Smart Cities, Dumb Infrastructure

Policy-Induced Competition in Vehicle-to-Infrastructure Systems

Korok Ray and Brent Skorup

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Abstract

The coinciding development of 5G wireless technology, autonomous vehicles, and smart city applications is creating commercial demand for vehicle-to-infrastructure (V2I) systems. In theory, roadside V2I systems and sensors could provide real-time services, such as supplementary mapping information to autonomous vehicles, traffic detection, and congestion pricing. Although federal funding of V2I systems has ramped up in recent years, federal regulators have largely retreated from their top-down design of V2I services and devices. These trends—undirected government funding and private construction of V2I applications and devices—leave state and local transportation officials with powerful discretion over the construction and design of V2I systems. We describe and anticipate the tradeoffs that lawmakers, regulators, and state authorities will face as they budget for and fund V2I roadside networks. We find that public-private partnerships likely will have greater prominence in the construction of roadside V2I networks. Finally, we apply the "policy-induced competition model" to inform when public intervention into V2I funding and design is effective. We propose regulator adoption of an open access model for long-lasting roadside assets. This "dumb infrastructure" model promotes competition and innovation in V2I while minimizing use of regulator resources and public funding of networks.

JEL codes: O3, L5, R42, R48

Keywords: autonomous, infrastructure, technology, V2I, V2V, car, transportation, innovation, P3, roadside, vehicles

Author Affiliation and Contact Information

Korok Ray
Mays Innovation Research Center
Texas A&M University
korok@tamu.edu

Brent Skorup
Senior Research Fellow
Mercatus Center at George Mason University
bskorup@mercatus.gmu.edu

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Introduction

For 25 years, federal and state transportation regulators have anticipated the widespread use of wireless systems to improve traffic, road financing, and roadway safety. Only recently has the necessary technology—including fiber optic networks, wireless networks, spectrum availability, and inexpensive devices—progressed to the point that widespread vehicle-to-infrastructure (V2I) communication is a possibility. Although federal funding of V2I systems has increased in recent years, federal regulators largely have retreated from their top-down design of V2I systems and devices. Technology and telecommunications companies are building V2I systems and devices that don't resemble earlier federal designs. These trends—government funding combined with commercial design of V2I and "smart city" applications—create uncertainty about the role of state and local transportation regulators.

V2I is related to the older vehicle-to-vehicle (V2V) paradigm, where connected vehicles communicate with other connected vehicles to increase travel efficiency and safety. Collectively, these technologies are called vehicle-to-infrastructure (V2I) technology, a subset of what transportation experts call intelligent transportation systems (ITS) and vehicle-to-anything (V2X). V2I builds on connected vehicle and V2V technology to include connected infrastructure, allowing connected vehicles to communicate not only with each other but also with roads, street signs, and intersections.

This push for more V2I systems will create more demand for rights-of-way access. Two developments have made road rights of way and "street furniture"—such as light poles and utility poles—increasingly valuable assets for transportation technology. First, the introduction of automated vehicles onto public roads has boosted demand for high-bandwidth and supplemental wireless services such as V2I and V2X. Second, operators around the country are installing cellular and wireless devices for "smart city," 5G, and internet-of-things services. Many of these services will include V2I services or will be installed alongside V2I-only devices and on street furniture. Technology overlap and convergence seem likely—these services all require roadside data networks and devices—and the commercial viability of these wireless services could serve to jumpstart the ITS and V2I networks that use similar inputs for deployment.

Given the quasi-public nature of roadways, rights of way, and smart city services, some form of public-private partnerships (P3s) likely will be used to deploy V2I systems.[1] We describe and anticipate the tradeoffs that lawmakers, regulators, and state authorities will face as they budget for and fund V2I and smart city systems. In particular, we provide a framework for where V2I investment should be allocated. We believe the policy-induced competition model we describe can help inform federal, state, and local transportation authorities as they consider P3s and V2I construction.

This paper proceeds as follows: The first section outlines the history of V2I in the United States, the recent government pullback from design of V2I systems, and the current capabilities of V2I networks. The next section discusses barriers to P3s and the various public-private mixes that could be effective to build and operate V2I and related infrastructure. The third section introduces "policy-induced competition" and its history in network regulation. That section also demarcates different categories of infrastructure needed for widespread V2I—basic

[1] *See, e.g.*, Clifford Winston, *How the Private Sector Can Improve Public Transportation Infrastructure* 16–32 (Mercatus Ctr. at George Mason Univ., Working Paper, 2013) (citing transportation privatization case studies).

infrastructure, network infrastructure, and devices—and their potential for competitive entry. The paper concludes with an application of policy-induced competition to V2I infrastructure.

Background on Intelligent Transportation and V2I Systems

In 1991, Congress created the Intelligent Transportation Systems Joint Program Office, which is administered by the US Department of Transportation (USDOT).[2] V2I systems are the primary component of ITS. The USDOT committed at the time to develop ITS via "a top-down, systematic process"[3] in which, the department said, "each component of the system" is prescribed by regulators.[4] In the decades since, the USDOT has retreated from that regulation-intensive approach. Nevertheless, federal funding for ITS and V2I systems has increased. Today, transportation authorities wanting V2I systems can draw from federal highway programs totaling more than $30 billion annually.[5]

The Retreat of Prescriptive Regulations

In the 1990s, ITS was developed because regulators and auto companies anticipated that V2I and connected vehicle applications would improve traffic light signaling, detect road anomalies (such as road construction and accidents), detect imminent auto collisions, and provide in-car

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[2] FCC, In the Matter of Amendment of the Commission's Rules Regarding Dedicated Short-Range Communication Services in the 5.850–5.925 GHz Band, WT Dkt. No. 01-90, para 6 (rel. Feb. 10, 2004).
[3] DEPT. OF TRANSP., NATIONAL ITS PROGRAM PLAN: SYNOPSIS 21 (1st ed. Mar. 1995), https://rosap.ntl.bts.gov/view/dot/2706.
[4] *Id*.
[5] The National Highway Performance Program allowed $22.8 billion in funding in FY 2017 for "[i]nfrastructure-based intelligent transportation systems capital improvements, including the installation of vehicle-to-infrastructure communication equipment." 23 U.S.C. § 119(d)(2)(L) (2018). The Surface Transportation Block Grant Program allowed $11.4 billion in funding in FY 2017 for "[c]onstruction of . . . infrastructure-based intelligent transportation systems capital improvements, including the installation of vehicle-to-infrastructure communication equipment." 23 U.S.C. 133(b)(1)(D) (2018). Most of this funding will go to more traditional transportation projects, but funding toward V2I likely will increase as the benefits of V2I systems become more evident.

entertainment, as well as perform many other functions.[6] For years, through their funding of pilot programs and tests, the USDOT and state departments of transportation (DOTs) were extensively involved in the specific design of ITS and its subsets, such as V2I and V2V technology. Despite their involvement, the complexity of wireless safety technology and the extensive infrastructure upgrades needed for ITS mean that progress has been slow. As the Government Accountability Office noted in a 2015 report to Congress, "V2I technologies are not likely to be extensively deployed in the United States for the next few decades."[7]

The most notable ITS development—the creation of dedicated short-range communications (DSRC) technology—revealed some of the drawbacks of the top-down design approach toward ITS. After spectrum was set aside for ITS uses in 1999, the Federal Communications Commission (FCC) codified DSRC transmission standards in 2003, and DSRC device development commenced in pilot deployments of ITS.[8] However, the USDOT perceived a slow development of DSRC devices; therefore, around 2010, the USDOT "took a lead role in the device development process."[9] To jump-start widespread DSRC adoption, in the waning days

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[6] *See* FCC, In the Matter of Amendment of Part 2 and 90 of the Commission's Rules to Allocate the 5.850–5.925 GHz Band to the Mobile Service for Dedicated Short Range Communications of Intelligent Transportation Services, ET Docket No. 98-95, RM-9006, Report and Order, para 10 (rel. October 22, 1999) (articulating "a need for up to 32 different DSRC" functions).

[7] U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-15-775, INTELLIGENT TRANSPORTATION SYSTEMS: VEHICLE-TO-VEHICLE TECHNOLOGIES EXPECTED TO OFFER BENEFITS, BUT DEPLOYMENT CHALLENGES EXIST 16 (2015).

[8] The FCC set aside 75 MHz of radio spectrum in the 5.9 GHz band for ITS uses in 1999. FCC, In the Matter of Amendment of Part 2 and 90 of the Commission's Rules to Allocate the 5.850-–5.925 GHz Band to the Mobile Service for Dedicated Short Range Communications of Intelligent Transportation Services, ET Docket No. 98-95, RM-9006, Report and Order (rel. October 22, 1999). In 2004, the FCC required ITS users to abide by DSRC standards. FCC, In the Matter of Amendment of the Commission's Rules Regarding Dedicated Short-Range Communication Services in the 5.850-–5.925 GHz Band, WT Dkt. No. 01-90, para 19 (rel. Feb. 10, 2004). Two years later, the FCC updated channel designations and power limits after parties petitioned for changes. FCC, In the Matter of Amendment of the Commission's Rules Regarding Dedicated Short-Range Communication Services in the 5.850–5.925 GHz Band, Memorandum and Order, WT Dkt. No. 01-90 (rel. July 26, 2006).

[9] U.S. DEPT. OF TRANSP., SAFETY PILOT MODEL DEPLOYMENT, 50 FHWA-JPO-16-363 (Sept. 2015). *See also* U.S. GOV'T ACCOUNTABILITY OFFICE, *supra* note 7, at 12 ("[T]o date, only small research deployments . . . have occurred to test V2I technologies."). Possibly because of the nonuse of the ITS spectrum, a 2012 law opened the door to non-ITS use of the band. Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. No. 112-96, § 6406, 126 Stat. 156, 231 (2012).

of the Obama administration, the USDOT proposed mandating DSRC-based V2V devices for most new vehicles.[10] With widespread V2V devices, the thinking went, state and local governments would have incentives to install V2I infrastructure needed for ITS.

Today, the federal government seems ambivalent about its top-down approach to designing ITS as it freezes (or withdraws) prescriptive regulation for ITS devices while it increases funding for ITS networks. On the one hand, regulatory directives for the USDOT have changed with the change of administration in 2017. During the past few years there has been steady improvement of non-DSRC V2I technologies, such as cellular, radar, and cameras. On the other hand, there is a growing sense, noted by the Government Accountability Office and others, that the state and local transportation authorities will not have the personnel and funding necessary to install and maintain an extensive ITS system.[11]

As a result, the USDOT is getting away from its earlier, prescriptive development of V2I. The most significant sign of this change is that the 2017 USDOT proposal to mandate DSRC V2V devices appears to have lost momentum in the federal government. The Trump administration has articulated a preference for a "tech-neutral" and deregulatory approach to ITS technologies.[12] Furthermore, USDOT-commissioned research published a few months before the proposed V2V mandate in 2016 identified technical deficiencies with DSRC.[13] To

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[10] 82 Fed. Reg. 3854, 3893 (Jan. 12, 2017).

[11] *See, e.g.*, U.S. GOV'T ACCOUNTABILITY OFFICE, *supra* note 7, at 21–24 ("Ten experts we interviewed, including six experts from state and local transportation agencies, agreed that the lack of state and local resources will be a significant challenge to deploying V2I technologies.").

[12] *See, e.g.*, Joan Lowy, *Gov't Won't Pursue Talking Car Mandate*, ASSOCIATED PRESS, Nov. 1, 2017, https://apnews.com/9a605019eeba4ad2934741091105de42. Since fall 2017, the USDOT position on ITS spectrum has been "technology neutral, meaning in this instance, DOT doesn't favor limiting the manner in which vehicles and infrastructure communicate with each other." Sam Mintz, *DOT Tries to Clear up Connected Car Stance*, POLITICO (Oct. 25, 2018) (quoting a USDOT statement submitted to *Politico*).

[13] The researchers found, *inter alia*, that the current error tolerances for DSRC V2V units "will fail to provide the desired levels of intended and reliable safety benefits." Ed Adams et al., *Development of DSRC Device and Communication System Performance Measures*, 5 REP. NO. FHWA-JPO-17-483 (May 22, 2016), http://ntl.bts.gov/lib/60000/60500/60536/FHWA-JPO-17-483.pdf.

preserve more technology neutrality and to avoid the premature mandate of a developing technology, the USDOT has recently paused the proposal to mandate DSRC V2V in new vehicles.[14] The Federal Highway Administration policy guidance therefore encourages private deployment of V2I systems.[15]

An Increase in V2I Funding

Despite this pause on the V2V mandate, federal funding for V2I has spiked to up to tens of billions of dollars annually. The 2015 FAST Act, for instance, authorized V2I reimbursements and grants to state DOTs across most of its Trust Fund programs.[16] The majority of federal highway funding is through the National Highway Performance Program (NHPP)[17] and the Surface Transportation Block Grant Program (STBGP).[18] NHPP funding for 2020 is estimated to be $24.2 billion.[19] This funding is typically allocated to state transportation officials, and the American Association of State Highway and Transportation Officials, the transportation standards body, would like to make 20 percent of US intersections V2I-capable by 2025.[20]

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[14] For instance, in fall 2017, the White House's Office of Information and Regulatory Affairs reclassified the V2V NPRM as a "Long-Term Action." *See* OFF. OF INFO. AND REG. AFF., FEDERAL MOTOR VEHICLE SAFETY STANDARD (FMVSS) 150—VEHICLE TO VEHICLE (V2V) COMMUNICATION, RIN 2127-AL55 (2017), https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=201704&RIN=2127-AL55. This classification means that no agency action is to be expected for 12 months. *See* Marc Scribner, *V2V Mandate Nixed*, COMPETITIVE ENTERPRISE INSTITUTE (Nov. 1, 2017), https://cei.org/blog/v2v-mandate-nixed-dot-ends-second-most-costly-us-regulatory-proposal.

[15] FED. HIGHWAY ADMIN., 2015 FHWA VEHICLE TO INFRASTRUCTURE DEPLOYMENT GUIDANCE AND PRODUCTS (2015), https://transops.s3.amazonaws.com/uploaded_files/V2I_DeploymentGuidanceDraftv9.pdf.

[16] NHPP, Highway Safety Improvement Program, Congestion Mitigation and Air Quality, Advanced Transportation and Congestion Management Technologies Deployment.

[17] The NHPP allowed $22.8 billion in funding in FY 2017 for "[i]nfrastructure-based intelligent transportation systems capital improvements, including the installation of vehicle-to-infrastructure communication equipment." 23 U.S.C. § 119(d)(2)(L) (2018).

[18] The Surface Transportation Block Grant Program allowed $11.4 billion in funding in FY 2017 for "[c]onstruction of . . . infrastructure-based intelligent transportation systems capital improvements, including the installation of vehicle-to-infrastructure communication equipment. 23 U.S.C. § 133(b)(1)(D) (2018).

[19] *See* FED. HIGHWAY ADMIN., *Fixing America's Surface Transportation Act or "FAST,"* FHWA WEBSITE (Feb. 2016), https://www.fhwa.dot.gov/fastact/factsheets/nhppfs.cfm.

[20] U.S. GOV'T ACCOUNTABILITY OFFICE, *supra* note 7, at 17.

Promising Commercial V2I Applications

The parallel development of autonomous vehicles (AVs) and smart city applications has created new demands for V2I applications. A widespread ITS system requires many of the same inputs as smart city, AV, and 5G systems: namely, roadside real estate, vertical assets for device attachment, and fiber broadband networks to connect nodes and devices. A fiber-connected light pole constructed for traffic signaling, for instance, could also serve commercial firms offering 5G, WiFi, or other wireless connectivity for pedestrians, residents, city services, and connected vehicles. There are about 25 million streetlights owned by cities around the country,[21] and 5G and smart city operators are interested in installing transmitters on many of those streetlights.[22] That means, in effect, that ITS need not be limited to government funding, tolling, or ads for revenue—wireless subscriptions (as the tens of thousands of macro cell towers show) can fund network deployments.

AV companies could be one of those new enterprise subscribers to always-on roadside wireless networks. Most computer processing of autonomous vehicle functions will occur using onboard computers and sensors, such as LiDAR and radar, but autonomous car company representatives have stated that their vehicles will use V2I and smart city applications to supplement their onboard units.[23] One possible area is assistance with lane detection: observations of lane markings are only as strong as the visibility of the markings themselves.[24]

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[21] Matt Kapko, *Sacramento's 5G Story Dimmed by Legal Spat Involving Verizon, XG*, FIERCE WIRELESS, Nov. 12, 2018, https://www.fiercewireless.com/wireless/sacramento-s-5g-story-dimmed-by-legal-spat-involving-verizon-xg.
[22] *Id.*
[23] Dmitri Dolgov, chief technology officer of Waymo, has made this point. *See* Dmitri Dolgov, *From Self-Driving Cars to a Vision for Future Mobility*, OFC PLENARY (Mar. 15, 2019, 2:53 PM), https://www.youtube.com/watch?reload=9&v=z0QWTw-WuFc&feature=youtu.be&t=631 ("[A]ll of our vehicle driving decisions are performed on-board. So while we don't rely on cell networks to make driving decisions, we can leverage it for expanded capability. So the promise of high-bandwidth and low-latency networks is something that we're very interested in and it's very welcome.").
[24] U.S. DEPT. OF TRANSP., INFRASTRUCTURE INITIATIVES TO APPLY CONNECTED- AND AUTOMATED-VEHICLE TECHNOLOGY TO ROADWAY DEPARTURES 38 (2018).

Unfortunately, when weather or lighting conditions are poor, lane markings are hard to see for both man and machine, which makes navigation difficult and dangerous.[25]

In the United States, there is progress with embedding solar-powered LEDs into lane markings to provide visibility of edge lines in poor lighting and difficult weather conditions.[26] This relatively simple technology costs $50 per pavement marking, inclusive of materials and labor. If LED markers were embedded in 50-yard increments, a one-mile stretch would cost only about $1,760. With such markings, the pavement marker is visible from a greater distance, which allows for a longer reaction time of 30 seconds, versus the three-second response time of traditional lane markings. Again, this technology could assist both human and machine drivers.[27] Therefore, it could be valuable for mixed traffic that includes both kinds of drivers on the road simultaneously.

Smart roadway lighting is a more significant and sophisticated technology, often contemplated in smart city plans. Today, lampposts and lights run all night, regardless of traffic.[28] This is especially wasteful on rural roads without much traffic. Adaptive roadway lighting can sense vehicles on the road and turn off and on as needed.[29] In addition, fully adaptive lighting can modulate depending on the time of day and weather conditions.[30] This kind of adaptive lighting could drastically save on energy costs, because the lights would turn off when there is no traffic.[31]

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[25] *Id*.

[26] *Id*. at 32; U.S. DEPT. OF TRANSP., *LED Raised Pavement Markers*, Rep. No. FHWA-SA-09-007 (2009).

[27] U.S. DEPT. OF TRANSP., *supra* note 24, at 39.

[28] *Id*. at 33.

[29] MARTIJN TIDEMAN ET AL., INST. OF ELECTRICAL AND ELECTRONICS ENGINEERS, A REVIEW OF LATERAL DRIVER SUPPORT SYSTEMS 992–99 (2007).

[30] *Id*.

[31] U.S. DEPT. OF TRANSP., *supra* note 24, at 33.

Pairing a roadside unit with a lamppost would allow the roadside unit to detect and communicate with autonomous vehicles and simultaneously adjust the light as needed.[32] This technology would require some investment up front but would provide benefits over time from the energy savings. The Virginia Tech Transportation Institute prototyped a simple system of on-demand lighting using DSRC, wireless lighting, and LED lights.[33] In this implementation, the vehicles send their location, speed, and route to a central server through DSRC, and the server sends the information back to the lights to control illumination and duration.

More advanced V2I technology involves dynamic speed harmonization. In roads across the United States, speed limits change depending on road curvature, traffic conditions, and other individual needs.[34] If sensors in the road automatically communicated speed limits to vehicles, autonomous vehicles could modulate their speed on the basis of those limits. One way that could occur is through variable speed limits, which are useful for reducing speed limits on an as-needed basis, such as when cars are approaching a crash area or during inclement weather.[35] Most drivers are not even aware when speed limits change, so not only could this technology improve compliance with the law, but it also could increase safety.[36]

Another smart city and V2I application is cooperative intersection controls.[37] If a sensor on a stoplight communicated with an autonomous vehicle, it could prevent navigation if the stoplight were red, allow navigation if the light were green, and slow navigation if the light

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[32] *Id*. at 33; *see also* Tideman et al, *supra* note 29.
[33] U.S. DEPT. OF TRANSP., *supra* note 24 at 33; RON GIBBONS ET AL., CONNECTED VEHICLE/INFRASTRUCTURE U. TRANSP. CTR., CONNECTED VEHICLE APPLICATIONS FOR ADAPTIVE OVERHEAD LIGHTING (ON-DEMAND LIGHTING) (2016).
[34] *Speed Limits,* TEX. DEPT. OF TRANSP., https://www.txdot.gov/driver/laws/speed-limits.html.
[35] Mehrdad Tajalli & Ali Hajbabaie, *Dynamic Speed Harmonization in Connected Urban Street Networks*, 33 COMPUTER-AIDED CIV. AND INFRASTRUCTURE ENGINEERING 510 (2018).
[36] U.S. DEPT. OF TRANSP., *supra* note 24.
[37] Lei Chen & Cristofer Englund, *Cooperative Intersection Management: A Survey*, 17 IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS 570 (2016).

turned yellow.[38] In this sense, traffic signals would not be mere suggestions to the driver but would actually be embedded into algorithms in the autonomous vehicle, just as with the variable speed limits.[39] This technology not only would increase compliance with the law but also likely would decrease accidents, given that autonomous vehicles no longer would run red lights. This is especially important because intersections are involved in 40 percent of crashes, 50 percent of crash injuries, and 25 percent of crash fatalities each year in the United States.[40]

Finally, perhaps the most advanced kind of technology to emerge with V2I is advanced road pricing. Tolls today simply allow a user to pay a certain amount for the right to travel on a road. In a more complex world, the tolls could be tailored to the specific attributes of the driver or the vehicle, such as vehicle size, weight, number of passengers, driving history, or accident record.[41] Little of that information is available in the pricing function today. Because of their size and weight, larger vehicles create more traffic and wear down road infrastructure more than smaller vehicles. A general principle known to transportation experts is that the damage caused to a road by a vehicle is the vehicle's axle load to the fourth power.[42] For example, vehicles with double-axle weight create 16 times more damage than those with single-axle weight. In principle, larger vehicles should pay higher tolls. Otherwise, large vehicles impose negative externalities and do not bear the social costs they create. More dynamic and adaptive granular

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[38] YINGYAN LOU & PEIHENG LI, SOLARIS CONSORTIUM, IMPACTS OF TRAFFIC SIGNAL CONTROLS ON A DISTRIBUTED TRAFFIC MONITORING SYSTEM USING V2V COMMUNICATIONS (2018).
[39] Alejandro I. Medina et al., *Cooperative Intersection Control Based on Virtual Platooning,* 19 IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS 1727 (2018).
[40] U.S. DEPT. OF TRANSP., *supra* note 24; Fed. Highway Admin., *Intersection Safety* (July 24, 2018), https://highways.dot.gov/research-programs/safety/intersection-safety.
[41] THE WHITE HOUSE, ECONOMIC REPORT OF THE PRESIDENT 181 (2018), https://www.whitehouse.gov/wp-content/uploads/2018/02/ERP_2018_Final-FINAL.pdf.
[42] This is called the Generalized Fourth Power Law. *See* U.S. DEPT. OF TRANSP., *Pavement, in* U.S. DEPARTMENT OF TRANSPORTATION'S COMPREHENSIVE TRUCK SIZE AND WEIGHT STUDY (2000), https://www.fhwa.dot.gov/reports/tswstudy/Vol3-Chapter5.pdf.

tolling would force those drivers and vehicles to bear their social cost, thereby moving society closer to efficient road usage.

Public and Private Models for V2I Construction and Financing

As is true with all infrastructure projects, financing V2I technology must balance competing needs, recovering fixed costs, and ongoing maintenance. Such projects would still require large upfront investments of capital and resources. Thus, the question becomes how to finance and structure the contract between the government, the user, the private sector, and the provider of technology. There is a long history of using P3s in transportation projects given the public nature of roadways and the efficacy or risk mitigation of contracting out elements of road projects to commercial firms.[43]

Public-Private Partnerships for V2I

Federal Highway Administration (FHWA) guidance currently allows private-sector use of roadside infrastructure for V2I devices, but private use must yield to public transportation uses.[44] How public and private use of roadside infrastructure is shared will depend on the terms of P3 contractual terms. A P3 is a contract between a private-sector entity, the service provider, and the government (the ultimate owner of the asset). For example, in the case of state highways, private parties can design, build, maintain, and collect revenue from a bridge or highway, while the state remains the ultimate owner of the asset.[45] The flexibility of a P3 allows the contract to farm out the regulatory or business risk to the commercial party.

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43 *See, e.g.*, Tracy C. Miller, *Role of the Private Sector in the Management of Highways: A Primer on Public-Private Partnerships* (Mercatus Ctr. at George Mason Univ., Working Paper, 2018).
44 *See* FED. HIGHWAY ADMIN., 2015 FHWA VEHICLE TO INFRASTRUCTURE DEPLOYMENT GUIDANCE AND PRODUCTS 11–12 (2015), https://transops.s3.amazonaws.com/uploaded_files/V2I_DeploymentGuidanceDraftv9.pdf.
45 *See generally* Miller, *supra* note 43.

In 2015, the FHWA announced guidance on V2I deployment.[46] It recommended private-sector involvement in V2I, given its relative strengths in technology, innovation, and deployment.[47] Primarily, the guidance aimed to encourage private-sector entities to develop these technologies and work with states and municipalities through P3 agreements.[48] For example, the private sector needed to ensure that the roadside units it developed complied fully with state and local laws and allowed public owner-operators to control traffic signals, monitor traffic, distribute security certificates to vehicles, and provide traveler information to vehicles through V2I communications.[49] The FHWA guidance also asked for priority treatment of public-sector fleets, including incident responder vehicles (e.g., ambulances).[50] At the highest level, the guidance insisted that P3 agreements guarantee V2I safety first and provide an exit option for termination should the private-sector uses degrade the V2V or V2I environment.[51]

P3s are still relatively rare in the United States.[52] Nonetheless, V2I presents an opportunity for new uses of P3s The FHWA allows state DOTs to use federal funds to structure these P3 agreements so that the private developer can deploy and operate the V2I system even if

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[46] *See generally* FED. HIGHWAY ADMIN, *supra* note 44.
[47] *Id.*
[48] *Id.* at 20.
[49] *Id.*
[50] *Id.* at 13.
[51] *Id.* at 11; 61 Fed. Reg. 45,618 (Aug. 29, 1996), as amended at 63 Fed. Reg. 12,025 (Mar. 12, 1998).
[52] The House of Representatives Transportation and Infrastructure Committee found that between 1989 and 2013, only 1.5 percent of the $4 trillion spent on highways was conducted and executed through P3 agreements. COUNCIL OF ECONOMIC ADVISERS, ECONOMIC REPORT OF THE PRESIDENT 196 (2018), https://www.whitehouse.gov/wp-content/uploads/2018/02/ERP_2018_Final-FINAL.pdf. A 2014 report from the Congressional Research Service predicts P3s to be capable of bringing in no more than 7–8 percent of overall transportation spending. WILLIAM MALLET, CONG. RESEARCH SERV., R43410, HIGHWAY AND PUBLIC TRANSPORTATION INFRASTRUCTURE PROVISION USING PUBLIC-PRIVATE PARTNERSHIPS (P3S) (2014), https://fas.org/sgp/crs/misc/R43410.pdf. There is widespread public support for more private investment in national transportation projects, where 78 percent of registered voters support the idea, according to a Rockefeller Foundation survey. HART RESEARCH ASSOCIATES/PUBLIC OPINION STRATEGIES, THE ROCKEFELLER FOUNDATION INFRASTRUCTURE SURVEY 4 (2011), https://www.swmpc.org/downloads/rockefeller_foundation_infrastructure_survey.pdf.

it exists on top of a public asset.[53] In that instance, the private developer becomes responsible for the highway (e.g., construction and maintenance).[54]

The FHWA guidance is not binding, but it establishes principles the federal government would like to see as this new area unfolds.[55] Most of the guidance is uncontroversial, with the small exception of the business model that the government recommends. The FHWA discourages private entities from receiving revenue directly from the user but encourages the revenue to come from use of the communications channel, such as through advertising.[56] Although advertising is one possibility, there is no need for the government to specify the right business model in advance. Instead, the government should let the market decide how best to monetize and finance the new technology.

In a typical P3, the private entity signs a design, build, finance, operate, and maintain (DBFOM) contract, and the state or city retains ownership and can restrict the terms of the contract in various ways.[57] These contracts are typically toll concessions to private firms, which

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[53] FED. HIGHWAY ADMIN., *supra* note 44, at 20.
[54] *Id.*
[55] *Id.* at 1. "Deployment of V2I technologies *is not mandated* and is not coupled with the National Highway Traffic Safety Administration's (NHTSA) advance notice of *proposed* rulemaking for Vehicle-to-Vehicle (V2V) communications. . . . The guidance, associated guides, toolkits, and products are to be a *useful resource* to help those considering V2I deployment and to leverage developments in V2V communications" (emphasis added).
[56] *Id.*
[57] CTR. FOR INNOVATIVE FIN. SUPPORT, FED. HIGHWAY ADMIN., P3 PROJECTS (2019), https://www.fhwa.dot.gov/ipd/p3/p3_projects/. For example, a private consortium built the 91 Express Lane, a 10-mile, four-lane express toll facility in southern California. CTR. FOR INNOVATIVE FIN. SUPPORT, FED. HIGHWAY ADMIN., PROJECT PROFILE: 91 EXPRESS LANES (2019), https://www.fhwa.dot.gov/ipd/project_profiles/ca_91expresslanes.aspx. This P3 gave the private consortium control for 35 years, but the state capped the rate of return. *Id.* Another example is the Dulles Greenway in Loudoun County. Va. CTR. FOR INNOVATIVE FIN. SUPPORT, FED. HIGHWAY ADMIN., PROJECT PROFILE: DULLES GREENWAY (2019), https://www.fhwa.dot.gov/ipd/project_profiles/va_dulles_greenway.aspx. A private consortium put together $40 million in equity and $310 million in privately placed debt. *Id.* The consortium repaid these loans with toll revenues. *Id.* The state set caps at roughly 2.8 percent per year as the limit at which tolls would increase. *Id.* Another example is the Indiana Toll Road. ITR Concession Company LLC, a private company, operates this 157-mile road after it was awarded a 75-year lease for $3.8 billion in 2006. The Indiana Finance Authority owns the toll road. IND. DEPT. OF TRANSP., INDIANA TOLL ROAD (2019), https://www.in.gov/indot/2413.htm. Since 2016, ITR has invested more than $200 million in improvements on the Indianan section of the toll road. ITR CONCESSION CO. LLC., INDIANA TOLL ROAD, *ABOUT US* (2019), https://www.indianatollroad.org/about-us/. The toll road spans three states.

construct and maintain roadways and collect tolls as a funding mechanism.[58] Virginia has successfully completed several transportation projects through DBFOM P3s. For example, a DBFOM contract between the Virginia DOT and Capital Beltway Express created the Capital Beltway Express Lanes. Other types of P3s, such as revenue-risk P3s, have also seen relative success in this area.[59] P3s can finance more than just the construction of roads, however; other examples include roadside infrastructure such as park-and-ride facilities and bus corridors.[60]

Budget and Expertise Constraints on Public Operation of V2I

Many state and local transportation authorities may find it useful to seek P3 alternatives to exclusively public construction and management of V2I systems. V2I deployment can be a costly investment for a state. The Government Accountability Office (GAO) estimates, for instance, that V2I intersections will have average nonrecurring costs of $50,000 apiece.[61] The nature of transportation funding does not always encourage purchases of high-quality, long-lasting V2I devices. As the FHWA's updated Traffic Detector Handbook noted,

> Budgetary problems that continue to plague traffic agencies have resulted in a cost consciousness that frequently focuses only on initial cost, rather than on lifetime cost. Consequently, less expensive products, materials, and processes are used in the original installation because of their lower initial cost.[62]

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[58] Miller, *supra* note 43, at 21–22.
[59] In 2017, a revenue-risk P3 contract was established between Cintra, Meridiam, and Va. DOT to rebuild a section of Interstate 66.
[60] In the Washington, DC, metropolitan area, a P3 to expand 22.5 miles of I-66 in Virginia included modifications such as reconfiguring on and off ramps; modifying toll collection; providing bridge and utility upgrades; constructing park and ride facilities with access to pedestrian and bike facilities; preserving a large median strip for future transit use; and providing new, expanded bus services along the corridor. CTR. FOR INNOVATIVE FIN. SUPPORT, FED. HIGHWAY ADMIN., PROJECT PROFILE: TRANSFORM 66 – OUTSIDE THE BELTWAY (2019), https://www.fhwa.dot.gov/ipd/project_profiles/va_transform_66.aspx.
[61] U.S. GOV'T ACCOUNTABILITY OFFICE, *supra* note 7, at 39–40.
[62] DEPT. OF TRANSP., TRAFFIC DETECTOR HANDBOOK: THIRD EDITION–VOLUME II 6-1 (2006), https://www.fhwa.dot.gov/publications/research/operations/its/06139/06139.pdf.

This cost consciousness caused significant problems within the Michigan V2I pilot programs. There, the USDOT installed 58 DSRC units in the Detroit area. Roughly half of the units failed within a year of installation, typically as a result of water intrusion.[63] As a California V2I program showed, V2I units require regular upgrades and represent ongoing costs as older generations of units become obsolete.[64] Furthermore, there has been a general degradation in transportation funding and infrastructure maintenance in the United States. Federal and state transportation departments employ more than 200,000 workers, many of whom are full-time employees devoted to regulatory compliance.

For many authorities, the prospect of V2I maintenance (which requires repairs, software updates, and cybersecurity patches for huge IT systems) is too risky for public operation. Other good reasons to consider private operation of V2I networks include the up-front costs, ongoing maintenance and management, and innovation losses from public operation and ownership of V2I street furniture, networks, and devices. There is also increasing public wariness of publicly operated networks that collect location information, audio, and video of people via ITS and smart city networks. Transportation regulators are, in other words, ill equipped to build, maintain, and upgrade V2I networks and devices citywide or statewide.

Framework for Competitive V2I

V2I systems represent transportation projects that are ancillary to road projects. These systems typically will occupy public rights of way, utility poles, and other street furniture. For new

[63] RICHARD WALLACE & VALERIE SATHE BRUGEMAN, MICHIGAN DEPARTMENT OF TRANSPORTATION VII TEST BED INVENTORY REPORT (Apr. 20, 2009), http://www.michigan.gov/documents/mdot/MDOTVIITestBedInventoryReport-20Apr2009_320014_7.pdf.
[64] STEVEN SHLADOVER, VEHICLE-INFRASTRUCTURE COOPERATION USING DEDICATED SHORT RANGE COMMUNICATIONS (DSRC) 1 (2015), https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/final-report-task-2297-a11y.pdf.

infrastructure investments that have yet to begin, V2I technology should be an integral part of the P3 that will govern the creation and maintenance of that project. More to the point, lawmakers should keep V2I technology in mind when they fund infrastructure improvements; although the cost of V2I technology is relatively low when compared to the total cost of a project, V2I technology will have an impact in determining the overall design and operation of the road.[65] Federal guidelines anticipate that private contractors of ITS services will provide many V2I services.[66] However, private and P3 construction of V2I infrastructure and devices could raise the prospect of anticompetitive treatment toward 5G and smart city operators. To allow for competitive ITS services, V2I infrastructure contracts with private firms should be designed with competitive device makers in mind.[67]

This allowance for device competition is important, because most V2I and connected vehicle services can be competitively provided (particularly the consumer services, such as traffic alerts, traffic metering, incident reports, and real-time public transit updates). Furthermore, V2I can be one of several data services provided by a wireless broadband network, alongside services such as consumer smartphone applications, smart city applications, and internet-of-things applications. The terms of a P3 contract for roadway projects are complex, but the policy-induced competition framework can help illuminate where competition is likely to succeed without unnecessarily damaging the financial viability of a project.

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[65] Khair Jadaan et al., *Connected Vehicles: An Innovative Transport Technology*, 187 PROCEDIA ENGINEERING 641, 642–43 (2017). For example, it matters greatly whether V2I will attach to a dedicated single road for autonomous vehicles or work on all lanes with both human and machine drivers. FED. HIGHWAY ADMIN., MULTIPLE SOURCES OF SAFETY INFORMATION FROM V2V AND V2I: REDUNDANCY, DECISION MAKING, AND TRUST 14 (2015), https://www.fhwa.dot.gov/publications/research/safety/15007/15007.pdf.

[66] FED. HIGHWAY ADMIN., *supra* note 44, at 20.

[67] Some V2I services, by their nature, must have a single service provider. There can't be "competitive" operation of traffic signaling. Similarly, tolling services likely will remain with a single operator.

Policy-Induced Competition

One method for introducing private competition into a network industry is through policy-induced competition. Policy-induced competition means that firms are required to interoperate at a specified market boundary, be it spatial, temporal, or customer based. Not every interoperability mandate works well. The approach has been proposed in many areas, such as internet service provider competition[68] and cable TV box competition,[69] though success has been rare. For that reason, we attempt to specify where policy-induced competition has the best shot at succeeding in creating competition with minimal monitoring by regulators.

In the literature, the seminal example of successful policy-induced competition is the development of a competitive market for phone equipment despite the monopoly power of the AT&T network in the mid-20th century.[70] In the 1970s, after complaints of vertical exclusion by AT&T of competitive device makers and a change in regulatory philosophy at the federal level, the FCC looked for ways to create a competitive networked device industry.[71] The FCC adopted simple standards specifying an open interface to connect a non-AT&T device to the AT&T public switched telephone network.[72] For telephony, there wasn't a market boundary for competitive devices—the FCC created one.

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[68] Anupam Banerjee & Marvin Sirbu, *Towards Technologically and Competitively Neutral Fiber to the Home Infrastructure*, CARNEGIE MELLON UNIVERSITY (2005), http://www.andrew.cmu.edu/user/sirbu/pubs/Banerjee_Sirbu.pdf.

[69] Brent Skorup, *Why the FCC's Plan to Improve Set Top Boxes Will Backfire*, PLAIN TEXT (Feb. 6, 2016), https://readplaintext.com/why-the-fcc-s-plan-to-improve-set-top-boxes-will-backfire-32e148e665c ("When the dust had settled, despite ten years of FCC efforts, Motorola and Cisco, who supply cable set top boxes to cable companies, [still] comprised about 95% of the STB market.").

[70] *See, e.g.*, Philip J. Weiser, *Regulating Interoperability: Lessons from AT&T, Microsoft, and Beyond*, 76 ANTITRUST L.J. 271, 274 (2009) (stating that the FCC regime "is viewed as an enormous success"); Gerald Faulhaber, *Policy-Induced Competition: The Telecommunications Experiments*, 15 INFO. ECON. & POL'Y 73 (2003).

[71] Faulhaber, *supra* note 70, at 76.

[72] PROPOSALS FOR NEW OR REVISED CLASSES OF INTERSTATE AND FOREIGN MESSAGE TOLL TELEPHONE SERVICE (MTS) AND WIDE AREA TELEPHONE SERVICE (WATS), First Report & Order, 56 F.C.C. 2d 593, 594–96 (1975), modified, 58 F.C.C.2d 716, modified, 58 F.C.C. 2d 736 (1976), *aff'd sub nom.* North Carolina Utils. Comm'n v. FCC, 552 F.2d 1036 (4th Cir. 1977).

As professor and former FCC economist Gerald Faulhaber writes about the AT&T experience,[73] the introduction of competition in a market in which competitors must interoperate with a monopolist in a vertically related market will be successful only if either of the following two conditions obtain:

1) The market boundary is simple, easy to monitor, and requires little information (that is, transaction costs across this market boundary are small); or
2) The residual monopolist is successfully enjoined from operating in the newly competitive market.

In a P3 agreement for the construction of V2I, the private contractor-operator will be a monopolist controlling roadside right of way, street furniture (such as utility poles and lampposts), and certain network equipment. The second condition won't obtain—the V2I contractor-operator won't be enjoined from operating a roadside wireless network. Therefore, for competitors to interoperate successfully and attach their equipment to roadside infrastructure, the first condition will need to obtain. To have competitive V2I systems, the market boundary specified in P3 contracts will need to be simple and easy for public officials to monitor.

Antitrust goes a long way toward opening platforms to competition; however, as Judge Richard Posner has written about the "new economy," it's the case that "the [antitrust] enforcement agencies and the courts do not have adequate technical resources, and do not move fast enough, to cope effectively with a very complex business sector that changes very rapidly."[74] Federal guidance currently places a premium on interoperability for V2I-related deployments, primarily on compatibility with DSRC technology.[75] Compatibility with DSRC is unlikely to

[73] Faulhaber, *supra* note 70, at 76.
[74] Richard A. Posner, *Antitrust in the New Economy*, 68 ANTITRUST L.J. 925, 925 (2001).
[75] *See* FED. HIGHWAY ADMIN., *supra* note 44, at 7–8.

succeed given the complex nature of wireless standards like DSRC. Rather than interoperability mandates with DSRC technology, regulators should consider access requirements to physical infrastructure, which need fewer prescriptive mandates and monitoring.

Competitive access requirements can be less socially costly than intensive device regulation or structural relief.[76] Adopting and enforcing access requirements, however, is feasible and worth the regulatory overhead only in certain circumstances.[77] Because V2I deployment often will be contracted out to private companies, resistance to access requirements from the private contractor is to be expected. However, in American competition law, preventing the loss of customers, assuring profits, and promoting a company's conception of the public interest are not cognizable efficiency defenses by firms resisting oversight.[78] Access requirements often fail in their purposes, but there are circumstances (such as with telephone devices during the Bell phone monopoly[79] or gasoline nozzles at fuel pumps[80]) where they succeed at preventing vertical exclusion.

Policy-Induced Competition Applied to V2I and the Right of Way

The vast majority of V2I infrastructure will take place in the public right of way, typically along roadsides, on utility poles and light poles, and on overpass bridges. The quasi-public nature of the right of way means that decisions about demarcating which V2I assets receive public investment and operation and which assets receive private investment and operation must be made carefully.

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[76] *See generally* Weiser, *supra* note 70.
[77] *See generally id.*
[78] *See* Otter Tail Power Co. v. United States, 410 U.S. 366, 380–82 (1973).
[79] As telecom scholar Weiser points out, the simplicity of enforcing the phone interface standards was so straightforward that the FCC delegated the policy administration to third parties in 2000. *See generally* Weiser, *supra* note 70.
[80] *See* 40 C.F.R. § 80.22 (2009).

We identify three main components needed for V2I systems, which mirror those of 5G and smart city systems: basic infrastructure, network infrastructure, and devices. Broadly speaking, we believe that public funding and policy-induced competition regulation is best directed at basic infrastructure used for V2I. This would resemble an open access model to street furniture.[81] V2I devices, on the other hand, are best left to competitive provision by the market. We find that the appropriate amount of regulation and funding of network infrastructure is fact dependent and difficult to characterize a priori.

Basic infrastructure. This category of basic infrastructure includes "passive" infrastructure, including the rights-of-way real estate, vertical poles, cabinets, and electric service. These assets are semipermanent installations that often last decades. We believe this category is where policy-induced competition is most likely to succeed.

Since basic infrastructure is, by government design,[82] largely a monopoly market, price regulation is required to prevent monopoly pricing.[83] It is generally feasible to have rate regulation and nondiscriminatory policy for basic infrastructure, and this has indeed been accomplished successfully for 150 years.[84] As a result, basic infrastructure such as roadside real

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[81] There is at least one provider in the United Kingdom proposing this approach. *BT Calls for Open Access to Street Furniture*, SMARTCITIES WORLD (Mar. 27, 2019), https://www.smartcitiesworld.net/news/news/bt-calls-for-open-access-to-street-furniture-4008.

[82] For more than a century, municipalities have limited the number of poles in the rights of way because of inconvenience and clutter. As the Pennsylvania Supreme Court noted in an 1888 case,

> The streets are already lined with masts sustaining an intricate web of wires, actually or potentially charged with an electric current. . . . [N]o argument is requisite to show the inconvenience that might result if the number could be infinitely increased. . . . [M]uch as they have multiplied in the past, we may believe that in the new future they will be still more numerous.

W. Union Tel. Co. v. City of Philadelphia, 12 A. 144, 145 (Pa. 1888).

[83] *See, e.g.*, Thomas W. Hazlett, *Cable TV Franchises as Barriers to Video Competition*, 12 VA. J.L. & TECH. 2, 15–16 (2007).

[84] As early as 1866, federal law opened up the rights of way along post roads to telegraph infrastructure, which included all roads in some major cities (St. Louis, for example). City of St. Louis v. W. Union Tel. Co., 148 U.S. 92, 100 (1893).

estate is used by multiple parties for different commercial uses. Coaxial cable, copper lines, and fiber optics, used for transmitting telephony, television, and data services, all make use of the right of way as well as electrical systems.

In many ways, basic infrastructure is a "utility for utilities." Basic infrastructure typically is owned by a regulated phone company, a regulated electrical utility, or a local government. Roadside real estate is an important element of basic infrastructure. Municipalities own or control most of the ground and air rights of way used by utility distribution systems.[85] Roads and the public rights of way are held for public, not proprietary, use by the municipality.[86] Cities already often contract out the negotiations with wireless operators to install devices on city property.[87]

It is fairly easy to monitor access requirement compliance to basic infrastructure, and regulation resembles classic common-carrier regulation of rates and terms.[88] Professor Christopher Yoo of the University of Pennsylvania Law School notes that access requirements and rate regulation work best "when the product is a commodity and where the quality of the

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[85] Harold Demsetz, *Why Regulate Utilities*, 11 J.L. & ECON. 55, 62 (1968).
[86] As a seminal treatise on public streets stated, "[I]f the state should take land for the purpose of a public way the purpose would be essentially public." 1 BYRON K. ELLIOTT & WILLIAM F. ELLIOTT, A TREATISE ON THE LAW OF ROADS AND STREETS 150 (4th ed. 1926).
[87] Kapko, *supra* note 21.
[88] As Prof. Christopher Yoo has said, "[T]he core elements of common carriage are the duty to serve, nondiscrimination, and rate regulation." Christopher S. Yoo, *Common Carriage's Domain*, 35 YALE J. ON REG. 991, 997 (2018) [hereinafter Yoo, *Common Carriage*]. Common carriage has never been adequately defined, but we hesitate to call the pole rates common carriage, because common carriage in most other contexts—telephony, air transportation, hotels, ferries—refers to "holding oneself out" indiscriminately to the public. Nat'l Ass'n of Reg. Util. Comm'rs v. FCC (NARUC 1), 525 F.2d 630, 641, 642 (D.C. Cir. 1976). However, rights-of-way access should be distinguished from complex franchise agreements, derived from rights-of-way access, containing many issues distinct from time, place, and manner of attachment. *See, e.g.*, Thomas W. Hazlett, *Cable TV Franchises as Barriers to Video Competition*, 12 VA. J.L. & TECH. 2, 20–21 (2007) ("Cable television franchises can easily run 100 pages" and regulate service area coverage, public television channels to transmit, connecting government networks, and customer service rules.). These requirements can be a significant part of the cost of deploying network facilities. Mark A. Zupan, *The Efficacy of Franchise Bidding Schemes in the Case of Cable Television: Some Systematic Evidence*, 32 J.L. & ECON. 401, 405 (1989) (estimating that more than 25 percent of capital costs are required by local authorities but deliver negligible value to consumers).

product does not vary."[89] Access requirements and price regulation, then, work tolerably well for water, natural gas, traditional telephony, and electricity distribution.[90]

There is already a history of policy-induced competition to basic infrastructure in other contexts. Federal standards for gasoline nozzles create a simple interface so that fueling stations can "interoperate" with any passenger vehicle. The interface is a clearly articulated nozzle dimension that can be monitored easily.[91]

Access requirements for utility poles have been federal policy since at least 1978. Pole access is a commodity:[92] the "quality" of the resource sought—typically, a foot of unoccupied wooden pole[93]—does not vary much. The Pole Attachment Act of 1978 gave the FCC authority to regulate attachments to investor-owned electric and telephone utility poles.[94] The legislation was originally intended for cable television companies but was expanded to all "telecommunications providers" in 1996. There is typically a "functional equivalence" test to see if the buyers view the alleged commodity asset as performing the same function.[95]

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[89] Yoo, *Common Carriage*, *supra* note 88, at 1013.
[90] *Id.*
[91] The *Code of Federal Regulations* states,

> Every retailer and wholesale purchaser-consumer shall equip all gasoline pumps from which gasoline is dispensed into motor vehicles with a nozzle spout that meets all the following specifications:
> (1) The outside diameter of the terminal end shall not be greater than 0.840 inches (2.134 centimeters).
> (2) The terminal end shall have a straight section of at least 2.5 inches (6.34 centimeters).
> (3) The retaining spring shall terminate at least 3.0 inches (7.6 centimeters) from the terminal end.

40 C.F.R. § 80.22(f) (2009).
[92] Yoo, *Common Carriage*, *supra* note 88, at 1007.
[93] Federal Communications Commission, In the Matter of Implementation of Section 703(e) of the Telecommunications Act of 1996, Amendment of the Commission's Rules and Policies Governing Pole Attachments, Report and Order, CS Docket No. 97-151 (Rel. 6 Feb. 1998), 22.
[94] 47 U.S.C. § 224 (2018).
[95] Yoo, *Common Carriage*, *supra* note 88, at 1008; Competitive Telecomms. Ass'n. v. FCC, 998 F.2d 1058, 1061 (D.C. Cir. 1993) (citing MCI Telecomms. Corp. v. FCC, 917 F.2d 30, 39 (D.C. Cir. 1990)); Ad Hoc Telecomms. Users. Comm. v. FCC, 680 F.2d 790, 795 (D.C. Cir. 1982).

Federal and state pole access laws are, in the words of the US Court of Appeals for the Seventh Circuit, "intended to facilitate prompt and economical extensions of telephone service by preventing municipalities and other local governments from using their locational monopolies to delay and extort monopolistic fees from companies that, in order to provide service, must frequently run wires and cables across local governmental boundaries."[96]

Basic infrastructure regulation has many of the major elements of utility regulation, namely the regulation of prices charged and a requirement for reasonable practices.[97] At present, federal regulation approximates marginal cost pricing for pole access. Pole and other rights-of-way lease rates typically are conceived of as "rent" paid to a municipality or private utility pole owner for access to the quasi-public property.[98] Access mandates and utility regulation can depress investment because the regulated firm loses some control over contracting pricing and terms.[99] However, most basic infrastructure is already constructed. This means that owners of basic infrastructure will seek to extract a portion of the producer surplus well in excess of their opportunity costs—the so-called holdout problem. Typically, the excessive rates are not plowed back into more infrastructure investment, and price regulation can have salutary effects. As the FCC points out in its pole access proceeding,[100]

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96 Diginet, Inc. v. W. Union ATS, Inc., 958 F.2d 1388, 1397 (7th Cir. 1992).

97 Joseph D. Kearney & Thomas W. Merrill, *The Great Transformation of Regulated Industries Law*, 98 COLUM. L. REV. 1323, 1330–31 (1998) ("For almost a century, public utility companies and common carriers had one common characteristic: All were required to offer their customers service under rates and practices that were just, reasonable, and non-discriminatory."). *See, e.g.,* MCI Telecomms. Corp. v. AT&T Co., 512 U.S. 218, 229–32 (1994) (calling the tariff-filing requirement "the heart of the common-carrier section of the Communications Act" and essential to ensuring reasonable rates).

98 *See* City of Dallas v. FCC, 118 F.3d 393, 397 (5th Cir. 1997) (noting that a cable franchise fee is "essentially a form of rent: the price paid to rent use of public right-of-ways").

99 *See* Yoo, *Common Carriage*, *supra* note 88, at 1011–12 ("Requiring providers to adhere to defined products and a posted, uniform rate schedule provides the type of standardization and information sharing that has long been recognized as a facilitating practice for collusion."). Nondiscriminatory access regulations for commodities can sometimes have the effect of legalizing collusion in cartel markets. To date, however, we are unaware of any claim that the federal laws about nondiscriminatory pole access have facilitated collusion.

100 Amendments of the Commission's Rules and Policies Governing Pole Attachments, Consolidated Partial Order on Reconsideration, 16 FCC Rcd. 12103, 12118 ¶ 24, 12119 ¶ 25 (2001).

> The dampening of investment incentives matters less when the network is already built out. When that is the case, employing rate regulation that dampens investment signals is less important. Moreover, if further entry is impossible, then short-run high prices will not stimulate new entry sufficient to shift out the supply curve and dissipate the supra-competitive returns. When "attachers . . . do not face a realistic 'make or buy' decision, the benefits of giving proper cost signals to new entrants are less pronounced."

V2I P3 contracts should be drafted to accommodate access requirements to basic infrastructure. If the V2I investment includes the installation of tolling V2I devices, the agreement should have terms related to nonexclusive use of the assets. If a P3 were to establish roadside units on lampposts across a high-occupancy toll (HOT) lane, the terms of the DBFOM contract would guarantee exclusive rights to tolling revenues. However, the terms should allow for nonexclusive attachment rights for V2I operators for nontolling services.

Network infrastructure. This category includes long-lasting network inputs such as fiber strands, data networks, and network handholds. Such systems are harder to monitor and separate into component parts than basic infrastructure. Fiber optics quality, for instance, varies more than for other roadside objects and street furniture. Product complexity means regulators need multifactor tariffing and quality dimensions when deciding fair rates and terms.[101] As Yoo notes, "The more complex the interface, the more problematic and protracted these disputes will be."[102]

Network infrastructure, such as data networks, has become fairly complex, which is why regulatory attempts to create competition in local phone and broadband have generally failed in

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[101] Yoo, *Common Carriage*, *supra* note 88, at 1012; Eli M. Noam, *Towards an Integrated Communications Market: Overcoming the Local Monopoly of Cable Television*, 34 FED. COMM. L.J. 209, 219 (1982) ("Historically, rate regulation is easiest to administer where the product can be clearly defined and quantified. . . . Rate regulation is much more difficult when it deals with complex and variable mixtures of services.").

[102] Yoo, *Common Carriage*, *supra* note 88, at 1014.

the United States.[103] For instance, the FCC failed at requiring AT&T to provide nondiscriminatory access to long-distance phone providers in part because of the information-richness of the market boundary—the long-distance and local phone networks.[104] Similar regulatory efforts failed in the United Kingdom.[105] The complexity of data networks and interoperation of networks meant that regulators had a difficult time monitoring compliance with access requirements.

Likewise, the "unbundling" mandates in the 1996 Telecom Act failed to generate local phone competition.[106] Under those legal provisions, local phone companies had to "provide nondiscriminatory access to all elements of their networks at any technically feasible point."[107] That "centerpiece" of the 1996 Telecom Act failed, despite the intense regulatory scrutiny of network operators.[108] Relatedly, the FCC's "leased access" regime for cable television[109] and the CableCARD regime are regarded as policy failures.[110] In short, utility regulation and

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[103] Christopher S. Yoo, *Modularity Theory and Internet Regulation*, 2016 U. ILL. L. REV. 1, 40 (2016) [hereinafter Yoo, *Modularity Theory*] ("If the element is tightly integrated with other components, any attempt to mandate access would be expected to fail regardless of whether it is a natural monopoly or is unavailable through other means.").

[104] As Yoo noted,

> The impact of the complexity of the interface on the implementation of a nondiscrimination mandate is demonstrated eloquently by the FCC's experience attempting to require AT&T to provide nondiscriminatory access to unaffiliated long distance providers. The complexity and information-richness of the interface of the boundary between long distance service and the local service needed to connect to that service "permitted a thousand ways in which a reluctant Bell System local access provider could hamper and restrict potential long distance competitors." The result is that long distance access was plagued by complaints that about non-price terms, such as delays by the incumbent in provisioning lines for new subscribers signed up by competitors and the number of digits required to access long distance services.

Yoo, *Common Carriage*, *supra* note 88, at 1014.

[105] Iain Moore, *BT Needs a Kick in the Ducts*, LIGHT READING (Nov. 12, 2018), https://www.lightreading.com/services/broadband-services/bt-needs-a-kick-in-the-ducts/a/d-id/747467 ("[L]egal separation [of BT and Openreach] has made not an iota of difference to UK broadband.").

[106] Mark A. Lemley & Philip J. Weiser, *Should Property or Liability Rules Govern Information?*, 85 TEX. L. REV. 783, 811 (2007) ("[T]he unbundling regime of the 1996 Act represents, on almost all accounts, a policy failure.").

[107] Yoo, *Common Carriage*, *supra* note 88, at 1014; 47 U.S.C. § 251(c)(3) (2018).

[108] Yoo, *Modularity Theory*, *supra* note 103, at 40.

[109] Yoo, *Common Carriage*, *supra* note 88, at 1016.

[110] Nate Anderson, *FCC Admits CableCARD a Failure, Vows to Try Something Else*, ARS TECHNICA (Dec. 4, 2009), https://arstechnica.com/tech-policy/2009/12/fcc-admits-cablecard-a-failure-vows-to-try-something-else/.

policy-induced competition fail when quality is variable.[111] We suspect that interoperability at the V2I network "layer" would often fail to generate the competition sought, but such competition cannot be ruled out in all cases. The history of open-access networks indicates that success or failure is dependent on fact and place.

Devices. Devices include customer-facing devices, typically radio frequency (RF) transceivers and wireless backhaul systems. According to a study conducted by the Government Accountability Office, more than 70 percent of identified experts on V2I technology believe that standardization and interoperability were significant or moderate challenges in the deployment of V2I.[112] The reticence about developing interoperability is well founded—the interface complexity problems mentioned for network infrastructure are even more pronounced for devices. As Yoo says, "Modular interfaces cannot be established anywhere; they can be created only at thin crossing points where the number of interdependencies is relatively low."[113] Devices are information rich, and attempting to create access requirements for competitive wireless services is unlikely to succeed.

Connected cars and AVs are simply the latest generation of "devices" attaching to wireless networks. There are innovation losses when the government is selecting device and transmission technologies. The DSRC saga, described earlier, suggests why there is widespread skepticism of device interoperability mandates' succeeding in the foreseeable future. The US government made a bet on Wi-Fi–derived DSRC V2I technology nearly 20 years ago, and the FCC set aside valuable spectrum real estate exclusively for DSRC technologies. Despite that,

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[111] *See* Frank Kahn, *Economic Regulation of Broadcasting as a Utility*, 7 J. BROADCASTING 97, 110 (1963) (proposing "quasi-utility" classification of broadcast given the variable quality of content).
[112] U.S. GOV'T ACCOUNTABILITY OFFICE, *supra* note 7, at 51.
[113] Yoo, *Modularity Theory*, *supra* note 103, at 40.

DSRC is still in an early stage of development and deployment—the first vehicle with DSRC capability in the United States was released in 2016. In the meantime, alternative connected vehicle technologies (such as radar, LiDAR, and cellular) have accomplished and superseded many DSRC functions.

Just as government agencies do not prescribe wireless phone communications standards, they should avoid prescribing wireless V2I standards and interoperability. The widespread deployment of small cells and 5G transmitters is evidence that there can be a competitive market for V2I devices.

Policy Obstacles to Effective V2I Deployment

Presently, P3s are seeing increased use in the United States for major transportation projects. However, federal restrictions on transportation projects pose a significant barrier to P3 use and to the policy-induced competition framework. One of the most disincentivizing regulations for states is the federal law that prohibits the collection of tolls by states on any federal-aid highway.[114] Because tolls are the main mechanism for states to recoup construction costs, this regulation removes a major revenue source.[115]

There are some exceptions to this general prohibition. For example, federal law permits federal participation in the "initial construction" of or "approach to" a toll highway, bridge, or tunnel.[116] Furthermore, there can be federal participation in the "initial construction" of lanes to increase the capacity of a highway or convert the highway to a toll facility, as long as the

[114] 23 U.S.C. § 301 (2018).
[115] The only exceptions to this rule are specific exemptions for states tolling on federally funded highways. 23 U.S.C. §§ 129, 166 (2018).
[116] 23 U.S.C. § 129 (2018).

number of toll-free lanes after construction is not reduced.[117] If the highway is part of the interstate system, the section permits federal participation in the "initial construction" of lanes to increase the highway's capacity, as long as the number of toll-free non-HOV lanes after construction is not less than the number of toll-free non-HOV lanes before construction.[118] Finally, the section permits federal participation in "the conversion of" an HOV lane on a highway to a toll facility.[119]

Pilot programs, such as the Interstate System Reconstruction and Rehabilitation Pilot Program (ISRRPP) and the Value Pricing Pilot Program (VPPP), have provided states with slightly more flexibility. The ISRRPP allows for no more than "three existing Interstate facilities," which must be located in different states, "to be tolled to fund needed reconstruction or rehabilitation on Interstate corridors that could not otherwise be adequately maintained or functionally improved." Meanwhile, the VPPP aims to "demonstrate whether and to what extent roadway congestion may be reduced through . . . congestion pricing strategies, and the magnitude of the impact of such strategies on driver behavior, traffic volumes, transit ridership, air quality and availability of funds for transportation programs." Studies completed through the VPPP provide encouragement for congestion pricing efficacy.

The increased flexibility for P3s in transportation projects is an encouraging recent trend, but policy and budgetary obstacles remain.[120] If rules liberalization is not expanded, commercial operators may be dissuaded from road and ITS projects.

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[117] *Id.*
[118] *Id.*
[119] *Id.*; 23 U.S.C. § 166 (expanding upon 23 U.S.C. § 129 by permitting state authorities to allow certain vehicles access to and use of HOV facilities that they otherwise would not be allowed to use, as long as the state collects a toll from such users).
[120] Financial barriers provide an additional and substantial barrier to the formation of P3s. For example, 26 U.S.C. § 124(m)(2)(A) (2018) places a $15 billion lifetime cap on private surface transportation projects. Since that section's enactment, two-thirds of that $15 billion has already been granted.

Conclusion

Substantial federal and state funding is dedicated to improving safety and services on US roadways. Given the financial risks of constructing and maintaining a V2I network, P3s for V2I network construction will be increasingly common. A selected V2I operator should be prevented from leveraging control over infrastructure into ancillary markets, such as smart cities and wireless data services. The policy-induced competition model can help inform federal and state transportation departments as they consider V2I improvements. Access requirements for "dumb" infrastructure could support orderly V2I network construction while also permitting a competitive and innovative market for V2I technologies, smart cities, and related wireless services.