STATE OF TRANSPORTATION PLANNING

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TRANSPORTATION PLANNING DIVISION
AMERICAN PLANNING ASSOCIATION

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Contents

FORWARD

Transportation Technology and Impacts on the Urban Form Over the Years

In response to the development of an interconnectivity between different generations of transportation planners, this article was written to discuss the changes in transportation technology and the impacts of such on the urban form over the years.

In the 30+ years since graduating from San Jose State University with a Master of Urban Planning degree, transportation planning has taken a far more prominent role in the arena of urban and regional planning. While environmental sustainability, spatial planning and urban design have their importance in the continual development of the day-to-day physical form in which we all live in, transportation-related issues, and the technological advancements being made in the transportation industry, continues to have a significant impact on our communities and regions.

In the period after World War II to the 1970s, the need for more and improved housing opportunities, combined with the increased availability of the private automobile and the development of controlled-access freeways radiating from our urban centers contributed to the development of the ubiquitous suburban sprawl that exists today. The early rail-based streetcar lines that existed in many higher density urban areas before the advent of World War II as a key transportation mode for many of these urban workers were virtually eliminated and replaced with transit buses that could operate on regular urban streets and highways into less dense neighborhoods.

While the physical growth of our urban development areas has not significantly abated over time, our urban street and highway systems have become increasingly congested during multiple peak periods resulting in the movement of business centers from the urban core into suburban business parks. The continued desire for more improved housing opportunities and, hopefully, shorter trips between home and the workplace, has resulted in the further development of the exurban areas that surrounded our urban regions. This apparent cycle of our transportation networks and related technologies supporting the continued sprawl of our urban areas would, by the 1970s, become unsustainable over the long term both financially and environmentally. The total costs, including those related to construction, maintenance and mitigation measures, of both continued highway building and urban sprawl could not be met through traditional public sector expenditures including taxes and levies.

By the mid 1980s, planning efforts were well underway towards the development of various forms of light and heavy rail transport systems in relatively low density suburban areas to provide meaningful alternatives to the private automobile for their trips. To support the costs required to construct, operate, and maintain these new systems, increased suburban housing densities would be required to be constructed along these rail transit corridors. Over the next few decades, the physical urban environment in many of our largest urban centers and their suburban areas would be altered significantly along these corridors through the development of new high-density transit oriented developments whose residents would be provided with easy transit access for their daily trip needs.

In a number of our older urban core areas, demand has increased for both businesses and residents beginning in the early 2000s with the advent of the "dot-com" businesses. The repurposing of many of these lower cost buildings, formerly used as offices and warehouses, into higher density residential lofts and specialty work areas used by those involved in Internet-based enterprises. Many of those employed in these particular enterprises and living in these urban core neighborhoods were less interested in owning private automobiles due to both increased sensitivity to environmental sustainability issues and restricted automobile-related infrastructure such as on and off-street parking. To provide these people with transportation accessibility, these urban centers provided dedicated bicycle lanes and related facilities, improved public transit options including express luxury coach services, and shared automobile services. The Internet-based enterprises themselves have also changed the transportation landscape with the development of improved hardware, software and connectivity so workers can continue to be productive while being physically away from their offices, as well as the creation of the increasingly popular ride-sharing services.

In the next few years, there will be the advent in electric cars and trucks designed to replace environmentally-damaging internal combustion gasoline and diesel engines. The technology is also advancing to the point that there can feasibly be some form of "driverless" vehicles, including airplanes, automobiles, and trucks, in which computers and technology will be integrated into the transportation vehicle and replace the human driver(s) required to operate the vehicle from point to point. How the integration of these new transport-related technologies will alter the urban environment has yet to be decided by both our leaders and future urban residents. Although these future transportation issues and their particular challenges that will impact the urban landscape will be uniquely different than those faced 30+ years ago, transportation planning specialists will continue to be called upon to assist in making those decisions at that time that will shape the future physical urban form as time rolls forward.

Dr. K.L. (Dan) Wong, PhD MITE

Dr. Wong currently is the Deputy Head of Department overseeing the Transport and Logistics department with the Modern College of Business and Science in Muscat, Oman. A 1985 graduate of the Urban and Regional Planning program at San Jose State University specializing in transportation planning, he spent nearly 26 years in transportation planning practice with the San Francisco Municipal Railway and the San Francisco International Airport. In 2010, he received a fully-funded scholarship to undertake a doctorate program at Queensland University of Technology in Brisbane, Australia. Since the conferral of his PhD degree in 2013, he has taught at the University of Central Missouri in Warrensburg, Missouri, and Prince Sultan University in Riyadh, Saudi Arabia prior to his current appointment in the Sultanate of Oman. Dr. Wong was previously the Airports Committee Chair for the APA-TPD for several years, and has served as both a member of the FAA Airport Land Use Compatibility Planning Committee and a subject matter expert and panelist with the TRB's Airport Cooperative Research Program. He is still a frequent speaker on numerous airport planning, management and design subjects, as well as being active in airport and aviation planning as a member of: ASCE-T&DI Aviation Planning & Operations Committee, TRB's AV050 Standing Committee on Airport Terminals & Ground Access, the University Aviation Association, the Institute of Transportation Engineering, and the APA-TPD. He travels the world with his wife, Donna, and their two pets, Isabelle and Oski, in tow.

Location Map


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LOOKING FORWARD

Planning for an Uncertain Future

By Dalia Leven

Transportation is on the verge of a series of quiet but profound changes, many of them being led by technology advances in communication and automation. New business models are developing around these technologies, bringing new options to passengers and freight alike. At the same time, choices and behaviors are evolving to adapt to the new options, while personal preferences continue to change as well. All of these forces are combining to impact transportation in significant ways. One of the major concerns for transportation planners is that no one is certain as to how these technologies, preferences, and business models will converge to change people's travel behaviors and impact transportation systems and the built environment.

Most transportation professionals agree that transportation will be different in the future. However, the problem is that there are still a myriad of unknowns. So, how do we plan for this uncertain but drastically different transportation system? How can our planning account for the uncertain future that we all know is coming? If we hope to harness these technologies, we cannot abandon advanced planning simply because we do not have an exact answer, or we run the risk of letting technology run rampant over our cities. For the first time in at least a generation, transportation planners must rethink how we approach planning to account for uncertainty, and acknowledge the fact that we will inevitably be wrong. But also, recognize that there are real benefits to our continued efforts to shape the future of our cities.

1.1 Border View

There is a wide range of technologies and behavioral trends that are likely to have interacting effects on the transportation landscape. Autonomous vehicles (AVs) are getting the most publicity these days, but AVs are not the only revolution coming. Because none of these changes are likely to occur on their own, planners must consider how these changes will interact with one another and impact the overall transportation system. Some of the most important trends that must be considered include:

+ Automated and Autonomous Vehicles (AVs): these vehicles can perform some or all of the driving tasks without input from a human driver. AV technologies are being developed for use in all types of vehicles: light-duty passenger cars, freight trucks, transit vehicles, delivery vans, and even aerial drones.

+ Connected Vehicles (CVs): these vehicles are able to communicate with one another (V2V), communicate with the roadway infrastructure (V2I), and/or communicate with other roadway users (V2X) like pedestrians. Also applicable to all types of vehicles, CVs have the potential to improve safety and general operations.

+ Electric Vehicles (EVs): Recharging and battery technology is making huge advances, with the potential to increase the range of EVs, time required to recharge, and the cost of electric propulsion.

+ Virtual Presence, e-Commerce, and 3-D Printing: although not specifically related to transportation, technologies that enable people to complete various activities virtually can significantly change travel demand, as in the case of telecommuting.

+ On-Demand Mobility: communications technologies are allowing for on-demand transportation services in many forms such as microtransit, Transportation Network Companies (TNCs), ridesharing, and others.

+ Sharing Economy: including the rise of carsharing, bikesharing, and ridesharing all have the potential to change how people get around every day.

+ Mobility as a Service: often considered an app, travelers can subscribe to transportation 'bundles' that include various modes and are priced by levels of comfort, convenience, and frequency of use.

+ Fewer driver's licences: recent trends show fewer driver's licences in younger population groups. Research has not yet proven that this trend

[1]World Health Organization: Road Traffic Deaths,' Global Health Observatory data, http://www.who.int/gho/road_safety/mortality/en/

[2]'Making the Most of Curb Spaces in a World of Shared Autonomous Vehicles: A Case Study of Austin Texas," Qinglu Ma, Kara Kockelman, and Marc Segal, forthcoming presentation at the 97th annual meeting of the Transportation Research Board, http://www.caee.utexas.edu/prof/kockelman/public_html/TRB17ReusingCurbParking.pdf.

will continue, but fewer drivers in the population may become a long-term reality.

+ Graying of the population: Much has been written about the aging of the Baby Boomers, and how it is shifting the population such that a larger portion will be over the age of 65. The generation's desire to age in place will shape the transportation landscape.

1.2 Impacts of the Trends and Technologies

The impacts of these technologies and behavioral trends have the potential to be extraordinarily far-reaching, including traffic operations, real estate markets, roadway design, municipal and state finances, trip making patterns, urban sprawl and/or densification, and mode preferences. A few of these impacts are highlighted below in Figure 1, but it is important to note that they are dependent on the deployment of the technologies, pricing relative to other options, enacted policies, acceptance of the technologies in the market, and the most uncertain aspect all: human behavior.

+ Traffic Operations: Connected and automated vehicles have the potential to improve the efficiency of roadways and intersections using machines[1] superior decision-making and faster reaction speeds. AVs and CVs will be able to travel closer together, increasing capacities and allowing vehicles to travel at higher speeds even at very high volumes.

+ Safety: One of the most significant improvements promised by CVs and AVs are the safety improvements, with the potential to drastically cut down on the 94% of accidents that are caused by driver error. These technologies could save over 32,000 lives per year in the US alone.

+ Fleet Size: Research has shown that AVs, CVs, microtransit, and other shared mobility options have the potential to dramatically decrease the fleet of vehicles required to service trips in cities around the world. Estimates indicate that the number of cars in major cities could shrink by as much as 80 percent.[2]

+ Parking: Along with a decrease in vehicle fleet size would come a decrease in the number of parking spaces required to store them. Additionally, parking spaces could be decoupled from activities, such that stores, restaurants, offices, etc. would not need to have parking spaces located directly adjacent to them. Vehicles capable of parking themselves could relocate to satellite parking lots, freeing up land in more populated, desirable areas.

+ Improved Mobility: These technologies, especially AVs, have the potential to provide mobility to people who have traditionally been severely limited, such as the elderly, the disabled, and children. Significant social and economic benefits could be realized through these technologies, although this could also cause increases in the amount of vehicle travel occurring in a region.

+ Travel patterns: Many of the technologies and behavioral trends are expected to have an impact on the number, type, and length of the trips people make every day. Additional reliance on internet shopping and 3D printing have the potential to decrease the number of shopping trips. Increases in telecommuting could decrease commuting trips. The extent of these changes will depend on how much people are willing to substitute in-person interactions. In addition, longer trips may become more attractive with the ability to be productive instead of having to drive.

+ Freight and Deliveries: Cost savings from reductions in labor costs could increase the amount of freight shipped by truck in the United States. Coupled with a potential increase in deliveries associated with e-commerce, and the number of trucks on American roads could grow dramatically.

+ Transit: Cost savings will be possible in the transit industry by removing drivers. The same cost savings will be seen in the taxi/ride-sourcing industries, changing the economics of transportation costs to consumers, and thereby changing how travelers make their mode choices. Researchers believe that significant increases in ride-sourcing are to be expected, leading to a dramatic increase in the amount of travel occurring in shared vehicles.[3]

+ Real Estate Development: Real estate markets are bracing for a series of potential changes. In particular, substantial amounts of land may become available for redevelopment when their uses are no longer needed, such as parking, gas stations, rest stops, and shopping malls. In addition, new developments will need to incorporate new design considerations, such as pick-up/drop-off points, ubiquitous Wi-Fi and other communications technologies, and decreased parking. Both increased density and exurban development[4] may become increasingly popular.

+ Municipal Finances: Impacts to governmental revenues could come from many directions, such as decreases in vehicle registration fees, losses in revenue from parking fees and speeding tickets, potential changes to property

[3]"Shared Mobility on the Road of the Future," Morgan Stanley, June 15, 2016, http://www.morganstanley.com/ideas/car-of-future-is-autonomous-electric-shared-mobility.

[4]'Spatial Economics: The Declining Cost of Distance,' Bain and Company, 2016, http://www.bain.com/publications/articles/spatial-economics-the-declining-cost-of-distance.aspx.

[5]'Help or Hindrance? The travel, energy and carbon impacts of Highly Automated Vehicles,' Zia Wadud, Don MacKenzie and Paul Leiby, Transportation Research Part A, February 26, 2016.

[6]'CR England Peloton Technology Platooning Test,' M. Roeth, November 2013. http://nacfe.org/wp-content/uploads/2013/12/CR-England.pdf.

tax revenues, and decreases in emergency response costs.
+ Environment: Many of these technologies have the potential to decrease the amount of transportation-related emissions. Electric vehicles and various charging mechanisms are more efficient and implementable with shared vehicle fleets. Eco-driving[5] and truck platooning[6] with automated vehicle technology have the potential to further decrease fuel consumption.

2. PERFORMANCE BASED PLANNING

For decades, planners have tried to implement transportation improvements that will have the largest positive impacts on the community. Performance-based planning and programming (PBPP) is the latest model under this paradigm, as it seeks to ensure that projects are selected based on their ability to meet established goals. Performance-based planning sets specific performance metrics that align with the stated goals,[7] and allows agencies to measure and assess the progress towards these goals.

Assuming that this planning paradigm will continue, planners will need to consider how new technologies, behavioral trends, and their associated impacts can be incorporated into the process. While new goals may or may not be

[7] "Performance Based Planning and Programming Guidebook," Federal Transit Administration, September 2013, https://www.transit.dot.gov/sites/fta.dot.gov/files/Performance_Based_Planning_and_Programming_Guidebook.pdf.

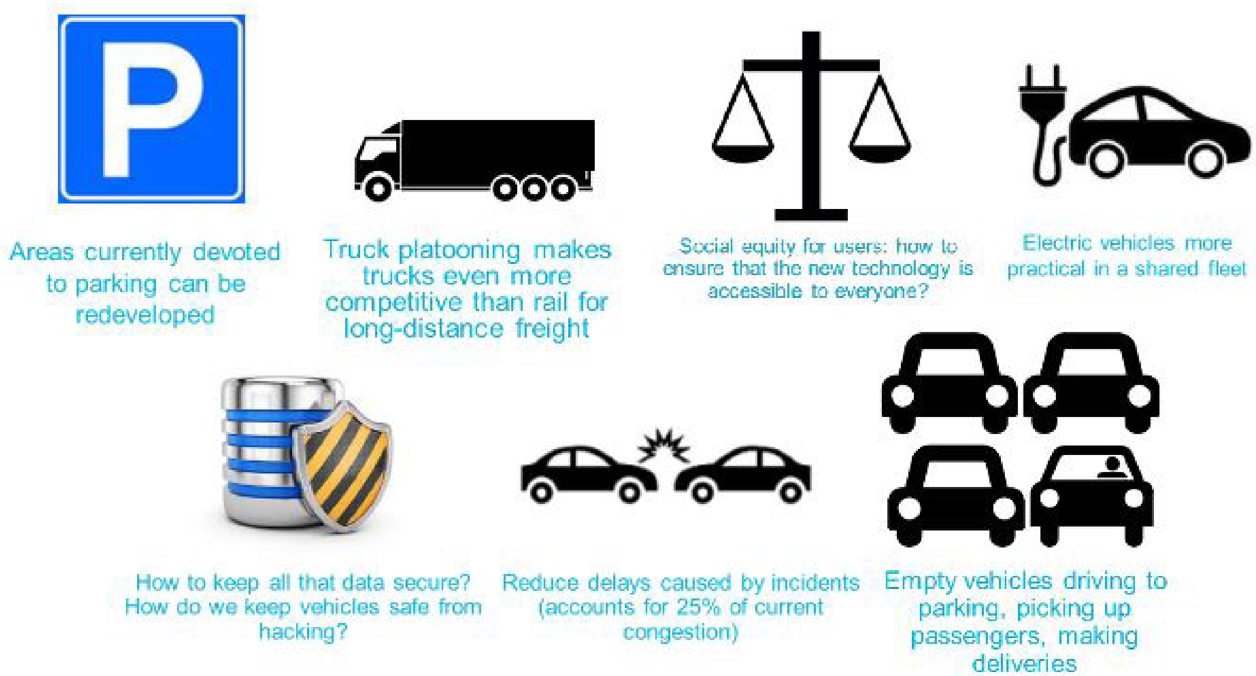

Figure 1.

necessary, planners will need to reconsider the performance metrics used to measure them. In addition, considering that the impacts of the technologies are still very uncertain, the planning process will need to accommodate that uncertainty in a meaningful and useful way.

2.1 Performance Metrics

There is a direct link between performance metrics and improvements in performance of any system, transportation included. As indicated in Peter Drucker's well known quote, "What gets measured, gets improved." This is one of the bases underlying performance-based planning, and highlights the importance of selecting the correct performance metrics. In most cases, regional goals cannot be directly measured, and the performance metrics that are selected are often proxies that are measurable and calculable with the data available. In many planning situations, the ability to forecast performance metrics in a future year, or to estimate a project's impacts on a metric without direct observation, is another constraint when selecting performance measures. For example, regions seeking to limit their transportation-related emissions may set Vehicle Miles Traveled (VMT) as a performance metric. Cities seeking to decrease congestion may measure the portion of the city that can be accessed within an average commute time (often referred to accessibility). Other common performance metrics include average travel time, transit ridership, crash rates, vehicle throughput, and traffic delay.

These types of performance metrics are intended to be indicative of the performance of the transportation system relative to specific goals and objectives, not to measure the problem itself. But the selected performance metrics can impact the types of solutions that are selected for implementation. In cases where performance metrics are tied to funding formulas, the selected measures can also determine how much funding an agency receives. One example of this unintended bias is when 'transit ridership' is used as a performance metric. Transit ridership is used to represent a number of goals and objectives, such as decreasing congestion, reducing emissions, and improving mobility for low income residents, but is not actually measuring the mobility of these residents. Its use as a performance metric that determines funding can lead agencies to pursue additional ridership at all costs, even when other alternatives (such as walking or biking) may be beneficial.

New and emerging technologies may provide new ways to meet regional goals and objectives that are not adequately captured using current performance metrics. For example, autonomous on-demand taxis could provide many of the mobility benefits traditionally associated with transit systems. But how do we measure those mobility benefits? Should we discourage these potentially beneficial services simply because they may detract from transit ridership? Are there better metrics to better measure mobility? These technologies should also provide significantly more data for analysis, allowing planners to calculate metrics that had previously been unavailable.

The formulation of performance metrics in transportation plans should consider the increased availability of data and how the technologies of the future may be able to achieve our transportation goals in different ways. When cities enter into agreements with technology companies, service providers and others, public agencies should ensure that their partners are required to provide the necessary data for the calculation of performance metrics.

3. TRAVEL DEMAND FORECASTING FOR AN UNCERTAIN FUTURE

Much of performance-based planning is based on analysis using various tools and models, in particular travel demand forecasting models. Many applications of performance-based planning use travel demand forecasting models to estimate the impacts of proposed projects on system performance, both in the current environment and often in future years as well. For decades, travel demand forecasters have been putting forth the notion that we can predict the future. It should come as a shock to no one that we cannot, but the problem is not where most people suspect. We cannot predict the future. We can predict many futures.

This should not viewed as a failure in accuracy of travel demand forecasting. There has always been uncertainty baked into the forecasting process, but so long as the assumptions being made were relatively certain, forecasts could be considered to be mostly a function of growth patterns in a given region. But at a moment in time when technologies and behavioral trends are making the future increasingly unsure this is no longer the case; there are too many uncertain interactions between the various potential technologies and other trends. This is best illustrated by the Cone of Uncertainty shown in Figure 2. This graphic illustrates how these uncertainties only increase exponentially the further into the future planners look.

None of this means that we should abandon travel demand forecasting as a method to prepare for the future. But it does mean that planners must rethink how they use these models and their results in the PBPP process. One of the most important considerations is the need for multiple scenarios in the forecasting process, instead of using a single version of the future. This will allow cities, regions, states, etc. to understand the range of potential changes that they can reasonably expect, and be sure to plan for this broader spectrum of possibilities. Under this paradigm, frequent recalibration of the scenarios will be necessary as more information becomes available and certain uncertainties are removed (no doubt to be replaced with new owns). This

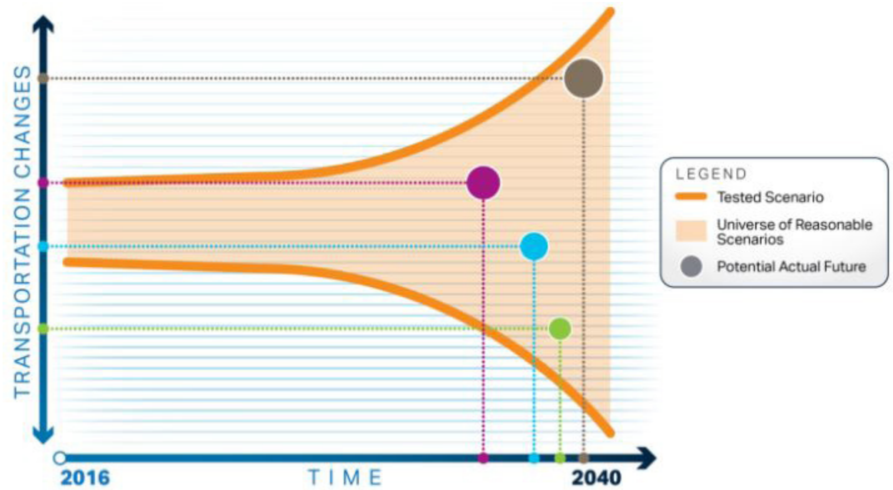

Figure 2.

will help governments ensure that they are investing in projects that will be beneficial regardless of which scenario comes to pass.

Forecasting multiple future scenarios adds an additional layer of complexity to the performance-based planning process. Planners and modelers must work together to figure out how performance metrics can be estimated for future years when there are more than one reasonably likely future. One viable option would be to calculate performance metrics for a number of possible futures, weighting the results by the relative likelihood of each scenario. This option is difficult in that it could require analysis of a prohibitively large number of scenarios, and calculating the probabilities of complete scenarios is in and of itself uncertain. Another option could be a process in which a more limited number of scenarios are analyzed that "bookend" or "triangulate" the future. Either option would necessitate frequent recalibration and reconsideration as the technologies and other trends are realized. Reanalyzing the likelihood of the various scenarios every few years will ensure that new developments are incorporated into the planning process.

4. FACTORS IMPACTING UNCERTAINTY

Beyond the development and market uptake of the technology itself, there are several other issues that are likely to impact how, when, and to what extent these emerging trends and technologies take hold in different markets. The result of many of these issues are also currently uncertain and/or unknown, but planners, policy-makers, and government agencies will likely have some say as to how these issues are resolved. As such, it is important for government agencies to understand how different options will impact their futures, so that they can make policy choices that impact their jurisdictions positively, and help to achieve their goals. This is yet another role for travel demand forecasting in the face of almost overwhelming uncertainty.

4.1 Legal

Legal conditions for implementation of emerging technologies can vary significantly from state to state, and even wider variation can be seen at the international level. Fortunately, in the vast majority of U.S. states, there are no laws that specifically prohibit CVs, AVs, or other emerging technologies. The Federal Government is considering legislation (the SELF DRIVE Act)[8] related primarily to passenger AVs, while the National Highway Traffic Safety Administration (NHTSA) has produced several draft policies[9] to identify roles and responsibilities in an AV environment. Independently, 21 states have passed legislation related to AVs. Most legislation has been friendly towards new technologies, hoping to encourage innovation. However, several major industries have thus far been left out of the proposed legislation, most notably transit and freight trucking.

Another legal issue that must be surmounted in the AV space relates to liability in the case of traffic accidents. Under the current system of U.S. auto insurance, liability is primarily assigned to the driver/owner of the vehicle in the case of an accident. Vehicle

[8] "HR 3388," http://docs.house.gov/meetings/IF/IF00/20170727/106347/BILLS-115-HR3388-L000566-Amdt-9.pdf.

[9] "Automated Driving Systems (ADS): A Vision for Safety 2.0", National Highway Traffic Safety Administration, September 2017, https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf.

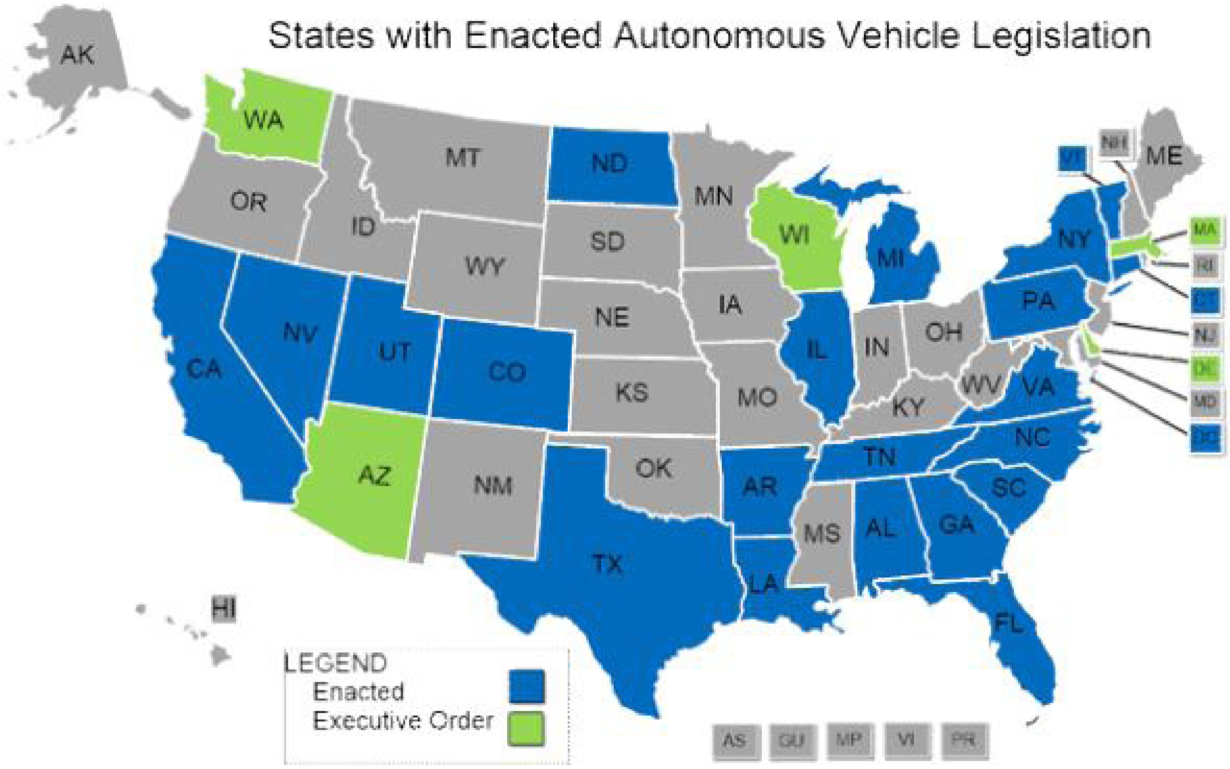

Figure 2. States with Enacted Autonomous Vehicle Legislation
Source: National Conference of State Legislatures

manufacturers are typically only found to be liable in the rare case of vehicular system failure. However, automation will remove driver fault from the vast majority of accidents and new insurance business models will be needed to insure the vehicle manufacturers against a higher percentage of on-road crashes. Insurance companies are also considering insurance products that insure mobility instead of vehicles. Similar to existing car-sharing companies, some manufacturers are planning to bundle insurance with other trip costs or provide pay-as-you-go insurance options. How these changes are enacted and incorporated into the legal system, and how much this new type of insurance costs will be major factors in determining how AVs are deployed.

4.3 Market forces

In the future, as in the past, price will play an important role in how people and corporations make their transportation decisions. Costs of emerging technologies relative to existing alternatives will therefore play an important role in determining how quickly these technologies take hold. For example, Google's first autonomous car included approximately $70,000 worth of sensor technology, pricing most potential buyers out of the market entirely. Current production estimates place that number closer to $250 by 2019, making the technology more affordable to a much broader population. Similarly, 3-D printers have been falling in price. Increased convenience may offset some of these cost differentials, but areas with strong and inexpensive transit service are likely to see different impacts than those without.

A strong argument can also be made that market forces will push the adoption of new technologies in places where conditions are currently the worst, and therefore the most gains are possible. For example, real estate in dense, mixed-use, transit-accessible neighborhoods continues to increase in price, making it more and more difficult for many people to live in these areas. Technologies that enable convenient living in cheaper locales may be highly desirable in these areas. Likewise, drivers and delivery operations in highly congested cities will see the most benefit from AV technology applications.

Various policies enacted at a local level have the potential to impact these market forces, guiding the technologies to solutions that are beneficial to a city or region. Pricing of vehicle operations, whether in the form of congestion pricing, a VMT tax, or a curb access fee can help to limit growth in auto travel and encourage the use of transit and non-motorized modes where viable. Dedication of CV-only lanes can provide time savings to drivers, potentially encouraging them to buy vehicles equipped with these technologies. Similar strategies were successful in encouraging the purchase of hybrid vehicles in the previous decade. Removing parking spaces from dense downtown areas can similarly encourage the use of various forms of shared mobility, by making owning and driving a privately owned automobile in these areas less convenient.

4.3 Other Technology Acceptance Issues

There remains significant fear and unease around many of these emerging technologies and behavioral trends. One recent survey showed that only 58% of the U.S. population was interested in fully autonomous vehicles[10], and the majority of those prefer owning their own vehicle instead of making the shift into the shared economy. Major concerns remain around the issues of safety, security, and privacy. The resolution of these complex issues may shape the user profile of many of these new technologies, and their overall proliferation in the market.

Privacy is one of the major areas of concern, both from the perspective of illegal cyber-attacks stealing user data, and from the perspective of who has legal access to the data and what they are allowed to do with it. Corporations are interested in leveraging data for targeted adds and other profitable applications of big data analytics. Cities and DOTs could also use the data to improve the planning process and otherwise upgrade our understanding of how the city works. Who owns the data and the equipment that collects it will determine available applications, but may also limit the user pool for various technologies.

Labor, organized or not, represents a major force in transportation-related industries, including transit, trucking, and taxis. Large-scale disruptions to these labor forces are expected with the wide-scale implementation of many of these technologies. The strength of these labor lobbies, and the extent to which new jobs are made available to workers in this sector, may impact how quickly and in which sectors new technologies can be deployed.

5. CONCLUSIONS

Perhaps this paper has presented more questions than answers. If so, it is wholly appropriate for a point in

[10] 'China's Car Owners Prefer Robot Taxis,' Friederike Meier-Burkert, Audi Urban Future Initiative, February 9, 2016, http://audi-urban-future-initiative.com/blog/china-robot-taxis.

time when so much about the future of transportation is uncertain. But in the face of this uncertainty, it is our job as planners to resist the temptation to throw up our hands and admit defeat. Planning is more important now than ever before, when decisions have the potential to turn the results significantly in one direction or another. Cities, states, and regions must now consider how to systematically incorporate that uncertainty into their planning and programming processes. This will require several steps:

+ Understanding the different technologies and behavioral trends at work and how they may impact your jurisdiction;
+ Developing a vision for your jurisdiction (if you do not already have one) and associated goals;
+ Selecting meaningful and measurable performance metrics that are aligned with the stated goals;
+ Considering how multiple potential future scenarios will impact these performance metrics including quantitative analysis tools such as travel demand forecasting;
+ Incorporating the results of these scenarios into the planning and programming process to ensure that any investments are sound choices; and
+ Periodically reconsidering the likelihood of various potential future scenarios based on new developments and observed behavioral patterns.

Armed with these tools and a solid understanding of how technology and other trends are likely to impact their communities, planners can continue to plan for a future in which technology serves the visions and goals of their cities.

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Transportation Agencies Adopt a Scenario Planning Approach for the Uncertain Road Ahead

By Les Brown & Tim Storer

Transportation innovations and the policies that influenced their adoption have had far-reaching impact on the form and character of America's towns and cities, as well as the quality of their economies and environments. Los Angeles, for example, was once home to the world's largest electric railway system and busiest intersection, with over half a million crossings daily.[1,2] However, with the arrival of affordable cars and decisions that encouraged driving at the expense of transit, the city's transportation system soon became synonymous with traffic, smog and sprawl. On the other hand, while Portland's transportation history followed a similar trajectory, its eventual adoption of an urban growth boundary and an ambitious transit investment plan, along with policies that directed growth towards these transit corridors, injected new life blood into the city's once-ailing economy.[3] Since the implementation of these plans and policies, Portland has routinely ranked as one of the most transit, pedestrian, and bicycle-friendly cities in the U.S., helping it to attract educated workers and the firms that follow them.[4]

Figure 1. Rail tracks ad overhead lines crisscross LA's bustling streets
Source: Electric Railway Historical Association of Southern California

EMERGING TECHNOLOGIES

Until recently, vehicles like those that ply the freeways of Los Angeles were seen as the heir apparent to the nation's transportation system, and with some exception, travel and development patterns were reasonably stable and predictable. However, the transportation landscape is evolving rapidly. Within the last ten years, the arrival of smartphones and other connected devices ushered in the mobile app revolution and sharing economy. In Silicon Valley, this gave rise to ride hailing companies like Uber that offered consumers the convenience of door-to-door mobility on-demand. These technology-enabled mobility services — which include ride hailing, bikesharing, and peer-to-peer carsharing – have spread rapidly and been especially popular in cities like Washington, D.C and Seattle that place high on the Shared Mobility City Index, which ranks cities according to factors like population density, commuting patterns, and parking costs.[5]

With the growing ubiquity of connected devices, and the reasonable assumption that these technologies will become better and cheaper with time, the likelihood of widespread vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) connectivity seems high. A study by the National Highway Traffic Safety Administration concluded that V2V technologies – these include forward-collision warning, blind-spot warning, and lane-change warning – could prevent more than three-quarters of all light-duty vehicle-involved crashes.[6] Likewise, the adoption of V2I technologies offers an opportune moment to advance mobility applications that address travel reliability, safety and reduce emissions. Such technologies may even have applications for future pay-per-use roadway funding mechanisms to replace motor fuel taxes as the primary revenue stream for state and federal highway funding (lawmakers in Massachusetts have proposed a set of bills that would require this payment model for autonomous vehicles).[7] However, in the absence of federal regulation mandating standardized V2V and V2I technologies for new vehicles, these gains may come at an incremental pace.

In addition to connected vehicle technologies, dozens of tech and auto companies are bringing automated vehicle technologies to market. A number of traditional automakers like Ford are betting heavily on a future mobility ecosystem where shared autonomous and electric vehicles play a major role, envisioning a confluence of mobility and technology trends that would result in the Shared-Automated scenario below (Figure 2). Many automakers are also following Tesla's lead toward electric power – a move bolstered by recent announcements from the governments of France, Britain and Norway that will ban the sale of gasoline- and diesel-powered vehicles in the coming decades. In addition to driverless vehicles, even intercity travel by vacuum tube now seems possible, with Maryland's governor granting approval to begin construction of a Hyperloop route that would eventually connect D.C. to New York in under half an hour. Flying cars are even in the mix, with Uber's plan to pilot an autonomous and electric "vertical takeoff and landing

[1]American Rails. (2017). The Pacific Electric Railway: Comfort, Speed, Safety. Retrieved from: https://www.american-rails.com/pacific-electric-railway.html

[2]Masters, N. (2012, August 1). Seventh & Broadway: Photos of Downtown's Crossroads through the Decades. Retrieved from: https://www.kcet.org/shows/lost-la/seventh-broadway-photos-of-downtowns-crossroads-through-the-decades

[3]Calthorpe, P. & Fulton, W. B. (2001). The Regional City 4th ed. Edition. Island Press.

[4]Rogoway, M. (2017, October 25). "Smart, young migrants drive Portland's 'astonishing' economic growth." The Oregonian. Retrieved from: http://www.oregonlive.com/business/index.ssf/2017/09/smart_young_migrants_drive_por.html

aircraft" service for travel within regions.

Despite these advances, the path towards widespread adoption of these technologies is unclear. Currently, there is a patchwork of driverless vehicle regulations between jurisdictions, with many awaiting federal legislation to address some of the thorny legal, ethical, and data issues surrounding the deployment of these technologies. Further, complex real-world driving conditions, including severe weather and interactions with pedestrians and bicyclists, may pose a technological challenge that could indefinitely delay the rollout of fully autonomous vehicles, limiting the practical applications of these technologies.

Additionally, there are a host of external factors that may influence the adoption of these technologies. These include an aging population with increased mobility needs; the growth of ecommerce and telecommuting; and the potential for widespread job loss in industries at risk of automation, including the 5 million people in the U.S. who work as drivers.[8] There is also good reason to believe that shared use of these technologies will depend on criteria like those used to rank the Shared Mobility City Index, and that shared mobility trends will continue to play out differently in varying geographies.

The complex interplay of these and other factors will ultimately determine the extent to which these technologies are adopted and the nature of their impacts.

TRANSIT AND HIGHWAY FUNDING TROUBLES

While shared mobility services and investments in emerging transportation technologies have proliferated, transit ridership has declined. In fact, from 2014 – 2016, ridership dropped in all but seven of the nation's largest metro areas, with a total decline of 4.5 percent for the country as a whole.[9] In cities like Washington, D.C. and San Francisco, home to some of the nation's most extensive heavy-rail systems,

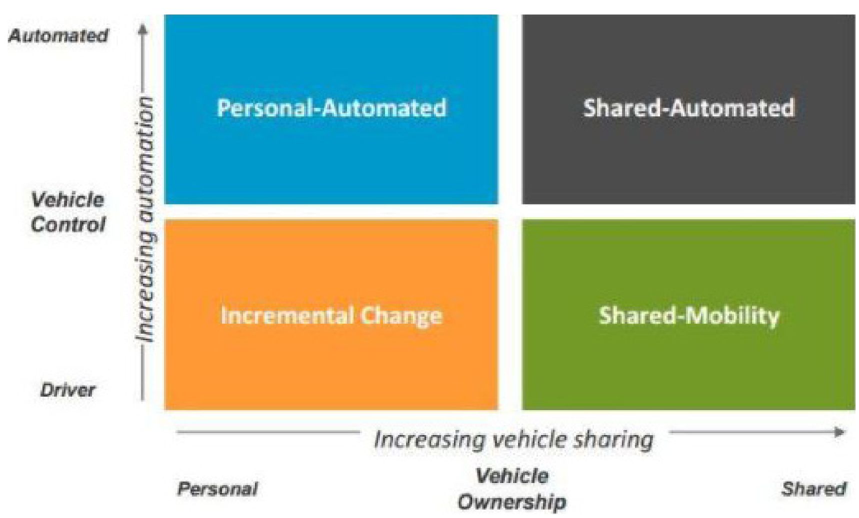

Figure 2. Future Mobility Scenarios (Source: US Department of Energy)

[8]Greenhouse, S. (2016 , September 22). "Autonomous vehicles could cost America 5 million jobs. What should we do about it?" Los Angeles Times. Retrieved from: http://www.latimes.com/opinion/op-ed/la-oe-greenhouse-driverless-job-loss-20160922-snap-story.html

[9]Puentes, R. (2017, May 17). "Ghosts of Transit Past: What can we do about declining transit ridership?" U.S. News. Retrieved from: https://www.usnews.com/opinion/economic-intelligence/articles/2017-05-17/how-can-we-reverse-declining-public-transit-ridership

maintenance woes are seen as a contributing factor. This is especially true for the New York MTA, which operates the nation's largest transit system, and faces the unique and daunting challenge of repairing flood damage from Hurricane Sandy on a system so antiquated that many replacement parts are no longer manufactured.[10] Buses are also seeing ridership decline. From the second quarter of 2007 to the same quarter in 2017, ridership on city buses dropped 13 percent nationwide, leaving many agencies to explore service cuts as a way to make up for lower fare revenues.[11]

There are a number of factors potentially contributing to ridership declines. These include degrading transit service quality, low gas prices, and continued growth in low density development patterns that are difficult to serve with transit. While the verdict is still out on the impacts of ride hailing, a study in New York concluded these services were taking a significant number of riders from transit (the study also concluded ride hailing was significantly increasing roadway congestion).[12] On the other hand, pilot programs in Boston, Kansas City, Dayton and elsewhere demonstrate the potential for ride hailing services to shuttle passengers to and from transit stations; complement paratransit service; extend service hours and routes; reduce parking needs; and provide a substitute for low performing bus or paratransit routes, thereby increasing the cost-effectiveness of transit systems.

Funding troubles are not limited to transit. Failures to adjust state and federal motor fuel taxes for inflation and increased fuel economy have led to growing funding shortfalls for the maintenance of many of the nation's roads and bridges.

PLANNING FOR UNCERTAINTY: JACKSONVILLE TRANSPORTATION AUTHORITY AND THE FEDERAL HIGHWAY ADMINISTRATION

The current moment offers planners and policy makers a unique opportunity to survey past and present transportation developments and begin to chart a course forward. While it is impossible to predict the future with certainty, scenario planning offers a systematic approach to explore a range of possible scenarios, identify a set of likely results, and consider plans and policies that could increase the likelihood of favorable outcomes. In the spring of 2017, a team led by Dr. Siva Srinivasan and Dr. Ruth Steiner of the University of Florida Transportation

[10]Fitzsimmons, E.G. (2017). "Key to Improving Subway Service in New York? Modern Signals." New York Times. May 1. Retrieved from: https://www.nytimes.com/2017/05/01/nyregion/new-york-subway-signals.html?_r=0

[11]Harrison, D. (2017, August 12). "America's Buses Lose Riders, Imperiling Their Future." The Wall Street Journal. August 12. Retrieved from: https://www.wsj.com/articles/americas-city-buses-lose-momentum-1502539200.

Institute (UFTI) conducted a scenario planning workshop for the Jacksonville Transportation Authority (JTA) — the 2016 recipient of the American Public Transit Association's Outstanding Public Transportation System award. This workshop convened JTA staff and a number of its peer agencies to address the impacts of emerging transportation technologies and shared mobility models, and begin to consider the road ahead.

The UFTI Team was tasked with looking 25 years into the future to cover the range of possible transit agency roles. Prior to the workshop, the Team conducted a literature review to develop the scenarios and used data from the regional activity-based travel demand model as well as State demographic forecasts to project Jacksonville's future population distribution and composition. Maps and a matrix of scenarios were then distributed to the group to help inform the discussion (Table 1).

Two sessions were conducted at the workshop. The first looked at the impact of various propelling factors on the different scenarios. These included an assessment of uncertainty about connected and autonomous vehicle (CAV) technology; shared mobility; policy and regulations; demo-

	Smartly Integrated	**Business As Usual**	**Insignificant Player**
Role	Regional Mobility Manager	Regional Transit Provider	Localized Transit Provider
Target Markets for Service	Choice Riders and Mobility Disadvantaged	Some choice riders but mostly mobility disadvantaged	Mobility disadvantaged and/or travelers along selected high volume corridors.
Business model	Provider of infrastructure and IT platform	Provider of infrastructure, some IT platforms for multi-modal connectivity	Provider of infrastructure, some IT platforms for multi-modal connectivity
Infrastructure and Service	Smart/autonomous buses (possibly multiple sizes) and possibly fixed guideway transit. Extensive V2V (vehicle to vehicle), V2I (vehicle to infrastructure), and V2X (vehicle to everything) connectivity. Regional coverage	Traditional buses and/or "smart" buses and fixed guideway transit, some level of V2V, V2I and V2X connectivity. Regional Coverage	Traditional buses and/or "smart" buses or just fixed guideway transit, some level of V2V, V2I and V2X connectivity. Limited Coverage
Relationships to other modes	Complemented by shared and owned AVs (first mile / last mile solution), seamless inter-modal transitions, maintains competitive edge in certain sectors of travel	Competing for market with shared and owned AVs (or human-driven vehicles). Some level of inter-modal connectivity via technology	Dominated by shared and owned AVs

Table 1. Future transit system scenarios (source: JTA).

graphic and life style trends; public sentiment; and government funding. The second session focused on the outcomes of different scenarios with respect to the attainment of the region's planning goals and operational impacts to JTA.

The group was generally optimistic about the timeframe for deployment of CAV technologies and the potential for these technologies to complement JTA's existing operations, including the ability to interface with JTA's Ultimate Urban Circulator – the agency's plan to modernize Jacksonville's Skyway monorail system and eventually provide on-demand and point-to-point capacity for system users (Figure 3). On the other hand, the group was uncertain about the timeframe for necessary federal regulations for CAVs, and concerned about potential issues related to funding, equity, workforce obsolescence, safety, and the expense of CAV technology procurement and repair. The "Insignificant Player" scenario was especially concerning to the group. In this scenario, some envisioned that increased competition from autonomous ride hailing services could put the agency in a funding "death spiral."

Following the conclusion of the two sessions, workshop participants were asked to provide feedback. Regarding future goals and objectives, the group agreed that the desirable aspects of future public transportation systems should resemble those pursued today, including equity, accessibility and integration with surrounding land use patterns. The group also identified a number of external factors that could influence JTA's deployment of emerging technologies including competition from private providers. Finally, to continue to achieve their core goals, the group concluded that JTA

Figure 3. A conceptual rendering of JTA's Ultimate Urban Circulator (Source: JTA)

should: (1) Promote itself in the community (2) Meaningfully improve service (3) Aggressively pursue new technologies and partnerships with shared mobility services (4) Identify where new technologies could complement JTA's operations in order to maximize efficiency and (5) Be closely involved in the land development process.

In addition to JTA, other local and state agencies have conducted various forms of scenario planning addressing technological readiness and uncertainty. The State of Texas, for example, commissioned a study outlining two technological deployment paths, while other agencies such as Baltimore Metropolitan Council and Washington State DOT have conducted similar exercises[13,14,15]. However, the number of city, regional, or state governments that have considered technology impacts in their planning and policymaking are few, and the number who have considered it through a scenario planning process are fewer. According to a 2015 study by the National League of Cities, only 6% of city plans had accounted for automated vehicle technologies and only 3% accounted for ride hailing companies.[16] Yet statutes like Florida House Bill 7061 (2016), which require the state's long range transportation plans to consider the infrastructure changes needed to accommodate emerging vehicle technologies, may begin to change this.

The rapidly evolving and technically complex nature of these trends can be overwhelming to local agencies that lack funding or institutional capacity to analyze these issues themselves. To help remedy this, the Federal Highway Administration (FHWA) is developing scenario planning guidance to address technological change in transportation. For this effort, government and industry experts were brought together to develop and test six exploratory scenarios focused on CAV deployment. This initial workshop harnessed the technical expertise of this group to refine the six scenarios, affirming that they were each internally consistent, logical given their assumptions, and plausible, albeit not necessarily equally so. Each of these scenarios hinged upon underlying assumptions on the capability, cost, and market share of connected and autonomous vehicle technologies, as well as certain other factors.

Each of the six evolutionary scenarios start from a baseline scenario called "Slow Roll" that was created to reflect the minimum plausible change that could occur within the 2035 planning horizon. Ex-

[13]*Baltimore Metro. (2014). "Maximize 2040 Plan, Appendix C: Scenario Thinking." Retrieved from: http://baltometro.org/phocadownload/Publications/Transportation/Plans/Maximize2040/AppC_Scenario-Thinking.pdf*

[14]*Zmud, J., Tooley, M., Baker, T., & Wagner, J. (2015.) Paths of Automated and Connected Vehicle Deployment: Strategic Roadmap for State and Local Transportation Agencies. Texas A&M Transportation Institute. Retrieved from: https://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/161504-1.pdf*

[15] *Washington State Department of Transportation. (2014.) Washington State Freight Mobility Plan. October. Retrieved from: http://www.wsdot.wa.gov/freight/freightmobilityplan.htm*

[16]*National League of Cities. (2016) City of the Future: Technology and Mobility. Center for City Solutions and Applied Research, NLC. Retrieved from: http://www.nlc.org/sites/default/files/2016-12/City%20of%20the%20Future%20FINAL%20WEB.pdf.*

pert opinion was crucial in determining baseline levels of connectivity and automation, as well as minimum deployment thresholds given existing technologies, rulemakings, and investments. The group also agreed on the importance of conceiving these scenarios as trajectories of change rather than simple snapshots in time, as the former links the evolution of these technologies with their possible uses and limitations. For example, one scenario assumes availability of SAE Level 4 automation, meaning vehicles can drive themselves without driver intervention. However, it also assumes that costs of these technologies remain high, and their capacity to navigate in unpredictable conditions and adverse weather would remain limited, meaning that practical applications of CAVs would be restricted to high-use services in cordoned areas, such as campus and retirement community shuttles. However, it is conceivable that successful use in niches might grow into more large-scale implementation scenarios. By considering the impacts of variables like the cost and capabilities of these technologies, the scenarios provide a set of possible options that a planner can use to assess the risks of current planning decisions and investments.

Planners from both state and local agencies recently convened at a second workshop to test these scenarios and examine possible impacts to planning processes. This workshop had two primary objectives – the first was to determine key risks and opportunities associated with each scenario to the effectiveness of current government planning and operations, and the second was to solicit feedback from planners on the most useful format for practitioner guidance.

Planners noted that in the advent of all scenarios, particularly the higher-impact ones, agency measures of effectiveness would need to change. For example, in scenarios with higher automation, the cost of travel time may be minimized as that time can be used productively, meaning that travel time reliability might come to have greater importance than travel times. Participants also noted that guidance to planners should focus on identifying planning impacts under each scenario, and then highlighting impacts that occur under all scenarios to provide suggestions on actions that can be taken now. Given the multitude of possible outcomes from CVs and AVs, the project aims to inform agency operations, allowing them to anticipate and plan for the advent of certain developments.

GETTING AHEAD OF THE CURVE

In this rapidly evolving mobility landscape, change seems to be the only certainty. By assessing opportunities and risks associated with a range of possible technological trajectories, and developing strategies to ensure they continue to meet their core goals despite these uncertainties, forward-thinking agencies like JTA are getting ahead of the curve. The robust connected and automated vehicle scenario planning guidance undertaken by JTA and currently being developed by FHWA provide models for other agencies as they consider the decision-making implications of these rapidly evolving trends.

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Impact of Future Technology in the 2045 Long Range Transportation Plan

By Lisa Colmenares, AICP & Tewari Edmonson

INTRODUCTION: FRAMEWORK

As the digital era increasingly reaches deeper into transportation, technological advancements are causing a shift in the way automotive vehicles are manufactured, as well as the way we plan, design and construct our infrastructure to accommodate them in the future. Transportation planners, are charged with the responsibility not only to keep pace with new developments, but also to ensure public safety, environmental sustainability, economic development, mobility, security and quality of life. Recognizing that there is a shift in the way people travel as a result of rapid technological changes requires transportation policy and regulations be put in place to address these changing patterns. Transportation Planning Organizations (TPOs) must incorporate these changes in the development of short and long term plans, specifically in the Long Range Transportation Planning (LRTP) document which is a comprehensive transportation infrastructure plan which covers a minimum plan horizon of 20 years. Long Range Transportation Plans are developed as part of the metropolitan planning process, and must be updated every 3 to 5 years.

The Miami-Dade TPO's upcoming 2045 LRTP update from the 2040 Plan includes an emphasis on land use, densification, transit emphasis, connectivity, multimodal mobility and innovative (non-traditional) financing throughout the long range transportation planning process. The LRTP is intended to reflect the community values and visions for improving the region's transportation system. The most recent LRTP update was adopted in October of 2014, and the next major update is anticipated to be approved by the TPO Governing Board in the fall of 2019. One of the major emphases of this plan update will be the consideration of innovative planning efforts which seek to balance access, mobility, affordability and finance, community cohesion, health and environmental quality and stewardship. This plan will highlight in-depth consideration of intermodal improvement opportunities, transit oriented development, innovative financing including the private sector bringing new ideas and resources to the table, freight and passenger movement, express transit service, park and ride, sustainability, performance measures and measures of effectiveness, Intelligent Transportation System technologies, transportation demand and Congestion Management Process (CMP) techniques to a greater extent than in previous updates. Miami-Dade TPO is tackling these issues early on to take advantage of potential future technology and include the results of the analysis in the upcoming 2045 LRTP. The TPO's plan update will consider high technology solutions to existing and future transportation challenges in Miami-Dade County. Technology will also be utilized in the planning process to ensure that the 2045 LRTP represents cutting edge best planning practices. Technological solutions in the plan will include automated vehicle technologies, connected vehicle technologies, smart cities improvements, Transportation Systems Management and Operations (TSM&O) and Intelligent Transportation Systems (ITS) solutions, and others. Technologies included in the planning process, include decision-making tools such as social media applications, interactive websites, mobile phone applications, 3-D visualizations, and other graphically rich visualization techniques. Future technology efforts included in Miami-Dade TPO's LRTP will make use of innovative and user-focused approaches which leverage emerging mobility services, integrated transit networks and operations, real-time data, connected travelers, and cooperative ITS. Future technology allows for a system that can provide options that are more traveler-centric, and collectively provide for real-time improved mobility options to all travelers and users of the system in an efficient and safe manner.

States have taken one of four approaches to Automated Vehicles (AV) policy. A few, including Florida, Tennessee and Georgia, have fully legalized vehicles without drivers. Other states have passed laws that permit testing, others have issued direct executive actions, and the rest are either developing laws or are waiting for the market to develop further. The figure below depicts the current stage of each state as


Figure 1

of May 2017.

In 2016 the State of Florida enacted House Bill 70611 stipulating that the Long Range Transportation Plans (LRTPs) in Florida consider the infrastructure changes needed to accommodate advanced vehicle technologies such as autonomous vehicles, which include connected vehicles (CV) and automated vehicles (AV). The various levels of autonomy are described below in Figure 3.

House Bill 70611 in the State of Florida represents one of the first policies adopted at the state level regarding autonomous vehicles in long range transportation planning. This is important because it establishes a policy framework for the TPOs to lead the planning process considering future technologies through the following tools and strategies: a) scenario planning, b) data collection initiatives to monitor emerging trends, c) implementing decision making

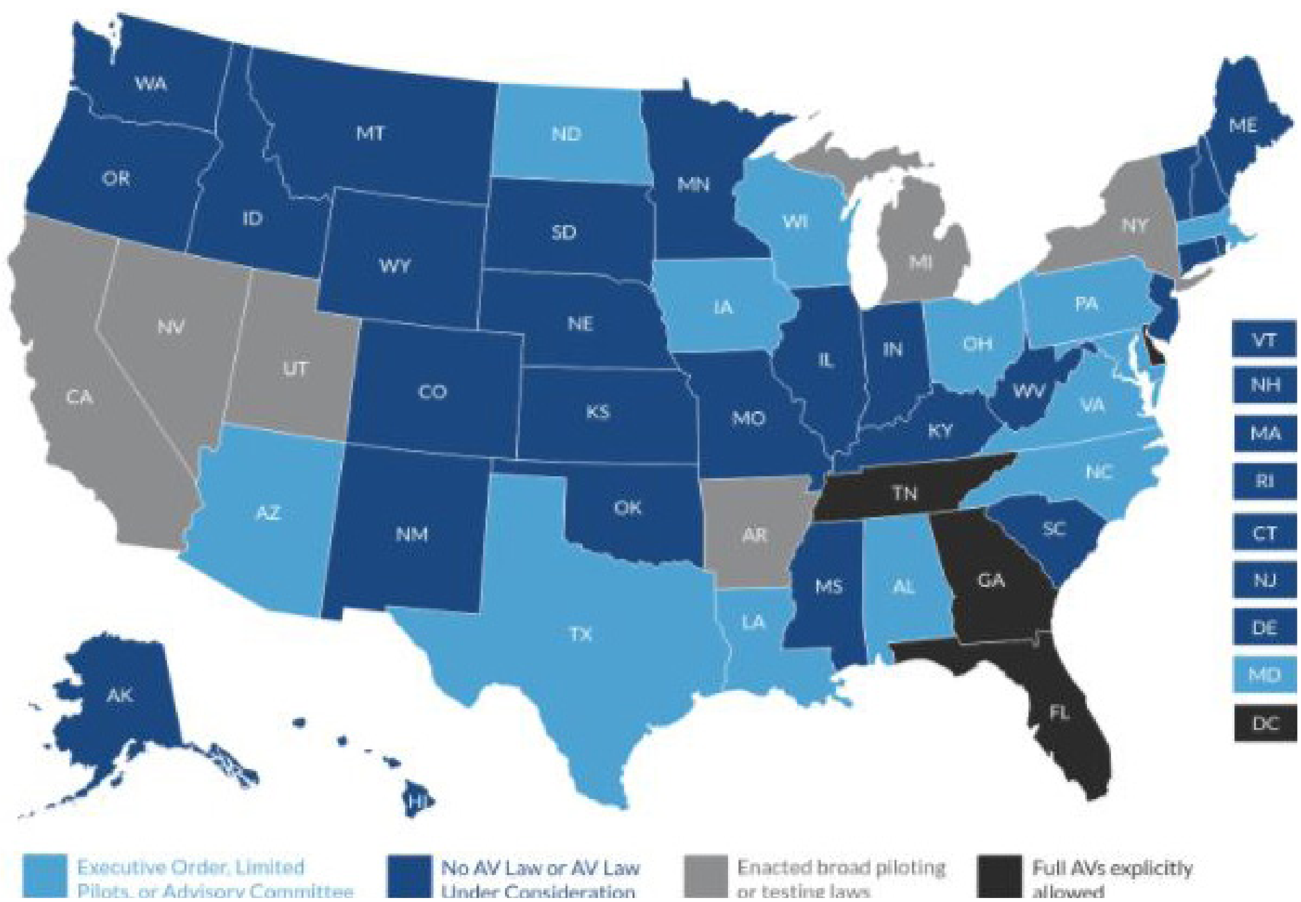

Figure 2
Source: National Conference of State Legislatures and Individual State Legislation. Created by Ann Henebery/Eno Center for Transportation

policy changes through planning, and d) utilizing forecasting procedures. Although there are no federal laws or rules on how to address technology in LRTPs, federal agencies, such as the Federal Highway Administration and Federal Transit Administration, recognize the considerable attention such emerging issues are receiving in national discussions and in efforts at the federal, state, regional, and local level. Consequently, these federal agencies are supportive of efforts to incorporate technology in these transportation plans.

In anticipation of the upcoming 2045 LRTP, the Miami-Dade TPO has completed several efforts including the following studies: Addressing Compliance of the 2045 LRTP Update, Federal Planning Emphasis Areas, Impact of Future Technology in the 2045 LRTP, and the Miami-Dade Multimodal Accessibility Based Need Assessment Tool.

The Miami-Dade Accessibility Based Needs Assessment tool provides the TPO a means to visualize the integration of systems and analyzes accessibility and multimodal connections, moving away from traditional approaches and utilizing more innovative and dynamic solutions to address existing transit issues. Figure 4 provides a visual representation of test project results

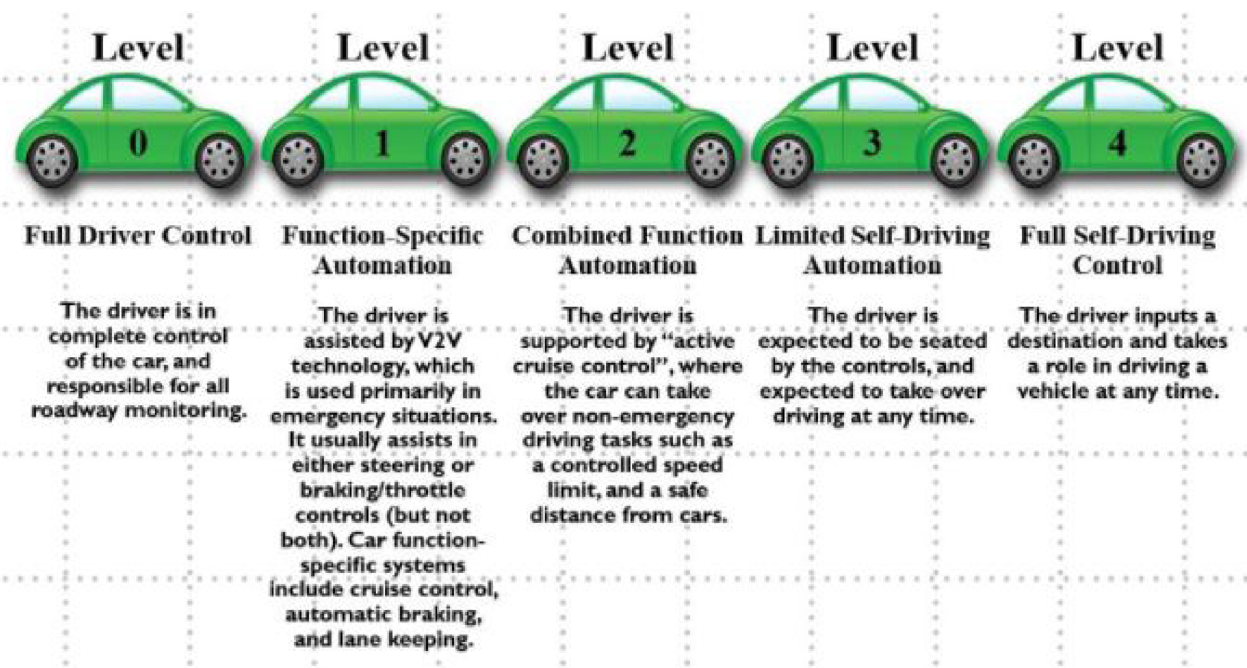

Figure 3
Source: National Highway Traffic Safety Administration

for a premium transit project along House Bill 70611 in the State of Florida represents one of the first policies adopted at the state level regarding autonomous vehicles in long range transportation planning. This is important because it establishes a policy framework for the TPOs to lead the planning process considering future technologies through the following tools and strategies: a) scenario planning, b) data collection initiatives to monitor emerging trends, c) implementing decision making policy changes through planning, and d) utilizing forecasting procedures. Although there are no federal laws or rules on how to address technology in LRTPs, federal agencies, such as the Federal Highway Administration and Federal Transit Administration, recognize the considerable attention such emerging issues are receiving in national discussions and in efforts at the federal, state, regional, and local level. Consequently, these federal agencies are supportive of efforts to incorporate technology in these transportation plans.

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The Miami-Dade Accessibility Based Needs Assessment tool provides the TPO a means to visualize the integration of systems and analyzes accessibility and multimodal connections, moving away from traditional approaches and utilizing more innovative and dynamic solutions to address existing transit issues. Figure 4 provides a visual representation of test project results for a premium transit project along NW 27th Avenue in Miami-Dade County, including bicycle and pedestrian improvements. The results highlight change in job accessibility by bicycle, walking and transit.

The Future Technology in the 2045 Plan provides the TPO with a framework to address the technological changes and comply with the state mandates in the LRTP. The following section highlights the results of the study.

FUTURE TECHNOLOGY AND ITS IMPACT ON THE 2045 LONG RANGE TRANSPORTATION PLAN

The Miami-Dade TPO evaluated the existing and future technologies that will impact and transform the transportation planning process. The study provided a framework to provide steps to incorporate technologies in the 2045 LRTP. The project's deliverables addressed the question: what will our community look like in 20-25 years?

The study prepared by the TPO included a literature review that covers over 200 sources and prepared 100+ abstracts to determine the most applicable solutions and elements for development in the 2045 LRTP. With autonomous and connected vehicles being one of the main drivers of the transportation revolution, it is also imperative that planning organizations consider their impacts as it relates to travel demand forecasting. An important consideration for autonomous/connected vehicles is the acceptance and future penetration rates, which refers to what percentage of the population is willing to utilize such technology. A reasonable approach would be to consider a number of alternative scenarios, make assumptions on expected behaviors and consequences, and conduct travel demand model sensitivity tests. Adjustments to the model and assumptions could be made after reviewing sensitivity results. As experience with autonomous/connected vehicles increases, models would be improved, as is always the case with new travel modes and facilities.

The existing architecture and infrastructure of the transportation system was also evaluated to determine deficiencies and the feasibility of implementing various new technologies. With Miami-Dade County being recognized as a Global Gateway which boasts the most popular cruise port, a major international airport and a seaport, it is essential that the systems architecture is able to adapt to new technology relating to these three economic engines. To address the Internet of Things (IoT), which has been defined in the TPO's document as the network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data which can be implemented and used as a way to evaluate deficiencies in the transportation system and in turn improve its efficiency, Miami-Dade County is already advancing toward being a robust IoT SMART Community by becoming the first county to launch an AT&T Smart Cities Operation Center. The platform gives municipality leadership visibility of their communities' conditions, all from one location and in near-real time. AT&T is also working to apply solutions that address intelligent lighting and smart transportation. And, in collaboration with their alliance member Hitachi, they will be deploying public safety solutions in our communities.

Highlights of the program include:

+ Remote monitoring and more efficient operations solutions for police and public safety officials.
+ Upgrades to the county's existing lighting infrastructure with smart LED lighting.
+ Reliable data to help inform decision making around urban transportation planning.
A traffic intersection network solution to help improve traffic flow.
+ AT&T has also committed to use our spotlight city program help address the Digital Divide. In early 2017 they launched a program at one of the County's public housing communities. Together with Ericsson, another smart cities alliance member, they provided 60 laptops for students and adults in the community to use in the community center, while also equipping the center with Wi-Fi connectivity. Miami-Dade students living in this community are now be able to log on to the Miami-Dade County Public Schools web portal to access their schoolwork while away from school. And adults in this community now have access to web content that can provide enrichment to their lives.

In addition to evaluating new technologies and their impact to future transportation planning, the TPO study also

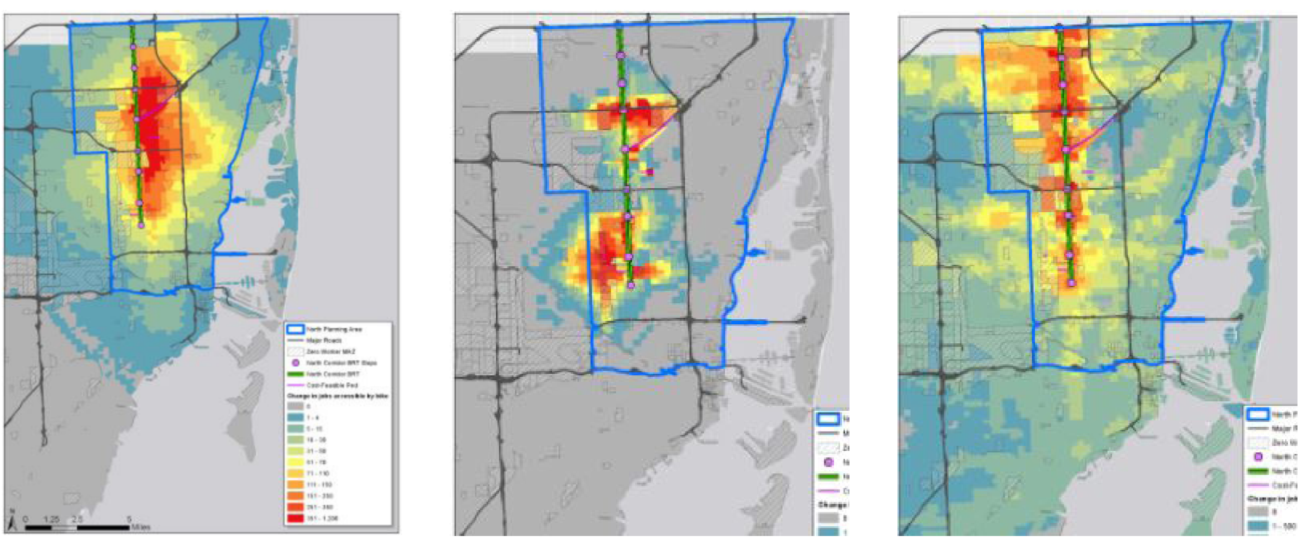

Figure 4
Source: Miami-Dade TPO Accessibility Based Needs Assessessment

highlights the importance of current and future county efforts related to SMART Cities and Connected Autonomous Vehicle (CAV) technologies. The current technology deployments and potential future projects are listed below:

+ Smart Traffic Signals Network and CV Technology currently connected and managed from the County's Traffic Management Center (TMC) as a part of the county's Transportation System Management and Operations (TSM&O) efforts

+ Universal/All-inclusive Trip Planner & Payment Application as currently deployed in Miami-Dade County's Metrorail and Metrobus system.

+ Integration of Transit and Private Ridesharing Services, and Implementation of Mobility as a Service (MaaS) and Autonomous Shared Vehicle Transportation Services. Due to the increase and popularity of ridesharing services, it is possible to anticipate the application of ridesharing model to public transit by providing on-demand flexible transit routes and partnering with private ridesharing services providers to effectively complement and augment transit coverage. In addition, it is possible to anticipate the implementation of MaaS and autonomous shared vehicle transportation services as a part of our 2045 LRTP update assessment.

- Autonomous Shared Vehicle Transportation Services: Expected to experience autonomous shared vehicle transportation services, including autonomous shuttles, ridesharing, carsharing, carpooling, etc.

- Implementation of Mobility as a Service (MaaS): The integration of public transit and private transportation service providers along with the modernization of the Department of Transportation and Public Works (DTPW) fare collection system and infrastructure will facilitate the implementation of MaaS concept. This will combine transportation services from public and private transportation providers (including shared-use transportation services, parking, tolls, etc.) through a unified gateway that creates and manages the trip, which users can pay for with a single account. Users can pay per trip or a monthly fee for a limited distance. This in turn will facilitate "chain-linked" trips and more affordable transportation options by providing additional mobility alternatives to car ownership. In the future, this could include autonomous shared vehicles, leading to a significant increase in shared-used mobility and access to more affordable housing,

Figure 5

reduction in the use of private car and repurposing of facilities and land uses.

+ Mobility Platform: Creation of a modular data platform that will collect, aggregate and analyze real-time traffic, transit and shared-used mobility information from different sources and providers. This will provide the analytics and shareable information needed to plan and manage the entire transportation network.

As a result of the TPO's Impact of Future Technology in the 2045 LRTP study, it was concluded that the key to planning for the future, the IoT revolution is to establish a network of technology infrastructure that is capable of supporting human needs. This network must provide for the technology infrastructure to be upgraded efficiently and quickly. Miami-Dade County will be at the forefront of this technology revolution as are other world-class cities.

The study also determined that to develop an IoT and a network of technology, collaboration between partners is necessary to develop a system that will connect different modes of transport to provide for seamless travel patterns. These scenarios and collaborative efforts are important to consider as part of the planning process in the LRTP.

COLLABORATIVE EFFORTS

Implementation of future technologies, including automated and connected vehicles, requires coordination to balance the needs of AVs with the needs of other travel modes. Collaboration between different levels of government, private and public sector agencies, partnership with universities are all important considerations within the planning process. It is necessary for transportation professionals to work with planning and implementing agencies to include bicyclists, pedestrians, transit, vehicles and AVs in the urban environment. Agencies have been collaborating nationwide and globally to adapt new technology to address mobility alternatives that will provide first and last mile options to the traveling public. How these are implemented need to be considered in the LRTP. Collaborative planning efforts through investments by federal, state, regional and local transportation agencies need to address the implementation of concepts that will best capitalize on the unique opportunity afforded by AVs to create safe, efficient, and livable places.

Future technologies provide potential benefits and opportunities that foster stronger relationships and partnerships between public agencies, private industry and universities. They also offer opportunities to stimulate economic growth through innovation and technological leadership that promote mobility, safety, sustainability, through leveraging recent advances in vehicle, infrastructure, pedestrian-based technologies, data, mobile computing, robotics, artificial intelligence, vehicle detection, and navigation. Connection between travelers, their mobile devices, vehicles and infrastructure is key to seek transformation in transportation that will serve the mobility needs of people and freight within the Miami-Dade urbanized area, while reducing transportation-related fuel consumption and air pollution. The future of technology introduces unpredictability in the environment. Long-range planning efforts led by traditional forecasting and analysis may not be relevant or accurate for a five-year and much less for a twenty year planning scenario.

It is important to foster rapid adaptation through our data and tools, by being really good at learning how to read and act on signals of change. Our TPO will be looking on how to best collaborate with successful partners that have succeeded through the implementation of best practices, business models, processes, and strategies that have adapted to new technology.

The answers may not be in the traditional way of planning, but we may need to look at other successful business models to ensure our transportation system remains safe, efficient, and reliable. When we're overwhelmed with changing information, how can our managers pick up the right signals to understand and harness change?

CONCLUSION AND FUTURE AREAS OF RESEARCH

The key to planning for the future is to establish a network of technology infrastructure that is capable of supporting human needs. Because we cannot predict the future transportation technology, this network must provide for the technology infrastructure to be upgraded quickly and efficiently. As part of the implementation of mobility option for travelers in Miami-Dade County, there have been successful deployment of strategies which have been reviewed in the TPO's Impact of the Future Technology in the 2045 LRTP.

The Miami-Dade Mayor Carlos A. Giménez, along with the Miami-Dade TPO Governing Board, has declared as a top priority for Miami Dade County,

Figure 6

the advancement of the Strategic Miami Area Rapid Transit (SMART) Plan, a comprehensive plan not to be confused with our 2045 LRTP, which intends to advance six rapid transit corridors, along with a network of Bus Express Rapid Transit (BERT) service to connect the entire county , which is strongly supported by public and private sector partners, residents, and other elected officials.

The implementation of the SMART Plan is the number one priority for the Miami-Dade TPO and will be key in the development of the 2045 LRTP. The SMART Plan will provide a tremendous opportunity for stakeholders in Miami-Dade County to work in collaboration with partners at the federal, state, regional and local level. The LRTP will provide the forum for stakeholders to discuss different mobility options and partner on building out the IoT throughout the region. The impacts, the potential benefits, and the disruptive changes to everyday life, as we know it, are just beginning.

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NEW TRENDS

Hyperloop's Potential

By Rebecca Leonard & Chris Zahas

Since the beginning of recorded history, transportation has fundamentally shaped our world by allowing trade and cultural interaction across geographic regions. Today, transportation technology is changing rapidly, promising to affect our world in many known and unknown ways. A future with high speed, autonomous transportation will shape both our cities and rural areas in positive and potentially negative ways. This article discusses some of those potential impacts in order to serve as a guide for planners. In such a rapidly-changing landscape, it is imperative that

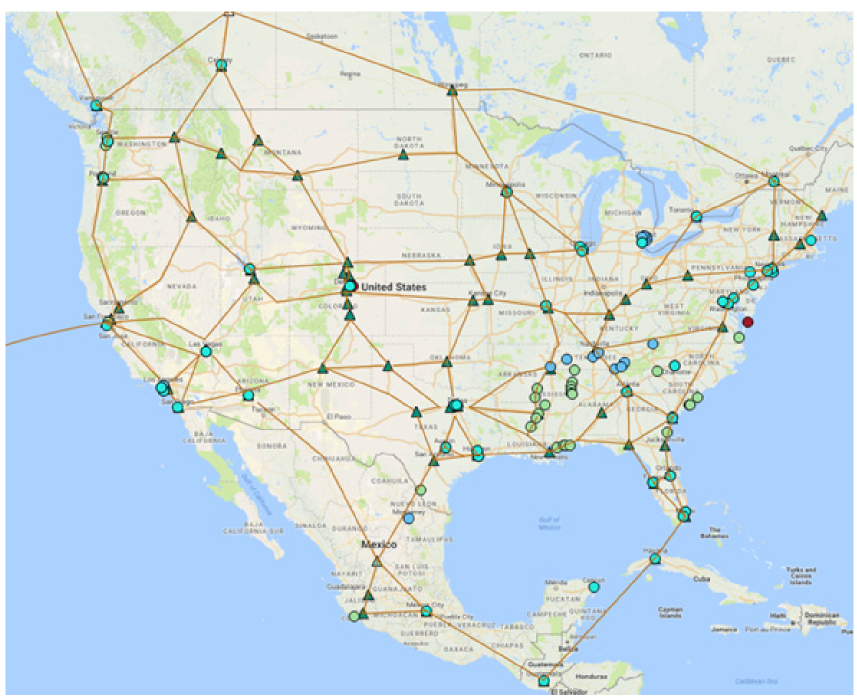


Figure 1, The Hypernet, a planned 40,000 mile hyperloop network, connects thousands of destinations across North America.
Source: Hypernet Holding Corporation and Map Data (C) 2018 Google

planners be engaged early on so that communities can proactively shape how this technology will benefit their futures rather than reactively responding to a changed world after the fact.

As described by its proponents, the hyperloop has the potential to provide major benefits to the communities it serves and the world as a whole. Rapid travel between cities will foster greater economic opportunities and will save time, all in a low-carbon and extremely safe mode. Tube-based transportation has been dreamed of since the 1800s, but did not gain serious momentum until the inventor Elon Musk published the Hyperloop Alpha paper in 2013, where he proposed the "hyperloop", a high-speed transport technology where passenger pods would travel in near-vacuum tubes at speeds upwards of 700 miles per hour. Trips between cities that now take hours would be reduced to minutes.

Since the Hyperloop Alpha paper was published, numerous technology companies have formed to develop the technology further. Given the magnitude of the task, the hyperloop industry is still in its infancy; however, firms such as Virgin Hyperloop One, Hyperloop Transport Technologies, Hypernet Holding Corporation, Arrivo, Transpod, Loop Global, and many others are vying to become the industry leader and first to market. Major milestones have included the development by Virgin Hyperloop One of a test track facility in the Nevada desert, development of pod prototypes through student competitions organized by SpaceX, and the recent announcement of a public-private partnership with the Colorado Department of Transportation and Arrivo to build a test track near the Denver International Airport. This rapidly-changing landscape makes it hard for cities to know how to prepare for or react to the hyperloop. On the one hand, the hyperloop could enhance local economies by accessing other markets more affordably, making it feasible to commute to high-cost cities from more affordable regions. Furthermore, the hyperloop promises to provide these benefits with resiliency, clean technology, and affordably. The hyperloop would also create opportunities for freight and passenger hubs and would improve the environment by replacing polluting modes of transportation such as trucks, planes, and cars. Conversely, there are potential negatives to the hyperloop such as physical and visual impacts from the tubes themselves. While the hyperloop is expected to bring economic benefits to the communities it serves, communities that do not have hyperloop access may lose out and fall behind in the new global economy.

IMPACTS ON CITIES

How the hyperloop will impact cities is an under-studied aspect and an area where planners can play a major role in ensuring that the hyperloop enhances communities. Some of the ways that the hyperloop will impact cities include:

Physical

+ Right of way will be needed for hyperloop routes. Routes will need to be very straight and flat, with extremely wide curve radii. While many hyperloop proposals have proposed it to be in above-ground tubes on pylons, a clear and accessible right of way will still be needed.
+ Alternatively, some proposals suggest that the hyperloop could largely be built in underground tunnels if new tunneling technology can make it affordable to do so. Under this concept, significant impacts to cities are still possible such as the need for stations, access points, and to ensure no conflicts with existing underground infrastructure.
+ Land will need to be acquired for hyperloop stations, or hubs. An unknown part of the equation is what a hyperloop hub will look like. How big does it need to be? How many "lines" will it connect? Should it be located in central cities or at the periphery of a region? Or can it accommodate both types of locations?
+ Intermodal connections for freight and passengers will be essential to maximizing the benefit of the hyperloop. How will hyperloop hubs connect to existing transit infrastructure such as rail, airports, and local transit?
If the hyperloop reduces the demand for air or rail transport (either passenger or freight), there may be opportunities to repurpose some of that infrastructure.
+ Hyperloop tubes may come in a variety of sizes. Standards do not yet exist. Without a standard, can a wider network be realized? How would the economic value come to be?

Financial

+ Who will pay for the hyperloop? Will it be completely privately-funded? From right-of-way acquisition to the development of hubs, there will likely be a need for public-private partnerships or even direct public investment.
How will the economic benefits of the hyperloop be captured locally? Should it be seen as a revenue source for cities? How will cities without a hyperloop benefit?

+ If the hyperloop reduces demand for air or rail transportation, there will likely need to be a plan to right-size that infrastructure.

To address these physical and financial impacts, planners can work collaboratively with the private hyperloop industry to conceptually explore options for each of these scenarios. From those exercises, best practices can emerge to have a productive community discussion around this new technology and to provide guidance for cities as they engage with hyperloop businesses.

IMPACTS ON RURAL AREAS

The fate of most transportation modes can be determined by how well they address the needs and desires of rural areas. The interstate highway system has become the most economically significant transportation infrastructure for many rural areas. The incremental barrier to entry is low for communities along the interstate. Once a community can fund a connection, it can proceed with development of the interchange and begin to realize the value of this transportation mode.

On the flip side, high speed rail has languished due to its high costs and organized rural stakeholder pushback. A recent high-speed rail effort in Texas has received little support in the rural areas. "It would divide my ranch in half," said one rancher. He went on to call the project "a textbook example of eminent domain abuse" and said it would diminish property values throughout the county. "The landowners will be paying the expense for the profit of a private business." Kyle Workman, representing the group Texans Against High Speed Rail said several counties in the path of the proposed "bullet" train were taking stands in opposition to the project. "There's no benefit for any of us in the middle," Workman said. "The numbers don't work, and we know that."[1]

The two main challenges hyperloop technology must overcome in rural areas are right-of-way (ROW) and access. The alignment of ROW, its impact on surrounding communities and landowners, and the method (and dollar amount) by which the ROW is obtained are of utmost importance to rural interest groups. Several hyperloop companies are exploring using railroad ROW. To some, hyperloop is comparable to rail (closed system and point to point) and therefore the new jargon developing around hyperloop has largely reflected that of rail (i.e., "stations", "platforms", and "operators").

[1] *http://www.corsicanadailysun.com/news/county-no-to-high-speed-rail/article_ff39925c-d1a2-11e4-8b04-8ba5eb4b5e60.html*

As private companies, the perception is railroads may be more motivated by profit and therefore easier targets for quick deal making than a large government entity such as the Federal Highway Administration. Using railroads as the analog to hyperloop may set in place a paradigm of thinking about hyperloop that limits other creative possibilities such as using existing interstate highway ROW, pipelines, power transmission lines, and even marine routes.

Whatever alignment is ultimately selected for hyperloop, the infrastructure must prove to be low risk and/or high reward for the communities and landowners surrounding the ROW. On the risk side, impacts on operations of ranches and small towns must be considered. Where possible, above or below ground tube options must be affordable and used frequently to alleviate perceived risks of interruptions to ground transportation and livestock operations. The ROW should be narrow and the infrastructure built in it must be clean, aesthetically pleasing, quiet, and able to adapt to other local needs.

Eminent domain might as well be a curse word in most rural, conservative communities. Americans in general don't support the idea of the government taking private land for the benefit of another private company. Therefore, hyperloop must also bring value to the landowners and communities through which it passes. The technology should be developed in a manner that allows frequent stops without impacting the high-speed flow of the main tube. This could be done with the equivalent of "offramps" and "interchanges", emulating the interstate highway system. The Hypernet, a product envisioned by the Hypernet Holding Corporation, works seamlessly with autonomous vehicles, making it comparable to a dedicated lane for autonomous vehicles moving at high speeds. Other hyperloop companies have pivoted on the vacuum technology and are accepting lower speeds in exchange for lower costs and better access. These off-ramps should be able to be built into the system over time to allow communities to increase access with growth. The infrastructure should also provide other benefits to communities to the extent that it can. For example, Hypernet Holding Corporation is exploring electric transmission and information communication technology opportunities in conjunction with unfettered access to their planned 20,000-mile network of tolled hyperloop tubes across North America.

CALL TO ACTION

The two main players in the hyperloop space right now are the technology companies and the regulators. One is thinking primarily of opportunities and one of largely constraints. Planners bring experience tactically moving through minefields of risk and metaphoric candy stores of opportunity, and are therefore integral to the success of this new transportation technology. In July, the inventor Elon Musk tweeted, "Just received verbal govt approval for The Boring Company to build an underground NY-Phil-Balt-DC Hyperloop. NY-DC in 29 mins." Within hours, city leaders in both New York and Washington, DC indicated that they were completely unaware of this effort and wondered aloud who gave this "verbal approval". This story represents the chasm between the opportunity-seeking technologists and the risk-burdened regulators. Planners can't be caught flat-footed when these two worlds collide. Planners must have a point-of-view on the technology, but dare they even lead its development? Imagine for a moment what a planner-designed transit system would look like. Would it be more accessible, affordable, green, and equitable? How can this vision influence the success of this fledgling infrastructure?

There are many existing questions that provide direction for future research in the field of planning. What hyperloop network offers the greatest value to the transportation of people? Which offers the greatest value for freight transportation? Who is most likely to use the hyperloop? What does the field of stakeholders in the hyperloop look like? What are the key issues of each stakeholder? What if people travelled in the pods like they do in an airplane (rows and aisles)? What if they drove their autonomous vehicles into a pod? What is the impact on efficiency of the system for every interchange or offramp? How does the network add value to rural communities and landowners between stops? How does a continental-scaled network enter a city? How and where does the infrastructure stop? How does a stop influence the land uses and built form around the stop? What is the cost of the tube network? Who are potential financing partners? Would are the appropriate delivery models (e.g., Design-Bid-Build, Design-Build, DBFOM)? Who develops the transit-oriented development around the stops? How are they financed? What is the cost of the transportation operations? How are operations funded?

These questions barely scratch

the surface of how planners need to engage in this transformation of transportation. An organization, Hyperloop Advanced Research Partnership (HARP) has formed to enable and promote the collaboration, research, funding, communication, and knowledge sharing that is essential for the development of hyperloop networks around the world. Instead of waiting for the technology companies to conduct the needed research, academic planners could partner with HARP and begin conducting research. Consulting planners could collaborate with hyperloop technology companies to ensure the needs of society, stakeholders, and the environment are considered from the beginning.

Planners bring lessons learned from a century of city building and are therefore well-suited to solve the challenges inherent in launching a new infrastructure of this scope and scale. As those most intimate with the needs of communities and who are ethically charged with serving the public interest at all times, planners should be setting the agenda for the technologists and requiring that they solve any challenges created by this new infrastructure – not the other way around.

Chris Zahas, AICP, is president of Leland Consulting Group, where he guides the firm's strategic position as a national leader in transit-oriented development, corridor and downtown revitalization, public-private partnerships, and private-sector development strategies. He is also a founding board member of the Hyperloop Advanced Research Partnership, a nonprofit research and educational organization to support the emerging tube-based transportation industry.

Rebecca Leonard, FAICP, is President of Hypernet Holding Corporation. She brings her 20 years of experience to the effort to commercialize hyperloop transportation. She serves as the Past Chair of the Urban Design and Preservation Division and the Chair-Elect of the Economic Development Division of the American Planning Association.

Emerging Transportation Technology, St. Lucie County, Florida

By David Engel, & Murriah Dekle

ABSTRACT

Joining the technology of real-time reservation mobile device applications and vehicle-routing technology with the delivery of same-day FTA classified "premium" service, suburban transit agencies now have the tools to effectively transform the way they deliver service. New transportation management software can now allow suburban transit agencies to broaden the population it serves, reduce economic barriers to more personalized transportation services, and offer a viable alternative to private automotive trips. Transit agencies and research institutions are now contemplating technology-enabled, real-time, ride share public transit service known as "microtransit."

Transit agencies across the nation have been grappling with how to cost-effectively deliver enhanced public transit for suburban land use densities. Traditionally, transit serves the general population of suburban areas through fixed routes where public access to transit is physically limited by proximity to bus stops. Transit agencies are fiscally constrained when attempting to comprehensively deliver adequate bus routes throughout the entire service area. Ultimately, suburban bus systems tend to be underutilized, rendering populations significantly underserved as a result of dispersed land use limiting mass transit accessibility.

Historically, the only alternative public transit service to the fixed route has been paratransit service. Federal Transit Administration (FTA) guidelines require paratransit trip reservations to be made at least one day in advance and this service is limited to the transportation disadvantaged population, namely seniors and the disabled. The average operating cost for delivering trips that do not require special need's assistance ("ambulatory trips")

Source: St. Lucie County Department of Communications

approximately $28 per trip. In a recent revision to the FTA Paratransit Circular, transit agencies are now permitted to establish "Premium" service identified by offering a same-day reservation capability. The new "Premium" service opens the door for suburban transit agencies to begin exploring an entirely new way to provide transit.

In recent years, transportation technology has created a paradigm shift in how transportation services are delivered. Led by the privately operated transportation network companies (TNCs) including Uber and Lyft, the public can now travel on-demand delivering much more convenient service not typically offered through public transit. Unfortunately, a new working paper by the University of California at Davis finds that TNCs contribute to, rather than decrease, roadway congestion. Even though TNC's typical fares are lower than conventional taxi services, regular TNC ridership is still an unaffordable option for many suburban residents. Publicly delivered microtransit does not come without challenges and obstacles. First, the enabling software required for microtransit is much more complex than the code used to provide TNC service. The microtransit software application requires system optimization capabilities to cost-effectively deliver "bunched" trips to realize a more cost-effective ride share platform vs. private single occupancy car service. New microtransit software also requires an artificial intelligence dimension to map frequent and common trip routes to regularly improve the efficiency and delivery of the demand response system. Second, suburban public microtransit cannot economically stand on its own. Microtransit must augment and be integrated into a traditional fixed-route and paratransit system or the cost of delivery will exceed typical transit budgets.

St. Lucie County is addressing the aforementioned micro-transit challenges in several ways. In partnership with Via Transportation, Inc., one of the leading transportation technology companies, the County is developing a demonstration pilot study designed to deliver a scalable application-enabled ride-share service. The study area identified to serve the microtransit demonstration is the regional mixed-use development known as Tradition, located in the City of Port St Lucie. The goal of this demonstration to produce an intuitive technology platform designed specifically for suburban microtransit service.

As part of a major update to the St. Lucie County Transit Development Plan, the entire regional transit system will be redesigned and optimized through establishing transit zones throughout the County where each zone will be served by its own system coordinated microtransit ride-share service, and trips outside the zone will be delivered to the regional fixed-route bus system. This new system will allow the transit agency to eliminate costly, underutilized fixed-route service with the new demand-response system. Second, the convenience of same-day real-time service will attract "ambulatory" riders who currently use the traditional paratransit system; ultimately migrating many of their trips to the microtransit system, reducing the cost of the delivered trip by up to 50 percent.

REGIONAL BACKGROUND

St. Lucie County, Florida is located in a rapidly developing region along the Atlantic coastline known as the Treasure Coast. St. Lucie County has a total area of 688 square miles and its population exceeds 310,000 residents. Due to the heightened pace of development in the County's largest city, Port St. Lucie, the County's overall population will likely grow by over 30 percent over the next decade. Port St. Lucie recently exceeded the population of the City of Ft. Lauderdale and is now one of Florida's major cities. Further, St. Lucie County is experiencing brisk commercial and industrial development, and is a popular tourist destination due to the County's warm balmy winter climate, popular water attractions, and recreational amenities, which significantly increase the seasonal population.

St. Lucie County's public transit system has evolved with the region's growth, and transformation from a predominantly rural and agricultural area to now suburban-urban. The

Source: St. Lucie County Department of Communications

original bus system began as a demand-response service in the 1990's operated by the Council on Aging of St. Lucie. Shortly thereafter, the transit system expanded to include fixed-route bus service now consisting of seven regular routes with interconnections to adjoining Indian River and Martin Counties. In an effort to grow the transit system to meet increasing demand, the St. Lucie County Board of County Commissioners had the foresight to enact a Municipal Service Taxing Unit transportation district for the County's Urban Service Area in 2003, which established a reliable source of local matching funds. As demand for more transit services increases, the County is at a crossroad; the transit agency faces the choice to expand expensive fixed-route bus service, which has limited reach to the dispersed suburban population, or develop a cost-effective alternative transit system using breakthroughs in transportation technology.

Source: St. Lucie County Department of Communications

Traditional Suburban Transit's Barriers to Success

The effectiveness of fixed-route bus service is limited due several challenges in St. Lucie County, many of which are typical to suburban regions across the United States:

+ Geography: Bus stops on the County's main routes are spatially dispersed in suburban areas, and street layout and extreme hot weather are often not conducive to walking long distances to bus stops.

+ Agency Resources: The County is not in a financial position to introduce an extensive system of new routes that would bring nearby service to significantly more residents even though the County Commission is dedicated to broadening mobility services.

+ Economic Disadvantage: Near fifty-percent of the County's households are barely meeting their monthly survival budgets, financially limiting mobility choices available to them. Accordingly, much of the population is without adequate and reasonable transportation resources.

+ Demographics: Twenty-percent of the County's residents are 65 or older, compared to 13 percent for that age group nationally, placing increased demand on its public transit services, especially the traditional demand-response service.

+ TNC Competition: Like many areas of the U.S., Uber and Lyft have substantial operations in St. Lucie County, giving those riders with means another alternative to choosing transit and generating more automobile traffic on roadways that are already congested, while not being affordable for nearly half of the County's households.

Escalating roadway traffic congestion is a national problem. Since 1995, the national road system volume capacity has grown by approximately 17 percent, but vehicle miles traveled are increasing at double that rate. These same forces have taken hold in St. Lucie County, and owing to the County's brisk expected growth, it is anticipating a further increase in traffic congestion and its corresponding strain on our roads. Based on current development patterns, St. Lucie TPO forecasts that county road improvement costs will approach $2 billion over the next 20 years. Any reduction in vehicle miles traveled could therefore have a substantial fiscal benefit for local government.

EMERGING TRANSPORTATION TECHNOLOGY AS A SOLUTION

Innovations in transportation technology are empowering cities and transit agencies throughout the United States to begin exploring how new technological tools can provide cost-effective solutions to the nagging issues facing most suburban transit systems, many of which are described earlier. U.S. transit agencies, including Lynx serving the Orlando, Florida region and Capital Metropolitan Transportation Authority in Austin, Texas, have created pilot programs to investigate using real-time application-based trip reservation and vehicle routing rideshare systems on a limited scale. Many have dubbed these innovative pilots as "micro-transit" – a more flexible form of shared mobility that utilize dynamic routing and smaller vehicles to more closely match supply and demand.

St. Lucie County aims to put

Source: St. Lucie County Department of Communications

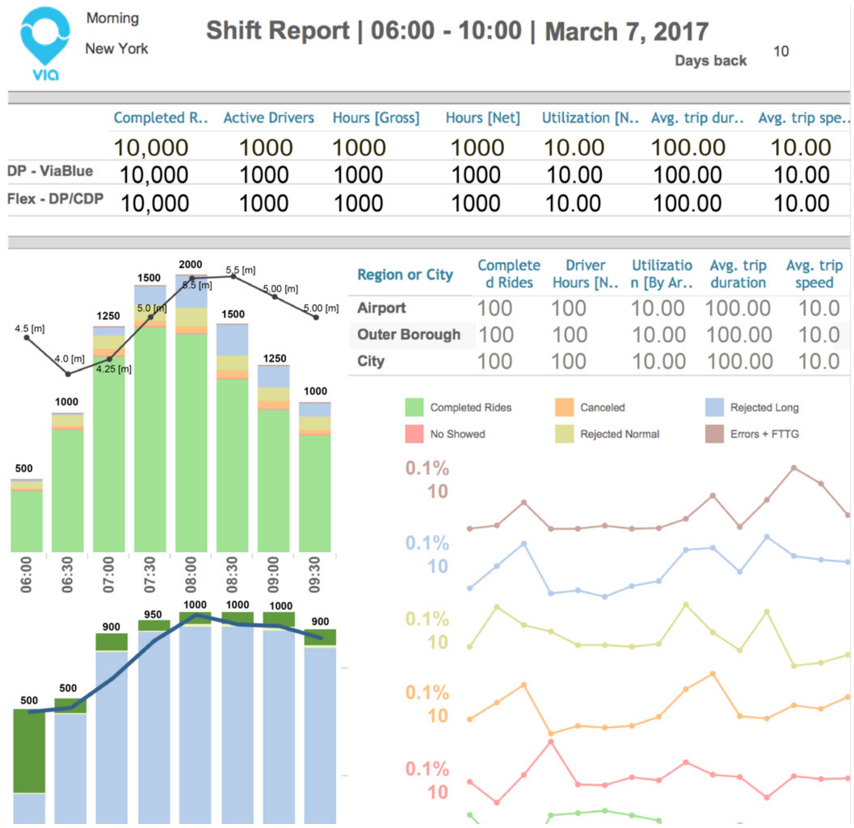
the same concepts to the test at a wider scale than has yet been attempted. The goal is to develop a real-time suburban microtransit service, working in conjunction with traditional fixed bus routes, that will efficiently deliver an affordable comprehensive public transportation solution that serves an entire suburban population. The proposed microtransit system will provide curb-to-curb local trips and feed passengers to a fixed-route bus stop or bus hub if a trip beyond the local service boundary is required.
St. Lucie County's objective is to create a technology-driven, demand-response, public transportation system that is completely integrated with transit fixed bus route service. It is the County's intention to develop a pilot program that can, if successful, be expanded throughout the entire region. The software that will be utilized will tolerate the complexity of a growing, diverse service area and have an intuitive learning ability to optimize vehicle routing and trip planning. As a result, this will promote sharing of vehicles and decrease the cost per trip, while accommodating a favorable rider experience.

St. Lucie County will create a fully-accessible, ADA-compliant service through a fleet of smaller cost-effective vehicles, such as minivans. Customers without smartphones and without access to the internet will be able to book rides by calling a county phone operator who in just a few clicks will be able to book rides on their behalf.

DECIDING AGAINST AN OUTSOURCED TNC MODEL

Recent studies, including an impact analysis prepared by the University of California at Davis (Research Report – UCD-ITS-RR-17-07, October, 2017), have found that TNCs do not provide a comprehensive solution to many of the transportation issues facing the nation's cities. For example, areas with established TNC services have exhibited a reduction in public transit ridership and an increase in automobile miles traveled whereby contributing, not reducing traffic congestion. Further, while TNC fares are less costly than conventional taxi services, most St. Lucie County households cannot afford TNC service as part of their regular mobility solutions. Lastly, due to the lack of predictability or control over the level of service or trip charges, private TNCs do not represent a sustainable, best practice solution for the public transportation challenges facing a suburban region.

POTENTIAL PAYOFF FOR PRACTICE



St. Lucie County identifies several potential payoffs for implementing the micro-transit innovation:

+ Increased System-Wide Utilization: The decision to choose transit often starts with the first (or last) mile. By more conveniently connecting suburban customers to the County's transit system, the County can increase the number of riders it brings into its fixed-route bus network.

+ Reduced Congestion & Road Impact: St. Lucie County and its roads are suffering from increased traffic congestion, and based on current development patterns, the County's improvement costs will approach $2 billion over the next 20 years. By bringing more customers into the transit system, and increasing vehicle utilization in suburban areas through shared modes like the one proposed, the County can reduce the strain on area roads.

+ Cost Savings: Due to lower density, the more suburban a county route is, the more inefficient it is, and therefore, the more expensive to operate. By improving the County's passenger miles traveled to vehicle miles travels ratio, the County can reduce the cost of delivering a ride, and preserve County resources.

+ Better ADA Service: By dispatching a fleet of wheelchair-accessible-vehicle-enabled connected with real-time booking technology, the County will provide riders of all physical abilities the power to book a ride in real time, eliminating the burdensome pre-booking requirement often required of demand-response rides.

+ Data Collection: By delivering service flexibly, the County will collect valuable data around demand patterns and origin/destination pairings that would be otherwise impossible to fully ascertain. The transit agency can use these data to instruct future service decisions in the County and share the data with other agencies that aspire to enact a similar service.

+ Best Practices: By operating this service day-to-day, and not simply outsourcing it to a TNC as has been done in other contexts, the transit agency can build up the County's ability to provide a range of service types beyond fixed route, and scale these learnings throughout the network and around the country.

TRANSFER TO PRACTICE

St. Lucie County has selected the Tradition master-planned community within the City of Port St. Lucie as the optimal host location for the initial pilot study. Tradition is one of the largest emerging development zones along Florida's Treasure Coast. The Tradition planned unit development (PUD), including the Southern Grove development area, will consist of over 25,000 housing units, 20 million square feet of retail, office, and R&D space, an 800-room hotel, a 200-bed hospital, and a 150-acre dedicated university site.

Tradition is currently experiencing rapid development around an existing population of approximately 15,000 residents. This includes a new Hilton Hotel property, a recently completed and occupied Kaiser University campus, a major state of the art healthcare center operated by Martin Memorial Health Systems, and various mixed-use, office, and retail establishments. The Tradition village square has become a major regional activity center and destination. Lastly, the Florida Department of Transportation has allocated $8.1 million to construct a major regional park and ride, and bus hub on the eastern side of the proposed service area, along Interstate Route 95, providing express bus service to West Palm Beach.

The Tradition area currently has limited public transit access with only one fixed-route bus stop located at the Landing shopping center on the easterly edge of the PUD. This bus stop is not reasonably accessible for the majority of residents and people visiting various locations throughout the Tradition "new town". The proposed technology-driven microtransit system will provide local trips within the Tradition area and provide feeder service to the fixed bus route.

PARTNERSHIP

To execute this study, St. Lucie County has teamed with the company it believes possesses the most powerful microtransit technology available to cities and transit agencies: Via Transportation, based in New York City.

Via provides an end-to-end system – including rider and driver apps, backend monitoring tools, and sophisticated analytics and reporting capabilities – that aggregates people traveling from multiple origins to multiple destinations in a highly efficient way, providing the convenience and flexibility of a custom ride at a much lower cost than conventional demand-response services. Their system optimizes the balance between maximizing vehicle utilization across an entire fleet, while providing each individual passenger with a high-quality experience. All service parameters are configurable.

Launched in 2013, Via created its service to help commuters reach work more conveniently at a transit-comparable price. Today, Via provides more than 1.5 million rides per month to over 850,000 members in New York City, Chicago, and Washington D.C. Via also licenses its suite of technology tools to public agencies and private transit operators, allowing them to deliver dynamic shared rides using their own vehicles, operators, and branding. By partnering with Via, St. Lucie County will create a custom-branded, localized service that can leverage their substantial experience to accomplish its goals.

CONCLUSION

St. Lucie County is currently securing funding to finance the Tradition micro-transit demonstration. The Florida Department of Transportation-approved Tentative Work Program establishes $300,000 in Service Development funding for the project. The County has recently applied for transit research funding through the National Academies of Science and Technology, Transportation Research Board to assist in the planning and start-up phases of the demonstration. St. Lucie County has secured wheelchair-accessible vans to service the initial phase of micro-transit service.

The micro-transit pilot program is designed to be operated for three years and, if successful, will be scaled up to include a wider geographic area including a major tourist and recreation attraction at nearby PGA Village, the New York Mets spring training center at First Data Field, and higher density residential and mixed-use developments in an area known as St. Lucie West. By the time St. Lucie County completes its major update to the regional Transit Development Plan around mid-2019, it is anticipated that the micro-transit demonstration will be generating important operational data which will be accounted for in the new St. Lucie transit master plan.

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GIS for Rail Transportation Asset Management

By Randall Rook

INTRODUCTION

Deployment of Geographic Information Systems (GIS) as a transportation asset management tool is not a new idea. GIS has been used by State DOTs since at least the 1990s and adoption by transit agencies and freight railroads has also been occurring in recent decades. While the focus here is on railroad and rail transit properties, the principles also apply to road, air, water, pipeline, bicycle and pedestrian modes.

The GIS application may be applied externally and internally, via public internet access or through credentialed intranet accounts. The building blocks of such systems include field capture and digitization of existing asset data, map creation and data integration, and web publishing of the final output, which enables non-GIS users to benefit from the system by providing search capabilities and graphic results. Brief asset snapshots may also be viewed with Google Earth-compatible KML or KMZ files which are exported from ESRI's ArcMap and contain GIS table records.

GIS-based rail transportation asset management has the ability to aid decision-making at all levels of an organization.

This location in Columbus, OH depicts assets for GIS capture, including track, signal appliances, signage and overhead bridge clearances (Source: author)

TYPES OF ASSETS AND ASSET CAPTURE

From a pure data inventory perspective, such systems can contain a wealth of information such as:

+ Milepost-based physical characteristics of rail lines (including track configurations, curvature, grades, timetable speeds, signal and buried cable locations and at-grade crossing warning device types). This might also include hyperlinks to cab-recorded video used in Train & Engine (T&E) crew training and contact information for the employee responsible for specific assets.

+ Rail line segment maintenance history, i.e., surfacing, rail grinding and tie replacement.

+ Yard, shop and industrial track diagrams indicating track lengths and key points for remote control operations Bridge and culvert locations, inspection records and maintenance history (with hyperlinks to drawings and photos). This might also include overhead bridge clearances, both vertical and horizontal.

+ Station information (including maintenance history, passenger and parking count, walkability scores, first mile / last mile connections, commercial activity, catchment area demographics and hyperlinks to the governing municipality's web site)

+ (Where electrified), age, wire parameters and maintenance history of overhead conductors and pertinent traction power-specific data (or third rail-specific data)

+ Valuation mapping and real estate transaction history T&E crew districts, operating patterns and labor productivity data

In addition to the enormity of field capture, one of the largest challenges for asset owners is merging data from disparate sources. For the information which is already in digital format, this is not a major hurdle. LIDAR can easily record the individual elements which comprise the physical plant in GPS coordinates. Present day maintenance and capital project information is often in digital format, aided by automated track geometry vehicle capture. Operations data such as train movements, tonnage and passenger counts (where fare instrumentation is electronic) may also easily be brought into GIS. The Class I freight carriers long ago made the transition from paper consist switch lists and bulletin orders and radio-based train orders to electronically transmitted data which may also be integrated with the GIS environment. Another operations component is satellite-based GPS for locating train movements in real-time.

What is more challenging is digitizing archives which exist in the form of paper, analog tape, microfilm and punch cards – in many cases some of these records may have decayed over time and the transfer process may cause further damage.

The dynamic nature of the rail industry, particularly in the freight market, makes ongoing maintenance of GIS data a critical task. Economics drives rapid changes such as traffic flows, line sales, abandonments or railbanking. This raises questions of what will happen to the GIS data when new shortline owners lack GIS capabilities, yet their property remains a valuable link to the national railroad network, or when railbanked lines lie dormant for an extended period.

TYPES OF USERS AND TYPICAL USES

While many users will only need data which is pertinent to their own department or discipline, GIS-based (Rail) Transportation Asset Management (TAM) prevents data silos by leveraging natural asset

This Northeast Corridor location in Newark, NJ depicts additional elements for GIS capture – electric traction systems (both overhead and third rail) and undergrade bridges (Source: author)

overlaps. Examples of typical users and their principal interests are below:

INTERNAL - WIDE ACCESS WITH DEPARTMENTAL LIMITS

+ Maintenance - local bridge and building staff may access inspection records and as-built drawings for ordering small part steel from a fabricator for minor repairs.
+ Engineering – design staff may access survey data, photos and, existing drawings as design aids.
Real estate – ability to view valuation maps, parcel and tax data.
+ Network planning and scheduling – analysis of operating performance and com-

modity flows for optimizing the rail network throughput.
+ Sales – marketing staff may access real estate and operations data when soliciting new business or coordinating existing shipper contracts or instructions.
+ Operations – train dispatchers, yardmasters and crew schedulers are able to better coordinate and schedule train movements with greater knowledge of system constraints and options.
+ Senior management – aid cost-benefit analysis and recommending capital planning decisions.

EXTERNAL - LIMITED WEB-BASED ACCESS

+ First responders – enables faster response with increased knowledge of locations with respect to public road networks.
+ Consulting planners and engineers – project-specific access to line segment data, operating patterns, inspection and real estate records and drawings.
+ Contractors – project-specific access to bid plans and key contact personnel.
+ Passengers – real-time train movement tracking and intermodal connection options.
+ Freight customers – real-time car tracing and availability.
+ Connecting carriers - real-time train movement tracking, delay data and detour options.
+ Governmental agencies such as NTSB and FRA – incident analysis.

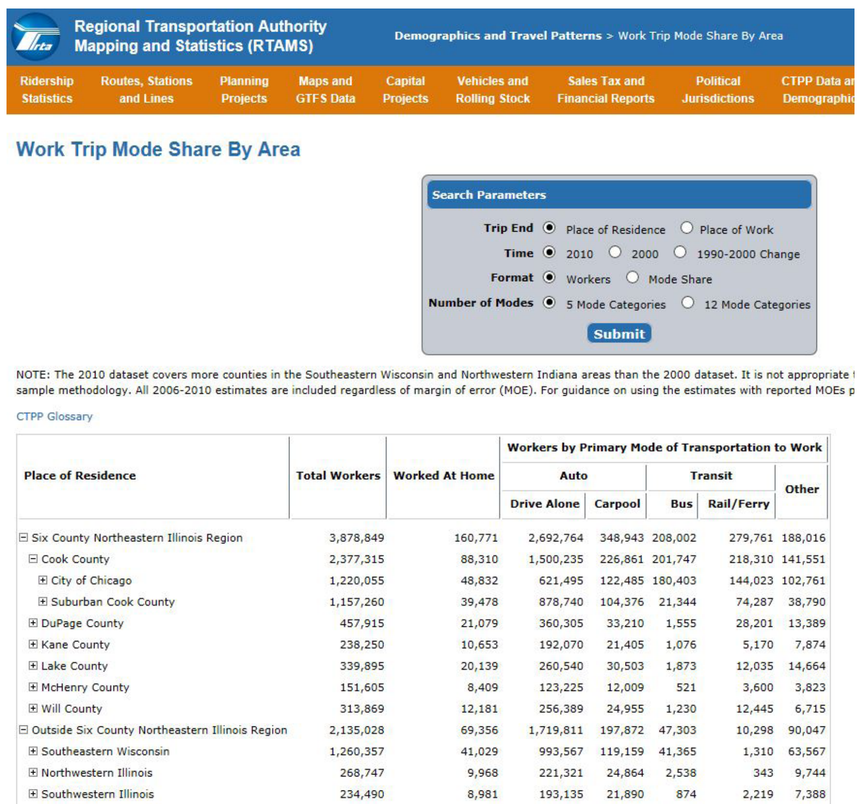
These two examples of the GIS usage were developed over ten years ago and represent external and internal applications.

RTAMS is a web-based data warehouse and mapping service developed by the Chicago area's Regional Transportation Authority (RTA) in conjunction with the University of Illinois. RTA is the umbrella agency for Northeastern Illinois' commuter rail, heavy rail rapid transit and bus services. The public-access web site also includes adjoining Northwest Indiana Transportation District's South Shore commuter rail service as well as the region's tollways. Interactive geographic datasets may be easily searched by asset topic such as route and station, ridership statistics, equipment, capital spending / planning, taxing data, land use and demographics.

Visit http://www.rtams.org/rtams/home.jsp for more information.

Turkish State Railways (TSR) developed its system largely for condition assessment, life cycle costing and incident investigation. TSR has divided the rail network by line segment and inventoried all components and operations data for maintenance, capital forecasting and spending, and operations planning. As a performance measurement tool, TSR analyzes the effects of assets and events on each other as an aid to decision making.

Screen capture of typical Metra commuter rail line data (Source: RTAMS)



Regional Transportation Authority Mapping and Statistics (RTAMS)

Demographics and Travel Patterns > Work Trip Mode Share By Area

Ridership Statistics | Routes, Stations and Lines | Planning Projects | Maps and GTFS Data | Capital Projects | Vehicles and Rolling Stock | Sales Tax and Financial Reports | Political Jurisdictions | CTPP Data ar Demographic

Work Trip Mode Share By Area

Search Parameters

Trip End: Place of Residence / Place of Work
Time: 2010 / 2000 / 1990-2000 Change
Format: Workers / Mode Share
Number of Modes: 5 Mode Categories / 12 Mode Categories

Submit

NOTE: The 2010 dataset covers more counties in the Southeastern Wisconsin and Northwestern Indiana areas than the 2000 dataset. It is not appropriate sample methodology. All 2006-2010 estimates are included regardless of margin of error (MOE). For guidance on using the estimates with reported MOEs p

CTPP Glossary

Place of Residence	Total Workers	Worked At Home	Workers by Primary Mode of Transportation to Work				
			Auto		Transit		Other
			Drive Alone	Carpool	Bus	Rail/Ferry	
Six County Northeastern Illinois Region	3,878,849	160,771	2,692,764	348,943	208,002	279,761	188,016
Cook County	2,377,315	88,310	1,500,235	226,861	201,747	218,310	141,551
City of Chicago	1,220,055	48,832	621,495	122,485	180,403	144,023	102,761
Suburban Cook County	1,157,260	39,478	878,740	104,376	21,344	74,287	38,790
DuPage County	457,915	21,079	360,305	33,210	1,555	28,201	13,389
Kane County	238,250	10,653	192,070	21,405	1,076	5,170	7,874
Lake County	339,895	20,139	260,540	30,503	1,873	12,035	14,664
McHenry County	151,605	8,409	123,225	12,009	521	3,600	3,823
Will County	313,869	12,181	256,389	24,955	1,230	12,445	6,715
Outside Six County Northeastern Illinois Region	2,135,028	69,356	1,719,811	197,872	47,303	10,298	90,047
Southeastern Wisconsin	1,260,357	41,029	993,567	119,159	41,365	1,310	63,567
Northwestern Illinois	268,747	9,968	221,321	24,864	2,538	343	9,744
Southwestern Illinois	234,490	8,981	193,135	21,890	874	2,219	7,388

Screen capture of typical Metra commuter rail line data (Source: RTAMS)

Suggested Reading for GIS-based Transportation Asset Management:

http://www.nctr.usf.edu/gis/archive/presentations/Regional%20Transportation%20Asset%20Management%20System.pdf

https://www.fig.net/resources/proceedings/fig_proceedings/athens/papers/ts20/TS20_3_Guler_et_al.pdf

http://www.esri.com/~/media/Files/Pdfs/library/newsletters/transportation-gis-trends/summer-2012.pdf#page=10

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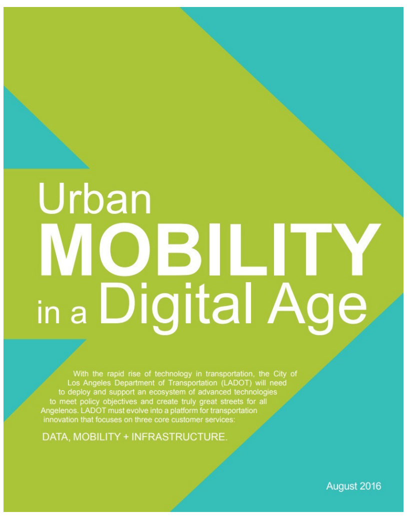
How LA is using Technology to Deliver Urban Mobility

By Karina Macias & David Somers



Source: Urban Mobility in a Digital Age website. http://www.urbanmobilityla.com/strategy/

On August 18, 2017 Mayor Eric Garcetti appointed the Los Angeles Department of Transportation's (LADOT) first Transportation Technology Strategist Fellow, Ashley Hand, to collaborate with LADOT General Manager Seleta Reynolds, LADOT staff, and then Chief Technology Officer Peter Marx to develop a strategy for Los Angeles. As its chief aim, the strategy was to inform how LADOT could help transform Los Angeles into a national model for sustainable, tech-enabled transportation. The result was "Urban Mobility in a Digital Age," or the City's Transportation Technology Strategy, which focuses on how LADOT can support rapidly emerging transportation technologies of shared mobility and autonomous vehicles (AV). The LA Transportation Technology Strategy recognizes that unprecedented transportation options could fundamentally alter the relationship between land use and transportation infrastructure and change how Angelenos travel in the future. The proliferation of AVs itself could yield both new challenges and opportunities. Vehicles that do not require a driver's attention to operate may eliminate barriers that make long distance drives alone unappealing today, which would substantially increase overall vehicle miles traveled (VMT) and hinder the region's climate action goals. Alternatively, local government can be proactive and develop the right balance of regulations and investments in anticipation of the introduction of AVs. In this context, AVs could encourage infill development by nearly eliminating the need for off-street parking, seamlessly connect people to transit and encourage ridesharing, and reduce injury from collisions on our streets, along with congestion, greenhouse gas emissions and household transportation expenses. With the right policy framework, city transportation officials from across the country see the advent of AVs as an opportunity to achieve desired transportation, safety and sustainability goals.[1] Los Angeles aims to realize the promise and minimize the risk of new transformative transportation technologies by promoting a culture of shared mobility through service delivery and regulation, while also adapting the digital and physical infrastructure to communicate with AVs in the future.[2]

There exists a broad gulf between today's conditions, where 68.5 percent of all Angelenos drive alone to work,[3] to a future where mobility is provided by a network of connected shared-ride AV technology. The LA Transportation Technology Strategy prescribes an incremental approach for LADOT to help realize the promise of urban mobility in the digital age. LADOT is preparing its staff and upgrading its systems to become more responsive as an agency by focusing on five core objectives:

+ build a solid data foundation,
+ leverage technology to design better transportation experiences,
+ create partnerships for more shared services,
establish feedback loops for services and infrastructure, and
+ prepare for an automated future.

An example application of these objectives: LADOT is analyzing emerging big data and engaging in data sharing partnerships to better evaluate its progress on policy objectives, such as increasing non-single occupancy vehicle (SOV) mode share by expanding access to transit through on demand micro-transit pilot programs. The greater reliance on micro-transit could instigate a feedback loop where greater utilization of these shared ride services could reduce the need for individually owned cars, and thereby the need to provide (as much) parking, further increasing the reliance on transit and shared-ride vehicles.

A little over a year has passed since LADOT released the transportation technology strategy, and LADOT is making important progress in laying the solid foundation of a digital age. With plans to foster mobility innovations that support more sustainable travel choices, the LADOT Planning and Policy Division will soon launch the VMT Calculator, a tool to measure the travel demands of new land use development projects as a means to track sustainable transportation outcomes as the city continues to build out. The VMT Calculator was funded as part of a $0.5 million grant from the State's Strategic Growth Council to help the City transition

[1]National Association of City Transportation Officials (NACTO). NACTO Policy Statement on Automated Vehicles. Published June 22, 2016. https://nacto.org/policy-2016/policy-statement-on-automated-vehicles/ - accessed on December 28, 2017

[2]Hand, Ashley Z. 2016. Urban Mobility in a Digital Age, a Transportation Technology Strategy for Los Angeles. Page iii

[3]United States Census Bureau."Summary File."2012-2016 American Community Survey 5-Year Estimates. U.S. Census Bureau's American Community Survey Office, Accessed December 28, 2017. https://www.census.gov/programs-surveys/acs/data/summary-file.2012.html

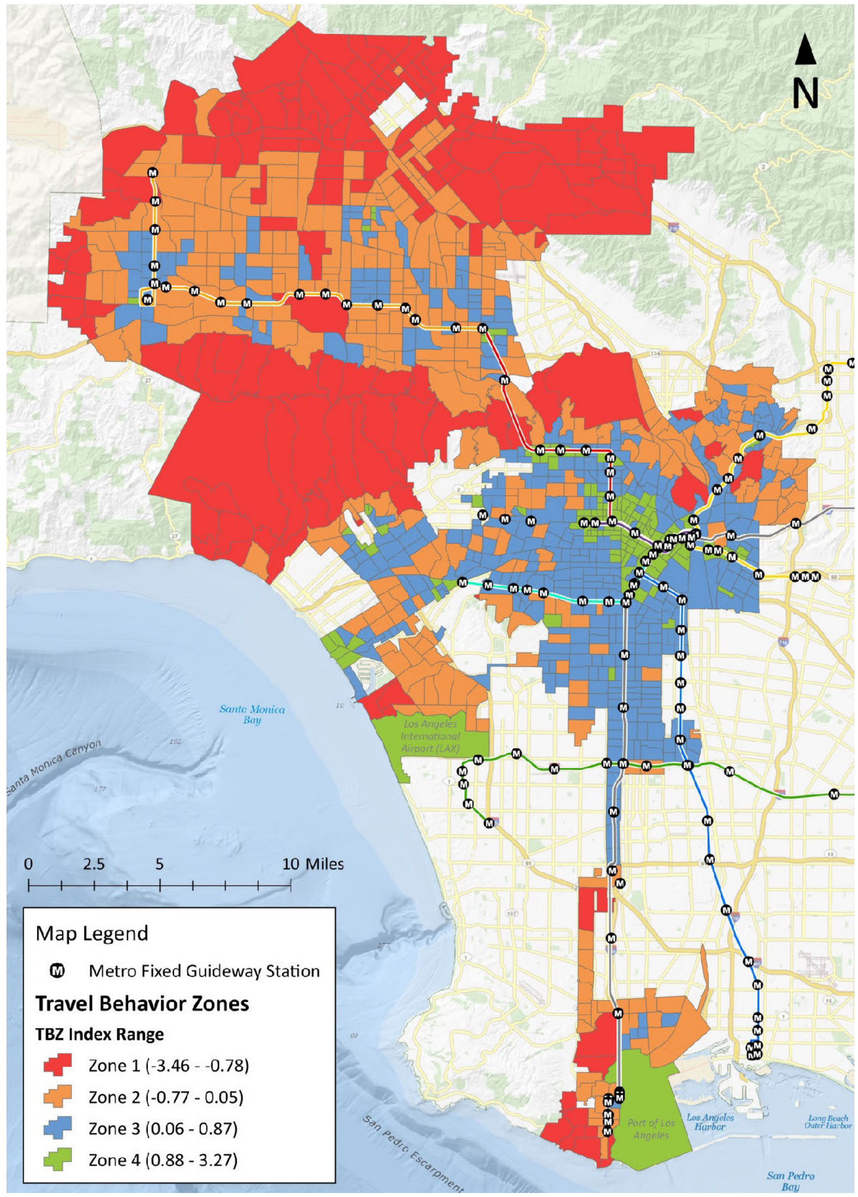
to measuring VMT per capita as recently required under the California Environmental Quality Act (CEQA) through the passage of Senate Bill (SB) 743. SB 743 requires lead agencies subject to CEQA to evaluate transportation impacts of land use and transportation projects based on VMT as opposed to the current approach of forecasting vehicular delay at major intersections that would result from a project build-out. Measuring a project's VMT accounts for the amount and driving distance of vehicle trips, better capturing the location efficient context of the development, how much the development reinforces other travel choices, or how it improves access to common destinations through proximity to transit, jobs and neighborhood services. Transitioning to measuring VMT as a metric also helps LADOT align with sustainability and climate action policies as captured in the City's circulation element, the Mobility Plan 2035, and the Mayor's Sustainable City Plan.

The VMT Calculator provides data as a service by informing city officials, community members, real estate developers and transportation planning consultants the most efficient locations in the city to support additional growth without excessive costs to the transportation system. For example, the VMT Calculator can identify employment areas where workers currently commute longer distances to their job, and where adding more jobs for the same income group would aggravate the city's work-related travel distances. Conversely, the VMT Calculator can identify residential areas that are in closer proximity to employment and other destinations, where adding more housing units would further support the city's VMT reduction goals.

The VMT Calculator is essentially a spreadsheet 'sketch model' with the building blocks of the VMT per capita calculation drawn from multiple data sources. VMT is a sum of estimated trips generated based on rates assigned to a given land use, or combination of land uses, the land use intensity, and the average travel distances in an area for specific travel purposes as forecasted by a regional travel demand forecasting model. Some have questioned the 'black box' nature of the estimating VMT during the legislative and rulemaking process to adopt VMT, asking how far the science has come in predicting travel behavior. Some neighborhood groups and transportation advocates have also long scrutinized the existing professional practice of estimating the travel demand of land use, assuming that traffic studies were either under- or overestimating how much people drive in Los Angeles. This scrutiny had some validity: most traffic studies apply the standard trip generation rates from the Institute of Transportation Engineers (ITE) Handbook, which are based on nation-wide samples across the country, and were gathered as far back as the earliest post-freeway suburban boom.

With the support of the Strategic Growth Council grant, the LADOT and the Los Angeles Department of City Planning (LADCP) worked with our consultants at Fehr and Peers to verify and adapt the most recent understanding of travel characteristics and land use. This localized understanding was needed considering that Los Angeles contains every development context in a modern North American city including quieter bedroom communities of the San Fernando Valley, relatively dense and job-rich coastal areas, and transit rich, dense urban centers of Koreatown and downtown Los Angeles. Figure 1 exhibits the four major Travel Behavior Zones in the city, which is how LADOT defines a given land use context by its corresponding influence on travel behavior.

To better estimate the trip



Source: LADOT

generation component of VMT, Fehr and Peers collected travel data from residential and office sites, and used these to verify updated trip generation rates from the Mixed-Use Development (MXD) Trip Generation model they developed[4] in

[4]Walters, J., B. Bochner, R. Ewing. Getting Trip Generation Right Eliminating the Bias Against Mixed Use Development. Planners Advisory Service, American Planning Association. May 2013.

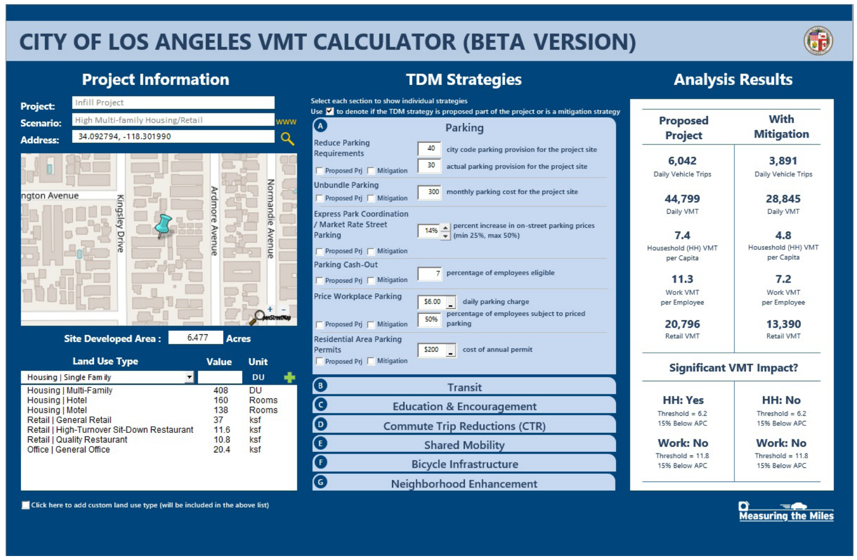
[5]Ewing, Reid, Michael Greenwald, Ming Zhang, Jerry Walters, Robert Cervero, Lawrence Frank, and John Thomas. 2011. "Traffic Generated by Mixed-Use Developments — Six-Region Study Using Consistent Built Environmental Measures." ASCE Journal of Urban Planning and Development 137(3): 248–61.

partnership with the US Environmental Protection Agency.[5] The MXD model accounts for built environment characteristics such as land use diversity, neighborhood density and design, access to transit, in addition to other neighborhood features. Since existing trip generation sources also do not consider how travel characteristics are influenced by household income, LADCP included in the scope to collect trip counts and parking utilization rates of 42 affordable housing projects in the City, as recent evidence from statewide household travel survey data demonstrated that driving rates can vary widely based on household income.

To better estimate the travel distance component of VMT, Fehr and Peers relied on 'big data' sources to update the City's travel demand forecasting (TDF) model so that travel behavior in the city can be predicted with unprecedented accuracy. The City's TDF model is based on a regional TDF model developed by the Southern California Association of Governments. This is a traditional '4-step' TDF model that predicts regional travel distribution across the street network based on regional population and jobs forecasts. To improve the model's predictive accuracy, Fehr and Peers relied on empirical travel behavior information from aggregate cell phone and GPS data purchased from StreetLight Data to calibrate how trips were distributed through the City between the origin and destinations of housing and employment centers. They also accessed General Transit Feed Specification (GTFS) data for the regional transit network from the County transit providers. The TDF model estimates were then validated by tapping into the loop detectors embedded in the roadway, which are used to control traffic signals and provide the network performance of city streets. Average trip lengths were estimated at the level of transportation analysis zones (TAZs), the basic unit of geography of the TDF model, and imported into the VMT Calculator, shown as a screenshot in Figure 2, to estimate VMT of a project in any selected area of the City.

The resulting VMT of a project is divided by the total population or employees estimated to occupy the property and compared to a VMT per capita performance benchmark for that geography. The benchmark threshold values vary by seven Area Planning Commission boundaries so to not over-penalize projects based on their geographic context, but to still advance incentives to improve

VMT performance. If a given project were to exceed the VMT benchmark for a given area, the VMT Calculator includes a list or transportation demand management strategies that would offer incentives to future site occupants to take other travel options than to drive alone. Example measures include providing discounted group-rate transit passes to all site occupants as a part of their lease, options to purchase or lease space without assigned parking on the property, and other promotional programs to participate in ridesharing or transit services. The VMT Calculator assigns reduction values for each strategy based on available evidence, helping practitioners to reduce project-related VMT and proceed with their entitlement or permit requests without more extensive environmental review.



Source: LADOT

The VMT Calculator is prerequisite step in upgrading the Los Angeles's digital infrastructure software that enables planners to advance mobility solutions that support non-SOV travel. As part of the review process, LADOT will require developers to commit to monitoring and reporting the occupant's travel behavior to better calibrate the VMT reduction benefits over time. The monitoring procedures create an opportunity for LADOT to further experiment with new mobility strategies and test their performance, helping to further innovations that may lead to even better outcomes. For example, TDM strategies tend to work best close to transit services, so developers building in areas further from transit may need to work harder to reduce their project's VMT. LADOT could partner with developers, Metro and transportation network companies to make available rideshare vouchers that drop people off at a transit station helping to solve the first-last-mile challenge. Advancing innovative solutions are often a chicken-and-egg scenario if there is little evidence on which to base the benefit or nexus. However, a commitment to data collection and monitoring would inform the VMT reduction value assigned to a strategy and formalize it as an option in the VMT Calculator. In this way, LADOT has begun to lay the data foundation and incentives that can help begin to realize the promise of a digital age.

Karina Macias is a transportation planner in LADOT's Transportation Planning and Policy Section. She develops strategic transportation planning initiatives, data-driven analysis methods, and effectuates sustainable transportation policies. Previously, Karina has managed the LADOT People St program, educated and engaged Angelenos on active transportation infrastructure, and conducted network analyses to study connectivity. Karina earned a bachelor's degree in urban studies from the University of California, Berkeley and a master's degree in urban and regional transportation planning from the California Polytechnic University, Pomona.
Karina Macias, LADOT, Transportation Planning and Policy Division, karina.macias@lacity.org
David Somers is a transportation planner with LADOT's Transportation Planning and Policy Section. As a part of this work, David is leading efforts to adopt sustainable transportation metrics that informs how the City reviews land use and transportation projects that incentivize reliance on transit and active transportation in Los Angeles. David also helped re-write the rules to guide public right-of-way improvements, and helped develop the Mayor's Great Streets Challenge program, a participant-driven program that empowers the public to redesign their streets in the vision of complete streets.
Transportation Planning and Policy Division, david.somers@lacity.org

Using Gamification to Provide Transport Behavior Incentives

By Scott O. Kuznicki, P.E.

INTRODUCTION

Imagine you've been asked to sort a stack of paper forms. As you wade through the dozens of variously-colored sheets, your mind wanders. Boredom sets in. Eventually, you just can't handle it any longer and so you grab your mobile phone and start playing Candy Crush.

Then it hits you: Isn't this the same thing as sorting a stack of papers? It's simply moving them around so they are all next to each other! Turning this process into a game with animation, ease of use, and immediate rewards transformed the mundane experience into something exciting, engaging, and, certainly, far more desirable.

Population growth and the growth of urban megacenters have placed enormous burdens on transportation infrastructure, particularly the freeway systems that function as the backbone of the transportation networks in many cities around the globe. Transportation planners have sought to mitigate the congestion on freeways by providing options such as transit and carpooling, limiting the supply of parking leading to increased cost, and increasing the price of using the freeway through various taxes, fees, and tolls. Some transport agencies work to reduce peak-period commute trips through various programs that provide for flexible employee schedules and work locations. While none of these actions address a structural deficit in capacity that exists, they are widely seen as partial mitigation to the problem of congestion, often by providing options that did not previously exist.

These actions encourage a change in mode, route, and/or time of travel. In general, they act on users' perception of known costs. Users recognize that they will save money on fuel and parking by choosing a different mode or working from home. They see that they will save time by traveling earlier or later. In cities with reliable and frequent public transit, workers find intangible benefits, as well, such as working or relaxing en route. What these forces often do not accomplish, however, is helping users understand all of the hidden costs associated with various choices. Furthermore, the result of each individual vector, that is encouragement or force to shift behavior in a particular direction, is limited by price elasticity, user preferences, and other factors. In fact, vectors can often cancel a user trend in any given direction.

Exploring the intercept of transportation system performance and the human desire for social interaction and competition led Transpo Group to recommend a "gamification approach" for improving transport system performance to a large transport authority in the Middle East. Our approach came about not after sorting papers, but in recognition the region's high data-connected mobile cellular device penetration. Using this asset to drive behavior would capitalize on a distributed non-infrastructure solution that was already accepted in the region for the purposes of transport information, navigation, fare payment, and even fines and fee management and payment.

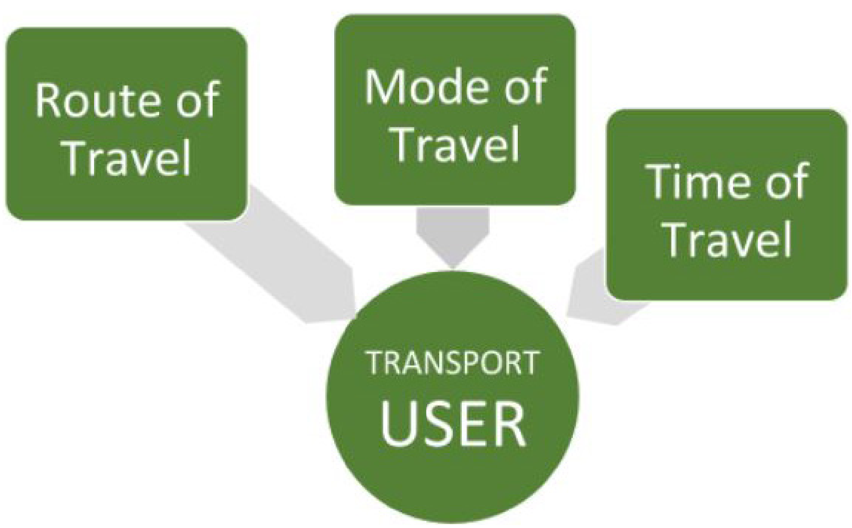


Figure 2. Gamification can be used to enhance a particular vector and drive user choice. It can reduce the effect of other vectors that are likely to have undesirable outcomes if not managed, such as a shift to a routing with limited capacity and greater propensity for social impacts. (Transpo Group, 2017)

GAMIFICATION

Gamification of regular tasks can be an innovative approach to influence human behavior and encourage compliance with rules and improve efficiency. Providing aspects of a typical mobile device gaming environment such as goals, incentive, animation, and reward can motivate people, increase brand and product loyalty, and bring a sense of accomplishment.

The purpose of gamification in the transport environment is to help users recognize and act on costs that they do not typically consider in making a transportation choice. It also provides the ability for users to accrue rewards that provide incentives for considering future travel choices. Costs that are not typically considered or directly known include point-source carbon emissions, impacts to other users and network performance, personal and public health, impacts to maintenance and operations, and even the user's own emissions profile. Avoiding stop-and-go traffic on a motorway, for example, and using an arterial roadway with a coordinated traffic signal system and a more constant travel speed may result in marginally-improved fuel economy but much less in the way of emissions.

In our research with leading global consultants on gamification, transport demand management, and human factors in user behavior, we determined that gamification has not been deployed on a network-level scale to address user choices in transport. We believe there is a high degree of applicability and, more importantly, we see gamification's key role in providing another means of vectoring user behavior. The gamification platform can amplify incentives for mode choice, for example, to overcome other influences that cannot be altered without dramatic and undesirable social and economic impacts.

SYSTEM DESIGN AND USER INTERFACE

The architecture of the system envisions integration with all transport agency data collection and dissemination functions, including ties with major navigation service providers. The core of the system is a deep learning platform that can accommodate millions of users, collecting data from the transport system monitoring and control functions in addition to collecting data from users themselves. This deep learning system relies on a massive data collection to understand system performance on how various choices can be manipulated to achieve certain outcomes; in this case, the likelihood of altered choices is also learned by the system based on user behavior and various feedback mechanisms. The primary interface for the public is the mobile application, which will provide security and authentication for each user. The mobile application will allow users to view commute choices and choose their route based on time of travel, cost of travel (including external costs previously not easily known), and earn points for various choices.

The application will provide contests and campaigns that are aimed at various commuters, based on usage statistics and transport system per-

formance needs. Complex games will be avoided, as will game interface during vehicle operation. The points users earn will be credited to a user account and may redeemed for tokens, social media engagement opportunities, and products and services provided by the transport agency or other government agencies.
The app will be similar in appearance to and likely integrate with many major navigation apps available today. Branding and packaging would be done in a fashion that engages people from a wide variety of cultural, economic, and social backgrounds. The experience will be customized to users who meet specific profiles, at the users' choice, in order to best serve users with a values system that appeal to their specific desires and likely patterns of behavior.

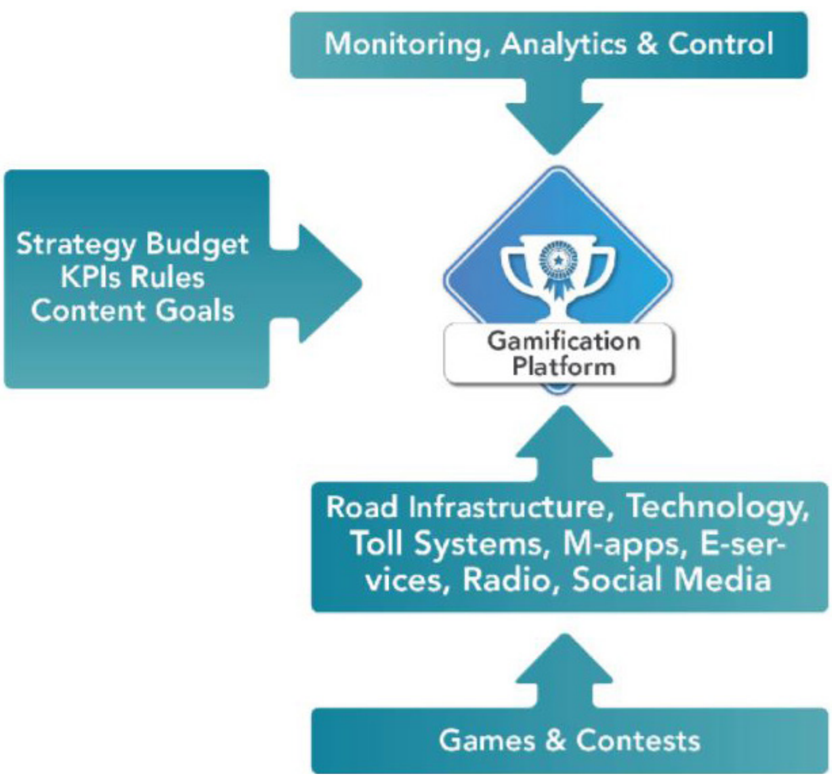


Figure 3. The gamification platform is complex but the user interface is one single app. A systems engineering process is essential for constructing a platform management architecture that ensures data inputs are managed at the appropriate level and key performance indicators (KPI's) are appropriately selected and aggregated. (Transpo Group, 2017)

Any applications, games, competitions or campaigns put in place as part of the gamification scheme must be kept current and novel. Goals and rewards should be relatively easy to achieve in order to trigger more interest and use. Users will complete the end goal or status level of a game or an application relatively quickly and be prepared for new games and rewards. The introduction of continuous new gamification strategies and applications is important to maintain the momentum and a very high level of engagement.

USER ENGAGEMENT

Two kinds of user engagement are envisioned. The "spot" user engagement is what occurs as the user chooses to use the app and relies on it for directions, feedback, and motivation. The long-term user engagement is the overall system of incentives that retain user interest and encourage complete saturation of the user's trip planning and execution efforts.

No technique or system deployment will allow or instruct the driver to look at or use the mobile devices gamification functions while driving. In fact, it is even possible to deny rewards to game users who pick up the mobile device while operating a vehicle. Visual cues can easily be replaced with auditory cues and even in-vehicle telematics integration with heads-up displays and other vehicle communications systems.

USER REWARD AND SOCIAL INTERACTION

Agencies need a fourth vector that can act on incentives for mode, route, and time choices. Active engagement with inverse pricing by means of the point system is the key vector that can drive choices where elasticity of price is insufficient. Because the users earn more points for more positive behaviors that best assure the public good, personalized interaction will deliver innovative and exciting rewards.
For example, in some urbanized areas, travel is restricted based on cordon zones or license plate number schemes. However, users who forego their assigned travel days could store up points and use those to buy into the system for personal automobile travel on another day when a penalty would be assessed, ensuring access to medical care or other appointments that cannot be kept with transit. Users will receive a personalized service that is tailored to their preferences, travel choices, and travel patterns.

The gamification platform is a tool for exponential leverage of the existing means of achieving desired user behavior. For example, if users receive points for choosing an alternate route but too many users begin to choose that route, it might affect toll revenue on the favored motorway. Lowering the incentive value (the points offered) may drive traffic back to the motorway, in particular, traffic that is willing to accept the price of travel on the corridor. The use of these multi-source incentive vectors allows for much greater influence over user behavior and enables fine-tuning of available incentives and disincentives to increase revenues and further optimize the use of transportation network.

The social media revolution has made competition with friends and society extremely compelling to users of various online games. Beyond travel choices, using social movements and even social stigma can be an effective means of changing behavior, including driving behaviors such

.."The gamification platform is a tool for exponential leverage of the existing means of achieving desired user behavior"

Figure 4. Three main outcomes of gamification are integrated as goals of the gamification platform. In fact, the outcome of social participation is often seen as a driver for social behavior. For example, campaigns intended to address impaired driving often rely on social stigma generated from social participation in group activities. (Transpo Group, 2018)

as following too closely and lane discipline. Additionally, user behavior such as alcohol abuse coupled with driving has been altered significantly where traffic safety campaigns have included a social stigma element. The power of social media engagement and user behavior is a key component of the gamification of transport choices.

AGENCY CONSIDERATIONS

For the agency implementing the gamification system, a change in organizational mindset will often be necessary. Communications integration both inside and outside of the agency requires new ways of approaching data security, access, and licensing. Integration with the agency's enterprise command and control center or similar traffic management and operations facility is essential, if only to ensure that enterprise transportation management is availed of all applicable data. Data feed to other providers can also provide the impetus for the development of apps entirely around the gamification platform. Additionally, user sentiment and behavior can only be understood with a high degree of certainty when there is user trust. This points to the key consideration of user data security and total protection of user information on route choice and travel patterns, in addition to a robust protection against GNSS "spoofing" and other compromise vectors. Users will also want to be able to liberate their data and, if they choose, provide that data to other providers in exchange for payment and/or services. The budget impact of implementing this system can be recovered with advertising, transit farebox recovery rate increases, and the offset of new infrastructure improvements. Because it generates the most efficient use of the infrastructure and builds support for increased funding, the optimization of user experience and infrastructure investment promise to lower the overall societal cost of providing transport.

The current models of travel demand management have failed to adequately inform users of the real-time external and unknown costs of transport-related decisions. Primarily, using user avoidance of these costs to structure a reward system provides for positive reinforcement and flexibility in allowing the transport user to decide based on information that can be readily understood by means of the value assigned by points. Heavy-handed restrictions, onerous pricing schemes, and deliberate capacity restriction frustrate users and lead to dissent concerning the funding of transport improvements, particularly for competing modes. Building user appreciation and excitement, on the other hand, by rewarding socially-responsible transport use with gamification systems, promises true transportation choices and incentives for the choices that benefit the overall system in any situation.

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Figure 5, Sample of how various rotes and mode choices result in points earnings in a given game campaign. (Transpo Group, 2018)

Transportation Energy beyond Biofuels: Using Low Carbon Fuels

By Kimberly Burton, P.E., AICP CTP, LEED AP ND

TRANSPORTATION ENERGY OVERVIEW

The world's energy use is primarily fueled by fossil fuels, and the transportation sector has been almost exclusively reliant on one of these fuels – petroleum, currently at 92 percent (see Figure 1).

Although other fuel sources for the transportation sector are growing, this trend is projected to continue. This heavy reliance on and usage of fossil fuels contribute to environmental damage, including climate change, air pollution, and extraction impacts; supply limitations of nonrenewable supplies causing price fluctuations; and security and dependability concerns related to nondomestic supply sources. To address the transportation energy-related issues, solutions can be grouped into three main categories:

+ Improve vehicle energy intensity
+ Use low-carbon fuels
+ Reduce vehicle miles traveled

An overview of these three categories was introduced in the 2013 State of Transportation Planning in the Transportation Energy Chapter, and the first category - improving vehicle energy intensity – was explored more in depth in the 2016 edition. Now this chapter will focus in detail on how to address the second category: using low-carbon fuels.

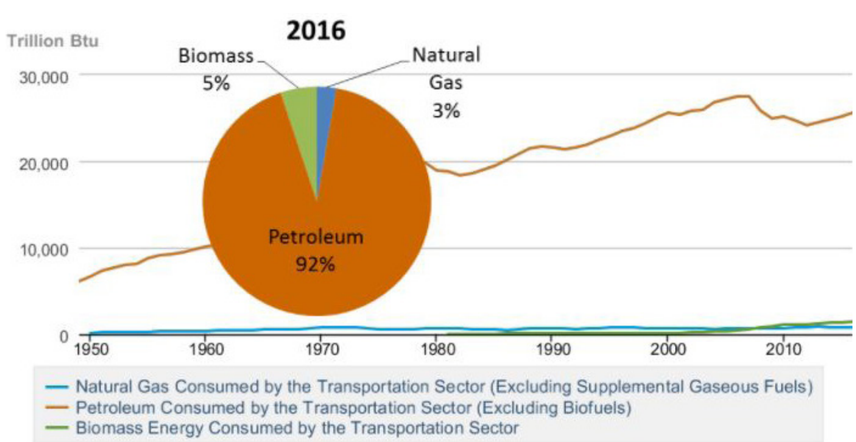


Figure 1: Transportation Sector Energy Consumption, 1980-2016
Source: U.S. Energy Information Administration, Monthly Energy Review, November 2017

LOW-CARBON FUEL OPTIONS

Since the 1974 oil embargo, there have been conversations about switching the U.S. transportation fuel supply to low-carbon, domestically-produced fuel sources, but there has been relatively little progress because petroleum prices have remained low and there is little support to change the oil industry. However, as environmental issues increase, and the limitations of nonrenewable energy supplies become more of a factor, development of new and better technologies to produce low-carbon fuels are becoming more prevalent. The low-carbon fuel options discussed below are linked to the efficient vehicle technologies that were detailed in the 2016 edition of the State of Transportation Planning, such as flex-fuel vehicles using ethanol or biodiesel, hybrid vehicles using electric-charged battery engines, and fuel cell vehicles using hydrogen sources. The main low-carbon fuel options for transportation are grouped into the following types:

+ Electricity
+ Liquid biofuels
+ Natural gas fuels
+ Hydrogen

Electricity is used to power electric vehicles, including Plug-In Hybrid Electric Vehicles (PHEVs), Battery Electric Vehicles (BEVs), and Fuel Cell Electric Vehicles (FCEVs) but currently is not widely used. Electricity can be generated from the grid or other direct types of sources. The energy source from plugging in to the grid for electricity can vary, from coal-fired power plants to more sustainable options like hydropower and wind, but 65 percent of grid electricity sources are current fossil fuels (see Figure 2).

Another option to the grid is to use localized, site-specific renewable energy sources, such as on-site solar panels, if available. Recharging electric-powered vehicles can be a challenge, but new technologies are currently under development to shorten the charging time and lengthen the battery life in between charges.

Liquid biofuels are a type of

Vehicle Charging Station. Photo by Kimberly Burton, 2017.

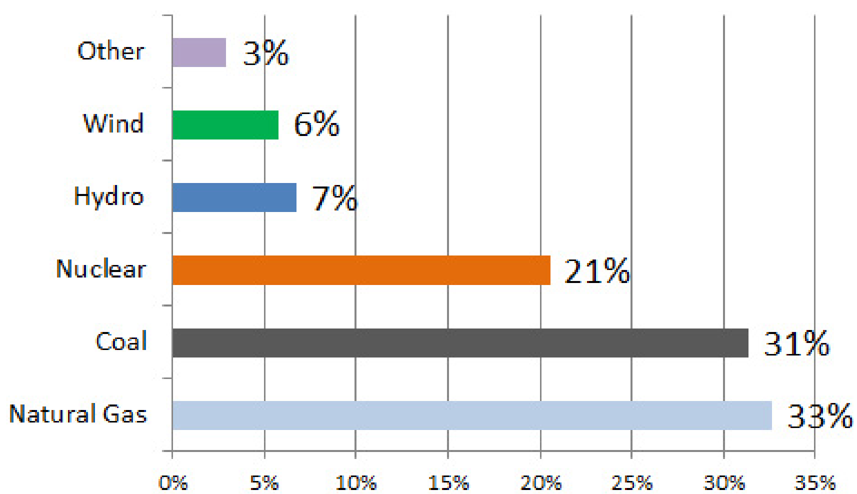


Figure 2: Electricity Net Generation, Major Sources 2016
Source: U.S. Energy Information Administration, Monthly Energy Review, November 2017

biomass energy. Biomass is vegetative and animal organic matter that can be converted into energy. Biofuels can be produced domestically and have lower net greenhouse gas emissions than petroleum-based fuels. The main two types of liquid biofuels are ethanol and biodiesel, which can be partially or fully substituted for gasoline and diesel fuels. Ethanol is typically made from corn or sugarcane. Fuel blends up to 10 percent ethanol and 90 percent petroleum gasoline can be used in most regular internal combustion engines. For higher blends, flex-fuel vehicles are needed. The main ethanol fuel type for flex-fuel vehicles is E85, which is an 85 percent ethanol and 15 percent gasoline blend (at least 15 percent petroleum is needed to prevent the fuel from freezing in cold weather conditions). Vehicles using E85 get between 5 to 12 percent fewer miles per gallon than with gasoline (E4S pg 340, Randolph, John & Gilbert Masters, Energy for Sustainability: Technology, Planning, Policy, Island Press, 2008.). Biodiesel is made from plant oils, such as soybeans, rapeseed, algae, and waste vegetable oil. It can be blended with petroleum diesel ranging from 2 to 100 percent. Biodiesel blends up to 20 percent can be used in regular diesel engines with little to no modifications.

Natural gas fuels include liquefied natural gas (LNG) and compressed natural gas (CNG). These fuels have much lower urban air pollutant emissions than petroleum gasoline or diesel vehicles and can be produced from domestic natural gas sources. They are primarily used to fuel buses and other large vehicles in metro areas not meeting National Ambient Air Quality Standards (NAAQS). CNG is produced by compressing natural gas to less than 1 percent of its volume at standard atmospheric pressure; and LNG is produced by super-cooling natural gas to -260 degrees Fahrenheit to turn it into a liquid (U.S. DOE, Alternative Fuels Data Center, 2017, https://www.afdc.energy.gov/fuels/natural_gas_basics.html).

Hydrogen is used for fuel cells. Fuel cell vehicles convert hydrogen fuel to electricity with zero emissions. Most of the hydrogen is currently produced from natural gas. For this fuel source to become more widely-used, several difficulties need to be addressed, including developing an inexpensive, small, lightweight fuel cell; producing enough of the hydrogen fuel; improving hydrogen storage methods; and having the available infrastructure to deliver the fuel.

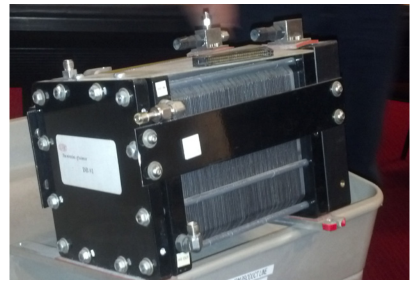
CURRENT TRENDS

Although petroleum-based gasoline and diesel fuels will continue to dominate the consumption trends in the transportation sector into the near future, the use of low-carbon fuels is expected to continue increasing.

Electricity: There are currently 16,533 electric vehicle charging stations throughout the U.S. (U.S. Department of Energy, Alternative Fuels Data Center, Alternative Fueling Station Locator, 2017, https://www.afdc.energy.gov/locator/stations/), but because electricity for vehicle charging is not solely provided at these charging stations (i.e. people can charge their electric vehicles at home), tracking trends on the usage of electricity to fuel vehicles is best connected to the number of electric vehicles in use. According to the International Energy Agency, the U.S. had approximately 0.6 million electric vehicles in 2016, ranking second in the world behind China, but the U.S. electric car stock is currently only 0.91 percent of the total number of passenger light-duty vehicles in use today. So the use of electric vehicles – and electricity as their fuel source – still has a long way to go before attaining a substantial portion of the vehicles in use. Current assessments indicate that the global number of electric vehicles will increase from 2 million in 2016 to 9 - 20 million (350 – 1800 percent increase) by 2020 and 40 - 70 million (800 – 3300 percent increase) by 2025. (OECD/IEA, Global EV Outlook 2017, IEA Publishing. www.iea.org/t&c).

Liquid biofuels: Both fuel ethanol and biodiesel have seen large increases in consumption over the past several decades (Figure 3). The amount of fuel ethanol added to petroleum gasoline went from 1.4 billion gallons in 1995 to 14.4 billion gallons in 2016; biodiesel increased from 10 million gallons in 2001 to 2.1 billion gallons in 2016 (U.S. Energy Information Administration, 2017, https://www.eia.gov/Energyexplained/?page=us_energy_transportation). In addition, there are currently 3,020 E85 ethanol stations and 199 biodiesel stations located throughout the U.S. (U.S. Department of Energy, Alternative Fuels Data Center, Alternative Fueling Station Locator, 2017, https://www.afdc.energy.gov/locator/stations/). Randolph, John & Gilbert Masters, Energy for Sustainability: Technology, Planning, Policy, Island Press, 2008.

Natural gas fuels: Natural gas fuels have typically been used to power high-mileage,



Fuel Cell. Photo by Kimberly Burton, 2014.

centrally-fueled fleet vehicles, like public transit buses. This type of use of natural gas fuels is expected to continue into the near future – as of 2016 only 0.15 percent of natural gas consumption is used for transportation fuel, but it has doubled since 2004, showing steady increases annually (U.S. EIA, Natural Gas Consumption by End Use, October 2017). In addition, there are currently 941 CNG stations and 76 LNG stations located throughout the U.S. (U.S. Department of Energy, Alternative Fuels Data Center, Alternative Fueling Station Locator, 2017, https://www.afdc.energy.gov/locator/stations/).

Hydrogen: There are currently only 39 hydrogen stations located in the U.S., excluding private stations (U.S. Department of Energy, Alternative Fuels Data Center, Alternative Fueling Station Locator, 2017, https://www.afdc.energy.gov/locator/stations/), which remains a key challenge to the widespread use of this fuel. A public-private initiative, called H2USA, was launched in 2013 by the U.S. DOE to promote the further expansion of hydrogen infrastructure. There are a limited number of fuel cell vehicles in use today, although a variety of motorized vehicle types have been researched for the incorporation of fuel cell technologies, from cars to buses, boats, motorcycles, and even bicycles. So the use of hydrogen as a vehicle fuel is expected to remain minimal into the near future.

Emerging Fuel Technologies: Research and development of emerging alternative fuel technologies may add to the low-carbon fuel options in the future. These options include biobutanol (produced from biomass), dimethyl ether (produced from biomass or natural gas), methanol (produced from natural gas), renewable hydrocarbon biofuels (produced from biomass), and anhydrous ammonia (produced from natural gas).

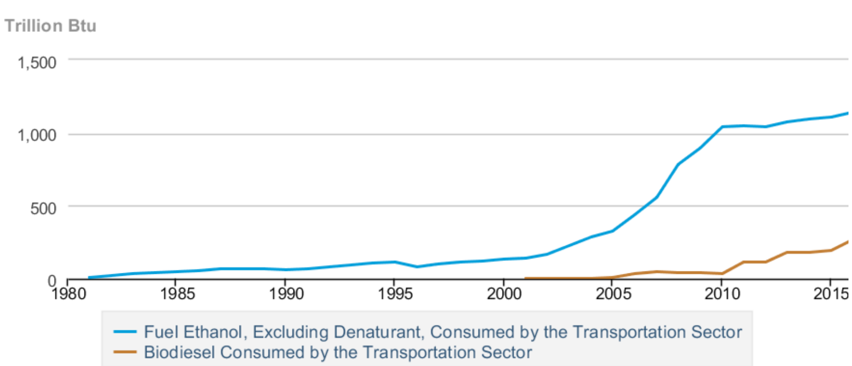


Figure 3: Fuel Ethanol & Biodiesel Consumption Trends, 1980-2016
Source: U.S. Energy Information Administration, Monthly Energy Review, November 2017

CHALLENGES & OPPORTUNITIES

If the use of low-carbon fuels is to substantially increase, there are several key challenges and issues that need to be addressed, including:

Policy Changes

Air Pollution
Food vs. Fuel
Research Development
Infrastructure
Oil Industry Investments

Policy Changes: Policy changes at the federal and state levels can increase the use of low-carbon fuels, including adding biofuel blending mandates; introducing low greenhouse gas fuel standards; adding a carbon tax to fuels; and incentivizing incorporation of low-carbon fuels in vehicle fleets.

Air Pollution: Although the low-carbon fuels described above would all result in reduced carbon emissions, air pollution is still a concern. The liquid biofuels and natural gas fuels still involve combustion and therefore some carbon emissions, and the source of electricity could be from a grid system run off of coal-fired power plants.

Food vs. Fuel: Liquid biofuels currently represent a large share of the low-carbon fuels market; however, many of the biofuel sources are currently food products, such as corn and sugarcane. Tying food to fuel can cause supply shortages of food and increase the cost of food, resulting in increased instances of starvation and poverty worldwide. Focusing liquid biofuel sources on non-food products (such as food wastes or cellulosic materials) would address this issue.

Research Development: The low-carbon fuels described above, including the emerging options, are quite varied; however, additional research is needed to further develop these technologies to make them more effective before they can be viable, marketable options, including researching source options and conversion technologies to improve efficiencies, standards, and costs of production.

Infrastructure: The infrastructure for low-carbon fuels is developing around the U.S. but needs to be much more widespread and easily accessible for all of these fuels before there is mass adoption.

Oil Industry Investments: Instead of pursuing low-carbon fuel options, most oil companies are focusing their investments on developing high-carbon unconventional fossil fuels. These fuels require more energy and are more costly to extract and process, resulting in higher environmental damage. Additionally, they are still nonrenewable, and many sources are not domestic, such as the tar sands in Canada, very heavy oil in Venezuela, and oil shale in the

United States.

NEXT STEPS IN USING LOW-CARBON FUELS

Using low-carbon fuels is one of the three categories of solutions that need to be addressed in order to transition the transportation sector off of its reliance on fossil fuels and onto more sustainable energy patterns. The use of low-carbon fuels is influenced by technology, infrastructure, available fuel alternatives, policies, and consumer choice, so solutions include:

Reducing/eliminating the use of nonrenewable fossil fuels to power vehicles
Charging plug-in vehicles with renewable energy sources
Developing liquid biofuels from non-food sources
Implementing more programs, grants, and policies that support research of low-carbon fuels and encourage the use of low-carbon fuels.

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London's Undocumented New Technology-enabled Mobility Solutions

By David Carrignon

SUMMARY

Londoners are using new technologies to solve their day to day mobility problems, but without being completely sure if it is legal. The lack of legal status and the spontaneous emergence of new solutions by the private sector means they are not being discussed in the official documentation. In the past, structured advocacy groups lobbied to promote new transport modes, but mobility as a service is not a transport mode. New regulations have been put in place to re-direct the UK infrastructure investment policy, but low-cost solutions have not been captured. It makes decades the transport planning profession wonders how to reduce traffic volumes while still enjoying economic and population growth, now we might have it, the authorities should react positively.

Imagine a world where transport planning documents would fail to mention automobile mobility. Well, despite being all around us, some modes of transport and mobility solutions are nowhere to be seen in the official documentation today. Ride-sharing apps, electric bicycles and other increasingly popular mobility solutions are not being captured in the transport planning documentation.


Figure 1

LONDON'S FOREVER STRETCHED TRANSPORT INFRASTRUCTURE

Back in 2001, Ken Livingstone, the newly elected first Mayor for Greater London presented the city's transport system as follows:

"As a great world city in the global economy, London has seen two decades of rising population and a decade of expanding economic growth and employment. However, growth has not been matched by the investment necessary to provide the public transport, affordable housing and public services that are essential for

[1]*The Mayor's Transport Strategy, July 2001*

[2]*Travel in London, report 10, Transport for London, 2017*

economic efficiency and the well-being of London's population.

As a result, we now face a growing crisis on London's transport system – with some roads approaching gridlock and severe overcrowding, discomfort, unreliability and equipment failures on the Underground and National Rail network." (The Mayor's Transport Strategy, July 2001)[1]

Over the past 17 years, London's transport infrastructure experienced major coordinated investments. With the exception of some key major rail projects, most investments were focused on network optimization (advanced traffic signals systems for both the rail and road networks, rail services frequency improvements, better customer information and ticketing systems, bus lanes, and targeted policies promoting a mode shift away from the automobile towards public transport, cycling and walking). These policies were successful in generating a significant mode shift away from the automobile as well as in accommodating the increased volume of daily trips.[2]

THE BRITISH NETWORK AUTHORITIES DILEMMA

The decision to invest in network optimization solutions was a by-product of the economic appraisal process. In the UK, budget allocation tends to favor infrastructure projects with high benefit-cost ratios. Low cost, high impact projects are therefore favored over high capital expenditures.

From a technical perspective, however, a highly optimised system is also very exposed to incidents and unforeseen events. For example, if a bus breaks down in London, such an incident can easily result in general traffic congestion on the road, but also in bus network crowding as the following bus is unlikely to be able to welcome all the passengers of the faulty services, etc... So, there might be a bus service every 6 minutes, which is great, but the alternative is often cycling or walking. If an incident happens, it has major consequences for the transport system. This lack of resilience of the transport system is a real concern for the authorities.

Another major issue in the UK is the fact that public sector intervention tends to be justified only on the grounds of market failure. "The public sector should only intervene in the economy when markets are not efficient and when the intervention would improve efficiency. Therefore, the first condition for public sector intervention is evidence that a market failure exists. The second condition is that the intervention will make an improvement. This will depend on how significant the failure is and on the public sector's ability to design and implement an effective intervention."[3] Two significant issues have therefore arisen:

+ Firstly, the concept of "mobility as a service", mostly composed of mobile phone applications developed by the private sector, is removing the pre-condition of the market failure for light touch, low-cost transport system network optimisation;
+ Secondly, the economic disbenefits of network incidents are much harder to capture than variations in standard day journey time. Justifying major infrastructure investments on the ground reliability benefits is difficult.

The risk is, therefore, that network authorities and transport agencies lose their legitimacy to intervene in the realm of urban mobility and, in the meantime, struggle to justify the economic benefits of major investments.

Other countries in Europe, like France, have a wider range of investment justifications at their disposal. Public sector intervention can be based on market failure, but it can also be based on legal requirements (the constitutional need to consistently equip the whole territory with comparable levels or infrastructure), and finally, there is "la raison d'état". This last justification including all strategic investments not covered by the previous two but seen as essential to preserving the national interest. The UK enacted a series of regulations providing comparable mechanisms to the one founds the French "raison d'état", with the following three acts:

+ **Civil Contingencies Act 2004** – establishes a framework for emergency planning and response, specifically providing a structure for co-operation and information sharing between emergency services, government authorities and utility companies.
+ Climate Change Act 2008 – established new responsibilities for the water, energy and transport sectors specifically to combat climate change. It gave the government more powers to ensure the preparation by organisations in key sectors for disruption due to climate change (e.g. flooding, drought, heatwave).
+ Planning Act 2008 – provided a new planning framework for major infrastructure projects in the energy, transport and water sectors. Ensures that the lifespan of a facility and its

[3]The rationale for public sector intervention in the economy, Greater London Authority, March 2006

[4]Draft Mayor's Transport Strategy, Sadiq Khan, June 2017

Figure 2

all-hazards adaptations are considered sufficiently during the planning process.

These regulations provide new tools to justify infrastructure investments, in particular in relation to network resilience.

Low cost, new technology orientated, mobility solutions, however are being spontaneously developed by the private sector, limiting the ability of the British public sector to intervene. Reflecting this out of scope situation, the latest Draft Mayor for London Transport Strategy[4] focuses only on conventional public transport solutions, cycling infrastructure and a clear objective to drastically reduce further car traffic. There is no mention of electric bicycles, smartphone apps, etc..., except to highlight that ride-sharing services could make it harder to deliver its strategic objectives.

THE HISTORICAL NEED FOR ADVOCACY GROUPS

Historically, advocacy groups undertook the necessary lobbying work to promote new modes of transport. Back in the 1920s, automobile clubs were instrumental in promoting the car as a mode of transport. Since the late 1970s, cycling campaigners in the UK were very successful in promoting the legal status of bicycles. Some of their achievements included their formal incorporation into the administration of Greater London, the de-penalization of cycling on footpaths, the opening of bus lanes to cyclists, the special legal status for electric bicycles as bicycles and not as mopeds, and now the creation of a comprehensive cycle infrastructure in London.

Some other advocacy groups, for example, supported mobility scooters for disabled people and secured amendments to the law and infrastructure provisions. Such vehicle specific progress, however, took a very long time to achieve.

For most other new mobility solutions, however, the situation is likely to be more complex. These solutions represent a step change in technology improvements rather than a new form of transport.

NEW TECHNOLOGY ENABLED MOBILITY

To cope with severely congested traffic conditions, the loss of parking spaces, a public transport system prone to severe incidents, and a rising cost of housing, London citizens are pro-actively finding solutions. Nowadays, typical coping mechanisms include:

+ Regularly working from home for a couple of days a week, coupled with hot-desking where office workers do not have a designated desk, but are desk nomads, sometimes even without a fixed office building;
+ Real-time re-routing of commuting journeys based on live network updates;
Commuting by car, but parking at a distance from their destination (sometimes renting someone's driveway) and finishing their commute using a folding bicycle or a kick scooter;
+ Increasing use of adult kick-scooters, e-scooters, and self-balancing vehicles (which are not legal in the UK);
+ The introduction of electric bicycles to make cycling friendlier on long distances and hilly terrain;
+ The use of taxi apps like Uber, etc...

The above coping mechanisms are largely enabled by new technologies like mobile internet, smartphones and new batteries. They improve the existing transport system, sometimes to the extent of creating a new solution. Most of them, however, are not regulated today or are illegal.

For example, planning regulations may not allow professional activity in a residence or rented accommodation. The premises may not meet health and safety regulations, and furthermore, the employers and the employees must address the practical consequences of accidents in the home while at work.

Similarly, some vehicles like adult kick-scooters, self-balancing vehicles, or very low maintenance bicycles like fixed geared bicycles are freely sold, but they are not street legal.[5] In case of a crash, the user is likely to be automatically at fault.

Moreover, the use of web-based applications to call a taxi or rent a parking space is increasingly on the radar of the authorities, as seen recently with Uber in London. These applications are truly helpful to the user but with the potential to run counter to public policies.[6]

Finally, some new vehicle types are transforming mobility concepts. With a foldable adult kick-scooter, moving with one's own vehicle from one mode of transport to another is becoming relatively convenient, something that could not have been achieved in the past with heavy foldable bicycles. This introduces a new concept of transmodality.

[5]https://www.askthe.police.uk/content/Q361.htm

[6]https://www.london.gov.uk/city-hall-blog/mayor-london-response-tfls-licensing-decision-uber

[7]http://www.wired.co.uk/article/tfl-finances-transport-for-london-deficit-passenger-numbers

LEGAL STATUS, LACK OF REPORTING AND INSTITUTIONAL REACTION

At present, the London authorities seems hesitant in initiating public sector interventions in relation to new technology for low-cost mobility solutions. This has resulted in the absence of any reporting or publicly shared monitoring of this phenomenon. For example, the Draft Mayor's Transport Strategy does not discuss this topic, leaving general press articles wondering why the passenger patronage is dropping on London buses[7] while the London's population is growing. It makes decades the transport planning profession wonders how to reduce traffic volumes while still enjoying economic and population growth. Yet, when it finally happens, authorities are not studying the trend but instead are focusing on the negative impact to the public transport agency balance sheet.

In parallel, Transport for London, the local government body responsible for the transportation network in Greater London, is strengthening its stance as a regulator. Yet, despite the well-publicized removal of Uber's taxi licence, the ongoing appeal process means Uber continues to operate in the capital. Moreover, no action is being taken to support enabling regulation to promote other mobility solutions, like electric kick scooters. Such technology has the potential to complement the public transport offering.

Two logical outcomes could emerge from the present situation. Either the authorities consider low-cost mobility solutions as part of the market economy, and as such, out of reach from public sector intervention, or, which is more likely, the authorities consider these low costs solutions as additions that add resilience to the transportation network.

If Transport for London would consider solutions such as working from home, electric kick scooters, and mobile phone applications as essential tools of its public transport network, an new realm of solutions could be possible.
In this context, Transport for London would need to start the monitoring of these solutions, identify complementarities, and actively lobby for an update of the regulation.

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Advances in Automated Bicycle & Pedestrian Counting

By Nathan Hicks

As the saying often goes, "If you aren't counted, then you don't count". This issue has continually plagued bicycle and pedestrian planning throughout the years while the methodologies for counting the number of motorized vehicles on roadways have progressed. Collecting data from users is necessary as it can influence a significant number of decisions. From being able to prioritize transportation projects effectively, determine policy, and understand the risks to bicyclists and pedestrians in an area, the collection of this data has wide implications. While there are many methods that are in use today to count bicyclists and pedestrians, recent advancements in technology lead us to reexamine how these might impact current methodologies. The rise of automated vehicles will likely impact many facets of society and our lives, but it also has the potential to change the ability of collecting data on bicyclists and pedestrians. Using computers and specialized software, we are now able to determine various objects within a roadway and thus able to track bicyclists and pedestrians.

EXISTING TECHNOLOGIES

Currently, there are numerous technologies for counting bicycles and pedestrians automatically within a roadway, bicycle lane, sidewalk or another environment. Equipment utilizing pneumatic tubing, piezoelectric strips or passive infrared are just a few examples that are often used to count bicyclists and pedestrians. Each of these has certain benefits but also drawbacks which can lead to issues with the data if not considered. A bicyclist may move out of a bicycle lane due to debris and thus not be counted by a device that is installed within the lane. Pedestrians may decide to cross a roadway wherever is easier for them, leading to undercounting. There could be other environmental interferences, such as sunlight and

[1]http://utc.ices.cmu.edu/utc/tier-one-reports/Pires_TSETFinalReport.pdf

[2]http://ppms.cit.cmu.edu/projects/detail/21

[3]http://docs.trb.org/prp/13-0745.pdf

temperature that cause issues with the devices and lead to over/undercounting. While this is not unique to bicyclist and pedestrian counting, overcoming these challenges can be challenging due to the variability of these users and their travel decisions.
CDM Smith recently completed a study for the Florida Department of Transportation called "The Non-Motorized Transportation Count Data Collection Study" which focused on developing a non-motorized transportation count program for the Department. As part of this study, data was collected at twenty-six different sites throughout South Florida for seventy-two hours to test four different technologies that could be used to automatically count bicyclists and pedestrians. These four technologies included passive infrared devices, pneumatic tubing, Bluetooth collection devices, and automated video imaging equipment. As part of the data review process, data was manually reviewed to compare the accuracy with what was reported automatically by the equipment. After completing this, the overall accuracy when comparing the data reported by the automatic video imaging equipment and the manually counted data was around 90%.

UPCOMING TECHNOLOGIES

In recent years, there have been advancements in the field of counting bicyclists and pedestrians with new and improved technologies. One area where advancements continue to be made is the use of video cameras and software to automatically count pedestrians and bicyclists while traveling through an intersection or roadway. While this technology currently exists commercially, additional research has helped the field progress further. For example, recent research at Carnegie Mellon University[1] has used Computer Vision, which extracts data by processing and analyzing video imagery, to count bicyclists and pedestrians in the City of Pittsburgh. Data was collected in 2015 and the accuracy was found to be 95.1% when tested. This research is being continued[2] and now includes motor vehicle counting, as well as traffic flow analysis.

Similar research was conducted at the University of British Columbia[3] where bicyclists were studied in various positions at a roundabout. The average accuracy of the automated counts was found to be around 90.5% when compared to the manual counts. Not only did this research include counting of bicyclists, but it also recorded how fast they traveled based on helmet usage, travel paths, lane position and group size. This type of research has important policy implications towards roadway safety for both motorized and non-motorized users. Improvements in this technology will continue to push the field towards innovative opportunities and allow professionals to learn more and promote better policies.

WHAT NEEDS TO BE DONE AND WHY

While significant progress has been made in recent years and these methods have shown promise, there is still much that needs to be done before they can be widely implemented. While many of the automated counting technologies that were mentioned earlier have been tested in various studies, there has not been any significant independent research on automated video detection devices according to the recent NCHRP Report 797,[4] Guidebook on Pedestrian and Bicycle Volume Data Collection. Also mentioned in this report is that 18% of the project practitioner survey respondents who counted pedestrians had used some form of automated video imaging and 17% used it for counting bicyclists in their programs. So, while this type of technology is not widely used yet, further research and improvements could change that.

There are limitations to this type of technology, namely that there is a need for these technologies and devices to be more thoroughly tested to determine their overall accuracy in diverse situations. For example, it is possible that there would be issues with collecting data in areas with low light and urban areas with many different types of users. There could also be issues with users avoiding areas with cameras due to privacy concerns and thus leading to a "bypass error".

CONCLUSION

The future of transportation is exciting with the many changes that are likely to come. As technology progresses, we're left to wonder what it will hold for us and how transportation will impact our lives and society. While there are many existing technologies in use today for counting bicyclists and pedestrians, technological advances will hopefully allow for this to become more widespread. We must be ready to embrace and understand these changes to benefit from them. With additional research, it may be possible to lessen the current limitations on automated video counting and increase the usage of this type of pedestrian and bicycle data collection technology.

[4] *http://www.trb.org/Main/Blurbs/171973.aspx*

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Better Data For Better Cities

By Kirk Kardashian

Strava metro is empowering transportation planners to make informed decisions about bike/pedestrian infrastructure.

[1]*www.strava.com*

[2]*www.metro.strava.com*

Every day, millions of people get on their bike or lace up their shoes to go from point A to point B. Smart cycling and pedestrian data can show which roads they use and intentionally avoid, what time they travel, where they go and much more. With the right analysis, this information can be the foundation of a renaissance in sustainable transportation.

How do most cities decide where to build or improve bicycle and pedestrian infrastructure? Historically, transportation planners have used retrospective surveys, bike/pedestrian counters in select locations, and anecdotal evidence of cycling activity. This information, while helpful, paints an incomplete picture of how people move through cities, and does a poor job of showing the long-term effects of improving infrastructure and promoting cycling and walking.

Thankfully, bicycling and pedestrian data has become much more robust in the past eight years. With the advent of Strava,[1] a GPS cycling and running app with millions of regular users, there are now trillions of data points on where people actually ride, run and walk.

Strava Metro[2] was launched in 2014, one year after a transportation planner from Provo, Utah contacted Strava to inquire if it had data that could help him know where to build better cycling infrastructure. It did, because millions of people upload their rides and runs to Strava every week. Metro anonymizes and aggregates this data, turning it into an effective tool for governments seeking to make their road and trail networks more inviting to bicyclists and pedestrians. In just four years, Strava Metro has already contributed anonymized cyclist and pedestrian data to more than 125 organizations and governmental agencies around the world.

How is Metro data packaged?

Metro data enables deep analysis of cyclist and pedestrian activity, including popular or avoided routes, peak commute times, and a lot more. Metro's top-level service, Enterprise, processes this data for compatibility with geographic information system (GIS) environments. Key features include:

+ Streets: Minute-by-minute activity counts across an entire network.
+ Origin / Destination: Understand activity starting and ending points, by region.
+ Intersections: Activity counts and wait times at every intersection.

For smaller cities and towns, Metro offers DataView, a web-based interactive visualization of cycling data, designed to facilitate quick insights about rider behavior. DataView is built on a Mapbox platform, and uses a blue and red color scheme on the street network for maximum visual ease. Users navigate DataView via the Dashboard, an intuitive control panel situated next to the map.

The Dashboard allows users to choose which view they want: counts and intersection wait times for Rides, Commutes or Cyclists, or a Heat Map showing the more general intensity of activity.

HOW IS METRO BEING USED?

Around the world, cities, towns, regional planning agencies, and advocacy groups are using Metro to learn more about their road networks and make infrastructure decisions. Here are some examples.

Oakville, Ontario: Creating a custom routing app

The Town of Oakville, a suburb of Toronto, is located on the shore of Lake Ontario and has a population of about 185,000. Oakville created its first Active Transportation Management Plan (ATMP) in 2009, calling for a network of bicycle and pedestrian infrastructure consisting of on-road signed routes, on-road bike lanes, and multi use trails (paved paths adjacent to the sidewalks). Today, the town boasts 185 kilometers of bike routes and lanes, and 110 bike racks.

As Oakville began the process of updating its ATMP, it sought to better understand how many cyclists and pedestrians are using the roads and paths, and where people are riding and walking. It also wanted to visualize that activity so the data can be easily displayed to the public. These goals are closely related. Knowing the quantity of cyclists and pedestrians gives planners an indication of the demand for infrastructure, and how that demand evolves over time. And being able to see cyclist and pedestrian activity on a map helps explain to the public why new or improved infrastructure is justified.

"We get lots of comments like, nobody cycles here, why do you need to build bike lanes?" said Jill Stephen, senior manager, Town of Oakville transportation engineering and construction department. "So we thought it would be helpful to get a sense of who actually is cycling and where they're going; compare the routes we have and the planned routes to the desired [routes] and, down the line, see how things have changed with use of the facilities as we build them."

Using the popular ArcGIS software, Oakville started developing an application in April of 2016 that would meet its needs for precise quantification and ease of visualization. Frank Goehner heads the town's Geospatial Solutions group, which has a staff of four GIS engineers. He asked one of his staff members to incorporate the Metro data and heat map into ArcGIS and experiment with the various features in the software. Without having to write a single line of code, Goehner's department created a customized online app in about a week.

The app, called Active Transportation in Oakville,[3] displays a street map of the entire town and is overlaid with the Metro heat map, which shows the popularity of cycling routes by intensifying the red color of the GPS points along map. In addition, when a user clicks on buttons for total cyclist activity, total commutes,

[3]http://exploreoakville.maps.arcgis.com

or total cyclists, numeric counters appear at the bottom of the screen showing the counts for the visible area of the map, categorized by time of day.

From a communications perspective, the app will go a long way towards informing residents and visitors of the most popular cycling routes, which will make it easier for people to discover new routes and decide where to ride. The app will also let the town show interested stakeholders, in a powerfully visual way, the depth and breadth of cycling activity in town, and thereby advocate for additional infrastructure where it makes the most sense.

Rapides Parish, Louisiana: Writing a new bike/pedestrian plan

Rapides Parish is located in the geographical center of Louisiana and has a population of 131,613. Alexandria, the largest city in Rapides Parish, is a high-density urban area of 27 square miles. Much of the rest of the parish consists of rural, low-density development and single-family homes. Eighty-three percent of the people in Rapides Parish drive to work in their own car. In 2015, Louisiana passed Complete Streets legislation, paving the way for more progressive and inclusive infrastructure planning.

The Rapides Area Planning Commission, which conducts transportation planning for the parish and advises cities and towns within the parish on transportation issues, recognized that the region is heavily car dependent, and wanted to give residents and visitors better options for cycling and walking. Local advocacy organizations were also pushing for additional bicycle and pedestrian infrastructure.

So when the planning commission began working on the parish's new long-range transportation plan and a separate bicycle and pedestrian plan, it partnered with Strava Metro to better understand cycling and pedestrian behavior in the region.

While many metropolitan regions have transportation plans in place that draw from bicycle count data, when Rapides Parish decided to draft its first bicycle and pedestrian plan, it was starting from scratch. The parish had never conducted bicycle or pedestrian counts, and it didn't have an inventory of its bicycle and pedestrian facilities. Furthermore, instead of outsourcing the creation of the plans to a private consultant, the planning commission decided to do the project in-house.

RAPC received the Metro data directly and found it easy to work with, and the accompanying user guide answered the questions that came up. The commission immediately saw the value of the activity and athlete counts on the road segments in the parish, as it gave planners the first comprehensive view of bicyclist behavior in the region.

RAPC completed the plan[4] by the end of 2016. It contains detailed goals and strategies, and includes a unique bike/pedestrian suitability index based on Metro data and other criteria. The index assigns a score ranging from one to five for each road segment. The more users on the segment, the higher the score.

Now it's up to the local towns to implement the plan, but the planning commission will promote it through educational programs, participation in state and national campaigns, and through social media.

Seattle DOT: Traffic safety study

In 2007, the city of Seattle created its first Bicycle Master Plan, and it laid out an aggressive goal: to triple ridership in 10 years. The challenges for the Department of Transportation were two fold: accurately measuring bicycling activity on Seattle's network of roads and bike paths, and making the city's streets more inviting to bicyclists.
At first, Seattle performed a manual bike count for a two-hour period in the downtown area on the same day each year, and consulted the American Community Survey for statistics on bike commuters. After a few years, the city added spot counts at 50 locations, and

[4] *http://www.rapc.info/Transportation/Bike_Ped/Bike_Ped_docs/BPP%20FINAL%20Web%20Edition%20012617.pdf*

then permanent counters at a dozen other intersections.

In 2015, the city incorporated Strava Metro data into its quiver. "What we've really focused on is combining our count data with Strava to give us a broader picture of what's happening with cycling across the city," said Craig Moore, who manages the traffic data and records group for SDOT. "The combination has really proved valuable because it's allowing us to say things about parts of the network we didn't have any data on."
Objectives

One major project that could benefit from more detailed bicyclist data was the Safety Analysis and Risk Exposure study, performed in partnership with Toole Design and the University of North Carolina. The goal was to establish risk factors for roadway designs by correlating collision rates (between cars and bikes, and cars and pedestrians) with infrastructure characteristics.

In the study,[5] which was released in 2016, Toole Design combined the SDOT bicycle count and Strava Metro data to create a more accurate citywide model of risk. Importantly, the dual-sourced data allowed the team to get beyond the misleading collision hotspots—where high traffic volumes cause high collision volumes—and establish a true rate of collisions that accounts for volume. "This gives us the ability to say, This street has a problem and this street doesn't," Moore said. Furthermore, the analysts could compare the characteristics of the high risk streets, identify the types of intersections or infrastructure that were most problematic, and look for those characteristics in other parts of the city. Once those areas are catalogued, they can be improved before the collision rate rises.

Queensland is a global leader in sustainable transportation, both in its commitment to building safe, direct, and connected bicycling routes, and in its use of smart data to help plan, build, and analyze cycling and pedestrian infrastructure. Queensland's efforts in this area go back a long time, but since 2003 alone it

[5]https://www.seattle.gov/Documents/Departments/SeattleBicycleAdvisoryBoard/presentations/BPSA_Draft_Public_093016.pdf

has dedicated more than $1 billion to build hundreds of kilometers of bicycle networks. This work is outlined in its comprehensive cycling strategy for 2011-2021, and supports the broader governmental goals of cutting Queensland households' carbon emissions by one-third by 2020, and reducing Queenslanders' obesity levels.

There are numerous ways to encourage cycling for commuting and recreation. The Queensland Department of Transport and Main Roads (TMR) believes the most powerful method is to simply build better infrastructure and create an environment where people feel safe and comfortable on their bicycle. To facilitate that development, TMR uses many kinds of data, from statewide participation and travel surveys to traffic counts on bikeways. In 2014, Queensland began working with Strava Metro to capture street-level bicycle usage and gain insights on a range of questions about bicyclist behavior, including preferred routes, peak days and times, average speeds, and gaps in the bicycle network.

As the organization responsible for implementing a key part of Queensland's cycle strategy, TMR must advocate for bicycling infrastructure and prove that new infrastructure is being adopted by cyclists. Strava Metro has become an important tool for both jobs. Prior to building a bikeway, TMR's transportation planners analyze the Metro data for bicycle usage on unsafe roads; they then use that evidence to make the case for cycling-specific infrastructure. After a new bikeway has been built, TMR examines its usage to make sure the bikeway is serving the needs of cyclists.

This strategy became especially useful in the aftermath of the 2011 floods, which washed away the New Farm Riverwalk, a floating bikeway and walkway in the middle of the Brisbane River. The 850-meter Riverwalk connected the neighborhoods of New Farm and Merthyr to downtown Brisbane and the Bicentennial Bikeway, and was a safe and popular route, seeing more than 3,000 cyclists, runners, and pedestrians every day. After a three year hiatus, the Riverwalk was rebuilt on solid ground, re-opening in September of 2014. The question was: how would its reappearance impact bicycle usage and traffic patterns?

The timing of the Riverwalk's re-opening proved advantageous because TMR planners could use Metro data to compare bicyclist patterns before and after the new path was built—a "delta analysis."

The differences between the two Metro data visuals were rather dramatic. Before the Riverwalk was re-built, bicyclists were diverted onto a busy street or into the hilly Fortitude Valley to get to the core business district. After the Riverwalk re-opened, cyclists' usage of the surrounding streets decreased and there was a significant increase in cycling levels in the New Farm area on the safer route. A damaged link in Brisbane's bicycle network had been fixed, and the Metro data showed just how much local residents were glad to have it back.

Proving this change in bicycling activity was important to TMR for two reasons: it showed the value of this particular investment and it confirmed what many bicycle advocates believe about dedicated infrastructure: If you build it, they will come.

DATA REPRESENTATIVENESS

Since Metro data is based on user data from Strava, which has a loyal following among avid cyclists, it's natural to wonder how representative Metro data is of the general cycling and bike commuting population. So far, at least two sources indicate that Strava data is highly representative of the way the broader cycling community interacts with road networks.

In a study by the Centers for Disease Control and Prevention,[6] researchers found a strong correlation between user-generated GPS-tracked activities on Strava and commuting data from the U.S. Census Bureau's American Community Survey for four U.S. cities. "These systems similarly rank census block groups according to the presence of active commuting," the report found, "and the

[6]Whitfield GP, Ussery EN, Riordan B, Wendel AM. Association Between User-Generated Commuting Data and Population-Representative Active Commuting Surveillance Data — Four Cities, 2014–2015. MMWR Morb Mortal Wkly Rep 2016;65:959–962. DOI: http://dx.doi.org/10.15585/mmwr.mm6536a4.

similarity might be stronger in areas that have a higher population density." It went on to state that Strava data "might provide critical information regarding active transportation to local health and transportation officials as a complement to traditional active transportation surveillance systems; these data might inform investments in active transportation programs and infrastructure."

The CDC study confirms what Metro has found in its own analyses. For example, a routine study of counter and Metro data from February to December of 2014 on the Fremont and Spokane Street bridges in Seattle revealed a close tracking of the two data sets. As the counter data showed a steady increase in riders, so too did the Metro data, even though Strava users represented just 2.7% of the riders crossing the Freemont Bridge, and 5.1% of riders on the Spokane Bridge.

A statistical analysis of the correlation found that the Metro data could predict the behavior of the overall bike population with an accuracy of 91% and 94% on the Freemont and Spokane bridges, respectively. This is about as robust a relationship as one can expect in the real world, which means that Metro data is a highly reliable representation of what is happening on the ground in cities.

Practically speaking, the accuracy of Metro data means planners can take what they know from their bike counters and extrapolate that data to every street and intersection in their city or region by using a multiplier. In Seattle's case, the multiplier was 27 (for every Strava user, there are 27 other riders). So if the Metro data shows 1,000 activities on a given street in one year, there are actually 27,000 activities on that street.

The multiplier applies to every metric the Metro data contains, such as riders, activities, and bicycle miles traveled. Once proven with statistical significance, you can apply the multiplier across the entire network.

16,297 Strava Bike Trips in 2014 x 27 Multiplier:
+ 440,019 year bike trips

+ 199,476 trips from 6-9 AM
+ 63,253,198 bike miles traveled

From these metrics, other statistics can spring. For instance, once you know how many miles people biked instead of drove, you can calculate the number of tons of carbon dioxide saved by your bicycle-friendly infrastructure.

Bicycle counters will remain a crucial part of any transportation planner's approach to data gathering. Now Metro is an equally important part. Together, they provide the best data and insights currently available on cyclist behavior.

Kirk Kardashian is a journalist based in Vermont. For more information about Strava Metro, please contact Metro staff member Brian Devaney at bdevaney@strava.com.

Personal E-Mobility Options for Last Mile Connectivity & Short Trips

By Jonathan Paul

Personal electric (e) transport technology consist of portable electric devices, designed for people standing, sitting or pedaling, operating at speeds between 10 and 20 mph (15 to 30 km/h). While definitions vary, personal electric transport devices generally consist of Segways©, e-bikes, hoverboards, e-scooters, e-skateboards, OneWheel©, e-skateboards, golf carts, and the Copenhagen Wheel©. Personal electric transport technology provides mobility choices to people traveling shorter distances. These devices and the mobility they provide have become more commonly referred to as personal e-Mobility (electric mobility).

Personal e-Mobility, along with Mobility as a Service (MaaS), and Autonomous Vehicles (AVs), are leading a revolution in mobility not seen since the advent of the motor vehicle. The primary goal of personal e-Mobility is to expand the distance of travel and reduce the time in which people can travel between origin and destination. One of the performance goals of personal e-Mobility is to enable a person to travel one (1) mile in less than five (5) minutes, on par with motor vehicles in urban areas, and more than 4X faster than the 20 minutes it takes to walk a similar distance. According to the latest US National Household Travel Survey data, most walking trips are less than 1 mile in length and bicycling trips are mostly less than 2 miles. The more surprising number that most don't realize is that of all trips by all modes in urban areas, 30% of trips are less than 1 mile in length and more than 50% of all trips are three miles or less. While most transportation planning focuses on the work commute, less than 20% of all trips are work related. Social and recreational trips, family and personal errands, and shopping trips comprise 70% of all trips. Studies have shown that most people can walk between 3 to 4 mph (5 km/h) per hour, bicycle between 7 to 12 mph (15 km/h) and ride personal e-Mobility devices between 10 to 20 mph (30 km/h). Based upon the percentage of trips being three miles or less in length and the speed at which personal e-Mobility travel, there are opportunities for personal E-Mobility devices to be a viable mobility option.

Personal e-Mobility devices often use sidewalks, paths or trails, creating potential conflicts with people walking, jogging, running and bicycling. Most communities lack regulations or restrict use of personal e-Mobility devices in on-street bicycle lanes. The challenge faced by governmental entities is determining how best to classify, regulate, and accommodate personal e-Mobility while also providing a safe and convenient transportation system for all users and balancing the demands for space for each mode in an increasingly crowded right-of-way.

Last mile connectivity and accessibility to transit is an issue planners, engineers and transit authorities struggle with daily. The typical distance a person is willing to walk, if they feel it is safe to do so, is no more than a ¼ mile (5 minutes) to a bus and ½ mile (10 minutes) to rail transit. While a person can bicycle quicker to access transit, most people don't feel safe bicycling on-street and face obstacles with the limited number of bikes that can be accommodate on a bus or lack of safe places to secure their bicycle. The smaller personal e-Mobility devices, except for e-Bikes, e-Scooters and Segways, have the potential to address storage, boarding and alighting issues. Larger personal e-Mobility devices like Segways and golf carts would function better as circulators in mixed-use developments.

The introduction of the Segway in 2001 was hyped as a transformative means of personal transport that would revolutionize how people moved about in their communities (Figure 1). The Segway was envisioned as greatly enhancing personal transport by extending both the distance of travel and increasing the speed of travel, all with minimal physical exertion. The Segway was also envisioned to reduce greenhouse gas emissions by running on a rechargeable electric battery.

Segways have gained a foothold in terms of use by security and law enforcement in areas not readily accessible by vehicles, by industrial, distribution and manufacturing traversing large spaces, and they have found a niche in the tourism industry that provide Segway tours. However, due to size, weight, cost and difficulty with storage, the Segway has not revolutionized personal transport as envisioned by its creator Dean Kamen. The self-balancing gyroscopic technology and rechargeable electric battery introduced by the Segway has resulted in an ever-expanding roster of personal e-Mobility transport devices (distinguished as primarily powered by an electric source) designed as efficient and effective environmentally friendly alternatives to gasoline-powered motor vehicles.

Figure 1. Segways
Source: NUE Urban Concepts, LLC

The miniPro Segway, a more affordable and smaller version of the original Segway, and the hoverboard have found a growing market among Generation Z (Figure 2). The use of hoverboards was set to expand exponentially in 2016, until cheap knock-off versions started to catch on fire due to overheated lithium-ion batteries which have led to bans on flights and in various locations throughout the US. The miniPro, manufactured by Ninebot, a Chinese company that has purchased Segway, has not faced the same mechanical failures as Hoverboards and has the potential to be a viable personal e-Mobility device due to its small size, lower cost versus Segway, its range of 14 miles, and a top speed upwards of 10 mph. Once patents and standards are enforced, higher quality hoverboards and future updates of the miniPro will make this a rapidly growing segment of e-Mobility devices.

Unicycles are often thought of as a device used in circuses or by street performers. However, an e-Mobility version of the unicycle has been gaining traction for its speed, with some versions traveling over 20 mph, and range upwards of 20 miles. Unlike the gyroscopic technology of Segways that creates a relatively self-balancing device, a greater level of skill and dexterity is needed.

The skateboard had gone electric as well with a variety of companies integrating rechargeable batteries and using both wired and wireless remotes to propel e-skateboards at speeds over 20 mph. Like e-unicycles, e-skateboards are not

Figure 2. miniPro Segway
Source: NUE Urban Concepts, LLC

self-balancing, they require a greater level of balance and skill to utilize as an e-Mobility device.

The most exciting new personal e-Mobility technology is a mix between a skateboard, snowboard and a Hoverboard. OneWheel©, a self-balancing device with a hypercore brushless motor inside of a center wheel, utilizes gyroscopic technology and a multitude of sensors to adjust to a variety of terrain conditions to help maintain balance (Figure 4). The OneWheel has a range of 5-7 miles, can go as fast as 19 mph and fully recharge within 20-minutes. OneWheel is a personal e-Mobility device that can be used seamlessly for both recreational and commute uses. Recently eight staff from Geek Wire, a Seattle technology news site company, staged a race using eight different modes of transport to navigate Downtown Seattle during rush hour. Out of the eight modes chosen, including ride, car and bike share services, OneWheel was the fastest mode of travel. To find out more about the race, checkout https://www.geekwire.com/2017/geekwires-great-race-pitted-cars-bus-bike-skateboard-rush-hour-surprising-result/

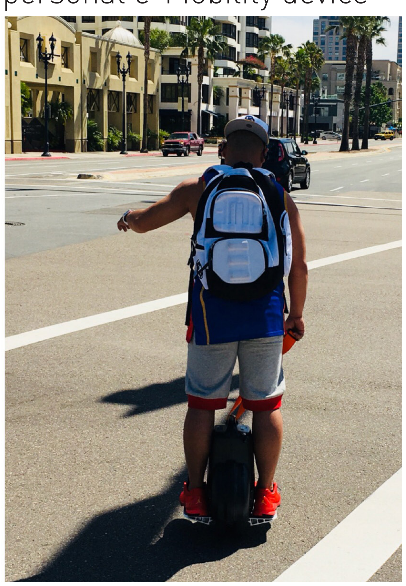

Figure 3. e-Skateboard
Source: NUE Urban Concepts, LLC

For distances less than 2 miles, the bicycle can be as efficient and effective as the motor vehicle in providing mobility and accessibility. However, especially in the US, the lack of safe places to ride a bicycle and the lack of a connected bicycle network significantly limit the share of trips made by bicycle. An e-bicycle can make the bicycle even more competitive against motor vehicles and extend the distance and increase the speed of travel (Figure 5). E-bicycles are more common in European Cities where the bicycle mode share is significantly higher than in the US. European Cities have also made significant investments in providing safe and separated facilities for bicycles and reduced speeds of motor vehicles.

There are three types of e-bikes. The most common is an e-bicycle fitted with an electric motor typically mounted on a rack above the rear wheel. These e-bikes can travel at speeds greater than 20 mph with ranges of 30 plus miles. Often e-bikes are designed to be hybrid systems where a person on a bike can pedal without assistance, pedal with the motor or rely completely on the motor. E-bikes do require that bikes be fitted with the proper supports for the battery and does add additional weight and cables to a bicycle. There are new conversion kits that have made it simpler to retrofit some existing bicycles.

One emerging personal e-Mobility device is a hybrid between a bicycle and a scooter (Figure 6). These personal e-Mobility devices feature streamlined bodies, often with scooter

Figure 5. e-bicycle
Source: NUE Urban Concepts, LLC

platforms to stand on, some include pedals, others do not. They typically can travel at speeds up to 25 mph and have ranges of 15 miles between charges. Scooters / mopeds require a driver's license, must be registered and be issued a license plate. These hybrid bike / scooters do not require a license and do not need to be registered. They are one of the fastest modes of personal e-Mobility devices. Due to the speed, and on some the lack of pedals, their use on bike lanes, trails and cycle tracks often fall within a regulatory grey area.

One of the newest entrants


Figure 6. e-Scooter / moped
Source: NUE Urban Concepts, LLC

into the personal e-Mobility space is the Copenhagen Wheel© (Figure 7). This device simply replaces the rear wheel of most standard bikes so there are no separate cables or supports needed. The motor, braking system and technology are all housed within the wheel itself. The Copenhagen Wheel, unlike traditional battery operated systems, is technology driven and synced via Bluetooth with a smartphone. The software and firmware can be updated to expand the functionality of the device.

Another unique feature of the Copenhagen Wheel is that the battery is regenerated through braking action, thus extending the range of the device and increasing times between needed recharging. The technology is adaptive and learns how each rider pedals and can vary the level of assistance based on need. The software has recently been modified to achieve a top speed of 25 mph. The Copenhagen Wheel features the longest range of any personal e-Mobility device at 30 miles, which can be extended through regenerative breaking.

Golf carts, not always considered a form of personal e-Mobility, have seen a significant increase in mode share within resort communities, retirement communities and more and more frequently in master planned communities. Within The Villages, a retirement community within Central Florida with over 90 miles of golf cart paths, 30% of all trips are made by golf cart and the community features an 80% community capture of trips. The South Bay subregion of the Los Angeles Metropolitan Area, a mixture of retirement and master plan communities

Figure 7. Copenhagen Wheel©
Source: SENSEable City Lab – Massachusetts Institute of Technology (mit.edu)

has achieved a 26% golf cart mode share. Peachtree City Georgia, south of Atlanta, has 35,000 residents, 10,000 households and more than 10,000 registered golf carts recording over a million miles a year of travel.

The State of Florida has taken significant steps to allow for greater use of golf carts as a means of personal e-Mobility. Florida Statute allows drivers as young as 14 years old to drive a registered golf cart on roads with speed limits less than 35 mph and that are designated for golf cart use by a county engineer. Haile Plantation, an early Traditional Neighborhood Development located in Alachua County, recently allowed golf carts on all roads with posted speed limits of 30 mph or less. Golf carts must be registered, equipped with headlights, turn signals and seat belts. The minimum age for a person to drive a golf cart in the County is 15 years old.

Viera, a Master Planned Community in Brevard County, allows golf carts on all local roads and on all multi-use paths (8' wide)

Figure 8. Golf Carts
Source: NUE Urban Concepts, LLC

and trails (10' or greater in width). Viera has already constructed more than 40 miles of paths and trails and has another 40 miles planned in future phases. Golf carts travel at maximum speeds of 15 mph and have a range of 25 to 40 miles between charges. Golf carts have been shown to significantly reduce overall motor vehicle use in mixed-use communities and has a high rate of use amongst high school students in communities that allow golf carts and have a high school within the development. As populations continue to age, especially in Sunbelt communities, golf-carts are an ever-increasing e-Mobility mode.

Personal e-Mobility devices can assist a community in becoming a 20-minute City or develop 20-minute neighborhoods with a mixture of interconnected land uses. The speed and accessibility offered by e-Mobility devices can address last mile connectivity issues to transit and help with addressing limitations due to areas with steeper terrain. E-Mobility devices can also be used to decrease overall motor vehicle use cut greenhouse gas emissions. The biggest impediment to further use of personal e-Mobility in the 21st Century is the same one that limits walking, bicycling, skateboarding and rollerblading today: the provision of safe, convenient, and interconnected multimodal facilities in the form of trails, protected bike lanes, paths and sidewalks wide enough to accommodate multiple users (Figure 9). Personal e-Mobility devices are intended to increase travel distance and reduce travel times, but can only do so if the proper multimodal facilities exist.

Conversely, a lack of multimodal facilities can lead to conflicts between people walking and bicycling and those using personal e-Mobility devices. A robust network of protected bicycle lanes, trails, paths and wide sidewalks, designed with adequate width to accommodate walking, bicycling, rollerblading, skateboards and personal e-Mobility devices, can result in an increase in mode share, accessibility and mobility for non-motor vehicle travel. Allowing personal e-Mobility devices in on-street bicycle lanes maybe another option to consider in appropriate locations. The use of personal e-Mobility devices may require specific legislation to permit and design,

Figure 9. People skateboarding, rollerblading and bicycling
Source: NUE Urban Concepts, LLC

along with pavement marking and signage may need to be amended to allow for both bicycles and personal e-Mobility devices to use on-street facilities. With the speed of travel offered by e-Mobility and the increased distance of travel, communities can provide viable 21st Century mobility options that are competitive with motor vehicles.

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TRACK 7
TRACK 5
TRACK 2

A DEEPER LOOK

Planning for Autonomous Vehicles: Distilling Reality from Fantasy

By David Heller

..”The battle for drib-erless cars is the 21st-century space race, with fierce rival-ries, insane technical obstacles and billions, possibly trillions of dollars on the lines.”

I. INTRODUCTION

“The battle for driverless cars is the 21st-century space race, with fierce rivalries, insane technical obstacles and billions, possibly trillions of dollars on the line.”[1]
Amid this 21st century race are the transportation planners and policymakers, who are tasked with the job of planning and designing the transportation systems that will accommodate these autonomous cars. This is a significant challenge since most American cities were built and designed around the automobile and driving has been a pervasive part of the American culture. How do we plan for a future with self-driving and autonomous vehicles? What are the challenges in planning for these? This article will delve into some of the major planning issues surrounding this potentially disruptive technology.

II. WHAT ARE AUTONOMOUS VEHICLES?

An autonomous car (also known as a driverless car, self-driving car, robotic car, autos) and unmanned ground vehicle is a vehicle that is capable of sensing its environment and navigating without human input. Autonomous cars use a variety of techniques to detect their surroundings, such as radar, laser light, GPS, odometry and computer vision. Advanced control systems interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage. Autonomous cars must have control systems that can analyze sensory data to distinguish between

[1] *Kevin Roose. “Detroit Hussle.” The New York Times Magazine. November 12, 2017. 12.*

different cars on the road.[2] Figure 1 below, depicts an autonomous vehicle.

A related, but not identical technology is connected vehicles (CV's). Connected vehicles allow vehicles to communicate with each other and the world around them. Many of today's vehicles include connected vehicle functionality. For example, GPS systems receive congestion information on the road ahead through cellular signals (3G, 4G, or LTE) and will map an alternative route if necessary. Most of the connected vehicles that are currently on the market have some autonomous functionality, such as self-parking or collision avoidance, but still require a human driver, which is not needed in a fully autonomous vehicle.[3]

While not fully automated, today's new vehicles include many automated features that make driving much safer. For example, some technologies monitor a driver's eyelids and can alert a driver if it senses he or she is becoming too sleepy. Other technologies will automatically brake the vehicle (if the drivers fail to do it themselves), in the presence of an obstruction. Similarly, other technologies can alert a driver if there is a person or some other obstruction when the car is backing up. These and other safety technologies use a combination of hardware (sensors, cameras, radar) and software that help a driver minimize the risk of getting into a serious crash, avoiding serious injury and even death.[4]

Although these automated features provide significant assistance to the driver, they do not reach the level of a fully automated vehicle. The Society of Automotive Engineers (SAE) has created a

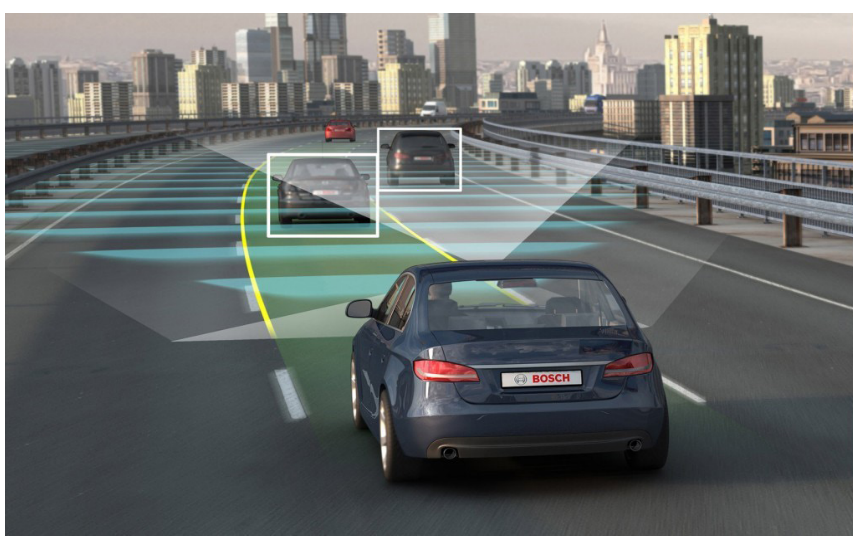

Figure 1 Autonomous Vehicle
https://www.geospatialworld.net/news/elon-musk-wont-use-lidar-in-upcoming-tesla-autopilot-update/. Accessed 19 November 2017.

[2]Wikipedia. "Autonomous Cars." At: https://en.wikipedia.org/wiki/Autonomous_car. Accessed 19 November 2017.

[3]Suzanne Murtha. "Autonomous vs. Connected Vehicles-What's the Difference?" At: http://www.atkinsglobal.com. Accessed 21 November 2017.

[4]NHTSA. "Automated Vehicles for Safety." At: https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety. Accessed 19 November 2017.

[5]Jon Gertner. "What Tesla Sees." The New York Times Magazine. November 12, 2017. 70.

[6]National Public Radio. https://www.npr.org/sections/alltechconsidered/2017/04/03/522099560/pittsburgh-offers-driving-lessons-for-ubers-autonomous-cars.. April 3, 2017.

[7]Roose. 26.

[8]https://www.theverge.com/2017/10/24/16504038/tesla-autopilot-self-driving-update-elon-musk. Accessed 19 November 2017.

[9]Roose. 76.

system for grading the level of automation in a vehicle (see Figure 2) that ranges from 0, for no automation, to Level 5 which includes full, reliable automation under all environmental conditions in any location. No Level 5 car has ever been publicly deployed, and it is doubtful one exists.[5] There are a few instances where Level 4 cars are being tested. Uber is testing self-driving vehicles in Pittsburgh. While the car does drive for stretches without any human intervention, on average, humans had to take control every 0.8 mile in a recent test, especially when navigating difficult situations, such as driving around an 18-wheel truck or getting out of a parking lot.[6]

Nonetheless, autonomous vehicles are being tested all over the world. Ford Motor Company has invested millions in autonomous vehicles, and hopes to release a vehicle that meets SAE Level 4 standards by 2021.[7] Tesla is one of the major companies testing and developing autonomous vehicles. In late 2016, using their semi-autonomous testing system known as Autopilot, they demonstrated that a vehicle could leave a garage, drive down the street, and self-park. However, the technology is not flawless, as evidenced by a 2016 crash that killed a man driving a Tesla Model S while using Autopilot. It also cannot detect speed limit signs and can get confused by certain intersections.[8]

ENGINEERING/DESIGN

Autonomous vehicles pose many challenges. Combining heavy equipment (vehicle) and complex software is difficult from a design and engineering perspective. Unlike some computer algorithms, driving a car is a complex operation, involving the "flawless simultaneous execution of a billion tiny and subtle reflexes.[9]" A self-driving car must "correctly identify and label millions of objects, understand city layouts and traffic laws, and operate in a variety of conditions." Cars must be equipped with enough sensors and software that can take a rich, clear picture of every element in the surrounding environment including people, bikes, signs, and other obstacles, and from all this data, safely and smoothly choreograph the path forward.[10] The car also must be taught how to handle incidents that may not effect a human driver, such as a piece of a debris flying up and knocking out a sensor.[11]

In addition to the fundamental design and engineering problems described above, there are also significant liability issues: Who is responsible when accidents happen--the driver, the vehicle, or the software? In the Guidance issued by the National Highway Traffic Safety Administration (NHTSA), "Liability and Insurance" are called out as important issues for States to sort out as they develop procedures and regulations for allowing automated vehicles onto public roadways. The Guidance states that "liability and insurance considerations may take time and broad discussion of incident scenarios, understanding of technology, and knowledge of how the ADSs (Automated Driving Systems) are being used."[12]

Cost

Cost is another major issue in the development and deployment of autonomous vehicles. As noted above, these vehicles require a variety of special sensors, computers, and controls, which currently cost tens of thousands of dollars at the outset. As with other major technical enhancements to the automobile; initially, autonomous vehicles are likely to be expensive novelties with restrictions on operating conditions. It may be a while (2040s and 2050s) before middle-class families can afford autonomous vehicles that can safely operate in all conditions, and even longer for used autonomous vehicles to be affordable to lower-income households.[13] However, there are non-ownership business models, most notably exemplified by the

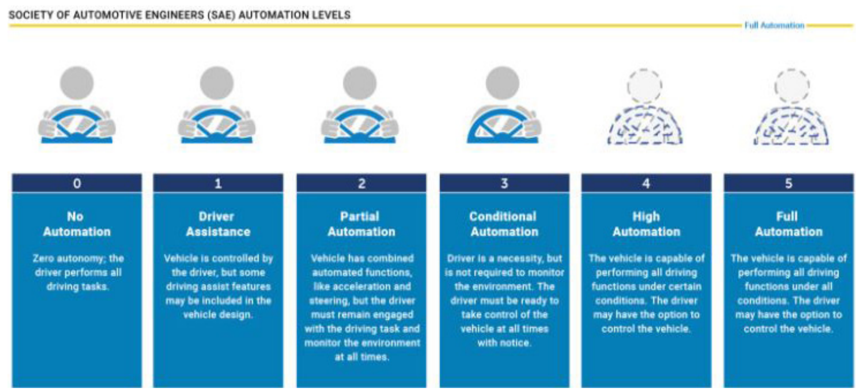

Figure 2 Levels of Automation
NHTSA. https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety. Accessed 19 November 2017.

[10]*Gertner. 70.*

[11]*Roose. 76.*

[12]*US DOT. NHTSA. "Automated Driving Systems 2.0 – A Vision for Safety." September 2017. 24.*

[13]*Todd Litman. "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning." Victoria Transport Policy Institute. 8 September 2017. 18. +*

e-hailing ride services such as Uber and Lyft, that are likely to be employed, at the least at the outset. In this instance, users don't own the vehicle, and purchase the service when they need it, usually via some sort of unifying platform such as a web or mobile app. This "Mobility as a Service" concept is described in more detail below.

Because system failures can cause fatalities to both the driver, passengers, and other vehicles, all the system components will need to meet high manufacturing, installation, repair, testing, and maintenance standards, which will also be relatively expensive. Autonomous vehicle operation may require special navigation services, which can add to the price of the vehicle. These costs are likely to add several thousand dollars to the cost of the vehicle, as well as a few hundred dollars in annual service costs.[14]

If only a portion of total vehicle travel on any given section of roadway is autonomous, the benefits of this technology are likely to be limited. Many of the system-level benefits of autonomous vehicles, such as increased traffic densities, narrower traffic lanes, a reduction in parking supply, or elimination of traffic signals--require that most or all the vehicle population on any given segment of roadway are autonomous.[15] Although the high cost of autonomous vehicles will incentivize manufacturers to invest in this technology, it is also likely to limit their purchase to all but the most affluent for many years. This limited implementation scale will add to the challenge of developing a suitable infrastructure system.

MARKET PENETRATION

At least in the initial phases, the operation of autonomous vehicles seems optimized for dense urban areas. People who live in urban areas are not as likely to be car-dependent as those who live in suburban and rural areas, as they have other alternatives to driving. They are more likely not to have a car or be willing to give up their car to use alternative forms of transportation, including autonomous vehicles. At

[15] *Ibid. 19.*

least initially, it is likely that the average trip length for many autonomous vehicles will be short, as it will be easier to monitor.

Further, successful deployment of AV's relies as much on vehicles communicating with other vehicles, commonly known as V2V communication, as well as vehicles communicating with the vehicle occupants. V2V comprises a wireless network whereby vehicles transmit messages to each other with information about their speed, location, direction of travel, braking, and loss of stability.[16] The density of cars in an urban area will allow the CV component of automated vehicles, which operate using a Vehicle-to-vehicle (V2V) model, to work more effectively. V2V uses a type of wireless network (similar to Wi-fi), known as Dedicated Short-Range Communications (DSRC). DSRC has a range of up to 300 meters, or 1,000 feet.[17] Self-driving vehicles also rely heavily on vehicle-to-infrastructure communication, or V2I.

V2I is basically a communications model that allows the vehicle to communicate with various components of the highway system, including traffic cameras, signals, streetlights, signage and parking meters. Like vehicle-to-vehicle (V2V) communication, V2I uses dedicated short-range communication (DSRC) frequencies to transfer data.[18]

The widespread adoption of driverless cars will require buy-in from parts of the United States that have yet to support new transportation technologies like autonomous or self-driving vehicles. These include rural and even some suburban areas, where people are likely to be more dependent on having a personal automobile to get around and do daily chores. Their average trip lengths are likely to be much greater than the person who lives in a dense urban area. They may also be apprehensive about giving up control of the vehicle or entrusting their safety to a machine. However, there are still many transit-dependent segments of the population that reside within these areas, such as the disabled and the elderly, that could benefit from the deployment

[16]*Bill Howard. "V2V: What are vehicle-to-vehicle communications and how do they work?" At: https://www.extremetech.com/extreme/176093-v2v-what-are-vehicle-to-vehicle-communications-and-how-does-it-work. Accessed 27 December 2017.*

[17]*Ibid.*

[18]*Vehicle to infrastructure (V2I or v2i)." At: http://whatis.techtarget.com/definition/vehicle-to-infrastructure-V2I-or-V2X. Accessed 27 December 2017.*

[19] Ibid.

[20] USDOT. NHTSA. 20.

of automated vehicles. To penetrate this segment of the market, manufacturers and vendors will have to make usage of automated vehicles very easy, and probably have to invest in a substantial public outreach and education campaign to allay people's fears or apprehensions about utilizing this new technology.

Many people are also wary of automation, particularly those who rely on driving a vehicle as their livelihood. There are more than 1.7 M truck drivers in the United States and another 1.7 M bus, taxi, and delivery drivers who fear losing their jobs to automation.[19] There will likely be many constituencies that will be lobbying hard to prevent automated vehicles from completely replacing driver-operated vehicles. In addition to people's fears, regulation of autonomous vehicles poses a challenge. In September 2017, the National Highway Traffic Safety Administration (NHTSA) released Automated Driving Systems 2.0: A Vision for Safety. While this guidance does a good job at clarifying and delineating the Federal and State roles in regulating autonomous vehicles, it is voluntary and rather general. Much of the burden will lie with the States, who, in conjunction with the municipalities, own and maintain many of the roadways and enact and enforce traffic laws and regulations.[20]

IV. HOW DO WE PLAN FOR AUTONOMOUS VEHICLES?

Autonomous vehicle implementation is just one of several factors likely to impact our future transportation system. Demographic trends, price changes, improved user information, and overall economic trends will also have a substantial impact. Thankfully, widespread deployment of autonomous vehicles won't happen overnight. During the 2020s and 2030s, transportation planners and engineers will primarily be preoccupied with understanding the technology behind autonomous vehicles, and testing them. Are these vehicles safe? What other modifications to public roads are needed to accommodate automated driving? Road lanes dedicated to vehicles capable of coordinated operation will likely have to be identified.[21] These tasks in and of themselves pose enormous challenges.

Even if autonomous vehicles achieve a high (30%+) market penetration, an incomplete market penetration poses challenges and could be dangerous. Given the supporting roadway infrastructure needed to support operation of autonomous vehicles, it is likely that at first, these vehicles will operate in a very confined area. What if an autonomous vehicle purposely or accidentally leaves this area, and travels on regular roadways? Drivers with standard operating automobiles will likely lack the necessary technology needed to communicate with autonomous vehicles, and as such, may not react properly in their presence. This could lead to accidents. Conversely, perhaps an automated vehicle may stop suddenly in the presence of a pedestrian or another vehicle, causing a potential chain reaction of vehicles colliding into one another at the back end of the incident. Until self-driving cars have been thoroughly tested and proven to be safe, their usage will be limited to well-defined, and adequately equipped areas.

The presumed benefits of autonomous vehicles—reduced congestion, parking demand, and increased safety face a longer time horizon--2040s and beyond, after the technology has been thoroughly tested and proven, and autonomous vehicles comprise a major share of the vehicle population. Table 1 below gives a good overview of the various impacts that autonomous vehicles will have on planning, and the appropriate time horizon for each impact.[22]

However, items that appear at first to be benefits may have collateral challenges. For instance, if vehicles aren't being parked, where will they go? If they are simply driving around waiting for the next client, this would likely lead to congestion. One possible solution is to build peripheral parking areas are to accommodate unoccupied autonomous vehicles for a few hours each night—similar to transit buses docking at a garage each night, or

[21]Litman. 15.

[22]Ibid. 16.

trains docking at a rail yard. Additional dead-head trips to and from these peripheral parking areas could lead to more congestion.

Considering the long-term horizon for many of these impacts and benefits to be realized, the 20-year planning horizon of most metropolitan transportation plans may be insufficient. However, there are opportunities that can be undertaken now to expedite our readiness for this sort of technology. For example, we could increase public investment in research and development of the technology behind the self-driving and automated vehicles, providing incentives to both universities and corporations to perfect this technology. This could also include continuing to perfect the technology behind electric and plug-in vehicles, since it is likely that this technology will also be utilized by autonomous vehicles. We should continue to fully test these vehicles to ensure they are foolproof.

In conjunction with this testing, we should continue to build closed testing sites such as the University of Michigan's MCity, or establish test corridors, as has been done in Michigan, Texas (see below), and other states, designed for testing this sort of technology. We could also continue to promote development patterns such as compact and transit-oriented development that are conducive to AV's avoiding, where possible, the development of massive surface parking lots and structures, since there will presumably be less of a need for them as autonomous vehicle deployment becomes more widespread. However, changes in development patterns is more of a longer-term strategy and more difficult to control, given that land use is largely a municipal function in this country.

CURRENT PRACTICES

State DOTs

Despite the long timeframe needed to develop, test, and evaluate the technology, not to mention the numerous legal and financial hurdles necessary for widespread deployment, there are at least a handful of agencies and transportation departments doing things now to prepare for autonomous vehicles. Michigan DOT (MDOT) is overseeing arterial testbeds to test communications between vehicles and signals that will provide information regarding both safety messages and recommended driving speeds.[23]

Similarly, in 2015, the University of Michigan built Mcity in Ann Arbor, a facility being used by automakers to test and experiment with self-driving cars. Mcity is the world's first full-scale simulated urban environment designed expressly for testing the performance and safety of automated and autonomous vehicles under controlled and realistic road conditions. It is a 32-acre site that was developed to resemble a real city, with 40 building facades, a traffic circle, a four-lane highway, a tunnel, bridge, and even a mechanical pedestrian to test if it can be sensed by an autonomous vehicle.[24] Figure 3, below, is a photograph of Mcity.

Texas DOT (TxDOT) has created a Connected Vehicle Task Force to identify Connected/Automated Vehicle (C/AV) opportunities around various parts of the state. TxDOT and the North Central Texas COG have identified a State-owned managed lane on I-30 between Dallas and Arlington as a potential C/AV testbed. Florida DOT (FDOT) also has several initiatives underway, including two vehicle test beds—in Orlando and Tampa. In addition, FDOT officials have engaged in extensive public outreach efforts to raise awareness and prepare for future coordinated efforts.[25]

MPOs

In addition to State DOT's, MPOs are starting to address autonomous vehicles in their planning. The Houston-Galveston Area Council (H-GAC) is working with the city to develop a wireless communications system that will soon cover all the signals in the City of Houston. This will eventually serve as a backbone that could be used in the future to collect and transmit data from connected and automated vehicles. The Genesee Transportation Council in Rochester, New York, has been identifying how to best integrate C/AV considerations into its long-range

[23]U.S. Department of Transportation. "Connected Vehicle Impacts on Transportation Planning. Technical Memorandum #2: Connected Vehicle Planning Processes and Products and Stakeholder Roles and Responsibilities." January 28, 2015. 28.

[24]http://www.businessinsider.com/university-of-michigan-builds-city-for-self-driving-cars-2015-7. Accessed 20 November 2017.

[25]US DOT. 29.

Table 8 **Autonomous Vehicle Planning Impacts By Time Period**

Impact	Functional Requirements	Planning Impacts	Time Period
Become legal	Demonstrated functionality and safety	Define performance, testing and data collection requirements for automated driving on public roads.	2015-25
Increase traffic density by vehicle coordination	Road lanes dedicated to vehicles with coordinated platooning capability	Evaluate impacts. Define requirements. Identify lanes to be dedicated to vehicles capable of coordinated operation.	2020-40
Independent mobility for non-drivers	Fully autonomous vehicles available for sale	Allows affluent non-drivers to enjoy independent mobility.	2020-30s
Automated carsharing/taxi	Moderate price premium. Successful business model.	May provide demand response services in affluent areas. Supports carsharing.	2030-40s
Independent mobility for lower-income	Affordable autonomous vehicles for sale	Reduced need for conventional public transit services in some areas.	2040-50s
Reduced parking demand	Major share of vehicles are autonomous	Reduced parking requirements.	2040-50s
Reduced traffic congestion	Major share of urban peak vehicle travel is autonomous.	Reduced road supply.	2050-60s
Increased safety	Major share of vehicle travel is autonomous	Reduced traffic risk. Possibly increased walking and cycling activity.	2040-60s
Energy conservation and emission reductions	Major share of vehicle travel is autonomous. Walking and cycling become safer.	Supports energy conservation and emission reduction efforts.	2040-60s
Improved vehicle control	Most or all vehicles are autonomous	Allows narrower lanes and interactive traffic controls.	2050-70s
Need to plan for mixed traffic	Major share of vehicles are autonomous.	More complex traffic. May justify restrictions on human-driven vehicles.	2040-60s
Mandated autonomous vehicles	Most vehicles are autonomous and large benefits are proven.	Allows advanced traffic management.	2060-80s

Table 1 Autonomous Vehicle Impacts by Time Period
SOURCE: Todd Litman. "Autonomous Vehicle Implementation Predictions." Victoria Transport Policy Institute. 8 September 2017.

Transportation Plan. In spite of the long timeframe that significantly exceeds the timespan of a typical long-range transportation plan, State DOTs and MPOs are starting to do extensive research, testing and planning for the eventual full deployment of this new technology. The examples listed above are just a few of the entities that have started to tackle this challenge.

V. FUTURE RECOMMENDATIONS

While much of the precise impact of autonomous and connected vehicles is still unknown and likely to stay that way for a while, not to mention the numerous barriers to market penetration, there are interventions that planners and policy makers should consider now that will put cities and their residents in a better position to accommodate this new technology:

(1) Similar to Recommendation #4 above, there needs to be a cultural shift away from personally owned modes of transportation (the predominant paradigm now), towards mobility solutions that are consumed as a service, a concept known as "Mobility as a Service." To the average American, auto ownership is perceived as a birthright. Under the "Mobility as a Service" concept, transportation services are provided through a unified gateway, generally in the form of a mobile or web app or centralized website, that procures and manages the trip. The gateway mechanism also enables users to pay for the trip when they need it.[27] Ridesharing and e-hailing services, such as Uber or Lyft, operate under this principle. If autonomous vehicles ever take off in a meaningful way, they will most likely start as part of existing e-hailing services, taxis, and other demand response services.

(2) Apply efficient road pricing (e.g. congestion pricing), to discourage single-occupant vehicle (SOV) drivers and encourage riders to use ridesharing services, especially in urban peak period conditions.[28]

(3) While Table 1 above seems to suggest that widespread deployment of autonomous vehicles will likely lead to a reduction in parking demand, as discussed above, there is also likely to be increased congestion due to the increased AV trips, especially if there are more parking lots built to accommodate unutilized AV's. Government planning agencies should be aware of the potential trade-offs between reduced parking and increased congestion. Perhaps peripheral parking

[27] *Wikipedia. "Transportation as a Service." At: https://en.wikipedia.org/wiki/Transportation_as_a_Service. Accessed 27 December 2017.*

[28]Litman. 17.

lots could be constructed at the outskirts of the city and connected to the CBD with premium transit service, subsidized by the City with congestion fees described above. As with the research and development also cited above, government could incentivize businesses to provide this opportunity. For example, they could offer them a tax rebate in exchange for funding the operation of such a service. While peripheral parking lots may alleviate congestion in the CBD, they are likely to result in more deadhead trip ends, as described above. In anticipation of this impact, land use policies and parking requirements should be revised to better accommodate "mobility as a service" options, including shared vehicles and alternative parking arrangements.

Figure 3 Mcity, Ann Arbor, Michigan
http://www.businessinsider.com/university-of-michigan-builds-city-for-self-driving-cars-2015-7. Accessed 20 November 2017.

(4) There needs to be a cultural shift in travel behavior. As has been done on a somewhat limited extent now, more workers should be given the opportunity to shift their work schedules outside the normal hours of 8:00 to 4:00 or 9:00 to 5:00 PM. Shifting this peak demand across a wider span of time will allow AV's to operate during a longer portion of the day and minimize the "deadhead" time as described above.

(5) We can research best practice land use strategies that allow for a greater density of mixed use, and thus create an environment more conducive to AV operation. As stated above, however, these policy changes are much more difficult to implement, given that land use decisions are largely a function of local government and alteration of land use policies usually entails altering the zoning code, which can amount to a very

time-consuming and often contentious process.

(6) While the recommendations above focus on altering the mindset of citizens, which is an important factor in adjusting to any disruptive technology, they do not address the economics. For autonomous vehicles to become widespread, the average cost of an autonomous vehicle must come way down, in parity with the price of an average gasoline-powered automobile on the market today. Even if autonomous vehicles become widespread enough causing most vehicle owners to relinquish their personal automobile , (most likely sharing autonomous vehicles or subscribing to an e-hailing service such as Uber or Lyft), the average consumer will have to realize a significant cost and time savings before they give up the freedom and independence that comes with personal auto ownership and operation.

(7) Cities, manufacturers, and service providers must come up with contingency plans should the service become inoperable or have to shut down for any period of time. This could be due to an extreme weather event, or perhaps the malfunctioning of an AV's operating system. As described above, in a system of connected vehicles, one errant car can have a significant effect on an entire platoon of vehicles. The plan needs to be as minimally disruptive as possible, which would probably be quite challenging in an AV/CV system.

VI. CONCLUSION

In summary, there is still much uncertainty surrounding the future impact of autonomous vehicles. Not only is a cost a prohibitive factor in widespread deployment of autonomous vehicles, there are also numerous regulatory and legal challenges, including liability in crashes, unique situations where a car may need the judgement of a human driver, and accessibility in more rural areas. Nevertheless, in spite of these constraints, many cities and communities around the world are embracing the concept of connected and automated vehicle technologies, perhaps the most exciting emerging technology since the personal computer a few decades ago. As described above, urban planners are incorporating them into their plans with policies focusing on maximizing efficiency and mobility, and safety. Planners are promoting the "mobility as a service concept," as a viable transportation option alongside more longstanding modes such as ridesharing and public transit. Perhaps the greatest challenge to emerge from this rapidly evolving technology is the importance of adaptability of planners and planning to ever-changing conditions. To quote Yogi Berra, "The future ain't what it used to be."

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Colorado
NO OUTLET
DO NOT DRIVE ON TRACKS
LOS ANGELES
NOT A WALKWAY
Metro Rail

SEARS
CLEAR
KEEP

The Future of Autonomous Driving & Its Impact on Transit

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This paper discusses the implications of autonomous vehicle technology on auto use and travel behavior, and the resulting impacts on public transportation. The paper goes on to explore how autonomous driving technology can be used to make more efficient use of bus transportation and to improve service to disabled individuals. The paper concludes with recommendations for transit agencies to engage with federal, state, and local governments and suppliers of autonomous vehicles to promote research, development, and policies that will allow the industry to reap the benefits of these revolutionary and disruptive technologies.

INTRODUCTION

Transit is an inherently conservative industry, and change is tough when users judge performance primarily on the ability to seamlessly deliver consistent service perfectly. Integrating new technology into daily operations has been a challenge for transit, because of costs and reliability issues. Autonomous driving technology will initially disrupt and bring sweeping change to the transit industry.

The Market and Competition from Ride-Hailing and Autonomous Driving

Transit riders can be categorized generally as either captive or choice. Captive riders cannot drive or do not have access to a car. Choice riders choose transit when it can offer a faster, cheaper, or more convenient trip although they may have access to cars. Choice riders can potentially avoid congestion, utilize passive transit to read, work, or sleep. Additionally, riders avoid parking and all associated car storage costs at their destination. Autonomous driving technology is being incorporated into autos, and together with ride-hailing services will create new mobility choices for both captive and choice transit users.

Ride-hailing services, such as Uber and Lyft, are already drawing riders from transit. Clewlow and Mishra of UC Davis recently published a study that showed that in major cities, ride-hailing has already accounted for a six percent reduction in bus ridership.[1]

Ride-hailing companies are making significant investments in autonomous driving. Since 2016, Uber has been testing autonomous driving Volvos in Pittsburgh and recently announced it was buying 24,000 Volvo XC-90's that will be equipped for autonomous driving. Lyft has partnered with General Motors to develop autonomous taxis. Waymo, Google's autonomous car division, is recruiting test customers for its fleet of automated Chrysler Pacifica minivans in the Phoenix, AZ metro area.

For those who wish to drive, automakers including Audi, BMW, Cadillac, Mercedes, Tesla, and Volvo are already offering partially automated "semi-autonomous" driving assistance system (ADAS) packages on some models. While current offerings tend to be expensive luxury vehicles, Tesla is producing a midrange $35,000 Model 3 which will have self-driving features at an additional cost. Other automakers are likely to follow with semi-autonomous driving at affordable prices to remain competitive in the industry.

Fehr Peers reported on the results of modeling seven scenarios in which autonomous vehicles would be available choices for travel. Their findings stated: "Total transit trips declined in five of the seven models tested by a range of -8% to -43%. Of the four models for which we were able to test specific types of transit trips, three showed declines ranging from -26% to -47% for bus trips and -13% to -40% for rail trips."[2]

[1]Clewlow, Regina R. and Gouri S. Mishra (2017), "Disruptive Transportation: The Adoption, Utilization, and Impacts of Ride-Hailing in the United States," Institute of Transportation Studies, University of California, Davis, Research, Report UCD-ITS-RR-17-07. https://itspubs.ucdavis.edu/wp-content/themes/ucdavis/pubs/download_pdf.php?id=2752.

Economics of Transit versus Automated Driving

The economics of transit versus automated driving, either in individually-owned or ride-hailing vehicles, are going to factor into how people decide to travel.

This paper focuses on bus transportation because buses carry the greatest share of ridership among the various transit modes. Based on 2016 data from the Federal Transit Administration (FTA) National Transit Database (NTD), the average operating expense per passenger mile for transit buses was $1.22.[3] Approximately 75 percent of the cost was attributed to labor, salaries and fringe benefits, while passenger fares only covered approximately 24 percent of the operating cost. The average fare per mile was $.296.

For disabled riders using demand responsive service, which is reported separately from transit bus, the average operating expense per passenger mile was $5.08 of which fares covered six percent of the cost, or $.312 per passenger mile. In many instances paratransit service is far inferior to regular scheduled bus service from the customer perspective. Reservations are required 24 hours in advance and pickup time windows can span two hours. The high cost and poor service offered to disabled passengers by conventional paratransit services point to the need for better solutions, which may be facilitated by autonomous driving.

Looking forward to the time when autonomous taxis will be positioned to compete with buses, ARK Investment Management LLC (ARK Invest) analyst Tasha Keeney projects that autonomous taxis will be in commercial service by 2019.[4] Keeney also projects that by 2020, the total operating cost per mile for autonomous taxis will be $.35 per mile compared with $3.50 per mile for taxis today.

Although the out-of-pocket cost for bus operations is slightly less than the estimated cost for autonomous taxis, some users may be willing to spend slightly more for efficient on-demand service. The current average subsidy is $.92 per

[2] *Fehr & Peers, "How will autonomous vehicles influence the future of travel?" http://www.fehrandpeers.com/autonomous-vehicle-research/ accessed February 5, 2018.*

[3] *National Transit Database, "2016 Operating Expenses," Federal Transit Administration, https://www.transit.dot.gov/ntd/data-product/2016-operating-expenses accessed February 5, 2018*

[4] *Tasha Keeney, "Mobility-As-A-Service: Why Self-Driving Cars Could Change Everything", ARK Invest, Inc., http://research.ark-invest.com/hubfs/1_Download_Files_ARK-Invest/White_Papers/Self-Driving-Cars_ARK-Invest-WP.pdf accessed November 21, 2017*

[5]US Department of Transportation, "Federal Automated Vehicles Policy - September 2016," https://www.transportation.gov/AV/federal-automated-vehicles-policy-september-2016 Accessed February5, 2018

[6]SAE International, "Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles," Standard J3016_201609, https://www.sae.org/standards/content/j3016_201609/ accessed February 5, 2018

bus passenger mile. From a transit funding perspective, this subsidy would almost be three times the estimated cost of an autonomous taxi trip. This cost difference will not go unnoticed by the governmental entities funding transit.

Autonomous Vehicles in the Transit Planning Process

Over the previous 50 years, transit planners assumed travel choices were limited to modes with familiar characteristics, such as bus, rail transit, and autos. Model parameters could be calibrated by using survey data obtained from users of those modes. Today, however, transit planners face an unprecedented challenge to predict the way on-road vehicles will be used when they become autonomous. Planners will need to find ways to properly characterize autonomous vehicles and include them in the spectrum of mobility choices.

Definitions of Autonomous Driving Capabilities

In the Federal Automated Vehicles Policy released in September 2016, the National Highway Traffic Safety Administration (NHTSA) changed its original five levels of automation (zero to four) to correspond with the six levels of automation (zero through five) developed by SAE International, which have become the accepted standard definitions, as shown in Figure 1.[5,6]

IMPLICATIONS OF AUTOMATION LEVELS ON DEMAND FOR TRANSIT

How automation will impact travel demand and the transportation infrastructure will depend on the degree of automation and the rate at which autonomous vehicles are introduced into the market. Many vehicles today are already equipped with ADAS packages with Level 1, 2, or 3 automation. Automation levels from one through four will still require a driver to be present in a vehicle. Level 4 relieves the human driver of the task of constantly monitoring the driving environment, which will change the experience of driving. Level 5, as defined by NHTSA and SAE, will open entirely new categories of travel because non-drivers will be able to make individual trips and vehicles will be able to shuttle empty, as needed.

Changing the Value of In-Vehicle Travel Time

Vehicle automation could ultimately revolutionize the in-car experience. Current drivers could potentially spend a large portion of in-vehicle time engaged in other activities only passengers traditionally engage in. The in-vehicle experience of the driver becomes comparable to a trip a transit passenger experiences. Evidence to support that hypothesis can be found by examining the direct elasticities of in-vehicle time for drivers and transit passengers. Zhang and Timmerman's report showed that information communication technologies (ICT's) make multitasking common among public transportation users and that travel time elasticity is positively affected by the ability to undertake some tasks while riding in public transportation.[7] Littman reports on travel time elasticities obtained from travel surveys in Portland, OR.[8] The Portland, OR data show that in peak AM hours, direct demand travel time elasticity for transit users was 57 percent of the comparable direct demand elasticity for auto drivers, and in the peak PM hours, travel time elasticity for transit users was only 26 percent of the comparable elasticity for auto drivers. The implication is that transit passengers are far less sensitive to changes in travel time than drivers, possibly because they can engage in other productive activities while in motion.

Level 3 Impacts on Driving

Level 3 automated vehicles allow the driver to perform tasks that would currently be considered distracted driving, such as texting, talking on the phone, or conversing with passengers. The driver, however, would still need to be ready to take control of the vehicle at a moment's notice. To ensure that the driver would be ready, some vehicle manufacturers are incorporating technology to monitor the driver's level of attentiveness and issue appropriate warnings. Vehicles could be equipped to provide both video and audio information to all vehicle occupants. The net result will likely be that time

[7]Junyi Zhang and Harry Timmermans, "Scobit-Based Panel Analysis of Multi-tasking Behavior of Public Transport Users," Transportation Research Record: Journal of the Transportation Research Board, No. 2157, Transportation Research Board of the National Academies, Washington, D.C., 2010, pp. 46–53. DOI: 10.3141/2157-06

[8]Todd Litman, "Understanding Transport Demands and Elasticities How Prices and Other Factors Affect Travel Behavior," Victoria Transport Policy Institute, 12 March 2013 http://www.vtpi.org/elasticities.pdf. Accessed July 31, 2014

spent in the driver's seat can be used to participate in activities passengers usually partake in like reading, viewing videos or pictures, writing, and conversing. The frustration, stress, and boredom of being caught in traffic will be considerably lessened as well. Another feature already being tested is autonomous valet parking. The driver gets out and the car proceeds at low speed to a parking space. Later, the driver summons the car from the parking space using an app on his or her smart phone. Vehicles equipped with this level 3 automation can be expected to encourage longer trips and more travel during peak periods because of the reduced active responsibility of the driver.

Level 4 Impacts on Driving

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Figure1: SAE Table - International Levels of Driving Automation for On-Road Vehicles 4

Level 4 vehicles are defined as cars being able to operate autonomously in predetermined areas or under certain conditions such as clear weather. A driver would not be required to remain constantly ready to take over the responsibility of driving. Vehicles could also be configured to allow more freedom for the driver to move about in the cabin, and engage in time intensive activities such as sleeping, grooming, preparing and eating a meal, or working out.

Level 5 Impacts on Driving

Level 5 vehicles are defined as fully autonomous vehicles that do not require a licensed driver to be present in the vehicle while in motion. That opens several unprecedented possibilities of potential new trips. Vehicles may be able to perform certain types of trips without any human occupants. Repositioning, or deadheading trips, which are common aspects of public transit and truck operations, would become feasible for personal autos. For example, one family member could use a vehicle for a commute trip and send the vehicle home for use by another family member. In another example, after dropping off a passenger, a vehicle could be dispatched to a remote parking or staging area to avoid parking charges in areas with limited parking availability and/or high costs. Vehicle interiors could potentially combine elements of automotive design and more comfortable accommodations. The autonomous vehicle could become a mobile extension of a home.

The ability of Level 5 vehicles to drive themselves without any riders supports a viable business model for autonomous taxis. As noted earlier, Uber and other "mobility on demand" providers are already making significant investments to develop autonomous driving vehicle fleets. Once the need to pay a driver goes away, the cost of a taxi ride can be reduced significantly, potentially becoming less than the cost of a similar trip on bus transit. In many areas, the convenience of on-demand autonomous taxi service will obviate the need to own a car.

[9]VanderWerf, J. et al, "Effects of Adaptive Cruise Control Systems on Highway Traffic Flow Capacity, " in Transportation Research Record: Journal of the Transportation Research Board No. 1800, Transportation Research Board of the National Academies, Washington, D.C., 2002, pp. 78-84. http://trb.metapress.com/content/u06km60x41v70p41/fulltext.pdf?page=1 Accessed July 4, 2013

[10]Tientrakool, P., et al, "Highway Capacity Benefits from Using Vehicle-to-Vehicle Communication and Sensors for Collision Avoidance," 978-1-4244-8327-3/11, in Vehicular Technology Conference (VTC Fall) 2011, Institute of Electrical and Electronics Engineers (IEEE), 2011

[11]CityMobil2, "Cities Demonstrating Automated Road Passenger Transport," web site, accessed November 12, 2015 http://www.citymobil2.eu/en/

[12]Citymobil2 Demonstration, Trikala Greece, https://www.youtube.com/watch?v=pLsmsTj393o accessed August 22, 2017

Changing Demand for Transit

Level 5 autonomous vehicles will offer mobility to those transit captives who cannot drive, and, in conjunction with automated ride-hailing, can offer mobility to those who do not have ready access to a car. For choice riders, self-driving cars can offer amenities similar to those of transit in terms of how one can use time while traveling, to read, sleep or work. According to studies, autonomous cars could double highway capacity.[9,10] If that is coupled with the ability to self-park, the transit advantage could melt away, resulting in a significant impact to transit ridership.

HOW CAN PUBLIC TRANSIT ADAPT TO, AND BENEFIT FROM, AUTONOMOUS OPERATION?

To meet the challenges posed by autonomous vehicle technology, transit agencies should adapt both technologically and institutionally.

Transit's Technological Response

Transit has been an early adopter of automation in fixed guideway rail systems. For "rubber tire" on-road transit, the European Union's CityMobil2 project led the way to autonomous driving by successfully demonstrating automated low-speed (10 kph) transit vehicles in seven European cites, carrying more than 60,000 passengers, and sharing the infrastructure with other road users.[11] CityMobil2 produced a video shared on social media of a demonstration in Trikala, Greece, shown in Figure 2, which foretells one likely future for public transit operation. An "official driver" sits at a desk remotely overseeing autonomous transit vehicles.[12]

Many local jurisdictions in The United States are undertaking demonstrations of low-speed, ten to twelve passenger autonomous vehicles based on the EasyMile vehicle developed for CityMobil2. Figure 3 shows one of these vehicles in a December 2016 demonstration in Tampa, FL. There are many opportunities for the transit industry and local, state, and the federal government to accelerate research and deployment of autonomous driving systems for transit buses. Compared with automobiles and trucks, there are approximately 100,000 buses and paratransit buses in service across The United States. Most bus original equipment manufacturers (OEMs) act as systems integrators but do not have the capacity, expertise or financial incentive to research and develop autonomous driving systems. Transit agencies will need to push for assistance from the Federal Transit Administration (FTA), state, and local governments to sponsor and fund the research and development.

Three specific areas of autonomous driving have the greatest potential to benefit the transit industry: 1) autonomous collision avoidance and emergency braking, 2) autonomous systems to enable bus platooning, and 3) autonomous driving technology to improve service to disabled passengers. These autonomous driving systems are not "pie in the sky" notions, but have been successfully demonstrated in pilot projects.

Autonomous Collision Avoidance and Emergency Braking

Because bus collisions have been a significant, long-term problem, Autonomous Collision Avoidance Systems can produce significant benefits for the transit industry. Data from the FTA NTD show that buses and vanpools have been involved in 85,391 collisions, experienced 1,340 fatalities, 201,382 injuries between 2002 and 2014, and created expenditures for casualty and liability expenses of $5.7 billion between 2002 and 2013.[13]

The average annual cost per transit bus for casualty and liability expenses is about $6,600.00. Data from a recent study conducted by the Washington State Transit Insurance Pool showed that 65 percent of $53 million in bus claims incurred over 13 years could have been prevented by using Autonomous Collision Avoidance and Autonomous Emergency Braking systems, resulting in significant reductions in collisions, fatalities, injuries, and insurance costs.

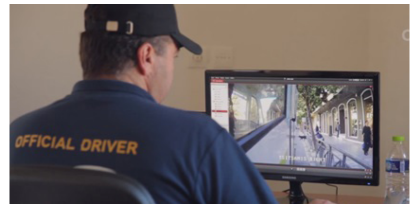

Figure 2: Trikala, Greece, the Bus Driver Telecommutes to Work

Figure 3: EasyMile EZ10 Twelve-Passenger Autonomous Vehicle

[13] *J. M. Lutin, A. L. Kornhauser, J. Spears, L. F. Sanders, "A Research Roadmap for Substantially Improving Safety for Transit Buses through Autonomous Braking Assistance for Operators," Compendium of Papers, Paper Number 16-1246, 95th Annual Meeting of the Transportation Research Board, Washington, DC, January 12, 2016*

Figure 4: Minnesota Valley Transit Bus on Shoulder System (BoSS) Pilot Project

[14]Spears, M. J., J. M. Lutin, Y. Wang, R. Ke, S. M. Clancy, "Active Safety-Collision Warning Pilot in Washington State'" Final Report for Transit IDEA Project 82, Transportation Research Board of the National Academies of Sciences · Engineering · Medicine, May 2017, 33 pages, http://onlinepubs.trb.org/onlinepubs/IDEA/FinalReports/Transit/Transit82.pdf, accessed August 22, 2017

[15]Craig Shankwitz, "Minnesota Bus on Shoulder System (BoSS)," Automating Public Mass Transit in the Connected and Automated Era, Presentation at the Transportation Research Board Annual Meeting, January 13, 2015

[16]J. M. Lutin and A. L. Kornhauser, "Application of Autonomous Driving Technology to Transit - Functional Capabilities for Safety and Capacity," in Compendium of Papers, Paper Number 14-0207, 93rd Annual Meeting of the Transportation Research Board, January 15, 2014, Washington, D.C.

Autonomous Steering and Lane Keeping

Autonomous driver assistance systems have the potential to improve the capacity and reliability of bus service. Autonomous steering control has been successfully demonstrated to allow buses to operate safely and reliably on narrow freeway shoulders and achieve travel time savings and lower operating costs than building light rail in the corridor. Figure 4 shows a Minnesota Valley Transit bus operating in a narrow shoulder on I-35 West, which was part of a Bus on Shoulder System (BoSS) pilot project to test the technology.[15] Buses were equipped with sensors and lateral guidance controls that autonomously keep the bus centered in the narrow shoulder.

Autonomous Bus Platooning

Level 3 autonomous driving technologies include Co-operative Adaptive Cruise Control (CACC) which has the potential to increase capacity by enabling buses to operate at close headways, called "platooning." CACC can produce dramatic increases in highway capacity from 103 per cent to 273 percent.8, 9 Drivers normally maintain sufficient separation from the preceding vehicle to allow them to come to a safe stop if the vehicle ahead suddenly decelerates. CACC will sense speed changes and react quicker than a human driver. Consequently, platooning can decrease the distance and time interval between vehicles following one another in a lane. Lutin and Kornhauser showed that CACC could increase capacity on the contra-flow Exclusive Bus Lane (XBL) into Manhattan shown in Figure 5 by 480 buses per hour, which would equal the capacity of a new commuter rail tunnel.[16]

Autonomous Driving Technologies to Improve Service to Disabled Passengers

One of the greatest benefits of driverless transit would be to improve service to disabled passengers. Paratransit service for disabled individuals is often inconvenient, unreliable, and very expensive for transit agencies to operate. Disabled passengers often need to reserve a trip at least 24 hours prior to departure and they are told that their pick-up may occur any time within a two-hour time frame. The average operating cost per transit passenger trip in 2014 was $3.68. 39 percent of that cost was covered by fares. In comparison, the average cost of a paratransit trip to serve a disabled passenger was almost ten times more expensive, $34.43, and only 8 percent of that was covered by fares. Applying autonomous driving technology to paratransit service could dramatically improve service and reduce operating costs. There are, however, numerous challenges that would need to be overcome. The needs of mobility impaired individuals must be considered in the design of autonomous vehicles. In particular, robotic assistance will be needed to facilitate boarding, alighting, and on-board device securement. The ability to remotely monitor and communicate with disabled passengers also will be necessary.

Precision Docking for Buses

Boarding and alighting from transit buses can be a daunting challenge for mobility impaired individuals. "High" bus floor levels can be approximately 35 inches (89 cm) above street level and require use of a lift, and "low" bus floors can be 7.5-15 inches (19-38 cm) above street level depending on the availability of a "kneeling" suspension. Low floor buses generally have a deployable ramp for use by mobility impaired passengers. Both lifts and ramps take time to deploy and to retract. Lifts can be unreliable and a frequent cause of passenger injuries.

"Level boarding" in which the bus floor is level with the bus stop is by far preferable for mobility impaired passengers and speeds boarding and alighting for all passengers. However, to comply with accessibility regulations for level boarding of light rail vehicles (which would apply to level boarding for buses as well), the horizontal gap between the vehicle and the platform edge must be no more than 4 inches (10 cm).[18] That gap can be difficult to maintain with manual driving.

Figure 5: Contra-Flow Exclusive Bus Lane into Manhattan[17]

[17] *Port Authority of New York and New Jersey http://www.panynj.gov/bridges-tunnels/lincoln-tunnel-xbl.html*

[18] *United States Access Board, "Subpart D -- Light Rail Vehicles and Systems," https://www.access-board.gov/guide-lines-and-standards/transportation/vehicles/technical-assistance-manuals-on-adaag-for-transportation-vehicles/subpart-b-buses-vans-and-systems, accessed August 23, 2017*

[17]Port Authority of New York and New Jersey http://www.panynj.gov/bridges-tunnels/lincoln-tunnel-xbl.html

[19]Gregg, R. and B. Pessaro, "Vehicle Assist and Automation (VAA) Demonstration Evaluation Report," FTA Report No. 0093, National Bus Rapid Transit Institute, Center for Urban Transportation Research, University of South Florida, Tampa, FL, January 2016, 61 pages, https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/FTA_Report_No._0093.pdf, accessed August 23, 2017

[20]Ibid.

Figure 6: Precision Docking Achieved by the VAA Pilot[20]

The Lane Transit District in Eugene, Oregon conducted a test that demonstrated the feasibility of autonomous precision docking on its Emerald Express (EmX) Bus Rapid Transit (BRT) line. The FTA sponsored pilot project, the Vehicle Assist and Automation (VAA) Demonstration, equipped a 60 foot (18 m) articulated bus with a lateral guidance system that followed a trail of magnets embedded in the pavement.[19] The magnetic guidance system consistently achieved horizontal gap standard deviations less than 0.76 inches (1.94 cm) from the target gap of 1.6 inches (4.0 cm). With the VAA guidance disabled, maximum standard deviation reached 4.4 inches (11.08 cm). Figure 6 illustrates the precision docking achieved by the VAA pilot.

Autonomous BRT as an Alternative to Light Rail

The net result of combining autonomous platooning with precision docking will produce a BRT-type service that can offer the same capacity and service as rail transit with significantly less cost. Cities considering whether to enter FTA's New Starts process for light rail or streetcars should consider that autonomous driving may make BRT a more viable and cost efficient option.

Rail transit will still offer advantages over autonomous BRT in a several situations. For example, where light rail systems already exist, it may make sense to use LRT for system extensions to avoid the need to transfer between modes and to achieve economies of scale. The need to overcome geographical barriers to major employment concentrations, such as bridging over, or tunneling under rivers, constitute situations in which rail's superlative capacity may be a more cost-effective and efficient choice.

TRANSIT'S INSTITUTIONAL RESPONSE

The transit industry's institutional response to the introduction of autonomous driving should be to:

(1) Promote shared-use taxis as a replacement for transit on many bus routes and for service to persons with disabilities. Auton-

omous vehicles have the potential to provide less expensive and superior service than conventional paratransit. As a precursor to autonomous taxis, ride-hailing services should be required to provide accessible vehicles and assistance in boarding and alighting for disabled passengers. Vehicle manufacturers should be required to make autonomous vehicles accessible for disabled, especially Level 5 autonomous vehicles.

(2) Concentrate transit resources in corridors where more auto traffic and parking will be too costly and too congested, and where transit can increase the people carrying capacity of a lane beyond that of a general traffic lane. As individually owned autonomous vehicles become a larger share of the auto market, longer commutes will become the norm and delays due to traffic congestion will not cause as much stress. There will be, however, practical limits to capacity and the tolerance of commuters. Public transit, bus or rail, operating on rights of way or exclusive lanes separated from auto traffic, will still be a necessity, especially on radial corridors connected to urban centers and employment concentrations.

3) Exit markets where transit load factors are too low to justify operating a transit vehicle. Ridership on urban bus routes is likely to be most vulnerable to autonomous taxis because ride-hailing services have already encroached on the market. Suburban bus routes, which often have very low cost recovery from fare revenue, and infrequent schedules, also will be severely impacted. Given the differential between operating costs for buses and autonomous taxis discussed earlier, it may make more sense in terms of service and cost to eliminate bus service and subsidize autonomous taxi rides for economically disadvantaged patrons.

4) Focus attention on land use – work with partners to create Transit-Oriented Development (TOD) that limits the need for driving and where trip-end density will provide enough riders for both transit and autonomous shared-taxi services.

[21]PClewlow and Mishra, (2017) Op. Cit.

The previously cited study by Clewlow and Mishra found that many trips on ride-hailing vehicles were shifted from walking and bicycling as well as transit.[21] As autonomous taxis reduce the cost of trip-making, further shifts from active transportation modes are expected, which could lead to adverse impacts on community health. Walkable and bikeable streets are integral to TOD. They provide opportunities for healthy, active transportation, and convenient access to transit stops which encourages transit use. Concentrated and mixed development also provide higher trip-end densities that will warrant more frequent transit service in both peak and off-peak periods and shorter waits for autonomous taxis. That, in turn, can promote more ride-sharing and reduce single occupant vehicle trips. Transit agencies and policy makers must become even more engaged in the land-use planning process.

CONCLUSION

Ultimately, transit will be operating alongside, and competing with, autonomous shared ride vehicles. As the auto industry moves closer to marketing autonomous vehicles, transit planners must become more engaged and make transit's voice heard by government and vehicle manufacturers to better take advantage of autonomous technology and to promote policies that insure access to all sectors of the public and create sustainable transportation infrastructure.

Emerging Transportation Technology

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Many professionals, business interests, city boosters, self-anointed opinion leaders and lifestyle mavens promote various urban, social, political and cultural agenda which are not always consistent, even though they are individually attractive or fashionable. The interest in transit, and especially fixed-guideway (FGT) and rail transit, has remained especially popular among urban and transportation planners, despite the generally insurmountable difficulties in development, operation and finance of those systems.

FGT is a concept that has evolved to describe a transit (public people movement) operation or system layout that is fully contained within a right-of-way where no FGT vehicle is able to operate off of the guideway's right-of-way. Often the FGT is underground, but it may be on the surface or elevated. Until recently FGT was confined to various forms of rail operations, but now it also includes roadways which restrict bus operations in the same way: busways, that are different from bus lanes where buses operate on as well as off of a right-of-way. FGT really means a transit service that creates a relatively permanent presence in the urban environment, and that reinforces and influences the development and use of nearby land amenities and services to generate large volumes of passengers. A bus lane on the other hand can be cancelled or modified so that adjacent land uses cannot be planned with the assumption of the operational impact of a long-lived facility. In addition, bus lanes can allow bus movement on normal streets for the collection and delivery of passengers in a diffused environment that does not provide the same level of land investment value that can be generated from a FGT station's concentration of movement.

FGT is usually a hoped-for panacea for the urban problems of traffic congestion, viable mixed land use development (read: old style main streets but for modern urbanites) and investment in place of decay. More cynically it is often something new that transportation and planning professionals would like to have in their technical tool box. The irony in this is that the benefit of FGT stems mainly from its 'fixed' condition and concentrated operation, while the urban environment it serves is un-concentrated. Unfortunately, zoning and building control are generally confined to jurisdictions too small to have significant impact on travel patterns and the ability to force concentration of the urban environment. The un-concentrated parts of the urban environment are served largely by private vehicles, with some support from urban bus service. As a 'third way' compromise, bus lanes have been introduced. As an effort to reduce the high cost of rail FGT, FGT busways use modified buses, but their rubber tire bus appearance diminishes the public response to that technology in comparison to rail FGT.

Even with the most attractive or most efficient FGT busways it is nearly impossible to create new FGT transit-supporting land uses. This is because a full and balanced loading of the transit vehicles requires corridor focused residential and work location pairs. Land use and transportation accessibility planning practice and research since the time of Pushkarev and Zupan, including that by the author in countries as varied as the United States, India, Pakistan and Kenya, shows that when either part of these pairs is off of the corridor, corridor transit use declines. That has led to a desire to orient both parts to the corridor, but this is difficult at more than one location due to the weakness of land use control at the metropolitan level. Even when significant quantities of both employment and housing are located on the corridor the chances are limited that these will translate into actual corridor travel pairs because the corridor is only a small part of the metropolitan area and both the employment and housing along it are not restricted pairs. What this means is that a resident on the corridor does not necessarily work on it even though he could, and vice versa.

Likely outcomes of government-directed land use and transportation planning are factory town development and corridor-oriented transit-oriented development (TOD). In factory town development, like that of the past, or as found today in countries like China and India (or even American university campuses), where workers live within walking distance of their actual work places, transit use is virtually eliminated, but access to other areas is also limited. In corridor (TOD) development attractive, dense and expensive, but unpaired land uses attract residents or workers who can afford private vehicles to access work and employment opportunities off the corridor (as evidenced by the retention of private automobiles even in some of the most successful transit corridors such as that in Arlington, Virginia) Well-serviced transit corridors, paradoxically, result in the need for parking space at transit nodes which raises the density and cost of developed sites because the space required for parking is not dedicated to generating and attracting land uses. In some cases the less affluent could be attracted to these higher cost locations if they reallocate their income away from private vehicles, but this would require a remarkable pairing of residence and work on the corridor.

From the above it can be seen that feasible FGT is nearly impossible to create in new urban environments without severe development controls and central planning that has as its goal some sort of FGT corridor with concentrated development at a limited number of mixed land use nodes. For a new system this would normally require almost all future development to be located only at those nodes, leaving the vast majority of metropolitan land outside the nodes at a very low density. That might be an acceptable outcome if people's travel behavior were confined only to transit corridors, but there is no assurance of that. If that preferred corridor travel did result nodal land along the corridors would gain the vast majority of increased metropolitan land values while almost all land outside of the nodes would lose value. . Such a situation is especially problematic in today's world where individually-owned real estate is one of the great investment opportunities for most people and only a few individuals could afford the nodal land. Still the planners keep working toward this model.

ON-DEMAND, SHARED AND SELF-DRIVING VEHICLES

With the advent of coordinated, un-licensed private vehicle management for mobility services such as Uber, Lyft, etc., and the recent extension of this model to include shared vehicle use offerings, the promise of much more efficient private vehicle operation has been introduced. In that operation the maximum potential mobility is expanded to all origin and destination pairs and the maximum potential efficiency is that of the entire road network capacity. The capacity under that scenario is currently limited by the vehicle size and passenger capacity, and by the road space required for human reaction time. Testing is under way of self-driving vehicles which do not require a driver, but rely on communications, sensor and artificial intelligence decision-making technology for operation. Use of such self-driving vehicles has the potential can offer almost unlimited road capacity and demand-responsive operation. In addition overhead costs would be significantly reduced and vehicle capacity increased without a driver.
Ownership of vehicles is a subject that has yet been little discussed. Although self-driven vehicles could be trip-maker-owned, few trip-makers are in continuous motion, but only make

a few trips per day with the result that the vehicle is in operation for a short part of the day. Mobility-provider-owned vehicles in contrast, could be in nearly continuous operation making the cost per mile or per trip extremely low so that it would be much more efficient for mobility service providers to own the vehicles.

These new technologies and operations offer the potential for high efficiency in urban environments within the road network, with two particular drawbacks - the need for separate drive trains in each vehicle compared to shared drive trains in rail transit, and the less than optimal efficiency of self-driving vehicles operating on roads with traditional human-operated vehicles. Given the vastly greater area covered by roads in comparison to that within FGT corridors combined with efficient vehicle loading from sophisticated passenger assignment algorithms, the cost of individual drive trains in self-driving vehicles would be offset by the benefits of the potentially universal origin-destination coverage of the emerging system. That leaves the second drawback of shared individual vehicle operation on roads alongside individual privately-operated vehicles. Although sophisticated shared ride services would certainly offer some improvements over traditional taxis, the need for human operators and vehicle operation on roads shared with human operators would greatly reduce the system efficiency because of the continued impact of human reaction time.

Today, roadways have capacity limits due mainly to low-occupancy in vehicles, to the interaction with other vehicles at intersections and to the spacing of vehicles to accommodate human reaction. However, if roadways were used exclusively for self-driving, shared passenger vehicles the roadway space capacity efficiency could be potentially increased toward almost 100 per cent (the amount less than 100% would be due to vehicle non-passenger space) as a result of increased acceleration, GPS-linked coordination and almost no reaction time needs. Self-driving S vehicles could start and stop at almost every location on the roadway with little friction from other self-driving vehicles because of the GPS navigation system movement optimization. In order to achieve the technical operations potential of self-driving vehicles, human-operated vehicles must be removed from the urban road system in order to allow for the necessary full access coverage for urban travel origins and destinations. The greater the density, number and area of trips, the greater would be the potential to assign passengers efficiently to vehicles. The efficiency of FGT is only along its right-of-way and for the parts of the origin-destination travel that are contained within its corridor - or more precisely, at reasonably spaced corridor stations. Outside of those corridors, trips must be performed or completed by non-FGT vehicles. Even trips within the FGT corridor itself may be diverted to self-driving vehicles as a result of their flexible schedules. When all trips can be more densely loaded and routed on the entire roadway network, there would be no need for corridor FGT for the vast majority of all trips, except for operation in low density environments. The potential to remove FGT would remove an expensive capital and operations cost from urban government general budgets, transfer the full cost of mobility to the users, and the profit to private operators. Mobility would be greatly increased, but the current public subsidy to transit and private vehicle capital and operations would also be removed and require a new regime to ensure equity of access.

SMART CITIES AND URBAN TOTAL SYSTEM MANAGEMENT

From this analysis it becomes clear that the goal of the promoters of self-driving vehicles is to establish a new transportation and mobility system composed of self-driving vehicles and the supporting operational system often termed the Internet of Things (IoT).
To achieve that, the main challenges will be to develop the IoT, impose control over the road network, remove private, human-driv-

en vehicles and allow only self-driving vehicles connected to the new vehicle operation system to use the road network. The scale of this effort would seem to be a tall order. However, 100 years ago there were many animals and animal-drawn vehicles on city streets, yet those disappeared within a very few years. Moreover, even today there are extensive vehicle restrictions on roadways, such as on those for high-occupancy and bus lanes.

How would the system function? All self-driving vehicles would need to be linked to a common GPS navigation system. The vehicle's own operational system would also have to be common. Even vehicle size and performance specifications would need to be standardized for the navigational system to coordinate. The same would be true for road and intersection design and regulation. In addition, sensors, traffic control devices and the central smart city control system would have to be fully compatible with all the above.

It is highly unlikely that local governments could operate and manage so much integration and standardization, in light of the general failure of metropolitan scale planning and systems operation. However, that failure is largely due to the nature of jurisdictional government. Non-jurisdictional systems providers on the other hand, such as Google, Microsoft, Amazon and Facebook, have managed to succeed in spanning their standardized control across almost all jurisdictions. What they have not demonstrated yet is the extension of this control to ubiquitous physical assets that operate in jurisdictions, although they are trying to achieve this in innovative ways. Ultimately uncontrolled cyber-technology can be transferred to self-driving vehicles and systems that have no relationship with or need for jurisdictions; but only need standardization, operational freedom and a unified system.

An existing physical system is present in the form of roads, which would not have to be assembled piecemeal, and whose ownership is almost exclusively public and for which there are no competitive private claims. That has some similarities to air and water spaces, except that roads and the origins and destinations they lead to are fixed.

The challenge of implementing such a mobility system can best be understood by a consideration of the system components and the current operators which are presented below:

+ road and intersection design and operations - governments
+ traffic control devices - governments
+ enforcement - governments
+ GPS navigation - individual commercial providers
smart cities sensors and monitoring - commercial providers, private operators, some governments
data base and computer
+ operating systems - limited commercial providers
+ vehicles - all users public and private, governments
vehicle design and performance - mainly individual business decision with some individual influence and some government regulation

All the above would need to be perfectly coordinated for the system to work. It would be challenging for government to combine the above components and fit them together to the precision necessary for the envisaged mobility system, especially considering the speed with which technology is currently advancing. Operation by technical government entities such as NASA, would also be possible, but is unlikely due to the separate and advanced development of specific technologies and vehicles by the private sector. Although it is conceptually possible for individual components and locations to be operated by different entities, the additional coordination of these would be challenging and costly.

That would suggest private operation and maintenance of the entire system - even the roads which have heretofore been largely in the public domain. A long-term leasing or concession arrangement subject to government oversight that would allow the deployment of unified systems and required maintenance by the operator. This would also provide an answer to the difficulties that local government has in maintaining roads and other related infrastructure. If a long-term lease or concession arrangement were adopted some sort of utility regulatory structure would be needed mainly to ensure fair pricing, proper operations and conformity with various standards and regulations. Moreover, due to the likely proprietary nature of operational software, vehicles and supporting equipment, it is unlikely that the initial system operator will ever be replaced. The mobility system operator would also need wide regulation and enforcement power to ensure that the system operation is not compromised. This would be especially noticeable on roads where only use by the operator would be allowed, which would eventually be all roads. That would restrict human-operated vehicles initially from priority roads, and this restriction would be rapidly extended to all roads to accommodate the efficiency needs of the investors and system operators. Accompanying this, the benefits of giving up private vehicles would be widely promoted and initially subsidized such as in the 'cash for clunkers' program or by tight control of mobility charges.

Increasingly sophisticated electronics in private vehicles and installation of electronics throughout the urban system are well under way providing the initial input to the new mobility system. An example of this type of system is the growing world-wide lobby for 'smart cities.' So-called smart city planning for city-wide integration of urban activities and services would initially entail the extensive installation of sensors, monitors and devices to efficiently link and monitor individuals, locations and behavior. The most well-known example of this is in the core City of London area where there is almost complete monitoring for security purposes. Beyond security, sensors, monitors and devices can also collect real-time, detailed and comprehensive information at the individual level about service demand and consumption.

In providing the potential

for ultimate efficiency, the mobility system would calculate specific charges for each individual at each time for each trip, reflecting the actual cost. This type of system has already been partially introduced through cell phone and ISP linkage with GPS tracking. This system would specifically calculate and apply real time user charges through a universal individual identification and monitoring system. Individual identification numbers connected to a database could also be used to apply subsidies such as for senior citizens, children, unemployed, handicapped, etc. The current transportation system imposes charges in various unconnected and indirect ways such as property taxes, gas tax, tolls, and ticketing, which separate capital, maintenance, operations costs and policy-based fare and access charges, distorting the perception of cost by making the actual cost of travel very different from the charge paid. The new mobility system would introduce a more transparent combined cost-based charge which would be a major change from the current travel pricing regime.

In addition, the smart city system would be used to capture revenues automatically and without the need for traditional human monitoring, enforcement and collection. Under this system debiting could be made in real-time from the designated source of funds. Anyone who has received an automated camera-generated speeding ticket has experienced the first stage of this automated and anonymous system. The next stage would be direct debiting rather than a bill.

It should be noted here that this specific use of the smart city internet of things (IoT) is for the mobility system. The majority of travel is work- and subsistence-related and so is unavoidable and largely involuntary. Management and operation of this system would provide the opportunity to charge a monopoly profit for a large part of human endeavor. Moreover, there would be little to stop its intrusion into all other sectors of life. As a result, the new mobility system is almost certain to become a regulated monopoly by jurisdiction if not by larger geographic region. This new transportation system is likely to resemble the regulated cable TV monopoly on steroids. Even with price regulation, the scale of the system is so large that the profits on individual components and on such a large part of human endeavor may dwarf all other investment opportunities. Moreover, since this new system would have major urban development, services, finance and consumption impacts, the additional and likely unregulated potential economic and political power to be derived cannot yet be imagined or overstated.

Self-driving vehicles would initially and mainly be in urban areas because of jurisdictional, travel density and cost reasons just as cable TV and high speed Internet have not yet reached many non-urban areas of the country. The needed private driver-operated vehicles in suburban and rural areas (where travel to individual destinations could not be grouped) would ultimately be restricted within urban areas, requiring transfer from non-urban to urban transportation systems, and even urban entry charges.

Moreover, the current road infrastructure paradigm is likely to change with an increasing portion of transportation infrastructure transferred to commercial operators and its associated costs charged directly to users. That would almost certainly mean the removal of gas tax and even property tax from urban mobility funding. Since urban mobility system users would be paying the direct costs for their mobility, they would object to subsidizing the huge portion of the national transportation infrastructure outside of urban mobility systems which would have to be supported by much higher gas taxes, property taxes or tolls in those areas.

This likelihood is suggested by the recent increase in professional discussions of implementing vehicle mile traveled (VMT) charges on the shared road infrastructure for private road users rather than using a common gas tax fund. Support for this approach will grow as electric vehicles are introduced and collection of gas tax decreases. This support is understandable since the administrative class is now more urban than it was a generation ago and more willing to impose new charges on less-affluent, non-urban and private car-owning families that they do not identify with. Ultimately this could provoke political opposition or increased migration to efficient urban areas.

THE NEED FOR MOBILITY-ORIENTED DEVELOPMENT

The establishment of separate urban and non-urban mobility systems would at some point be intolerable for the suburban and rural populations who would be forced to lower their standards of living space and independence. For some, this could be facilitated by a priority program to make urban density affordable. One way to achieve this is through the greater use of vertical space, shared living and working facilities, etc. Even in his Plan Voisin for Paris 100 years ago, le Corbusier envisaged shared child care, recreation, parking and open space for the early motor age.

Perhaps, the necessary form of future urban development would be more like that of Doxiadis' Ekistics than the traditional modernism of le Corbusier. Doxiadis envisaged the ultimate meeting of all urban neighborhoods and settlements as conglomerations. While some shared services such as fire, police, shopping and recreation may necessitate some degree of urban density clusters, the need for high density nodes to support FGT would fade away. As a result, the currently fashionable, but expensive and difficult to achieve transit-oriented development (TOD) model would rapidly disappear from the planner's toolkit. In its place would be development at densities and concentrations driven by other social, economic and financial forces, and a new paradigm would be established - mobility-oriented development (MOD).

Even in this predicted radical change for future mobility and urban development, historical patterns will remain. In some ways the future is likely to present a return to earlier more energy efficient urban patterns that existed before the automobile and street car eras. The underlying force behind these changes, beyond technology, is the impact of a decline in standards of living . At the same time as mobility is actually increased for most of the population, some forms of freedom and affordability of the new urban environment are reduced.

THE EMERGING NEW URBAN POLITICAL ECONOMY

Recent years have seen the emergence of power cities that dominate and eclipse secondary cities and their hinterlands both at the regional and international levels. The increased density, cost, scale of management, and loss of freedom that will be caused by the self-driving vehicle system's ultimate operation will primarily be experienced only in advanced and wealthy cities. The less developed world will not be able to introduce the same level of operation because of management and financial constraints associated with the mobility system that is foreseen for developed cities, although much less efficient self-driving operations may be possible in mixed road operation alongside human-driven vehicles. In light of the increasing trend toward income disparities throughout the world it is likely that a combination of spatial stratification and special roads for the rich and powerful will emerge in less developed cities.

CONCLUSION

Self-driving vehicles , changing urban form, and smart city management will introduce an urban planning environment that phases out traditional transit service, greatly expands the use of technology and personal information, and confirms the use and regulation of integrated larger scale urban development and service provision. The result will be the need for increased understanding of how the relationship between technology and human activity is managed increasingly through public-private partnerships. This will be far different from the historical transportation and urban planning experience.

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