SJSU SAN JOSÉ STATE UNIVERSITY

MTI MINETA TRANSPORTATION INSTITUTE

Full Potential of Future Robotaxis Achievable with Trip-Based Subsidies and Fees Applied to the For-Hire Vehicles of Today

Project 1903
August 2019

John Niles, MS

Automated For-Fire Vehicle (FHV) in a Waymo Fleet Offering Rides in a Pioneering Deployment in Chandler, Arizona
Source: Waymo.

Introduction: Automated Vehicle Markets Follow Two Paths[1]

As described by Grush and Niles in their textbook, *The End of Driving: Transportation Systems and Public Policy Planning for Autonomous Vehicles*,[2] there are two distinct market states for the future of automobility as vehicles become increasingly automated. The first, Market-1, is comprised of all vehicles that are manufactured and sold to private owners and used as household vehicles. This private consumer fleet will—through automated driver assistance systems (ADAS)—be increasingly capable of hands-off operation, even self-driving in certain environments such as limited-access expressways. The second category, Market-2, represents all the vehicles made expressly for the service market, i.e., roboshuttles and robotaxis, meant to be eventually driverless in prepared, defined areas and streets. Ford, GM, Lyft, Uber, Waymo, and dozens of other companies assert that they are preparing vehicles for Market-2.[3]

Clearly, there have been markets for *purchasing* private vehicles and for *renting* service vehicles since the automobile was invented. Indeed, the advent of ride-hailing companies that depend on their drivers' personal vehicles means that some vehicles operate in both markets: they were purchased for use in Market-1 and were then deployed in Market-2 when the driver went on duty with a ride-hailing firm. The dichotomous market model explained here describes the use to which a vehicle is applied.

As vehicle automation evolves, Market-1 participation will largely be a continuation of household ownership, which has been underway since the invention of cars. Market-2 taxicabs and transit have also been around since the horse and buggy, but now something new is happening: increasing competition between Market-2 and the buses and trains of public transit.[4] In the S-1 filing for its IPO[5], Uber clearly described its market view, explaining that finding ways to integrate and collaborate with public transportation is important, but that selling rides also clearly represents a market in which the private sector can compete with public transit. While Lyft, in its S-1 filing,[6] described only integration with public transit, Lyft does in fact compete with bus service in response to business opportunity by offering on-demand rides along public transit corridors.

In seeking ways to satisfy their preferences, travelers will typically prefer not to make compromises or transgress their personal limits when it comes to door-to-door trip time, financial cost, and personal comfort. If these predilections are not able to be regularly satisfied by Market-2 ride services, then most travelers who can afford to do so will elect to take advantage of Market-1 because of personal travel expectations habituated over a century of expanding vehicle ownership. Private household vehicles, automated and increasingly affordable, will provide highly-competitive satisfaction as the best mobility option for many consumers unless Market-2 commercial ride services become routinely and consistently comfortable, affordable, fast, and instantly available.

Market-2 vehicles can be operated on a fixed-route schedule or according to an on-demand, where-requested fashion, exemplified now by transportation network companies (TNCs), and by robotaxis in the future. Ride services operating in a fixed-route transit fashion can be, for instance, regularly-scheduled buses and shuttles of various sizes. In either scheduled or on-demand modes, they can move in jitney-like fashion within delineated neighborhoods or as first-/last-mile on-demand shuttles systems connecting to trunk lines.

No reliable forecast is possible for the level of vehicle ownership in 2070 or even 2030, or for the corresponding mix of Market-1 and Market-2 vehicles. Some Market-2 vehicles may continue to be government-operated like the public transit buses of today, and other Market-2 offerings may be operated within commercially-managed robotic fleets. For the foreseeable future, there will always be a portion of privately-owned Market-1 vehicles on the road. This claim stems from considering the realistic requirements some travelers have for carrying special personal appliances, work tools and loads, children in car seats, or other preferences for personal comfort or privacy that will be difficult to satisfy with standardized Market-2 fleet vehicles needing to serve many ride buyers in rapid succession. The desired goal, given the multiplicity of consumer requirements, is a governance system that is flexible enough to permit varying levels of ownership even if public policy were attempting to move certain zones of a city toward a higher ratio of Market-2 to Market-1 participants.

The main thesis in this essay is that a productive, efficient system of on-demand Market-2 mobility can evolve from incentive-based governance—here termed "harmonization management." This approach strikes a contrast with rigid regulation of a style seen with big city taxicabs and based on using constrained service classifications or per-vehicle medallion approaches. This essay recommends that transportation authorities set up systems of robust pricing signals—incentives and fees—delivered through a universal, mandatory system providing efficient, equitable distribution of these signals.

Even though a growing ratio of Market-2 to Market-1 vehicles is considered by many urban transportation experts as desirable,[7] this outcome is not guaranteed, nor has it been determined yet how such an outcome might be promoted in transportation governance to achieve a high level of optimization for travel time, energy consumption, and fleet size. Multiple fleets of public service vehicles will create complexity in ongoing work to improve urban livability related to land-use patterns, congestion, and walkability. Furthermore, how will a progressive urban society ensure social equity with respect to mobility affordability, availability, and accessibility for lower-income or disabled travelers?

In making the distinction between Market-1 and Market-2, the assumption is made that both markets will be supplied by private companies. Vendors in Market-1 will sell cars, as now, and private companies operating taxis, shuttles, and jitneys will make up Market-2. When ubiquitously available and inexpensive, commercial Market-2 vehicles will serve up a significant competitive challenge to public transit agencies.

Without something like harmonization management operating as a force in the public interest, competing small-vehicle mobility services may cause a decline in demand for bus transit ridership on low-volume routes. This competition is highly likely to lead to more road congestion due to low-cost service redundancies from multiple fleets, along with the potential for poor coordination among these fleets and existing high-capacity transit modes such as urban rail, bus rapid transit, and commuter express buses.

If this threat can be expected as a *laissez-faire* outcome, then how might thinking around the *meaning* of "public transit" be reorganized to fend off this threat and to leverage the expected technological developments toward enhancing public transit? A harmonization management approach is detailed in the remainder of this essay to address this challenge.

Anticipating 2030–2050

Despite the potential of a *relative* downturn in personal Market-1 consumption in the decades ahead, North American households in aggregate will likely use motorized conveyances at least as much as they do now and for largely the same spectrum of purposes.[8] Urban regional populations will continue to grow.[9] Entrepreneurs, as always, will continue to create place-based experiences that masses of people will want to see, hear, and taste in person, and humans tend to consume more of whatever remains sufficiently convenient and economically accessible. In other words, there will be no overall drawdown in *absolute* demand for automobility in spite of a potential drop in *ownership* among some cohorts.

Users will continue to make travel choices based on personal preferences and budgets. If car operating costs and ride-hailing fares both drop as convenience in using cars rises, travel per capita is expected to increase, constrained obviously by physical limits on the amount of any person's activity within the 24 hour day. Estimated quantitative levels for the likely increase in personal travel are unreliable, as they are based on imperfectly-related historical evidence and a modest understanding of how currently stated preferences predict future revealed preferences. Concomitantly, average trip frequency and distance can also be expected to increase, although the same provisos on limited evidence and understanding of preferences apply.

One can expect, albeit with some uncertainty, that the high-capacity rail systems of today will continue for decades to come, although they may be upgraded, automated, expanded, and operated with shorter headways. Overall, a highly recognizable urban world in the 2050s is likely to emerge with two notable changes: (a) many road vehicles will not have human drivers, and (b) individuals and families will begin to own or lease fewer private motorized vehicles per capita for travel on public roads because of new readily-available ride services made possible by automation and easy digital ride-hailing.

The assumption that congestion will decline even as a regional population grows and car ownership wanes remains difficult to defend, since the relative numbers of travelers migrating from Market-1 to Market-2 consumption are not yet quantified. Even worse, many optimistic assumptions include without justification the unreliable assumption that a high level of multi-passenger ridesharing will prevail rather than simple taxi-like solo traveler use of ride services.

We turn next to sketching out a means to deliver incentives that would influence personal travel behavior to reflect public policy goals.

What Might Be Achieved with Automated Vehicle Fleets?

The mobility governance problem is framed as follows: How can local governments most effectively unleash the promised benefits of automation, maximize accessibility, preserve or enhance social equity, and reduce (or at least not increase) congestion and environmental harms—all while understanding and respecting the motivation of for-profit operators who have come on the scene and are catalyzing innovation. If the goal for sustainability is to encourage urban travelers to buy rides instead of cars, urban leaders need to consider the sort of governance moves that need to be implemented in response to competing Market-2 fleets now under development by several well-capitalized companies. Managements of these firms have automation toward driverless operation in view, described in the IPO descriptions of Uber and Lyft.

Incentives reflecting public policy need to be considered. Commercial fleet operators in a completely *laissez-faire* market will act to maximize their shareholder's business interests—whether long-run or short-run—seeking sales, market share growth, and profit. Profit-seeking private providers may tend to emphasize ridership volumes over equitable geographic coverage and universal access, but government incentives as a form of intervention in the private business model could be aimed toward balancing ridership volume with equitable access for all sub-regions and socioeconomic groups, a balance explained thoroughly by Walker in *Human Transit*.[10] Against this background, facilitating integration of ride-hailing fleets with access to fixed-route public transit nodes via subsidized service provided to citizens judged unable to bear the full cost of service would maintain and expand social equity.

Merely achieving reduced household ownership of passenger vehicles is inadequate for the quality of urban mobility sought by those observers and advocates who would like to see a vast majority of trips in *shared* autonomous vehicles and high-capacity transit. Instead, urban leaders in the United States and Canada should find ways to deploy Market-2 vehicles in an intelligent, high-quality manner that encompasses all three dimensions of sustainability: economics, environment, and equity.

The argument here assumes Market-2 automated fleets—when they are eventually deployed—will be largely owned and operated by multiple competing private operators, each trying to optimize their fleet configuration, energy consumption, and network coverage while focused on cost and profit. To capture market share in a competitive environment, the operation of economics and the pursuit of customers will lead for-hire vehicles (FHVs) to configure an array of service levels, service frequencies, service areas, prices, and business strategies.

While Cohen and Cavoli discuss government provision of automated vehicle ride services,[11] most governments in USA and Canada are severely limited by both budget and mandate in offering multiple levels of quality, convenience, privacy, and personalization in services. Such variety is needed to persuade middle-to-higher-income travelers to abandon personal vehicle ownership while still addressing core social equity issues. "Social equity" here refers to relative access to jobs, shopping, social events, and all other basic activities of life within a reasonable time and cost, and regardless of age, economic circumstances, personal physical abilities, race, or gender. *One goal of a Market-2 harmonization management system would be to secure more socially-equitable attention on the elements that profit-seeking enterprises in this regime would not place as a primary focus.*

Harmonizing Competitive Fleets of Automated Common Carriers

Without a new governance model for personal surface transportation and transit to match the approaching capabilities and features of digitalized mobility, growing numbers of automated road vehicles are likely to increase congestion and motivate residential sprawl as vehicle automation diffuses. In other words, without suitable governance, automated vehicles are unlikely to achieve these widely-sought benefits of the "new mobility": a diminishing environmental impact, less land devoted to parking spaces, improved social equity, expanded access, increased trip availability for all, less over-burdened infrastructure, and better urban livability.

If regional transportation authorities do not develop tools to manage urban mobility, private and commercial fleets of automated vehicles would be more likely to compete in a dysfunctional manner—cherry-picking preferred users, for example—while slowing and complicating the movement of people and goods, including cyclists and pedestrians. Private fleets would compete for both participants and space,[12] in the same way that goods delivery, transit, cyclists, and private vehicles compete today for road space just as they have done for over a century.

Clearly, there is value in a competitive market for mobility. However, if every vehicle or fleet operator plans to use its vehicles to optimize a private or commercial outcome on inevitably limited road space, curb space, and parking capacity, urban surface transportation systems will increasingly operate in a hyper-competitive style, to our economic and environmental detriment—as TNCs have begun to show in the congestion they generate.[13,14]

Vehicle automation facilitates enhanced mobility, but a systems approach is needed. Mobility is a market that needs some rules that fit with an intelligent, nuanced approach now made feasible by ride-hailed and driverless vehicles *with* digital governance. A good transportation network requires *operational governance*, making sure vehicles are safe and well-maintained, and easily hailed by apps or by showing up on schedule. At the same time, cities and regions require *managed competition* in the use of their transportation infrastructure, to make sure legislatively and legally authorized social purposes and goals are achieved through market offerings. In the next section, the reader will find a sketch of how to achieve these characteristics, both now and when automated robotaxis are in service.

Performance Metrics

If governance of future Market-2 robofleets were to incorporate just four key performance components, then the private sector could be nudged toward several valuable transformations. With suitable calibration and measurement, the performance metrics proposed below would address many livability and environmental externalities addressable by FHV (for-hire vehicle) fleet operators even as they are seeking to grow market share profitably. These environmental outcomes include congestion abatement, efficient vehicle routing, customer satisfaction, higher vehicle occupancy, parking reduction, and regional connectivity. The four performance-based criteria are:

- **Maximize vehicle occupancy**: maximize the ratio of personal miles traveled to vehicle miles traveled; that is, work to grow the PMT-to-VMT ratio. Six passengers in two taxis occupy less road space than six people riding in three, four, five, or six taxicabs.

- **Lower the share of private vehicles in the aggregate public and private fleet**: maximize the ratio of miles of travel in shared, ride-selling Market-2 passenger vehicles to Market-1 vehicles. This criterion assumes that deadheading by Market-2 vehicles carrying no passengers can be minimized with high-technology dispatching.

- **Safeguard social equity**: maximize accessibility, affordability, and spatial reach for all customers willing to buy rides, with policies and tools to provide subsidies for specific destination categories to targeted demographic groups like seniors, youth, low-income, and disabled.

- **Leverage existing transit**: maximize connectivity to high-capacity transit trunk lines, such as rail and express bus lines, to take advantage of existing capacity that can provide efficient mobility if well used.

These four performance metrics can be implemented within digital fleet-management architecture to replace the regulation of supply now typically provided by taxi medallion systems, TNC bans (as in British Columbia through mid-2019) or TNC caps (as in New York City). The goal is to ensure a fleet size that provides requisite public access to mobility while preventing the excessive capacity that generates road congestion and degrades the efficiency of overall human mobility.

There are, of course, many other concerns: for example, safety, security, privacy, and road and parking pricing. These issues, which must be addressed, would also apply to automated Market-1 vehicles owned and used by consumers, not just Market-2 ride services—but these issues are not covered in this essay.

Each of the four metrics above could be incentivized and measured through a combination of targeted performance-based subsidies. Using available data cloud and hand-held device applications, a digital method could be devised that supports traveler desires specific to a region and for specific user submarkets. Such a method must be flexible enough to comply with changing regional needs and to support technological innovation.

A Policy Management Platform for Ride-Hailing Fleets

The End of Driving textbook[15] proposes a real-time, cloud-based platform that encompasses the requirements outlined so far. It is termed a harmonization management system, abbreviated HMS, and it would provide any urban region or subset of its jurisdictions with the capacity to manage performance-calibrated subsidies that create, enhance, and extend community transit services by forming goal-specific collaborations with FHV providers. This approach amounts to changing and expanding the definition of public transit.

To broaden fixed-route public transit service coverage, reach, and effectiveness, HMS is envisioned to manage multiple, aggregated schedules of subsidies and incentives sourced from transit budgets and road-user fees, and potentially from commercial, retail, employer, and other sources who would have to be authorized to participate via HMS in shaping transportation and parking.

HMS is an actionable means to nudge a regional set of FHV providers, whether today or tomorrow, at any level of automation, "to fill gaps in the public transit network, right-size vehicles, and replace underperforming public transit routes... [and to] also expand the reach of public transport to a wider range of geographic territories, such as suburbs and rural areas."[16] The remainder of this essay provides detail on the operation and potential of an HMS beyond what is covered in *The End of Driving* textbook.

Figure 1: This regional map of the San Francisco–Oakland–San José area shows numerous local governments potentially comprising a single, human- driven or driverless ride-hailing management region with variable performance subsidies and road-use fees per local jurisdiction.
Map source: Wikipedia

HMS could be designed to operate in a revenue-neutral manner instead of consuming public funding. A transportation authority could nudge up vehicle occupancy, reduce parking demand, and motivate high service levels for the mobility-disadvantaged with trip-by-trip incentives paid for with road-use fees dedicated to achieving these and other policy-focused performance outcomes in ride services. HMS could be a tool supporting the measurement and audit of trip-based road use fees assessed to ensure a sufficient subsidy source for incentives. The system design could be set to let a ride service operator avoid fees by earning an offsetting performance subsidy.

HMS turnkey elements not detailed in the textbook could include:

- **Support for delivering subsidy amounts that yield lower customer fares for particular trip origins, destinations, and times of day**. HMS would store all origin and destination information for subsidies and road use fees. Specification of targeted locations would be maintained in geographic information system (GIS) polygon shape files for transit stops and stations, ridership catchment areas for first-/last-mile trips, transit deserts, drop-off and pickup sites for retail and employment locations, and other policy-driven targets. This database would also store subsidy accounting information such as financial amounts, times of day when the subsidies are available, and limits.

- **Trip finder.** HMS accepts the origin and destination for a desired trip, reports available trip subsidies to the ride customer, and then connects the ride-seeking user to a selected ride provider. It is at this gateway that trip data are captured. HMS would not assign rides, drivers, or routes; nor does it handle payment. It supplements systems offering mobility as a service (MaaS) to travelers and would be integrated with available trip-finder smartphone apps.

- **Accounting**. HMS would confirm trips, allocate and distribute subsidies and any road-use fees, prepare invoices, and keep audit information on behalf of the supervising authority running the system.

HMS would operate in a way similar to how the dedicated Lyft app subsidizes rides to selected transit hubs of Pierce Transit in a pilot project funded by Federal Transit Administration in the Tacoma region of Washington State,[17] but with six added advantages:

- **HMS is meant to be agnostic regarding ride-providers**. HMS helps a region and its cities collaborate with multiple competing TNCs and taxi operators through a single gateway. HMS would enable the definition of those collaborations, and then handle communication, distribution, and reconciliation of subsidies, while the region and its municipalities and citizens receive maximum mobility benefits. This approach creates an open, government-supervised, fully commercial market for mobility.

- **HMS would enable full data capture**. Optionally, all trips gated through HMS—regardless of subsidy eligibility—would include anonymized data capture indicating origin, destination, and time. Occupancy, vehicle type (green subsidies and occupancy ratios), wait time, and independent customer feedback are options.

- **HMS would enable cost-neutrality by metering road use fees.** This option would require that all ride-hail trips are brokered through HMS as a government-supervised platform so that all trips could be assessed for road-use fees that are made to vary based on distance, time, and/or place. Only TNCs and taxi fleets that register on HMS would be eligible for trip subsidies.

- **HMS enables a focus on the mobility-disadvantaged**. By setting different subsidies for areas or times of limited transit availability, HMS could be tailored to support seniors who no longer have driver's licenses or for riders with disabilities. As is the case today, a variety of ride-hail providers would offer different accessibility options, for example, vehicles capable of loading passengers in wheel chairs. A base level of required alternatives for specified disabilities could still be government-mandated for fleet operators, and with ride-by-ride incentives provided to support economic sustainability for the private sector fleet operators. Also, the geographic and time-of-day targeting capabilities of HMS could be integrated with special subsidized lower fares authorized and provided to particular demographic groups such as youth, seniors, and disabled holding appropriate identification.

- **HMS enables regional coordination while enabling different jurisdictional priorities**. Each municipality within a region could set its own subsidy and road use fee schedule. HMS aggregates these data into a single subsidy per trip, even when a trip crosses jurisdictional boundaries. Hence, the service side of a trip would know no transit boundaries, but its fees and subsidies are audited, re-aggregated, and paid separately on a municipal basis. See Figure 1.

- **HMS attracts additional and alternative transit funding** by giving a region and its cities the ability to collaborate with private stakeholders (retail, employers, sports, entertainment, and others) to enhance and extend transit services to particular destinations with subsidy payments from private resources.

Thus, HMS would manage multiple schedules of subsidies and incentives set by any number of municipalities and potentially with commercial interests within a region. See Figure 2.

Each combination of location, time, and subsidy grant amounts to a rule. For instance, "getting dropped off at the Hillsdale train station between 10:00 and 15:30, M–F, subsidized at $4.00" is a single rule. Meanwhile, "getting picked up at the Hillsdale station between 08:00 and 23:30 on Saturday is subsidized at $2.50" is a second rule. HMS would handle any number of rules. Rules include locations (represented by shape files in a geographic information system), times, days of the week, and monetary amounts. Exceptions, such as holidays, would require additional rules.

HMS's rule-based system is designed to support a public policy focus on performance metrics that matter for congestion, ridership, and social equity. For example, HMS can manage subsidy increments for higher vehicle occupancy or for electric vehicle use. HMS is especially pertinent for trip integration with transit and service provision to the mobility-disadvantaged, such as seniors with no car access.

The user experience would be simpler than this description indicates. The user simply sees on a smartphone app, or hears on any telephone, a list of ride services, with a fare that is the net of any subsidies, each one satisfying her request; she picks the one preferred. HMS would handle everything else via data flows and invoice exchanges with the selected ride provider and with the appropriate regional, municipal, or commercial subsidizer.

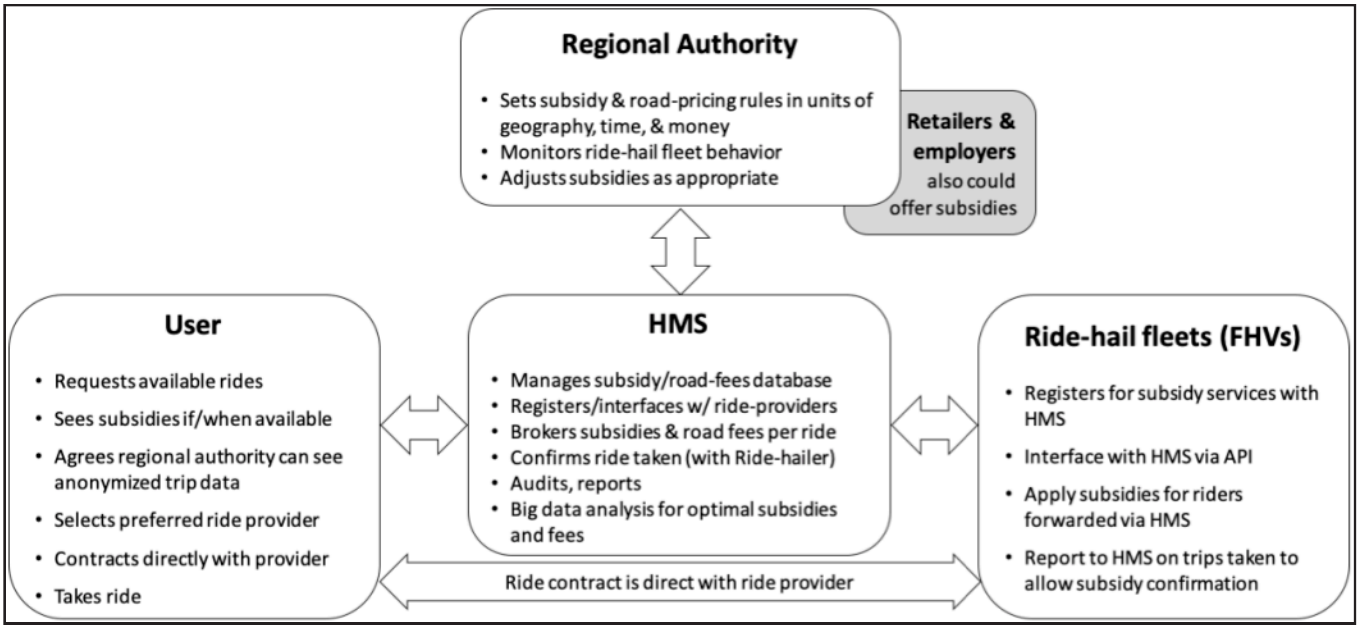

Figure 2: HMS Roles Overview

Source: Grush Niles Strategic.

Conclusion

When you called for a taxi in the pre-Uber world, there was almost always a competitor's taxi closer to you, but there was no way for you to know that. The smartphone apps from Uber and Lyft bridge that information barrier if you check them both before ordering a ride. Mobility-as-a-service apps are poised to expand service quality even further by presenting good options from many available modes and suppliers and letting the customer choose the best option. Massive, *governed* robofleets can contribute to this optimization in the future.

The current world of drivers alone in private vehicles fending for themselves—the core of today's surface transportation reality—implies urban transportation systems of incomprehensible non-optimality mixed with struggling transit systems. Mobility door-to-door is the world's largest market, but the potential is mostly wasted in execution. According to Adam Jonas, a sophisticated market observer from Morgan Stanley, this is

> "… a century-old ecosystem being ogled by outside players hungry for a slice of a $10-trillion mobility market. Many want in. It's just beginning. And it won't stop."[18]

A new governance system like HMS for publicly available conveyances is needed as this optimized, commercial transit technology continues pushing existing mobility systems aside, illustrated in the case of Uber and Lyft arriving in U.S. cities and taking market share from public transit.[19]

A *safer roadway* is reasonable to expect as vehicle automation diffuses and collisions become less frequent, but there is no guarantee of a *more efficient or less congested roadway* unless competitive behaviors are *channeled and harmonized*. Demand on congested road and curb space will increase as urbanization continues and automation makes cheap and personal motor travel available to more people and for longer distances, unless a shift to shared vehicles and shared rides is both effective and dramatic.[20]

Digitalization enables automation and connectivity for vehicles as well as mobility-as-a-service and transit apps for trip management and digital managers for fleet optimization. Furthermore, digitalization can be expanded to harmonize fleet traffic in order to preserve the *role* and *value* of public transit within our current road infrastructure by supporting operational efficiency and social good. This is not to say transit itself will not change: it must change in order to survive. The solution proposed in this report preserves the social roles and values of transit, albeit with updates to current systems and methods to yield more and better service provision using the base of public revenues that the leaders of each region choose to invest in new, more effective approaches to public transportation.

A reliable and affordable supply of on-demand trips from the ride-hailing services of today can be used to fill gaps in existing public transit offerings, provide first-/last-mile access that complements rather than erodes ridership, and provide better reach and accessibility for mobility-disadvantaged populations. This expansion of public transit's very meaning ahead of the arrival of robotaxis could precipitate a decline in automobile ownership that paves a way to reduced traffic congestion while door-to-door, on-demand mobility opportunities grow for all segments of society.

ENDNOTES

1. The author is grateful for the assistance of Bern Grush in preparing this essay.

2. Grush, B. and Niles, J. (2018) *The End of Driving: Transportation Systems and Public Policy Planning for Autonomous Vehicles*, Elsevier.

3. McCall, M. (2019) “Why Autonomous Vehicles are Such a Game-Changer for Uber and Lyft” *Investor Place*, March 25, https://finance.yahoo.com/news/why-autonomous-vehicles-game-changer-203806837.html.

4. Schaller, B. (2017) “Unsustainable? The growth of app-based ride services and traffic, travel and the future of New York City,” http://schallerconsult.com/rideservices/unsustainable.pdf.

5. Uber Technologies, Inc. (2019) IPO S-1, https://www.sec.gov/Archives/edgar/data/1543151/000119312519103850/d647752ds1.htm.

6. Lyft, Inc. (2019) IPO S-1, https://www.sec.gov/Archives/edgar/data/1759509/000119312519059849/d633517ds1.htm.

7. Sperling, D. (2018) *Three Revolutions: Steering Automated, Shared, and Electric Vehicles to a Better Future*, Island Press.

8. Litman, T. (2019) ”Autonomous Vehicle Implementation Predictions: Implications for Transport Planning,” Victoria Transport Policy Institute, https://www.vtpi.org/avip.pdf.

9. McKinsey Global Institute (2016), “Urban world: Meeting the demographic challenge in cities,” https://www.mckinsey.com/featured-insights/urbanization/urban-world-meeting-the-demographic-challenge-in-cities.

10. Walker, J. (2012) *Human Transit*, Island Press.

11. Cohen, T. and C. Cavoli (2019) “Automated vehicles: exploring possible consequences of government (non)intervention for congestion and accessibility,” Transport Reviews, Vol. 39, NO. 1, 129–151, https://doi.org/10.1080/01441647.2018.1524401.

12. Clewlow, R., and G. Mishra. (2017) “Disruptive Transportation: The Adoption, Utilization, and Impacts of Ride-Hailing in the United States.” Research Report, UCD-ITS-RR-17-07, UC Davis, Institute of Transportation Studies. https://itspubs.ucdavis.edu/wp-content/themes/ucdavis/pubs/download_pdf.php?id=2752.

13. Schaller.

14. Erhardt, G. et al. (2019) “Do transportation network companies decrease or increase congestion?” *Science Advances*, May, https://advances.sciencemag.org/content/5/5/eaau2670.

15. Grush and Niles, Chapter 13.

16. Shaheen, S. (2018) Foreword to Grush and Niles, p. xviii.

17. Pierce Transit (2018), "Limited Access Connections," https://www.piercetransit.org/limited-access-connections/.

18. Moore, B. (2015) *EV World*, "Adam Jonas and the End of Automobile Ownership" http://evworld.com/blogs.cfm?blogid=1317.

19. Graehler Jr., M., R.A. Mucci and G.D. Erhardt (2018) "Understanding the Recent Transit Ridership Decline in Major US Cities: Service Cuts or Emerging Modes?" Paper presented at Transportation Research Board 2019 Annual Meeting, http://usa.streetsblog.org/wp-content/uploads/sites/5/2019/01/19-04931-Transit-Trends.pdf.

20. UITP, International Association of Public Transport (2016) "Autonomous vehicles: a potential game changer for urban mobility," Policy Brief, https://www.uitp.org/sites/default/files/cck-focus-papers-files/PolicyBrief_Autonomous_Vehicles_LQ_20160116.pdf.

About the Author

John Niles is Founder and President of Global Telematics, a policy research consultancy based in Seattle, focused on designing policies and actions for transportation improvement. As a Research Associate at Mineta Transportation Institute he has led team studies on transit oriented development, urban freight mobility planning, bus rapid transit, and park-and-ride productivity analysis. He is co-author of the text book, The End of Driving: Transportation Systems and Public Policy Planning for Autonomous Vehicles (Elsevier, 2018), as well as many technical reports and articles. He earned his MS at Carnegie Mellon University, and his SB at Massachusetts Institute of Technology.

MTI MINETA TRANSPORTATION INSTITUTE

MTI is a University Transportation Center sponsored by the U.S. Department of Transportation's Office of the Assistant Secretary for Research and Technology and by Caltrans. The Institute is located within San José State University's Lucas Graduate School of Business.