflict arise as more laws relating to automated vehicles are enacted. Proposals for exclusive automated vehicle highway lanes have already been floated to some state legislators.[356] A proposed law in Illinois would require infrastructure updates for networked sensors that would collect vehicle and pedestrian traffic data and send it to automated vehicles.[357] These laws are likely just the beginning. Further, there is a recent history of cities attempting to regulate only to have states preempt them and reverse those rules.[358] Advocates have also expressed concern over proposed federal automated vehicle laws that preempt "unreasonable restrictions" on these

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[353] Derek Thompson, *Airbnb and the Unintended Consequences of 'Disruption'*, The Atlantic Feb. 17, 2017 https://www.theatlantic.com/business/archive/2018/02/airbnb-hotels-disruption/553556/.
[354] *Id.*
[355] April Glaser, *A robot-delivery startup helped write state laws that are locking out competition*, Recode Apr. 22, 2017 https://www.recode.net/2017/4/22/15273698/robot-delivery-startup-starship-state-laws-lock-out-competitors.
[356] Tom Banse, *Dedicated Lanes on I-5 For Self-Driving Cars Get Ears Of Washington State Officials*, NW News Network Oct. 17, 2017 http://nwnewsnetwork.org/post/dedicated-lanes-i-5-self-driving-cars-get-ear-washington-state-officials; Rick Romell, *Driverless car lanes on I-94 being studied for Foxconn*, Milwaukee J. Sentinal Nov. 13, 2017 https://www.jsonline.com/story/money/business/2017/11/13/driverless-vehicle-lanes-94-being-studied-foxconn/860515001/.
[357] Connected Multimodel Mobility Act, HB 2997 100th Gen. Assembly Sec 15 (2017-2018) https://custom.statenet.com/public/resources.cgi?id=ID:bill:IL2017000H2997&ciq=AsteigenHAV&client_md=ff84cafdb9162f7303cc19e4a57a9a17&mode=current_text. V2I communication will require a network protocol to communicate; so prematurely regulating V2I statewide could lock in certain network protocols over others.
[358] Nicole DuPois, City Rights in an Era of Preeption: A State-by-State Analysis 2018 Update, National League of Cities, 3 (2018).

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products.[359] Not only could the law upset the regulatory balance between the federal government and states (and localities by extension), but the term "unreasonable restrictions" is seen as overly vague.[360]

In addition, legislating to specific verticals of robotics may prevent cities from planning holistically as technologies converge in robotics platforms. Consider the state laws enabling PDDs. Six state laws allow PDDs and define them as "*an electrically powered device that (i) is operated on sidewalks, shared-use paths, and crosswalks and intended primarily to transport property.*"[361] This definition serves its purpose of providing explicit permission for delivery robots to operate within the state. It is written narrowly to cover delivery robots as they currently exist.[362] However, new robots are already being marketed that can serve more than one function; they can be delivery robots, or security robots, or personal mobility devices.[363] What had previously been distinct categories of robot are beginning to converge into a multifunctional platform. If a machine can be both a delivery robot and a security device, which law applies? Does the applicable law change depending on how the robot is being used? Delivery robots are also defined as machines that operate on the sidewalk, but it is at least conceivable that engineers could build a robot that is equally capable of operating on both the sidewalk and the street. In fact Bloomberg Philanthropies and the Aspen Institute categorize delivery robots as a type of automated vehicle.[364] The convergence of delivery robots and automated vehicles could accelerate if cities redesign their streets for mixed robotic traffic, as some have suggested.[365] So far the states with PDD laws have left room for cities to act, although some are more permissive than others. For instance Idaho allows cities to regulate PDDs for "safe operation,"[366] but it is not clear how the Idaho law would handle the technological convergence described. This is another reason to allow cities the freedom to experiment and regulate accordingly.

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[359] Tina Bellon, *U.S. push for self-driving law exposes regulatory divide*, Reuters Sep. 5, 2017 https://www.reuters.com/article/us-autos-selfdriving-analysis/u-s-push-for-self-driving-law-exposes-regulatory-divide-idUSKCN1BQ24J.

[360] Tina Bellon, *U.S. push for self-driving law exposes regulatory divide*, Reuters Sep. 5, 2017 https://www.reuters.com/article/us-autos-selfdriving-analysis/u-s-push-for-self-driving-law-exposes-regulatory-divide-idUSKCN1BQ24J.

[361] Florida Legislature CS/HB 1027 (2017) https://www.flsenate.gov/Session/Bill/2017/1027/BillText/er/PDF; Idaho Legislature HB 204 (2017) https://legislature.idaho.gov/sessioninfo/2017/legislation/H0204/; Ohio Legislature HB 49 Gen. Assemb. 132 (2017) https://www.legislature.ohio.gov/legislation/legislation-summary?id=GA132-HB-49; Virginia Legislature S. 1207 2017 Sess. (2017) https://lis.virginia.gov/cgi-bin/legp604.exe?171+ful+CHAP0251; Wisconsin Legislature Act 13 SB148 (2017) http://docs.legis.wisconsin.gov/2017/related/acts/13; Arizona Legislature HB2422 53rd Sess. (2018) https://legiscan.com/AZ/text/HB2422/id/1688912.

[362] Except for Marble's robots, of course.

[363] Nick Lavars, *Segway's Loomo transporter does double duty as a robot*, New Atlas Mar. 6, 2017 https://newatlas.com/segway-loomo-transporter-robot/53677/.

[364] Bloomberg Philanthropies & Aspen Institute, Taming the Autonomous Vehicle: A Primer for Cities, 14-15 https://avsincities.bloomberg.org/downloads/Taming_the_Autonomous_Vehicle.pdf; see also National Association of City Transportation Officals, Blueprint for Autonomous Urbanism (2017) https://nacto.org/wp-content/uploads/2017/11/BAU_Mod1_raster-sm.pdf.

[365] National Association of City Transportation Officals, Blueprint for Autonomous Urbanism (2017) https://nacto.org/wp-content/uploads/2017/11/BAU_Mod1_raster-sm.pdf.

[366] Idaho Code 49-605.

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There are of course some situations where regulatory certainty and uniform guidelines are warranted, and preemption may be the appropriate tool to achieve that policy end. We simply caution that when it comes to urban robots, preemption is a design issue in addition to a legal question.

D. Preemption recommendations

This section lays out specific recommendations for federal, state, and local authorities to craft their rules governing robots to avoid preemption interfering with local design.

Perhaps most pressingly, the preemption provisions of the SELF DRIVE and AV Start Acts should be amended and clarified to preserve local authority over the built environment even when decisions about the environmental design have impacts on design or performance. The definition of "performance" specifications that are subject to preemption should not include the operational domain, i.e. the built urban environment. The AV Start Act should include a specific exemption so that local governments are not preempted when regulating their own built environments that constitute the operational domain of AVs. A sunset provision for this exemption may be appropriate to reflect the fact that AVs are still in an experimental stage, but that stage will not last forever. The SELF DRIVE Act has already passed in the House, but it will likely need to be amended to resolve the differences with the AV Start Act. SELF DRIVE's preemption language should be narrowed, and the authority of cities to act as sites of experimentation expressly recognized.

These changes are the minimum needed to preserve cities as sites of experimentation. An even better model to follow is the Drone Federalism Act and the FAA's own policy statements on preserving state and local authority in certain spheres. This approach could be combined with the Massachusetts model, which allows cities to coordinate and cooperate with state regulators and industry. This would allow cities to experiment to find the design and operational domain for AVs and the governance structures that best promote autonomous technology and the public good.

For other forms of urban robots, legislatures should expressly recognize and carve out authority for cities where the law impacts environmental design, including the deployment of related sensors and other information communication systems. States should recognize city home rule authority over environmental design, and over system design to the extent it impacts environmental design. The state PDD laws that do this, especially Illinois', are a good model to follow. Again, FAA policy on state and local authority and the Massachusetts model for AVs are good approaches. Legislatures should consider the relative costs for firms and cities that preemption can create by forcing certain design parameters or precluding market competition. Robotics laws should work in the public interest and not force cities to bear socialized costs of system design.

Courts should recognize that local government design choices over their public rights-of-way are legitimate exercises of police power, not obstacles to federal rules meant to encourage the

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adoption of robots. They should define conflict in preemption cases related to robots narrowly. Choices about whether to offer robot fast lanes, whether to create designated robot zones, how to structure parking for shared robo-taxi fleets, and even how to price congestion to reduce traffic, all have a local character. Courts should only find preemption if it is clear that federal or state legislatures intended to preempt those design choices. This also means courts should avoid field preemption because broad readings of legislative intent will displace city prerogatives in local design.

Cities should not tempt fate by regulating so heavily that they draw a preemption challenge in court or inspire legislatures to act.[367] Robotics ordinances should work with state and federal laws, not against them. Chicago was wise to create exceptions to its ordinance to avoid a preemption conflict.

Altogether, we advocate for a true federalism in the system of robotics law. Cities should serve as the sites of experimentation for robotic system, environmental, and legal design. States can provide backstop rules that ensures cities act in the public interest, for example by setting rules against privacy harms or discrimination that could be exacerbated by robotics.[368] They can also handle intrastate regional issues as they arise. The federal government can provide technical and regulatory guidance; issue grants; and, after the technology has had a chance to evolve through experimentation in cities, create rules for robots in interstate commerce. In this way, each level of government plays to its relative institutional strengths,[369] while preserving local autonomy. Lawmakers at every level of government should remember that development of both robotics systems and the built environment can evolve over time, sometimes in unexpected ways. They should be platform agnostic to avoid earl “lock-in” of design or the built environment. Robotics technologies are also likely to converge, which may render some rules out of date.

Part VI. Counter arguments in favor of preemption of local governments

This part concerns counter arguments, such as the need for regulatory clarity and consistency, the idea that state and national regulators are in a better position to negotiate with firms than cities, and the notion that cities do not necessarily act in the best interest of the region.

A. Need for regulatory clarity/consistent rules

Proponents of preemption might cite the need for regulatory clarity or consistent rules to ease the way for firms. Automated vehicle manufacturers have made such arguments in favor of the

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[367] The ACS notes that instances of punitive preemption, where state legislatures target cities to overturn specific laws, are on the rise. Richard Briffault et al, *The Troubling Turn in State Preemption: The Assault on Progressive Cities and How Cities can Respond*, American Constitutional Society 5 (2017) https://www.acslaw.org/wp-content/uploads/2017/09/ACS_Issue_Brief_-_Preemption_0.pdf.

[368] Judith Donath, *Driverless Cars Could Make Transportation Free for Everyone -- With a Catch*, The Atlantic Dec. 22, 2017 https://www.theatlantic.com/technology/archive/2017/12/self-driving-cars-free-future/548945/.

[369] For a discussion of this dynamic specifically applied to drones and privacy, see Margot Kaminski, Drone Federalism: Civilian Drones and the Things They Carry, 4 Cal. L. Rev. Cir. 57 (2013).

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federal SELF DRIVE Act.[370] Having to plan for and comply with 50 state automated vehicle laws is more complicated, and therefore more costly, than just dealing with one federal law. In addition, being cars, automated vehicles are highly mobile and will eventually cross state lines. For the legal requirements to differ between states such that an automated vehicle from California cannot cross the border into Nevada without violating the law would be troublesome, to say the least. Overcoming such obstacles to interstate commerce is one of the reasons the federal government exists in the first place. Put another way, scale matters with technology.

We are sympathetic to these arguments and even grant that regulatory uncertainty can be a burden on firms, but the burden to firms is only part of the overall story. First, uncertainty creates a cost, and costs can either be internalized by firms or socialized to the public. Avoiding preemption allows for cities to be sites of experimentation and true partners in the system and environmental design for urban robots. Preemption may cut off that process too early. There will be a time when nationwide standards make sense, but it should be after cities have had a chance to experiment. In the meantime, the principle of permissionless innovation, which likely applies to automated vehicles and many other robots,[371] should insulate firms from the worst regulatory excesses. Second, innovation proceeds unevenly, so regulatory standardization should as well. Certain safety standards may make sense to implement on a statewide or national level now.[372] But there will be other areas where cities require room to experiment, especially as it impacts environmental design. There are situations with technology where scale can have undesirable consequences. For example possible concern with creating a national health database is fear of a massive data breach that compromises the personal health data of every American, and as the integration of surveillance technology expands in service to the transportation industry, these issues will be compounded. Scaling a system of unsafe or inefficient AVs by acting too early is not a desirable outcome.

It is also possible to achieve some harmony and an environment that favors innovation without imposing a nationwide standard with broad preemption of local governments. The system of federalism for which we advocate recognizes roles for state and federal regulators. It merely preserves the design space for cities.

B. State/National agencies are in better bargaining position vis a vis firms

Another critique that is somewhat related to the first one is that scale matters in regulation. State legislatures and attorneys general may have more bargaining power as negotiators of the public interest. National regulators have even more bargaining power. Cities may become caught in a race to the bottom by attempting to lure firms, or they may get captured by special interests.[373]

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[370] Tina Bellon, *U.S. push for self-driving law exposes regulatory divide*, Reuters Sep. 5, 2017 https://www.reuters.com/article/us-autos-selfdriving-analysis/u-s-push-for-self-driving-law-exposes-regulatory-divide-idUSKCN1BQ24J.

[371] See Adam Thier & Ryan Hagemann, Removing Roadblocks to Intelligent Vehicles and Driverless Cars, 5 Wake Forest J. of L. & Pol'y 339 (2015).

[372] Prohibitions on PDDs carrying hazardous material may be one.

[373] The competition for "Amazon HQ2" is a prominent contemporary example of this problem.

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Concerns that cities will race to the bottom by giving away public goods to robotics firms are warranted; we raised them ourselves above. For that reason we think state rules that guard against socialized costs are a good idea. This is part of the reason that we hold up Massachusetts as a model, it allows cities to experiment while the state acts as a backstop to preserve the public interest. Still, any preemption provision for urban robots should weigh the potential regulatory economies of scale against the benefits of innovation with cities as distributed sites of experimentation. Further, cities have their own power as market makers when they are able to deal directly with firms.[374]

C. Cities do not act in the best interest of the region (NIMBY)

One might argue that cities will not plan in the best interest of the region or state as a whole, but instead regulate for narrow interests defined by NIMBY-ism (Not In My Back Yard). NIMBY-ism has been a problem in other intractable urban and regional planning issues like housing[375]and transportation.[376] The Competitive Enterprise Institute, a libertarian think tank, worries that ridesharing companies will pressure cities to outlaw private ownership of automated vehicles by touting the environmental benefits of shared fleets.[377] The group praised states that preempt cities in their laws to avoid just this outcome.[378]

We are sensitive to this concern as well. Cities are not and should not be the only stakeholders in regional planning. For cities to succeed in our model they must operate within a patchwork of federal and state regulation and cooperate with private companies and regional stakeholders. We agree with Sarah Fox that regional tools like environmental impact reports or statements can support density or other positive regional planning goals.[379] We also envision a possible role for Metropolitan Planning Organizations that can coordinate the needs of multiple cities in a given region; this is a common tool in regional transportation planning.[380] Still, giving cities the tools to regulate robots means that some cities may abuse those tools. Further, the notion of experimentation implies that some failure will occur. But if cities are the site of experimentation, at least those failures won't proliferate across the entire state or country by fiat. Cities are not

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[374] Jan Whittington, Ryan Calo, Mike Simon, and Jesse Woo, Push, Pull, and Spill: A Transdisciplinary Case Study In Municipal Open Government, 30 Berkeley Tech. L.J. 1967 (2015) page 1964

[375] Caroline O'Donovan, The Rent is Too Damn High: In Search of the Truth About Airbnb's Imact on Housing, Buzzfeed Jun. 9 2015 https://www.buzzfeed.com/carolineodonovan/the-rent-is-too-damn-high-the-truth-about-airbnbs-impact-on?utm_term=.ebNpR84Z4#.ypxOApdnd.

[376] Doug Monroe, Where It All Went Wrong, Atlanta Magazine Aug. 1, 2012 https://www.atlantamagazine.com/great-reads/marta-tsplost-transportation/.

[377] Marc Scribner, Uber Wants to Make it Illegal to Operate Self-Driving Car in Cities, Competitive Enterprise Institute Feb. 1, 2018

[378] Marc Scribner, Uber Wants to Make it Illegal to Operate Self-Driving Car in Cities, Competitive Enterprise Institute Feb. 1, 2018

[379] Sarah J. Fox, Planning for Density in a Driverless World, 9 Northeastern University L. Rev. 151, (2017).

[380] Regional Councils, COGs & MPOs, National Association of Regional Councils (last visited Aug. 31, 2018) http://narc.org/about-narc/cogs-mpos/

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the only actors who can err in urban planning. For instance, some scholars believe that federal policy has contributed to suburban sprawl and low density housing.[381]

To the specific concern that cities will ban individual car ownership, it is also possible that states could use preemption and enact policies that favor individual ownership to benefit entrenched interests, such as car manufacturers.[382] Without taking a specific position on individual ownership of automated vehicles, we note that almost any policy choice will favor some interests over others. The question is which level of policymakers will make those choices. We argue in favor of local political bodies, as they must deal most directly with the consequences of those choices and are the most politically accountable for those choices.

Part VII: Conclusion

Widespread deployment of robots in cities has the potential to drastically alter the way cities organize their public spaces and built environment. As the test beds for this emerging technology, cities must room to regulate these technologies in ways that fit the realities of the local built environment and local constituencies. While this technology is in the experimental stage, state and federal lawmakers should avoid broad field preemption to preserve a regulatory space for cities to design public spaces in a way that best serves the public interest. Rather than rushing prematurely to a state or nationwide standard, state and federal lawmakers should implement regulatory floors and backstops against a race to the bottom. Issues that do not implicate the design of the local built environment, such as vehicle safety or cybersecurity, may be ripe for such intervention. State and federal governments can also serve as conveners and disseminate experimental results and best practices in order to build consensus toward nationwide standards. The potential of robotics technology to deliver convenience, efficiency, and other benefits is exciting, and the urge to standardize in the name of promoting innovation is understandable. But that urge is misguided when the impacts of the technology are likely to be consequential yet unknown.

For their part, cities must ensure that robots promote the public interest rather than socialize costs that ought to be borne by firms. They should recognize their power as market makers when dealing with companies seeking to test their technologies in urban spaces. Local policy makers have both a civic and moral duty to do so. More work is needed to explore the possibility of a fiduciary duty or standard of care for cities that implement pilot programs or procure new technologies.[383] City policy makers should be able to demonstrate their careful consideration of the impacts to privacy, safety, public finances, and public spaces. The implementation of citizen review committees for surveillance technologies may be one step toward this goal.

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[381] Gerrit Knapp, Emily Talen, Robert Olshansky, & Clyde Forrest, Government Policy and Urban Sprawl, Illinois Department of Natural Resources (2014) http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.505.9245&rep=rep1&type=pdf.

[382] Marina Lao, Debbie Feinstein, and Francine Lafontaine, Direct-to-consumer auto sales: It's not just about Tesla, Federal Trade Commission May 11, 2015 https://www.ftc.gov/news-events/blogs/competition-matters/2015/05/direct-consumer-auto-sales-its-not-just-about-tesla.

[383] Thank you to Anthony Luppino for suggesting this concept to us in our discussions.

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Urban robots are likely to reorganize not just the built environment but the social fabric of cities as well. Challenges to traditional notions of privacy (or lack thereof) in public spaces is just one manifestation of the social impact of urban robotics. For instance, marginalized communities of color could experience urban robots differently than more affluent communities, especially as a tool of law enforcement. There are also concerns that AVs could be used as a tool of social control by governments, or for companies to exert undue influence on their passengers.[384]

Preempting a city's ability to regulate "performance," as AV Start and SELF DRIVE do, could have far reaching implications beyond the technical specifications of the autonomous system. Robotics technologies such as AVs are envisioned as key to components in the creation of cutting edge "smart transportation" system.[385] However if preemption prevents cities from directing these new transportation services, then local governments may struggle to ensure equity and access. A city that wishes to direct AV services to poor or minority areas might be prevented from doing so if a court finds this to be an "unreasonable" restriction on the AV's performance or operational domain. Or, preemption could remove a city's leverage to push companies toward more equitable services because local governments are forced to allow AVs on their public rights of way. This problem is not merely academic; a ridesharing company called Via was found to have discriminated against poor and minority communities for years by confining its services to affluent areas of the city in violation of local law.[386]

The importance of design in local preemption debates should have application beyond robotics. As cities flex their power as economic and cultural engines in American society, they have repeatedly come into conflict with state and federal lawmakers. Preemption has been central to issues ranging from ride sharing to short term rentals . Considerations of design and the built environment may not be the principal factor in deciding how to allocate authority over policy making in these spheres, but they may still prove a useful facet through which to understand these problems.

More broadly, this paper urges regulators at all levels to think carefully about the nature of robotics and the role of cities as sites of experimentation. For the sake of simplicity and organization we have treated AVs, PDDs, security robots, entertainment robots, and drones as

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[384] Self-driving cars offer huge benefits--but have a dark side, The Economist Mar. 1, 2018 https://www.economist.com/news/leaders/21737501-policymakers-must-apply-lessons-horseless-carriage-driverless-car-self-driving; Judith Donath, *Driverless Cars Could Make Transportation Free for Everyone -- With a Catch*, The Atlantic Dec. 22, 2017.

[385] Yuming Ge, Xiaoman Le, Libo Tang, & Darrel M. West, *Smart transportation in China and the United States*, Center for Technology Innovation at Brookings (2017) https://www.brookings.edu/wp-content/uploads/2017/12/smart-transportation_final.pdf; see also Bloomberg Philanthropies & Aspen Institute, Taming the Autonomous Vehicle: A Primer for Cities, 14-15 https://avsincities.bloomberg.org/downloads/Taming_the_Autonomous_Vehicle.pdf; National Association of City Transportation Officals, Blueprint for Autonomous Urbanism (2017) https://nacto.org/wp-content/uploads/2017/11/BAU_Mod1_raster-sm.pdf.

[386] Mark Joseph Stern, A D.C. Ride-Sharing Service Illegally Discriminated Against Minority Communities for Nearly Two Years, Slate Apr. 9, 2018 https://slate.com/technology/2018/04/via-discriminated-against-minority-communities-in-washington-dc.html.

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distinct devices. This is in part because the law has applied different rules as well. However, these devices share some common technical features and may have similar impacts as emerging technologies. Right now governments apply different regulatory regimes based on the device classification and the nature of the right of way in which they operate: sidewalks versus streets versus airways. But as the technology converges this regulatory separation may not be appropriate. Rather, from a designer's perspective the sensible approach could be to treat cities as a single operating domain for this family of technologies we call robots. Doing so will require a paradigm shift in regulatory approaches, and an emphasis on the city as the site of experimentation for new governance models. Cities, for their part, must learn to navigate the minefield of preemption and environmental design issues to foster experiment with new technologies and new governance models for the sake of the public good. Cities are on the forefront of other important policy debates, such as how to implement a universal basic income.[387] This paper has attempted to help cities understand all of the tools that are available to them and the limits and contours of their authority to accomplish this task. The robotic future will be made in cities, and will be felt most directly by the people who live there, so cities must take an active role in shaping it.

[387] Matthew Keegan, Benefit or burden? The cities trying out universal out universal basic income, The Guardian Jun. 27, 2018 https://www.theguardian.com/cities/2018/jun/27/benefit-or-burden-the-cities-trying-out-universal-basic-income.

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