Putting Communities at the Center of Connected, Automated Mobility

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Abstract

This project explores ways that communities can reclaim control over their streets as Connected and Automated Vehicles (CAVs) and associated technologies become part of the urban fabric. Historic loss of flexible public space associated with the introduction of cars in the early 20th century and emerging concerns about management of CAVs today indicate that local governments and communities must reassert control over the planning and operation of streets. We define how technology can serve as a common language between citizens and CAVs, allowing communities to determine the design of streets and what the rules of a CAV-accessible road network should be. Critical to this approach is a direct relationship between policy and technology, with planners and regulators using technology to accomplish long-standing social objectives. Our analysis first describes *possibilities*—ways to leverage CAVs to create positive change in the built environment—and *constraints*—social, legal, and technological limitations on CAV functionality—from a review spanning planning, engineering, technology, policy, and sociology. Next, we investigate how cities and communities have begun to reimagine the use and management of streets in the face of disruptive technologies and diverse needs for which existing practices are inadequate. Building on current efforts in transportation planning, particularly efforts to increase flexibility and "tactical" action in streets, we propose strategies for increasing local control over urban streets using technologies inherent to CAVs. These strategies do not prescribe a single approach for all streets, but acknowledge differences of place and culture by returning decision-making power to the people living alongside those streets.

Introduction

A navigation app has become one of the most controversial pieces of software available on a smartphone. Waze, an app that uses real-time traffic information to route drivers on the quickest routes to their destinations, frequently sends commuters down side streets in order to avoid backups on major roads. Waze has no sense of local land use, and if a residential street is faster than congested highway, that's the route it will recommend. Residents living on formerly quiet streets are getting angry, and along with local politicians have begun to demand curbs on Waze. In Los Angeles, a City Councilmember has asked the City Attorney to take action, stating, "Waze has upended our City's traffic plans, residential neighborhoods, and public safety for far too long" (Pampanin, 2018). Leonia, New Jersey banned all non-resident traffic from their primary roads in order to address Waze-induced congestion on residential streets (Foderaro, 2018). So far, Waze remains largely unmoved, and its co-founder told a reporter, "All roads are the public domain and therefore the right of everyone to use" (Salem, 2018). Indeed with few exceptions, passenger vehicles do have the right of way on public streets. Governments may regulate speed, direction, and curb usage, but for the most part a public road is an open road.

Some engineers see the Waze problem as a traffic management issue. They argue that a more advanced navigation system could proactively balance traffic loads across streets, ensuring that residential roadways don't become over-congested (Sun and Park, 2017). The problem with this approach, however, is that it remains fundamentally systems-oriented, rather than place- and community-focused (Thai et al., 2016). What we already observe with navigation apps will only become more evident once connected, automated vehicles (CAVs) become a significant proportion of the vehicle fleet. CAVs, while ostensibly safer and more efficient at the systemwide scale, are likely to have significant impacts on urban streets and neighborhoods due to their likelihood to increase road capacities and vehicle miles traveled across the road network (Litman, 2017). Given these developments, we observe a disconnect between the deployment of new mobility technologies on city streets and cities' desire to operate roadways that are sensitive to local context and responsive to residents' needs. In this paper, we examine what communities seek from their streets and propose an alternative approach to deploying CAVs and other mobility technologies that account the communities along the roadside. In so doing, we address the longstanding issue of control of urban streets, finding vehicle automation to be an opportunity – if cities wish to seize it – to assign control primarily at the community level, rather than the system-wide level.

In this paper, we city and community objectives for urban streets, highlighting recent movements, such as tactical urbanism and context-sensitive street design, which emphasize maximizing local control and flexibility in how streets are operated. We begin with a review of key concepts: CAVs, public right-of-way management, and tactical urbanism and describe a conceptual framework linking these concepts. Building on recent, non-technological efforts by cities to increase local flexibility and control of streets, we propose how CAVs and other mobility technologies may be deployed to enhance, rather than diminish, city and community objectives on local streets. Our findings have implications for how cities both regulate CAVs and design streets for those living alongside them. Ultimately, we argue that the advent of CAVs and other technologies on urban streets is an opportunity to return a level of control and democracy to streets that has not existed since the advent of the automobile more than a century ago.

Literature Review

CAV Technologies

Automation[1] technologies in transportation have been developing for nearly a century. Aircraft autopilot technology was developed in 1933 to make longer flight travel times more manageable; nor or automated vehicles new, conceptually. Cruise control, now a standard in most vehicles, was developed in 1945 and applied commercially in 1958 (WIRED Brand Lab, 2016). GM's Futurama exhibit at the 1939 World's Fair brought mainstream exposure to the concept of autonomous vehicles, exhibiting families playing board games while traveling down the highway in a driverless car (Futurama, nd). Stanford's Cart was the first self-driving wheeled vehicle, beginning in 1961 as a lunar rover utilizing a single camera to detect and follow a white line painted on the ground and later utilizing a stereo vision system to move on its own, photographing its environment and adjusting its route accordingly (WIRED Brand Lab, 2016). These and other early explorations of driver-assist and automation technologies were precursors to the race in developing fleets of driverless vehicles marketed to ostensibly make streets and lives safer, more efficient, and more enjoyable.

Similarly, information technologies have enabled the digitalization of our road network, which has undeniably changed how we navigate our environment, especially in areas of unfamiliarity. We're now able to pull small devices out of our pockets and dynamically look at our surroundings, even search for the nearest Indian Restaurant or used book store and plan our route there with a few taps of a screen. Mapping technologies have also enabled automobile and technology companies to make a big leap into the future of automated vehicles, advancing from following a white line path into complex systems of location and sensing technologies (Luettel et al, 2012). Utilizing roads in this new way—in the digital realm—allows for cars to be controlled by a region wide system and network, rather than allow autonomous, relatively unconnected human drivers to navigate along a physically defined network.

Connected and automated vehicle (CAV) technology utilizes hardware and software components that, together, identify a holistic mobility system, its functions, and its interactions which are programmed to work toward a specific goal. A variety of hardware components enable vehicles to sense things in their environments, communicate with other vehicles and information systems, and to move. A multitude of software components interpret information gathered from sensing and conversing enabling a vehicle to make informed decisions about how to move most appropriately. Those decisions are then communicated to the actuators, "the components of a machine responsible for controlling and moving the system" (Huang, 2018).

Despite having nearly all of the world's roads mapped, CAVs require a much more sophisticated level of location technologies, such as GPS, than is currently used by most consumers. Accuracy within a few meters is completely sufficient for a human driving to an address and then walking to the door, but for avoiding collisions with objects and other vehicles, locations need to be accurate within a few centimeters (Plungis, 2017). Several remote-sensing technologies—most commonly cameras, radar, and LiDar—are used in combination to intentionally generate redundancy that helps to compensate for the weaknesses inherent in each

[1] Please note, we use the terminology "automated" over "autonomous" to describe the primary innovative technology underlying what colloquially are often called driverless vehicles. "Automation" describes the replacement of formerly human-executed functions, such as steering a car, by technology. "Autonomy" is actually a more specific condition, in which the vehicle does not require external control to operate. In fact, human-driven vehicles are highly autonomous, but not automated. Future driverless vehicles may be any combination of autonomous or "connected" to other vehicles and infrastructure, depending on the automation system.

individual technology (Plungis, 2017). Connectivity hardware "enables the autonomous vehicle to talk and receive information from other *machine agents* in the environment" (Huang, 2018). It is essential for this connectivity to be two-way; each vehicle is not only gathering information from other sources, but is also communicating with the world. V2X references the connection of vehicles to everything, the ultimate goal, and includes all of the more-explicit connections. Three connections are fundamental to operation: V2I, V2V, and V2C. V2I represents the connection between vehicles and road infrastructure, including elements such as traffic light information, lanes, signage, and more. V2I promises dynamic manipulation of the rules of the road, such as immediate changes to recommended speeds to account for school letting out or extreme weather (3M, n.d.). V2V, the connection of vehicles to one another, allows vehicles to know where other vehicles are and what is happening on the road up ahead. V2C indicates the connection of vehicles to the cloud, both facilitating information sharing and relieving the need for massive physical data storage in each vehicle.

CAV technology equally depends on software programs to allow a vehicle to perceive the environment, plan behaviors, and control actions—essentially, to think, problem solve, and make decisions throughout the driving task. Software enables vehicles to translate raw data from the environment into recognizable objects—such as a pedestrian—and then use knowledge about how they should and can behave to make decision and act accordingly—such as stopping before the pedestrian, avoiding a collision (Huang, 2018). Various levels of automation allow for different involvement of the human and automated driver, see the table below (WIRED Brand Lab, 2016). Table 1 illustrates different levels of automation. Cruise control represents Level 1 automation, while newer vehicles with adaptive cruise control and lane-centering steering characterize Level 2 automation. Uber's self-driving cars piloting in Arizona are an example of Level 3 automation, depending on a human as a backup driver when the software is unsure how to make a decision or behave. Level 4 and Level 5 are the ideals developers are working towards, and it is only at these levels that most of the projected safety and efficiency benefits will manifest.

"The promise of self-driving cars is that they will see better than humans, never get lost, and almost never crash" (Plungis, 2017). Companies developing CAVs boast many inherent benefits of their technologies, both at an individual and a system level. At the individual level, benefits are directly targeted to improving the lives of humans. Increased safety and crash reduction promises that you won't be hit by a vehicle while walking to get your morning coffee. Promises of travel time dependability imply that there will no longer be guesswork of how long you may be stuck in traffic on your commute. Relief of the driving task promises greater productivity in the ability to read a book or begin the day's work while in transit. At the system level, benefits are targeted to the larger system of a community, city, or locality. CAVs can pick-up and drop-off their passengers at the their destinations, potentially reducing the need for parking and thus free up precious real land in cities for redevelopment. V2I and V2V technologies allow for vehicles to travel closer together even at high speeds which could either increase road capacities or allow cities to reduce lanes and lane widths, freeing up right-of-way space for other modes of transportation or other activities entirely. Automated shuttles promise to provide first- and last-mile services to increase mobility and accessibility. "Most of the benefits of AVs really only kick in when we have full autonomy—a swarming fleet of shared vehicles that operates as a public good" (Speck, 2017). However, regardless of timing, the connected, automated future promises a transportation system that is far more controllable, inasmuch as vehicles are subject to strict parameters for operation and coordinated among each other and the infrastructure. However, the type of control, as well as the entities most responsible for CAV control, remain largely underdetermined.

Table 1. Levels of Driving Automation			
Level of Automation	**Description**	**Human Driver:**	**Automated Driver:**
0	No Automation	Performs the entirety of the driving task full-time	Is not involved
1	Driver Assistance	Performs the driving task, can delegate one component to automation under certain circumstances	Provides driver assistance in steering ***or*** acceleration/deceleration upon request from human driver
2	Partial Automation	Acts as captain, delegating some tasks to automation under certain circumstances	Able to control steering *and* acceleration/deceleration under certain circumstances and on request
3	Conditional Automation	Acts as captain, delegating the whole driving task to automation under certain circumstances, resuming the full driving task when requested	Performs the complete driving task under certain circumstances, depending on the human to take over when necessary
4	High Automation	Delegates the complete driving task to automation in certain conditions, performs the driving task in other conditions	Performs the complete driving task under certain conditions
5	Full Automation	Is not involved	Performs the entirety of the driving task full-time
Source: Society of Automotive Engineers, 2018			

History of Public Rights of Way in America

Over the course of the twentieth century, plans, policies and design guidelines have oriented public rights-of-way away from pedestrians, bikes, and forms of transit and toward the efficient, safe use of automobiles. Peter Norton (2008) outlines the diverse interests vying for control and space in cities in his book *Fighting Traffic: The Dawn of the Motor Age in the American City*. Up to the 1920s, streets were treated as a public good to be used for public uses – pedestrians, police departments, city officials, business leaders, automobile manufacturers, and street railways all shared the public right of way, despite their conflicting interests. Within this context, from a legal and regulatory standpoint, cars were considered to be “individual, private property” (Norton, 2008). Not only were automobiles private modes of transport in public space, but they also brought with them significant public health impacts - by 1925, two thirds of deaths in cities with populations greater than 25,000 were a result of traffic accidents, a third of those deaths being children (Thompson, 2014).

Met with regulations and restrictions that not only limited their ability to operate automobiles in cities, but also limited future prospects of automobile use generally, automobile interests coordinated to "redefine the street" (Norton, 2008, pp. 19). Instead of accepting streets as a public good whose use should be managed by governmental entities, automobile companies and their allies sought to define streets as a consumer commodity that should be managed by the free market. In this way, an automobile being characterized as an inefficient, dangerous, and inequitable mode of transportation in cities was not a justification for regulation; if automobiles were in fact so bad, the market would force them into obsolescence (Norton, 2008).

Even further, automobile interests came up with creative rhetorical strategies to blame pedestrians for automobile accidents. While motorists at the outset were responsible for accidents, both legally and rhetorically, such responsibility was eroded using strategies like the popularization of the term "jaywalking". The term "jay", a derisive term used to describe someone from the country, came to be applied to those who stepped off the curb and onto the street without looking both ways. The campaign was so effective that by 1924, the term jaywalking was in the dictionary, defined as "One who crosses a street without observing the traffic regulations for pedestrians" (Thompson, 2014).

With city streets largely designated for automobiles by the 1930s, a new design and policy challenge emerged for cities: automobile storage. For many places, the response was zoning for parking. While zoning for parking was initially a process applied to specific projects or land uses, it has grown to become a standardized element of development protocols. A policy of minimum parking requirements, or the minimum number of parking spaces that must be built with new development, has become the most common approach to zoning for parking. Although there are no exhaustive contemporary studies on zoning for parking nationally, Erik Ferguson (2005) contends it is likely that nearly every locality currently has zoning ordinances that account for parking in some shape or form. Donald Shoup (1999), one of the harshest critics of minimum parking requirements, contends that minimum parking requirements as a policy have lacked analytical rigor and largely skewed toward the provision of free parking. The result has been a built environment that prioritizes the allocation of parking in public rights of way and the build-up of parking lots as development occurs, crowding out space for other uses of public and private space.

Additionally, design guidelines of public rights of way have been produced in response to, and in parallel with, the trends and policies that have resulted in automobile-centric cities. The American Association of State and Highway Transportation Officials (AASHTO) produce the dominant standards, known as the "Green Book," which draw on engineering principles to advise transportation officials on how to design streets for safe, efficient automobile use. While in the sixth edition of the Green Book, published in 2011, pedestrians, cyclists, and stakeholders looking to protect the environment are given some consideration, few efforts have been made historically to accommodate other modes of transportation or other uses for streets and curbs besides automobile use. Contrariwise, the National Association of City Transportation Officials (NACTO), has developed an alternative set of street design guidelines which explicitly flip preferences for different modes, favoring walking, bicycling, and transit as much as cars (NACTO, 2013). Critically, NACTO's guidelines, replicated and echoed by many cities in the US and globally, are forms of context-sensitive street design, where streets and the use are fundamentally responsive to the needs of the people and uses along the right-of-way (Bochner, 2004). In the case of on-street parking as well, new conceptualizations of curb usage have arisen as well, with flexible management of the curb taking priority over inflexible vehicle storage (Zalewski, et al., 2012).

Tactical Urbanism and the Right to the City

In response to local governments' inability to sufficiently plan and manage streets for local communities, a collection of initiatives that fall broadly under the categories of Do-it-Yourself (DIY) or tactical urbanism have emerged. According to Talen (2015), these initiatives, initially undertaken by activists inspired by critical spatial philosophers Henri Lefebvre and David Harvey, emerged in opposition to formal, neoliberal planning methods. The initiatives involved resident-led, guerilla-like interventions to transform urban spaces to meet community needs, filling the void left by formal planning methods for the built environment. These interventions often involved the use of light-weight and inexpensive materials, so as to be flexible and responsive to individual needs (Lydon, 2012).

While such methods were cultivated as an alternative to traditional planning, the movement has grown to incorporate interventions that involve collaboration between individuals, community groups, nonprofit groups, and governmental stakeholders. As Table 2 outlines, the tactical urbanism-like interventions have been used across various scales to make space for various uses in public rights of way, including other forms of mobility, commercial activities, green infrastructure, and recreation.

Table 2. Levels of Tactical Urbanism Intervention

	Name	**Location**	**Target**	**Description**
Sidewalk &	24/7 Pick-up and Drop-off Zones	Washington, D.C.	Safety	The District Department of Transportation designated curb-space at five entertainment hubs throughout the city as 24/7 pick-up/drop-off zones. Officials hope the zones will prevent ride-sharing vehicles from double-parking and blocking bike lanes, practices that create congestion and unsafe travel conditions for pedestrians and cyclists. (Lazo, 2018)
Parking	Plaza 98	Miami, FL	Community Event	Through the Miami-Dade Quick-Build Program, Street Plans, and community stakeholders, a parking lot nearby to a shopping center and theater was converted to a pedestrian plaza. A mural was painted alluding the area's pineapple farming roots, and community events are held each month on the site. (Quick Build, n.d.)
Alleyway	Avalon Green Alley Network	Los Angeles, CA	Environment	The Avalon Green Alley Network is a partnership of the Trust for Public Land, the City of Los Angeles, The New 9th, and community members. The organization completed alley cleanups and installations of sustainable stormwater technologies in residential areas of South LA. The alleys improved connectivity to schools and other community institutions as well. (LA Stormwater, 2016)

Vehicle Lane	Superblock Program	Barcelona, Spain	Transit	The Deputy Mayor for Ecology, Urbanism and Mobility oversees the intervention. In a grid of nine blocks, main traffic stays outside, and only local, one-way traffic enters the superblock. Road speeds are reduced, and street parking is limited. The roads are available for games, sports, and other recreational activities. (Bausells, 2016)

As mentioned above, early DIY and tactical urbanism movements were partly inspired by, and have made manifest, Lefebvre's vision of the right to the city. Though human rights advocates and urban activists have adopted the language of the right to the city broadly, Lefebvre's original conception of the idea was narrowly formulated on two specific ideas: first, the right to self-management, a separate right characterized by grassroots decision making and the decentralization of control to autonomous local units; and second, the right to the city, characterized by the appropriation of, and participation in, urban space by urban inhabitants. Lefebvre's theoretical conclusion is that, together, the struggle for these rights would undermine the existing capitalist order, making way for new relationships between individuals and urban space (Purcell, 2013). DIY and tactical urbanists exercise their right to the city by appropriating urban spaces to better meet their needs; what these groups have lacked is a sustainable, recognized unit of self-management with a democratic form of authority (Iveson, 2013). To realize the urban vision sought after by Lefebvre and DIY or tactical urbanists, local units of authority must be granted not only formal authority, but the information necessary to make responsible decisions about their urban spaces; furthermore, such decisions must be able to be incorporated and synchronized into the city-level formal authority.

Conceptual Framework

With the increased digitalization of cities and the system-level changes to the mobility infrastructure brought about by CAVs, new systems of participation, appropriation, and self-management can be generated, affording communities greater access to and control over public rights of way. Based on the findings above, we propose a conceptual framework for considering technology-driven approaches to context-sensitive, flexible control of urban streets. Our framework is comprised of three assertions based on the review above:

1. *Longstanding and Potentially Accelerating Auto Dominance of Urban Streets* - Public rights of way historically have been reserved for cars, with limited flexibility to accommodate other uses. The advent of automobility represented a loss of flexible public space in rights-of-way. Now, as CAVs are being developed for deployment on urban streets, autos may increasingly dominate streets system-wide, without regard to community context. In addition, information technologies, which are already directing vehicle flows, are removing human decisionmaking, in the form of driver discretion, from how streets are used.
2. *A Demand for Increased Control* – Communities are demanding more from public rights of way. They want more control and flexibility, as evidenced by the growth of the DIY and tactical urbanism movements. Communities, both through municipal governance and bottom-up tactics, are using streets for a wide range of personal and public action: non-motorized travel, markets, carts, and food trucks, parks (e.g. Park(ing) Day), gatherings and protests, and more. Importantly, the appropriate level of control often lies between

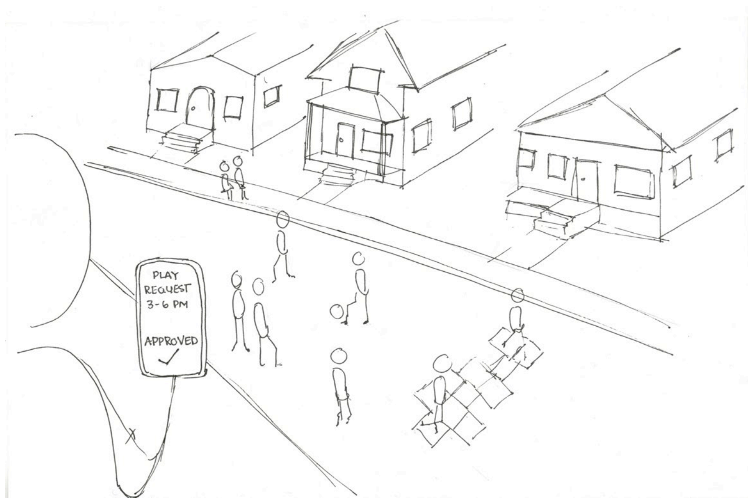
the complete system and the individual: reinforcing that collective action and decisionmaking are an essential part of street planning and management.

3. *Managing Technologies for Communities* – CAV and information technologies are often conceptualized as allowing for more control at the transportation system level and at the individual level (e.g., CAVs won't hit pedestrians, and people can decide where they want to go.). However, new mobility technologies can also be designed and managed to allow for community control of local streets. Cities can set the appropriate agents of control (inhabitants vs. system managers and engineers), the scale of intervention (neighborhoods vs. system-wide), and the parameters of concern (time-of-day, emissions, speeds, land use adjacencies, events, etc.). In so doing, technologies can serve community concerns, facilitating more flexible and context-sensitive streets.

Proposals for Integrating Technology and Community-Controlled Streets

Drawing on the conceptual framework for flexible, community controlled streets, we consider the ways in which such a system could be used to meet the needs of specific communities. The following are a series of proposals for utilizing technology towards those ends:

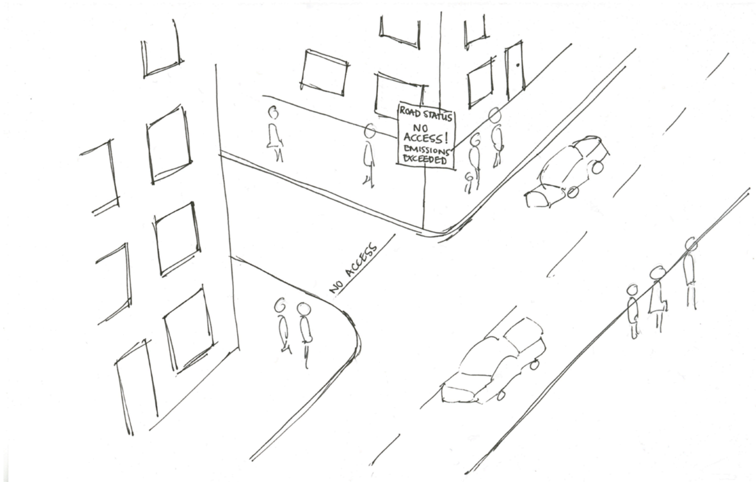
Proposal #1: Playtime



A first example of a flexible, community-controlled system is inspired by Peter Norton's articulation of city streets prior to the domination of the personal vehicle. Prior to the vehicle, city streets were often used by children for play; this use became impossible due to the danger posed by personal vehicles driving through streets. With a new model of community control, we envision a scenario where a group of kids in a neighborhood decide they would like to play outside. Because members of the community have control over their local streets, a parent, or group of parents, can use a personal device to request the shutdown of traffic on a local street for a few hours. The request can be submitted, analyzed for impacts to the overall traffic system, and, if acceptable, approved in just a few moments. At a local level, vehicles will be restricted from entering a neighborhood street (with the exception of any residents living on the street or emergency vehicles, which may be permitted to use the street at reduced speeds); at a system level, CAVs will adjust navigation routes in response to the street closure. At the end of the requested session, the children will clear the street and vehicles may return to normal operation.

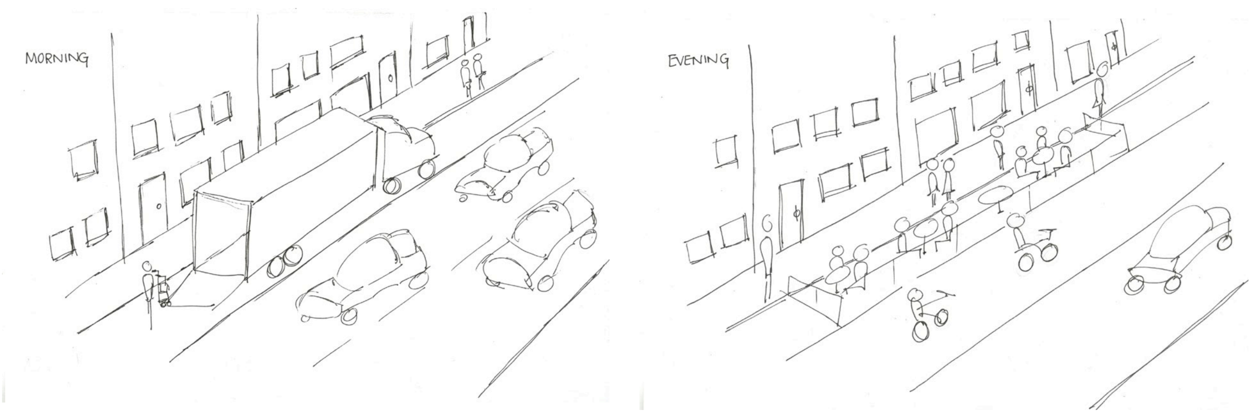
This first example takes advantage of V2I technologies and integrated, system-level navigation systems to allow for community control of local streets while mitigating impacts to the overall transportation system.

Proposal #2: Performance metrics for emissions



A second example may also take place at the neighborhood level - placing limits on allowable tailpipe emissions in a neighborhood. A neighborhood may request that vehicles emitting certain levels of pollutants may be restricted from the neighborhood, or place a limit on overall emissions in the area. Using sensor and information technologies, neighborhood infrastructures can measure emissions levels of cars attempting to flow through the neighborhood; if vehicle emissions exceed a certain level, its access to the streets in the neighborhood will be restricted. Upon communication of the restriction, the regional CAV system will adjust flows to address the community parameters. In this scenario, neighborhoods can control local streets to create improved environmental conditions. One can imagine the system being used similarly to limit noise or light pollution levels by cars as well.

Proposal #3: Curb management



A third example is a system that involves curb management in a commercial corridor. Curb spaces are traditionally used for vehicle storage and delivery truck parking for loading and unloading of goods. As mentioned above, however, curbs are becoming contested elements of the public right of way. With the proposed system of locally controlled streets, one can envision a scenario where business owners flexibly manage curbs based on business and customer needs and time of day. For example, in the morning, business owners may agree to limit curb access to delivery trucks. Once the businesses open, owners may restrict all vehicles from using the curb, instead using the curb space as an extension of their business, whether it be chairs and tables for a restaurant, or additional tables with goods for sale. At the same time, in the morning, all vehicles may be allowed to use the street lanes outside the businesses; once businesses open, vehicle access is restricted, making way for pedestrians and cyclists. In this scenario, business owners are able to flexibly manage their streets to operate their businesses and delight their customers.

Proposal #4: Protest

A final proposal envisions how the right to the city might manifest in a world with connected, automated vehicles. Gatherings and protest in public rights of way are a fundamental right of urban inhabitants. Stopping traffic in order to express social and political outrage is a longstanding part of urban life; more than half of 1,400 Black Lives Matter protests between in 2014 and 2015 ended up shutting down transportation systems (Badger, 2016). In the case of future protest, it will be essential for the system *not* to automatically account for protests by seamlessly rerouting traffic around and away from mobilizations. Protest on street, which inherently seeks to inconvenience travelers, could continue to do so, with algorithms that link the physical act of protest with true time costs for travelers, as well as information about the protest.

These limited examples provide a sense of the opportunities associated with flexible, locally controlled streets that enable communities to make better use out of public rights of way. The community-based agents with jurisdiction over local streets are empowered to make decisions about public space; CAV and navigation technologies enable these decisions to be made and integrated into the overall transportation system with minimal disruption. We acknowledge that these scenarios have significant regulatory, economic, and political implications that we discuss further below. However, these straightforward scenarios are developed to help planners envision the possibilities and begin to reckon with the implications and requirements for implementation.

Discussion

Our initial examination envisions an alternative approach to managing CAVs and other mobility technologies, an approach that privileges local decisionmaking and flexible use of public rights-of-way. While we argue that these approaches are feasible, based on the technologies of connection and automation, we know that this paper raises many questions, both for practitioners and researchers. Major technical questions remain to be resolved. For example, we do not yet know when Level 5 automation will become widespread, particularly on urban streets. Connectivity with an infrastructure that can receive local control directives is currently undeveloped. There may be system resilience and safety concerns associated with providing so many individuals access to control facets of the transportation system. Would such a system make the overall CAV-enabled transportation system more vulnerable to hacking, relative to one managed only top-down? Despite these issues, public organizations, such as NACTO (sharedstreets.io) and the City of Los Angeles (Mobility Data Specification), are currently developing systems that would be able to encompass the complex sets of information about streets and vehicles necessary to manage them locally and flexibly. Private companies as well, such as Google with their Coord subsidiary, are developing private models of street management.

In addition to technical questions, we must consider legal or jurisdictional questions. Can and will cities devolve control of management of public rights of way to citizens or citizen groups? Tactical urbanism exists because of the limitations and failures in the top-down municipal governance of public rights-of-way. What types of control are cities willing to accede to communities, and how would they be managed? Of course, neighborhoods in themselves may seek to exclude in prejudicial ways, and control can be abused to prevent neighborhood access to vulnerable groups. The multi-scaled definitions of rights and democracy in this framework require significant development. Ultimately, these are significant challenges not just of technology but for urban society. However, today's roads already have given over so much to the circulation of vehicles, without significant concern for the people and places alongside them. The revolution in vehicle and mobility control coming into focus due to CAVs and information technologies is a critical opportunity to change the trajectory of street management toward communities and flexibility after more than one hundred years of automobile dominance.

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