Networking Transportation

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CONNECTIONS 2045

GREATER PHILADELPHIA FUTURES GROUP
ENGAGE, COLLABORATE, ENVISION

DELAWARE VALLEY dvrpc REGIONAL PLANNING COMMISSION

The Delaware Valley Regional Planning Commission is dedicated to uniting the region's elected officials, planning professionals, and the public with a common vision of making a great region even greater. Shaping the way we live, work, and play, DVRPC builds consensus on improving transportation, promoting smart growth, protecting the environment, and enhancing the economy. We serve a diverse region of nine counties: Bucks, Chester, Delaware, Montgomery, and Philadelphia in Pennsylvania; and Burlington, Camden, Gloucester, and Mercer in New Jersey. DVRPC is the federally designated Metropolitan Planning Organization for the Greater Philadelphia Region — leading the way to a better future.

The symbol in our logo is adapted from the official DVRPC seal and is designed as a stylized image of the Delaware Valley. The outer ring symbolizes the region as a whole while the diagonal bar signifies the Delaware River. The two adjoining crescents represent the Commonwealth of Pennsylvania and the State of New Jersey.

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EXECUTIVE SUMMARY

The digital revolution is connecting more devices to the Internet, increasing data collection and availability, allowing actions to be completed remotely, and providing real-time communications that flatten distances and transaction costs. Digital technologies can provide information that promotes safer and more efficient use of existing transportation infrastructure. Real-time information allows individuals to determine the option that best meets their personal travel needs. This information can help to balance demand across modes and use of individual facilities within modes.

The digital revolution is generating new energy, entrepreneurship, and creativity to address transportation challenges. New digital shared mobility services are expanding transportation options and mobility, particularly for less mobile populations such as the young, the elderly, and individuals with disabilities. Networked transportation is made up of a variety of components, including: 3-D printing, Artificial Intelligence (AI), automated vehicles (AVs), Big Data, connected vehicles (CVs), digital mapping, Intelligent Transportation Systems (ITS), the Internet of Things (IoT), smart cities, real-time information, transportation network companies (TNCs) and other digital transportation providers, unmanned aerial systems (UASs), virtual communications, and more.

New digital transportation providers, such as TNCs, are creating innovative business models that change how we get around, increasing travel options, and making transportation more convenient and customer oriented. The analysis identified more than 40 TNCs and other types of digital service providers currently operating in Greater Philadelphia. These are still largely getting started, and are likely to be even more transformative in the future. Already, though, they offer the opportunity to reduce household transportation costs through lower vehicle ownership rates, and they can be used to supplement transportation needs. Other potential benefits include reduced parking demand, flexible employment, more customer service, enhanced safety, last mile to transit connections, innovation, pricing to balance supply and demand, and more flexible operations. However, TNCs face challenges that could slow their growth and even threaten their viability, such as: employee status, insurance coverage and liability, impacts to public finances, equity concerns, regulating shared mobility services, safety and security risks, and increased traffic.

Networking Transportation identifies four plausible future scenarios for TNC operations and growth of the digital transportation network. Figure ES-2 shows the extent of digital transportation network for Greater Philadelphia in each scenario. Table ES-1 contrasts the 'digital transportation' future with 'Auto-oriented' and 'Active' transportation theories that remain the primary influence in other parts of the region in the four shared mobility scenarios.

Figure ES-1. An Integrated, Multimodal Transportation Network

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Networking transportation will mean more options, increased safety & efficiency, and less congestion.

Government provides flexible oversight, and builds partnerships with private companies and other institutions.

- Ensure low-income and environmental justice communities can access and benefit from new technologies and services.
- Connect infrastructure, and update institutional practices & regulations for a digital world.

Transit serves as the backbone to an integrated multimodal network, and needs to be flexible and adaptable to fast changing conditions.

TNCs are receiving substantial venture capital & must grow fast to maintain their value.

- Growth may require changing travel behavior.
- At the same time they face labor, regulatory, cost, and potential technological disruption issues.

In the future, HAVs and UASs may revolutionize passenger and goods movement.

- This promises even greater safety and efficiency, and lower costs.
- The potential loss of driver and other jobs means government must prepare workers for the jobs of tomorrow.
- Achieving the full benefits of HAVs may require separate facilities.

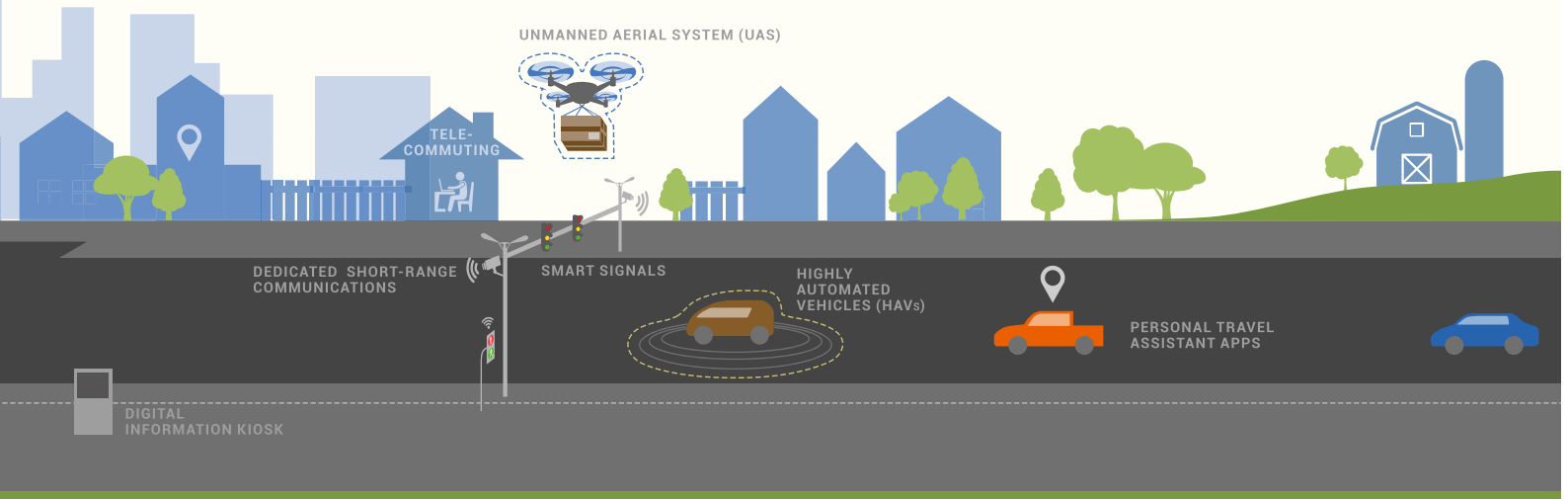
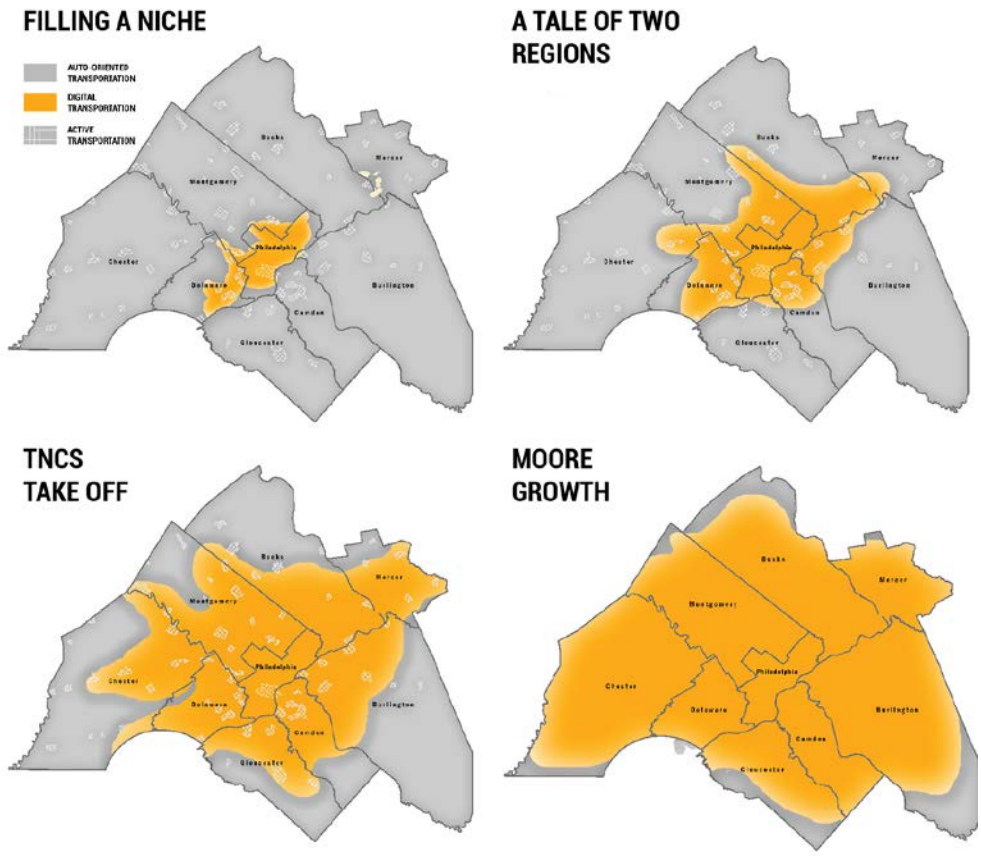


Figure ES-2. Geographic Distribution of Different Transportation Engineering Systems in Each Shared Mobility Scenario



Source: DVRPC, 2016.

Table ES-1. Different Transportation Engineering Systems

	Auto-Oriented	Active Transportation	Digital Transportation
Overall Goal	Increase mobility	Increase accessibility	Increase information
Land Use	Separation of uses	Mixed use, high density	Live/work where you want; recognition that size and density have network effects
Trip Priorities	High speed	Short trips, getting exercise	Customization, cost, reliability, use time other than for driving
Safety	Safe mobility	Vision Zero	Connected technologies, warning systems, feedback loops, and data enhance safety
Key Metrics	Level-of-service, vehicle hours of delay, travel time index/savings	Bike/Ped level of service, trip length, total travel time, vehicle miles traveled, greenhouse gas emissions, transit trips	Real-time data, person throughput, wait time, personal ratings, Big Data and analytics
Investment Priorities	New and wider roads	Connections between modes; walking, biking, and transit facilities	Multimodal Smart Roads that increase safety and efficiency
Rationale for Investment	Fight congestion; reduce delay	Build livable communities; sustainability; improve health	Create an integrated, multimodal network, profit (private market)

Source: DVRPC 2016, adapted from Ian Lockwood, "Livable Traffic Engineering," CNU Orlando, video published November 17, 2012, https://www.youtube.com/watch?v=o7IXblXNOPk (accessed June 4, 2015).

Four scenarios for the future of shared mobility in Greater Philadelphia:

- **Filling a Niche:** TNC operators do not grow beyond specialized trips. Transit and regional transportation largely remain in status quo.
  - This scenario risks missed opportunities to improve transportation options and job access, reduce vehicle ownership, and promote entrepreneurship.
- **A Tale of Two Regions:** TNCs and transit agencies build partnerships to create an integrated, multimodal transportation network in the region's core. In lower-density areas, traditional auto-oriented transportation remains dominant.
  - This scenario risks two very different transportation systems emerging in the region, leading to different development patterns, and difficulty traveling from one area to the other.
- **TNCs Take Off:** TNCs operate independently and are quickly able to respond to changing market conditions, and has led to a significant scaling down of transit operations, and a worsening of congestion.
  - In this scenario, the region's transportation network is largely controlled by the private market. This risks low-income people being priced out of the system if they are not subsidized, with greater potential for monopolies forming, which could reduce options and affordability.
- **Moore Growth:** Mobility-as-a-Service (MaaS) and partnerships between TNCs and transit agencies blur the line between them. The number of shared mobility trips routinely doubles, along the lines of Moore's Law for the growth of computing power. Convenient motorized options, and increasing traffic volumes and/or vehicle speeds reduce walking and biking.
  - This scenario risks a loss of beneficial network effects and an overreliance on motorized transportation, energy, and complex technology.

None of these are an ideal future but are useful in highlighting and better understanding key challenges the region may face as digitization progresses. The preferred vision for a digital future is to create an integrated, multimodal transportation network, which uses digital devices connected to the Internet to collect data. This data will provide real-time information about how to more efficiently move people and goods within existing transportation facilities, and how to use a variety of active and shared modes to get around an area or region quickly. Network thinking is critical to seamlessly blending together the many different transportation modes operating in the region today. Government's role is to ensure these technologies provide maximum, widely distributed public benefits.

Key Infrastructure Implications:

1. **Digital transportation and new shared mobility modes offer an opportunity to build a safer, more efficient, and less costly transportation network.** New mobility services are still in their infancy, and markets are trying to figure out how to meet transportation demand in a profitable manner. Mobility-as-a-Service—where private-market companies either directly provide multiple multimodal transportation options or partner with existing providers to deliver a

variety of transportation options for a monthly subscription or payment plans—may be the next big thing in shared mobility.

2. **The regions that best leverage digitization will use careful government planning and flexible oversight of new technologies, while building partnerships with the private market and other institutions.** They will create physical and digital platforms that others can build upon and open access to data—while recognizing proprietary, cybersecurity, and privacy limitations—to enable their citizens to be problem solvers. Lack of strong public leadership risks a more fragmented, inefficient transportation network in the future.
3. **Existing transportation providers can be successful in the new digital transportation realm if they are flexible and adaptable.** They may need to reinvent themselves by finding new niches in the marketplace. They will need to understand how and why change is occuring and react to it accordingly.
4. **Funding a digital transportation network may rely more heavily on partnerships with the private market.** However, new digital technologies will make funding options, such as vehicle miles traveled (VMT) fees and congestion pricing, more feasible. Enacting new payment methods can provide system efficiency benefits, while also strengthening the public role in defining new mobility.
5. **Highly automated vehicles (HAVs) are likely to be the next major transportation disruption.** While they promise many improvements, realization their benefits may require HAV-only facilities. Redesigning cities and regions around HAVs is unlikely to be a panacea that solves all transportation problems. Instead, areas should focus on developing a full range of digital technologies that help to build network effects and agglomeration economies.
6. **Digitization reinforces the basic fundamentals of good urban design.** Competitive regions will continue to prioritize dense, mixed-use communities that limit demands on the transportation network and reduce how much infrastructure is needed to meet travel needs. Doing so requires prioritizing space efficient walking, biking, and transit trips, using active transportation engineering philosophies, and centralizing major destinations within multimodal development centers.

The region should use markets, good community design, and technology as tools for achieving the goal of creating a safe, integrated, multimodal transportation network. Networking transportation for the digital age requires rethinking infrastructure, regulations, and institutions. Particular attention should be paid to the needs of low-income individuals and Environmental Justice communities, who are at risk of being left further behind the digital divide with increasing use of technology in transportation.

Infrastructure Recommendations:

- Make Connections Between Transportation Modes Seamless.
  - Create standardized multimodal digital payment systems and alternative payment systems.
  - Build multimodal transportation hubs combining transit stations and stops with carsharing, bikesharing, and pick-up/drop-off zones.

- Work with the private sector to build a regional 'Mobility Internet.'
- Improve access to real-time information for both transit and road users.
- Improve domestic and international mobility connections to the nation and world.
- Integrate paratransit with new mobility options.

- Enhance Safety.
  - Incorporate TNCs and other digital transportation providers into Vision Zero plans to reduce transportation-related injuries and fatalities.
  - Use digital technologies and networks to improve the reach of emergency communications.
  - Create evacuation plans for larger numbers of carless households.

- Make Infrastructure More Efficient and Multipurpose.
  - Change pricing structures and use sensors and real-time information to increase the use of off-street parking spaces and increase the availability of on-street spaces.
  - Prioritize shared and transit vehicles.
  - Pursue transit-first strategies, such as: transit signal priority, off-board fare payment, and dedicated bus lanes. Use Big Data, on-demand, and automated technologies to optimize bus routes in ways that better meet demand by time and location.
  - Build connected vehicle-to-infrastructure technologies through traffic signal upgrades and roadside warning devices.
  - Use digital technologies and pricing to reduce congestion and balance demand for road space with available supply.
  - Improve pavement condition and create management systems for enhancing the maintenance of signs and lane markings, and timing and location for road construction activities.

Regulatory Recommendations:

- Build Competitive Transportation Networks.
  - Limit barriers to entry and allow for the formation of new firms and innovation.
  - Avoid exclusive agreements with singular service providers.
  - Determine where technology and data sharing can complement customer protection regulations.

- Promote Equity.
  - Work with shared mobility companies to enhance service in low-income and Environmental Justice (EJ) communities.
  - Collaborate to develop pilot projects, awareness of options, and subsidies to increase access for low-income individuals to shared mobility services.

- Regulate Shared Mobility for the Digital Age.
  - Provide public oversight of new shared mobility services in advance of regulations.
  - Clearly define the process for licensing and regulating new private-market transportation services.

- Review taxi regulations in light of the rules developed to govern TNCs.

Institutional recommendations:

- Promote Open Data and Big Data Analytics.
  - Adopt open data and open-source software policies.
  - Create data-sharing agreements with private transportation operators that ensure transportation data is open and freely available, while protecting competitive and proprietary information, and personal privacy.
  - Create interdisciplinary regional or local data coordination teams.
- Improve Cybersecurity.
  - Appoint a digital risk officer.
  - Use up-to-date cybersecurity strategies.
  - Protect customer privacy by safeguarding sensitive data.
- Build Partnerships.
  - Incentivize the private sector, nonprofits, and public-private partnerships to speed up and incorporate new technologies into infrastructure development.
  - Ensure all modes operate together as a seamless network.
  - Seek mutually beneficial partnerships between transit agencies and TNCs and other digital transportation service providers.
  - Encourage mobility-as-a-service multimodal travel pass or ticket options.
- Reform Planning and Zoning.
  - Develop an economic vision for the digital age.
  - Integrate shared mobility into long-range plans.
  - Set goals and indicators to track performance and progress toward attaining them.
  - Develop expectations for equity, data sharing, and public asset use.
  - Revise zoning and regulations to offer density bonuses for developments that incorporate shared mobility infrastructure.
  - Reduce parking minimums.
  - Conduct research into best practices for digital infrastructure development and partnerships.
  - Ensure HAV regulations reflect and respond to specific needs of dense, urban areas.
  - Find ways to share in the risks and rewards of smart city investments.
- Modernize and Speed Up Procurement.
  - Digitization will require purchasing and maintaining new types of technology, and may challenge traditional procurement practices.
  - Undertake flexible, low-cost pilot projects to test ideas in advance of major capital expenditures.

BACKGROUND

Transportation seems to be entering an era of rapid systemic change, similar to what has been experienced by many other industries since the rise of the digital revolution. This report considers how technological innovation can be applied to improving Greater Philadelphia's transportation system. This study will consider potential growth rates for Transportation Networking Companies (TNCs) and other potentially disruptive digital transportation technologies and services. Specifically, it considers how newly forming TNCs and other digital transportation providers are changing regional travel demand patterns, impacts on transportation equity, and the cost of mobility. It will analyze what all this change means for the region's infrastructure, regulations, and institutions.

Tasks include:

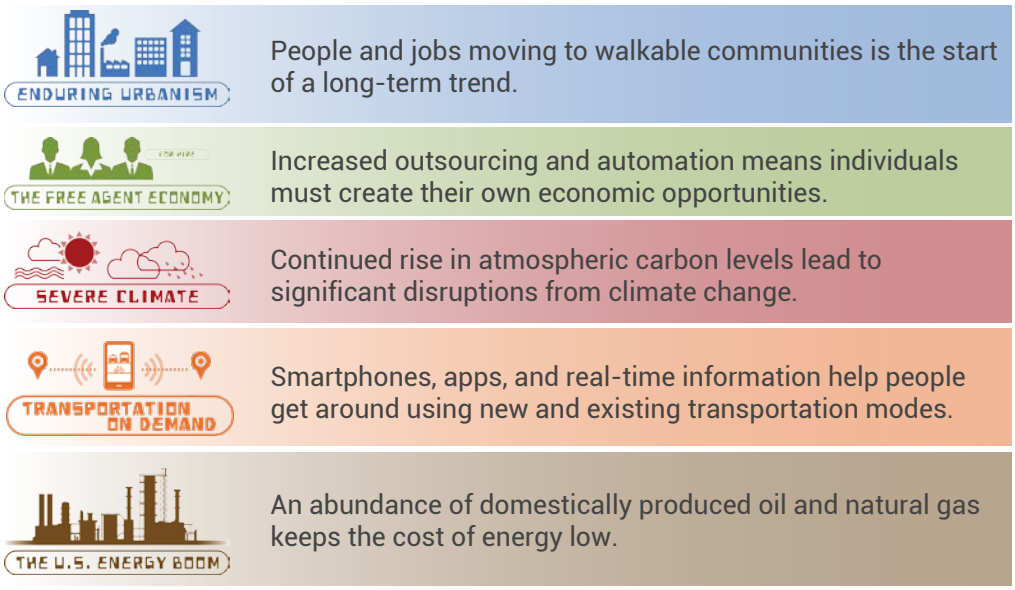
1. Identify the TNCs and other digital transportation providers operating in the region right now, along with innovative approaches around the nation and world.
2. Consider how readily TNCs and other digital transportation providers can fill first/last-mile transit connections; affect car ownership rates; and change the need for residential, commercial, and institutional parking space and other infrastructure over the next 20 years.
    a. What are the equity issues? Do TNCs make it easier (by providing service to areas traditionally underserved by transit and access to low-cost, on-demand transportation services, reducing the need for car ownership) or harder (by reducing availability of taxis, harming transit, requiring smartphones for system access) to get around?
    b. Will it be cheaper than owning a vehicle?
    c. What happens if there is less parking and gas tax (due to an increase in electric or other fuel sources for vehicles) revenue? How do municipalities, states, and the federal government continue to pay for infrastructure?
    d. What is the role of government and that of the private market in developing infrastructure for TNCs and other new digital technologies?
    e. What are the safety impacts of TNC drivers being distracted by using their smartphones and apps while driving?
    f. How should demand for curbside space be managed?
3. Consider what regulatory needs for TNCs are appropriate, and how they can contribute to a more flexible and resilient transportation system. What is needed to ensure that low-income and Environmental Justice (EJ) communities can benefit from and are not unduly burdened by these services?

Two particular examples of upcoming regional investment decisions are of particular interest to this study, and both relate to Philadelphia International Airport (PHL):

- Two of the three proposed alternatives for the Northeast Corridor High-Speed Rail Environmental Impact Statement would include a new station with access to PHL.

- Current plans to expand and improve PHL would include new parking facilities. It is not clear if TNCs will change current parking demand levels.

This report follows up on *Connections 2045: Greater Philadelphia Future Forces* (Main version DVRPC publication #16007A; Technical version DVRPC publication #16007) exploratory scenario analysis, which identified driving forces of change that create an increasingly uncertain future. It went through a process to identify the most critical Future Forces for the region:



The analysis identified specific opportunities and challenges that may arise as a result of each force and made a series of recommendations the region can undertake to better prepare for the future should any of the forces come to fruition. The Digital Revolution can be seen as a cause of at least two, if not three of the Future Forces. By directly connecting buyers and sellers and cutting out the middleman, helping firms operate leaner, strengthening outsourcing, bolstering automation and robotics, and flattening transaction costs, the Digital Revolution is largely behind the rise of contract employees in The Free Agent Economy. Through real-time communications technologies and remote actions the Digital Revolution is enabling Transportation on Demand. Network effects are an indirect way in which the Digital Revolution is driving Enduring Urbanism. In addition, digital technologies could help to more efficiently use resources and reduce greenhouse gas emissions in the fight against Severe Climate. *Networking Transportation* will take a deeper dive on the Transportation on Demand scenario. It also considers the impacts of some of the other scenarios impacted by the digital revolution, particularly The Free Agent Economy and Severe Climate.

Networking Transportation also considers how the digital revolution is shifting transportation engineering perspectives, comparing traditional auto-oriented, planning driven active transportation, and the emerging digital transportation philosophies. These perspectives can be seen in the Future Forces. The U.S. Energy Boom mostly continues the auto-oriented perspective, while Enduring Urbanism

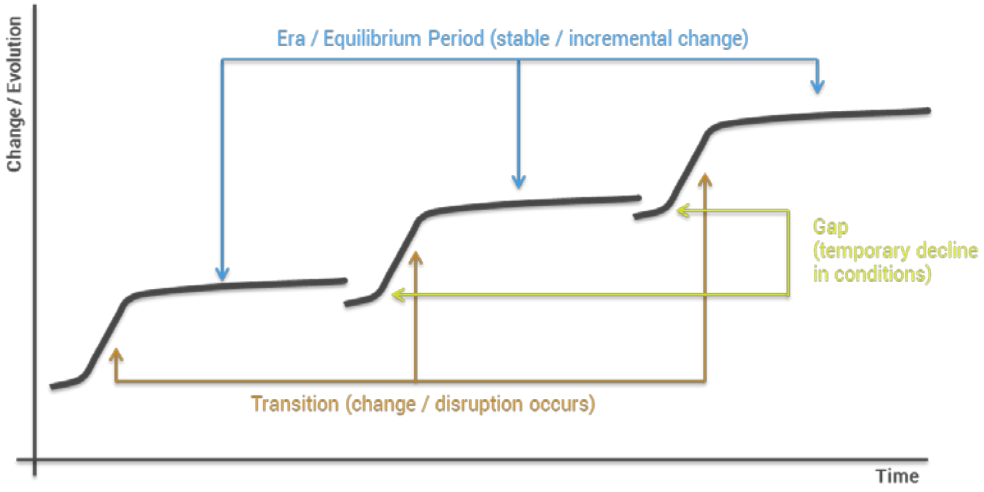
most directly reflects active transportation. The Free Agent Economy sees transportation through an economic lens. Transportation on Demand attempts to understand how technology will change travel demand and patterns.

This study is consistent with feedback received during DVRPC's public outreach visioning workshops for the development of the *Connections 2045* Long-Range Plan. The top issue identified by participants was the need for more walkable communities and options in how to get around the region.

Long-range planning often jumps straight to the horizon year being planned for and ignores transitions that may occur in the intermediate period. These transitions are important for better understanding long-term change. Eras exist between these transitions. Periods of stability last as long as they can until either an external or internal stressor breaks down the status quo.

The previous *ribbon cutting* transportation era of highway expansion began with the 1956 Interstate Highway Act and lasted through the 2000s.[1] The ribbon cutting era lasted until aging infrastructure began to stretch available funding. The current era is one of *managed decline*, where growing focus is on preservation and maintenance of existing assets.[2] This report anticipates that the next major transportation era will be digital. This view of eras being periods of relative stability and transitions where sudden and rapid change can occur is consistent with the evolutionary biology model of change: punctuated equilibrium. In some cases these transition periods initially take a step back from the previous era's conditions while a new stability takes hold.

Figure 1. Punctuated Equilibrium



Source: Adapted from Bishop and NCHRP.

[1] Peter Bishop, "The Case for Foresight," Presentation at TRB Scenario Planning Workshop, Portland, OR, August 14, 2016, http://onlinepubs.trb.org/onlinepubs/conferences/2016/Scenario/presentations/PeterBishop.pdf (accessed October 11, 2016).
[2] Ibid.

The managed decline era has continued along as the transportation system is being held together until a new stressor creates the need for change. Lack of funding to maintain and improve the system may be one such stressor. *Greater Philadelphia Future Forces* identified several other potential stressors, including climate change, shifting lifestyle preferences, global employment and economic patterns, and digital technologies. Paying more attention to potential intermediate transitions, as is done with digital technologies in this report, can help to better inform and guide both near-term and long-term decision making.

INTRODUCTION

Transportation has long been an area of innovation, from building the first canals and trains to move goods more quickly in the 19th century, continuing with the invention of the automobile and manufacturing improvements that brought mobility to the masses, and airplanes that connected continents and regions around the world in the 20th century. From the end of World War I to the early 1970s, transportation innovation was based on continually increasing travel speed.[3] Humankind entered the jet age at the end of World War II, and by 1971 the Apollo 10 mission traveled 25,000 miles per hour (mph). Starting in 1976, the Concorde offered commercial flights traveling at twice the speed of sound.

From a speed perspective, transportation advances have reduced pace in recent decades. Commercial aviation has been slower since the Concorde fleet was retired in 2003. Apollo 10 remains the fastest that humans have ever traveled.[4] As our highways have filled with traffic, personal vehicle speeds have declined. Today, a number of problems plague transportation: congestion; greenhouse gas emissions from burning fossil fuels; safety, with more than 30,000 people dying on U.S. roads each year; the cost of maintaining a vast and expensive, largely publicly financed network of roads, bridges, traffic signals, transit lines, airports, and other facilities and assets; among others.

Speed Counterpoint: High-Speed Rail

One area where speed is advancing is passenger rail. Japan's bullet train, the Shinkansen, became the world's fastest train in 1964, with a top speed of 200 mph (320 kilometers [km]/hr). In 2004, the Shanghai Maglev began operations with a maximum speed of 267 mph (430 km/hr). In 2012, Alstom's AGV "V150" set the world's rail speed record by traveling 357 mph (575 km/hr). These are top speeds for both; their designed operating speeds are lower. Although the United States remains behind much of the world in developing high-speed passenger rail, progress is being made in the Northeast Corridor, with Amtrak's new NEC Vision Plan; California's high-speed rail between Los Angeles, San Francisco, and Sacramento; two billion dollars in track improvements between Chicago and St. Louis; and private-market efforts with All Aboard Florida developing new service between Miami and Orlando, and a proposed new service in Texas linking Houston and Dallas.[a]

[a] Laura Bliss, "Faster Rail Service Is Coming to America—Slowly," *The Atlantic CityLab*, December 12, 2016, http://www.citylab.com/commute/2016/12/faster-rail-service-is-coming-to-america-slowly/509954/ (accessed January 4, 2017).

[3] Jason Pontin, "Why We Can't Solve Big Problems," *MIT Technology Review*, October 24, 2012, https://www.technologyreview.com/s/429690/why-we-cant-solve-big-problems/ (accessed December 8, 2014).
[4] Ibid.

The construction of the Interstate Highway System brought about the golden age of auto-oriented transportation engineering. This philosophy focused on the safe mobility of automobiles, building of new and wider roads, and a separation of land uses leading to wide-scale suburbanization. While it has provided a quality lifestyle for many people and families, it has created environmental problems from worsened air quality, to loss of open space, and increased greenhouse gas emissions; and it has led to significant road congestion.

Regions around the country have been trying to build their way out of congestion for decades, with little progress to show for their efforts. Duranton and Turner have shown in *The Fundamental Law of Road Congestion* that traffic increases in lockstep with road expansion.[5] Their analysis found no difference in congestion levels between cities and regions that have built many new roads and other areas that have built few new roads.[6] Each 1 percent increase in highway lane miles corresponds to a 1 percent increase in regional VMT.[7] When roads are expanded there is a "rebound effect" that increases VMT through a variety of ways:

1. Spatial: Some drivers change their routes to use the improved facility during peak hours.
2. Time: Some drivers begin to use the facility during the peak period, rather than another time.
3. Mode: Some transit commuters start driving.
4. Frequency: Some people start to drive more often.
5. Locational decisions: Households and businesses make different decisions on where they choose to live or conduct their operations.

Widening roads through an automobile-oriented transportation planning mindset leads to a cycle of increasing auto dependence. When roads are built for cars, they can become barriers to pedestrians and other modes. People and businesses locate further and further from regional core areas to avoid congestion. Parking lots become oversized, creating another barrier to alternative modes. Vehicle ownership rates increase as people have fewer options for how to get around. As development continues to spread out, the need for auto-oriented transportation is further enshrined. The rebound effect and cycle of automobile dependency show that, rather than solving problems as intended, building new and wider roads actually makes congestion worse over time. The rebound effect has typically taken years for the full repercussions to become apparent. A recent $1.1 billion reconstruction of Interstate 405 in Los Angeles, which also added new carpool lanes and improved exit ramps, saw longer travel times in the afternoon rush hour than before the construction commenced.[8] This five-year project was billed as congestion relief, but the facility, which carries 374,000 vehicles per day, remains one of California's worst

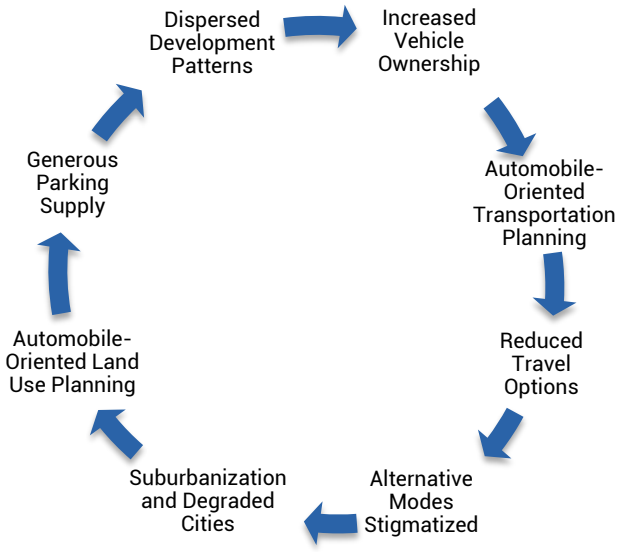
[5] Giles Duranton and Matthew A. Turner, *The Fundamental Law of Road Congestion: Evidence from US Cities* (Cambridge, MA: National Bureau of Economic Research, Working Paper 15376, September 2009), http://www.nber.org/papers/w15376.pdf.
[6] Ibid.
[7] Ibid.
[8] Adam Gropman, "$1.1 Billion and Five Years Later, the 405 Congestion Relief Project Is a Fail," *LA Weekly*, March 4, 2015, http://www.laweekly.com/news/11-billion-and-five-years-later-the-405-congestion-relief-project-is-a-fail-5415772 (accessed November 15, 2016).

"We often believe traffic is like a liquid; prevent it from going down one road, and it'll just flow down a nearby one. But in reality, traffic is more like a gas: a gas compresses or expands based on how much space you give it."

- Jeff Kenworthy
Professor in Sustainable Cities in the Curtin University Sustainability Policy Institute

performing.[9] The Southern California Association of Governments, the metropolitan planning organization for the Los Angeles region, is now studying congestion pricing on the facility.

Figure 2. Cycle of Automobile Dependency



Source: Victoria Transportation Planning Institute, undated.

Duranton and Turner found that increasing lane miles of roadway correlates with population growth. A 10 percent increase in lane miles led to a 1.3 percent increase in population within 10 years.[10] In slower growth regions, new roads may lead to a spreading out of existing populations. In higher growth regions, new roads may direct the location of future development. While new infrastructure will direct development location in both low and high growth regions, the impact of the rebound effect may be less severe in lower growth regions, where the overall rate of change is slower.

While more travel is generally better for the economy, unnecessary overconsumption of transportation can also be seen as an inefficient use of economic and other resources, which can also price out lower-income individuals. Studies have found that bicyclists and pedestrians spend less per visit, but frequent more often, leading to higher spending over time with local retailers, services, and entertainment venues.[11] Growing concerns for safety, the impact of transportation on our built environment, and the damages to the natural environment, mean that there are many competing priorities for improving transportation.

At least two new visions for the future of transportation are emerging, which are calling for new investments and a significant rethinking of how we get around. Their

[9] Ibid.
[10] Duranton and Turner, *The Fundamental Law of Road Congestion: Evidence from US Cities*.
[11] Kelly Clifton, Sara Morrissey, and Chloe Ritter, "Business Cycles: Catering to the Bicycling Market," *TR News*, May–June 2012, http://nap.edu/22758 (accessed October 28, 2016).

new goals are focused on enhancing safety, improving accessibility, increasing reliability, and becoming more efficient and sustainable.

The first is based on building livable, walkable communities. This vision calls for expanding active transportation by building new transit, walking, and biking facilities. Encouraging the development of denser, mixed-used communities can reduce trip lengths and make the active modes more accessible. Active transportation can help individuals in these communities get to their destination while exercising and benefiting health. Efforts such as Context Sensitive Design have worked to integrate auto-oriented and active transportation, using each where it is most appropriate. The Vision Zero campaign is an example of how the active philosophy is rethinking transportation. Vision Zero sets a goal to eliminate fatalities and serious injuries on roadways and maintains a core belief that loss of life is not an acceptable price for mobility. Implementing Vision Zero requires the breaking down of municipal silos and building partnerships with police, educators, firefighters, transportation agencies, and others to work together toward a common cause and developing strategic and effective actions.[12]

The second is a reflection of the paradigm shift in transportation emerging around the continued evolution of digital technology: creating an efficient, integrated multimodal transportation network.[13] The first generation of digital transportation is reflected through ITS. These systems include closed-circuit television (CCTV) cameras to monitor roads and bridges and more quickly react to traffic issues, variable message signs along roads to relay real-time travel information to drivers, coordinated and adaptive traffic signals, and others.

Network thinking is critical to seamlessly blending together the many different modal systems operating today. Networked transportation aims to expand the availability and improve the accessibility of transportation information so travelers can make better and more efficient choices. Technology can be applied to vehicles, through connected communications systems and automation, along with roads and other infrastructure that improves safety and efficiency. Information includes modal options and aims for an integrated, multimodal network. While walkability has a role to play in digital transportation, it has a less central focus in the digital realm as it does in active transportation. There is a concern that digital data collection, availability, and analysis tend to favor vehicular movement and auto-oriented transportation solutions.[14] If active transportation remains a major regional policy goal, this bias may need to be recognized and accounted for.

Definition:

Integrated, Multimodal Transportation Networks use digital devices connected to the Internet to collect data in order to provide real-time information about how to more efficiently move people and goods within existing transportation facilities, and how to use a variety of shared modes to get around an area or region quickly.

The Future Shared Mobility Scenarios in Greater Philadelphia section of this report develops alternative futures where different areas of the region are primarily

[12] David Bollier, *The City as Platform: How Digital Networks Are Changing Urban Life and Governance* (Washington, DC: The Aspen Institute, 2016), http://csreports.aspeninstitute.org/documents/CityAsPlatform.pdf.
[13] "Episode 2: Shared Mobility Conversation with Susan Shaheen," *ITE Talks Transportation* (podcast), June 27, 2016, https://www.spreaker.com/user/ite-talks-transportation/episode-2-shared-mobility-conversation-w (accessed June 28, 2016).
[14] Joe Cortright, "The Downsides of Data-Based Transportation Planning," *The Atlantic CityLab*, August 17, 2016, http://www.citylab.com/commute/2016/08/the-downside-of-data-based-transportation-planning/496250/ (accessed October 6, 2016).

influenced by a continuation of traditional auto-oriented transportation engineering, or the emerging active and digital transportation philosophies.

There is a third competing theory, less developed in this analysis, based on using markets—most notably variable pricing for congestion or demand—to better align the supply of and demand for transportation. Digital transportation technologies will increase the feasibility of demand-based pricing and other forms of charging for infrastructure. Digital technologies make alternative funding options—such as congestion pricing, VMT fees, or tradable driving credits—more feasible by flattening transaction costs and enabling easy transactions that cause less inconvenience, such as slowing down traffic. Technology, urban design, and markets are three of the most important tools we have to create socially optimal outcomes and bring about a shared vision for just, equitable, and sustainable communities. The United States has relied almost solely on the use of technology to solve problems and has too often ignored the value of how we design our neighborhoods and markets for creating better and more competitive regions.[15]

The Canal Keeper's house near the National Mall in Washington, DC, serves as a reminder of the canal building era. L'Enfant's original plan for the city called for the construction of many canals. The Washington City Canal opened in 1815, followed by the Chesapeake and Ohio canal in 1833. They carried little commerce, due to the rise of railroads, and were abandoned in the 1860s. They were filled in starting in the 1870s.

In *The Surprising Design of Market Economies*, Alex Marshall recounts the history of transportation funding and how the provision of transportation infrastructure has swung back and forth between the private and public markets with each successive innovation, with lessons as to why some level of public oversight over private markets is still essential. The success of the Erie Canal led the federal, state, and local governments to embark on financing canal projects throughout the country.[16] What they did not foresee in these investments was the invention and rise of the railroad.[17] As rail siphoned business from canals, governments experienced significant losses on their investments. This meant government had little appetite for direct investment in new rail infrastructure and the private market built railroads—with considerable federal, state, and local government incentives.[18] For instance, the 1864 Pacific Railway Act gave 10 miles of land on each side of the Transcontinental Railroad to rail corporations. Unfortunately the railroads suffered from the excesses of Gilded Age business practices. Titans of industry waged pitched battles and rammed locomotives into each other in a struggle for control over lines.[19] Tracks and trestles were torn up rather than being ceded to competitors.[20] Routes were poorly laid out and haphazardly built with unsafe grades.[21] Cutthroat competition left little room for concern over public safety or general welfare.[22] With lackluster governmental oversight, a very poorly planned and

[15] Ralph Buehler, John Pucher, and Uwe Kunert, *Making Transportation Sustainable: Insights from Germany* (Washington, DC: Metropolitan Planning Program at Brookings Institute, 2009), http://www.brookings.edu/research/reports/2009/04/16-germany-transportation-buehler.
[16] Alex Marshall, *The Surprising Design of Market Economies* (Austin, TX: University of Texas Press, 2012).
[17] Ibid.
[18] Ibid.
[19] Robert L. Heilbroner, *The Worldly Philosophers: The Lives, Times & Ideas of the Great Economic Thinkers* (New York: Simon & Schuster, Revised Edition 1961).
[20] Ibid.
[21] Ibid.
[22] Ibid.

inefficient rail network emerged. Many rail companies went bankrupt, and what remained acted as a monopoly that slowed trade.[23]

When bicyclists began calling for the paving of roads in the 1890s, followed by automobile enthusiasts shortly thereafter, the private market initially tried its hand at road building.[24] Construction of the Lincoln Highway began in 1913 with the intention of connecting New York City and California. Before it could be completed, the federal government stepped in and led state and local interstate road construction. Roads swung the pendulum back to government construction, finance, and operation of transportation infrastructure.[25] Given the experience of the railroads, it is little wonder that the desire was for public investment and control over transportation. However, public finances for roads have been declining in recent years and public appetite for more road taxes remains low.

Improving fuel efficiency, decreasing VMT, increasing road construction costs, and aging infrastructure that needs to be reconstructed have limited the ability to continue to build new facilities. Increasing fuel efficiency will further reduce the flat-rate gas tax revenues that fund most transportation projects, making it even more difficult to maintain the system in the future. By 2025, Corporate Average Fleet Economy (CAFE) standards will require that manufacturer fleets achieve a 54.5 mile per gallon average for the fleet of vehicles they produce. Nearly 30 vehicle models for sale in 2017 already met this requirement.[26] Though, this will require continued political support. Early indications from President Trump's administration suggest that CAFE standards may be reconsidered.

Local and state governments have found the public willing to invest in transit, trail, and pedestrian networks. The 2016 election season had nearly 400 transportation referenda.[27] There were 48 local and state transit funding initiatives, of which 33 passed. Measure M in Los Angeles will raise $120 billion for new transit lines, bicycle, and pedestrian infrastructure.[28] In Seattle, Sound Transit 3 was passed with a goal of adding 116 miles to the region's light rail system over the next 25 years.[29] Atlanta passed a five-year, 0.4 percent sales tax increase that will fund the Beltline trail network, 15 Complete Streets projects, expansion of the city's bikeshare program, and sidewalk improvements.[30] Local funding, which is more flexible, is becoming the key to improving transportation networks all over the country.

The private market seems poised to take more of a lead in developing digital transportation infrastructure. This may mean a new world of financing

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[23] Marshall, *The Surprising Design of Market Economies*.
[24] Ibid.
[25] Ibid.
[26] "2017 Green Vehicle Guide," Environmental Protection Agency, Last Updated February 21, 2017, http://www.fueleconomy.gov/feg/download.shtml, (accessed February 21, 2017).
[27] Aarian Marshall, "U.S. Cities, Spurned by Washington, Fund Transit Themselves," *Wired*, November 10, 2016, https://www.wired.com/2016/11/us-cities-spurned-washington-fund-transit/ (accessed November 11, 2016).
[28] Josh Cohen, "How Mass Transit Fared in the 2016 Election," *Next City*, November 9, 2016, https://nextcity.org/daily/entry/vote-transit-bills-2016-election (accessed November 14, 2016).
[29] Ibid.
[30] Ibid.

Definition:

Digital transportation providers supply information or services through the use of digital networks.

infrastructure, one that might rely more heavily on public-private partnerships (PPPs). Already, private-market digital transportation providers such as Uber, Lyft, and Bridj are offering new services and using "surge" or peak-period pricing, to better manage supply and demand. It may also make other best practice recommendations, such as pay-as-you-drive insurance policies, more feasible. Increasing private market investment could come in different forms, such as tolling. It may come from new ways of doing business in the digital world. In a knowledge economy, data is currency.[31] Companies may collect and find ways to monetize data as a way to get a return on their investment. This would create challenges for open data.

Definition:

Shared Mobility is the shared use of bicycles, vehicles, and other transportation modes. It provides options to find the most efficient way to get around, rather than relying on one specific mode for most trips.

Pennsylvania's Act 164 of 2016 establishes new regulations for TNCs, which it defines as "a person or entity that obtains a license to operate a transportation network service by the authority and uses a digital network to facilitate prearranged rides." TNCs are just one of many ways in which the sharing economy and the digital revolution are trying to find new transportation efficiencies through shared mobility and new communications technologies.

Before delving into the implications of TNCs and new digital transportation technologies, a better understanding is needed of the driving force behind them: the digital revolution.

[31] *New Mobility* (Toronto: WSP, August 2016 update) http://www.wsp-pb.com/Globaln/WSP-Canada/In%20the%20media/Project%20News/2016/16-08-31%20-%20New%20Mobility/WSP%20Metrolinx%20New%20Mobility%20Report%20July%202016.pdf.

THE DIGITAL REVOLUTION

Before we can understand the implications of TNCs, HAVs, Big Data, the IoT, and a number of related transportation technologies, we must better understand the driving force behind all of them: the digital revolution. The digital revolution has been reshaping nearly every industry in an ongoing process of connecting more and more things to the Internet, drastically increasing the amount of data available, flattening transaction costs, and allowing actions to be completed remotely and in real-time communications over vast distances. Shawn Dubravac, Chief Economist for the Consumer Technology Association, has identified five key elements of the digital revolution:[32]

- ubiquitous computing;
- Internet access;
- proliferation of digital devices;
- the declining cost and rising capacity of data storage; and
- sensors that gather data, process it, and turn it into actionable intelligence.

Definition:
The **Internet of Things** (IoT) is a network of people, animals, and objects that exchange production, operational, or locational data using embedded electronics, sensors, and other forms of connectivity.

The digitization of devices is driving the Internet of Things (IoT). This process uses sensors and radio frequency ID to capture and analyze infinite amounts of new data.[33] IDC, a market research firm, estimates there are more than 200 billion devices that could be connected to the IoT.[34] Only about 10 percent (20 billion) were connected as of 2014, with a forecast of 30 billion connected "things" by 2020.[35] Some examples of potential IoT applications could include: buildings that automatically call the fire department if a fire breaks out, wearable devices that track patient data and help doctors to preemptively diagnose and treat illnesses, and the ability to get specialist treatment through virtual communications that break down geographic distances and lower costs.[36]

Definition:
A **platform** is a physical and/or digital infrastructure that serves as a base upon which others can build, play, and/or iterate new applications, processes, or technologies.

These connected devices and the data they generate are predicted by some to be even more impactful than the two Industrial Revolutions.[37] Increased access to data will change viewpoints and behaviors and allow for more customization in everything we produce. It promises improved decision making, reduced loss and waste, and increased productivity with lower costs.[38]

Platforms are things that can be built upon, such as how a computer's hardware and operating system serve as a platform for software, document creation, gaming, and any other of the multitude of uses for a computer. The value and utility of the

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[32] Shawn Dubravac, *Digital Destiny: How the New Age of Data Will Transform the Way We Work, Live, and Communicate* (Washington, DC: Regnery Publishing, 2015).
[33] Ibid.
[34] Ibid.
[35] Ibid.
[36] Jack Karsten, "Why Pokémon Go's Technology is No Fad," *Brookings Institution*, July 22, 2016, http://www.brookings.edu/blogs/techtank/posts/2016/07/22-pokemon-go-technology-no-fad (accessed July 25, 2016).
[37] Dubravac.
[38] Ibid.

system is continually being discovered and expanded, not just by the developer but also by users and customers. The Internet is a digital platform that continues to evolve with mobile technologies. The Internet provides network benefits by connecting people and things. Networks bring people together and connect them in ways that would not occur if they were not there, and help to build agglomeration economies. A social network, such as Facebook, has exponentially increasing value based on the number of people using it. Switching networks can be time-consuming and less interesting if one has fewer friends or connections on the new network. For this reason, economists have concerns that networks lead to winner-take-all outcomes, also known as monopolies. Network effects also apply to TNCs, where larger sizes of both the driver pool and customer base ensure more driving work, shorter wait times, and potentially lower costs.[39]

Definition:

A **network** is a group of interconnected people and things.

Definition:

Agglomeration economies occur as larger regions become more productive due to knowledge sharing and the concentration of industries, firms, suppliers, and skilled labor. Industries benefit from access to ideas and larger labor pools, while employees benefit from higher wages.

Definition:

A **network effect** is how a good or service becomes exponentially more valuable as more people use it.

Cities and regions are generally seen as physical platforms, and thinking about them tends to focus on physical conditions in the real world. This view may consider infrastructure to be the hardware, with government playing the role of the operating system from which we build our communities, economy, institutions, and nearly everything else. The digital revolution is changing the physical-only view of cities and transportation. In the growing "digital economy," cities and regions are increasingly recommended to see themselves as a "digital platform." People today are virtually connected to places all around the world through real-time information, intelligent devices, remote databases, and participatory crowdsourcing.[40] Increasingly, a municipality's residents are interacting more and more online and expecting city services to be available there as well.[41] The IoT and other things are blending the physically real and virtual worlds. This is turning previously hard-to-collect analog data in the real, physical world into readily accessible, ubiquitous digital data. This process is called *digitization*.

Definition:

Digitization is the process of turning an analog object, image, sound, document, or signal into a machine readable binary code for data processing, storage, and/or transmission.

Digitization increases fragmentation. This can be seen in television and movies, where companies like Netflix offer anytime-streaming services, opening a wider array not only of shows that can be watched but also how we experience and enjoy TV and movie watching. As digitization reaches any new industry it upends dominant market players, introduces new ways of producing and consuming, and brings down the cost of doing so.[42] This impact of digitization can also readily be seen by the impact of Amazon on traditional brick and mortar retailers, or digital cameras on the analog film and camera industries. As digitization grows, it is accelerating the substitution of labor with capital and will replace low-digital jobs with high-digital ones.[43]

Another easy-to-grasp example of digitization is looking at what has happened to the music industry over the last couple of decades. Dominant retailers and recording studios resisted making virtual digital files available for sale throughout

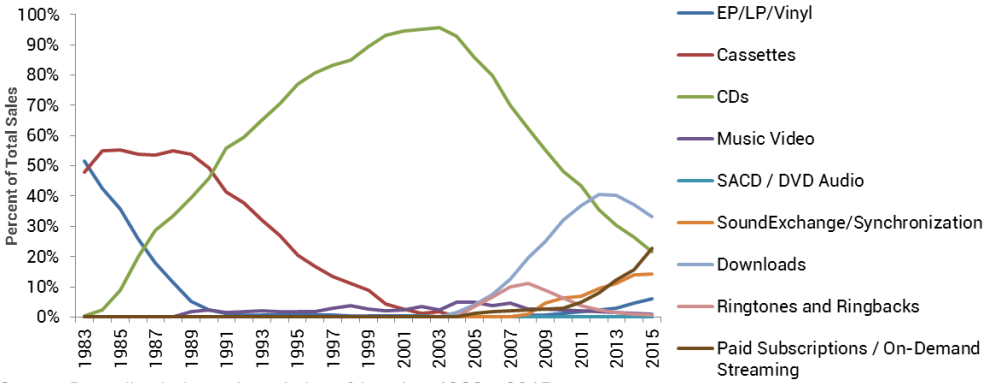
[39] Joe Cortright, "Let a Thousand Ubers Bloom," *City Observatory*, August 1, 2016, http://cityobservatory.org/let-a-thousand-ubers-bloom/ (accessed August 3, 2016).
[40] Bollier.
[41] Ibid.
[42] Ibid.
[43] Dubravac.

"The past 100 years, or the past 2,000 years, we can think very much of a world where there are centrifugal technologies that enable us to spread out, and centripetal technologies [that] draw us in. The future of cities will be shaped by these technologies."

- Edward Glaesar

the 1990s and early 2000s, instead preferring to sell compact discs, which contain digital information but are still a physical object. User-driven online communities grew up to share virtual digital music files, such as Napster. While illegal, it took years of fighting in court to shut down these file-sharing sites. In the meantime, this created bad feelings between the music industry and consumers. Outsiders, such as Apple with iTunes and the iPod, then led the way to a legal version of the digital revolution in the music industry. Recently, digital music is shifting again with a move to streaming services such as Pandora and Spotify.

Figure 3. Change in Music Industry Sales, 1983-2015



Source: Recording Industry Association of America, 1983 – 2015.

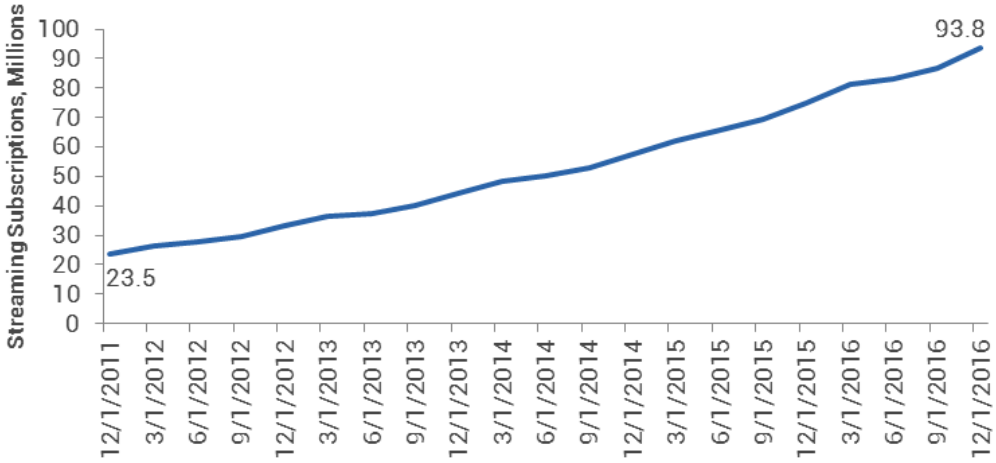
There are a few key takeaways from this example. First, user-based networks will spontaneously emerge if dominant market players do not fill the digital gap. Waze is an example of this from the transportation realm. It began in 2006 as a community-based program called FreeMap Israel. It quickly grew into a worldwide presence, leading to Google's purchase of it in June 2013 for $1.1 billion.[44] The second key lesson is that fighting digitization is a largely useless endeavor. It will happen whether dominant industry players desire it or not. Fighting against it is more likely to lead to disruption by upstarts over the long term. Major transportation providers need to find their role, where they can add value to a digital transportation network.

Digital industries can quickly scale up their businesses with only a minimal cost of doing so.[45] There are no restrictions of shelf space or physical area in the digital world. A good example of this is how TNCs can ramp up service quickly with no additional cost as surge pricing convinces additional drivers to hit the road when demand spikes. Similarly, a digital company like Netflix can expand its streaming services with no physical infrastructure requirements. Netflix launched its streaming service in 2007 and as of December 2016 had more than 93 million accounts. Streaming accounts have been growing rapidly as the company expands worldwide, by about 60 percent annually. This means account growth has been roughly doubling every two years. This is in line with Moore's Law, a key digital growth concept, which originally stated that computer processing power would double

[44] "Waze," *Wikipedia*, last updated October 22, 2016, https://en.wikipedia.org/wiki/Waze (accessed November 7, 2016).
[45] Dubravac.

every two years. A corollary to this law states that research and development costs will increase exponentially as consumer costs decline.

Figure 4. Growth of Netflix Streaming Accounts



Note: Netflix launched its streaming service in 2007. Until July 2011, Netflix's U.S. streaming and DVD-by-mail operations were combined in a single plan that let members receive both streaming content and DVDs. In July 2011, Netflix separated these plans, allowing members to choose either or both the DVD-by-mail and streaming content options. Prior to 2011, Netflix did not separately track streaming memberships.

Source: Netflix 10-Qs, 2011–2016.

Netflix's growth may be slowing thanks to increased competition—and market fragmentation—from Amazon, Hulu, Crackle, and other Internet-based on-demand TV and movie streaming companies. Digitization has increased data collection on TV viewers, leading to shows being more creative and targeted to specific audiences. This has freed producers from the constraints of mass media and ushered in a new "golden age of television."[46]

Digital retailers also collect considerable customer purchasing patterns and behaviors. While traditional retailers may have a customer rewards card that tracks what an individual purchases, an online retailer knows everything that an individual has looked at, how long they looked, and what they went on to look at next.[47] Internet retailers can test out different web page layouts to see what is more effective for selling products.[48] They can then customize marketing and advertising back to the user, perhaps with discounts to incentivize the purchase.[49] They can analyze all customers' data to get a better insight into their needs or desires.[50] All of which can be done in real time. Beyond data, digital retailers have a second leg up on traditional retailers through physical space advantages. Digital retailers have lower carrying costs compared to traditional brick-and-mortar stores.

[46] Ibid.
[47] Abbas Mohaddes and Peter Sweatman, *Transformational Technologies in Transportation: State of the Activities* (Transportation Research Board, May 2016), http://www.trb.org/Main/Blurbs/174370.aspx.
[48] Ibid.
[49] Ibid.
[50] Ibid.

A meme that has floated around the Internet, generally attributed to Tom Goodwin, notes that something interesting is going on with digital companies asset-light business models. For instance, Alibaba is the world's largest retailer by sales, but it doesn't carry any inventory. AirBNB is the world's largest accommodation provider, but it doesn't own any real-estate. Facebook is the most popular media provider, but it doesn't create any content. Instagram is the most valuable photography company, but it doesn't sell any cameras. Netflix is the fastest growing television network, but it doesn't broadcast through traditional TV distribution channels. And last, Uber is the world's largest taxi company, but it doesn't own any vehicles.

Multisided platforms, also known as matchmakers or two-sided markets, directly connect marketplace participants and are now seen as the key to business and industry organization.[51] They provide network benefits, where the more members of one group that are using the service (for example, consumers using a specific credit card brand), the more another part of the market will want to offer it (merchants accepting payment with that credit card brand). Physical-world examples of multisided platforms include temp agencies (workers and employers), credit cards (merchants and cardholders), and shopping malls (shoppers and merchants).[52] New and fast-growing digital examples include search engines (advertisers and web users), Craigslist (sellers and buyers, activity organizers and participants, etc.), Square (merchants and cardholders), Tinder (online dating), WeChat (social media messaging), and sharing-economy companies such as Uber and Lyft (drivers and passengers) and Airbnb (travelers and room/apartment/home owners).[53]

Uber is a digital transportation company that has grown rapidly since its founding in 2009. Google Trends tracks growth in Google searches for the term Uber, which can serve as a proxy for the company's growth rate. As of September 2016, Uber has 693,000 active riders and 19,000 drivers in Philadelphia.[54] It has an average four-minute arrival time once it has been hailed in the region.[55] Uber operates in more than 500 cities in 72 countries, with over five million daily trips.[56] Globally, there are 1.5 million active drivers and around 600,000 in the United States.[57]

The digital revolution is often considered to be flattening distances in communications and between information and action.[58] Communications technologies enable some individuals to live wherever they want, and work remotely anywhere in the world. Virtual communications eliminate the need to live within easy transportation distance of a workplace, and break down the notion of a region being the commute shed around a principle city.

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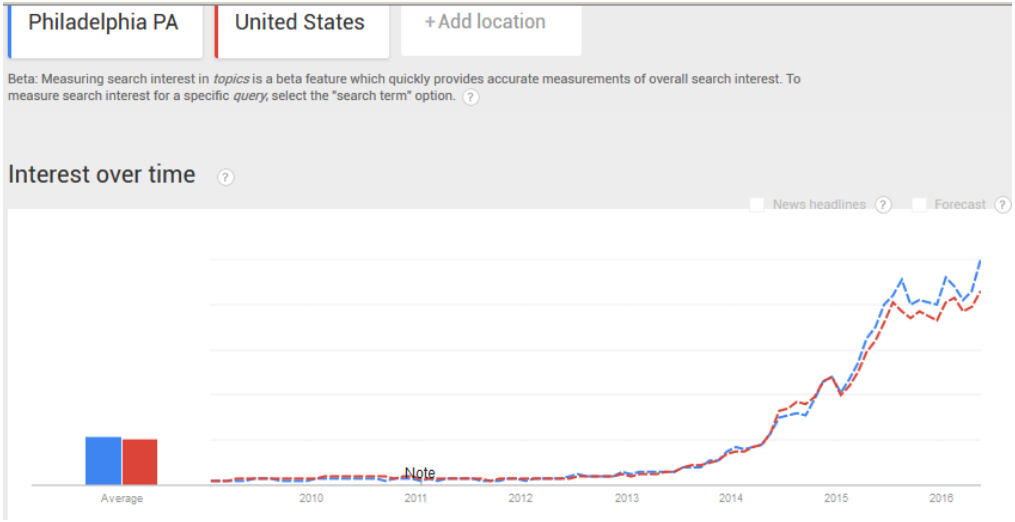
[51] Dubravac.
[52] Ibid.
[53] Ibid
[54] Shari Shapiro, e-mail message to author, December 15, 2016.
[55] Ibid.
[56] Ibid.
[57] Ibid.
[58] Dubravac.

Figure 5. Uber Company Search on Google Trends



Source: Google Trends, 2016.

Traditionally, economies of scale led to decreasing costs with increasing production of physical objects. Digitization flattens the effects of economies of scale, meaning increasing production no longer necessarily leads to decreasing costs.[59] Before punctuated equilibrium, a previous theory of change called *path dependence* suggested that once decisions or investments had been made, they set an individual or community on a path that became very difficult, if not impossible, to change. The standard QWERTY keyboard layout arose not because it is easier to type with, but because it slowed typists down and prevented a typewriter's keys from jamming. Even though computers have long since made this a nonissue, the failure to change to an easier-to-type-with keyboard layout, such as Dvorak, is often cited as an example of path dependence. While in the past it was difficult to physically change a keyboard, today's computers can switch keyboards with the click of a box in the operating system. The ease with which things can be refigured in the digital world means that issues with path dependence are also being broken down.[60]

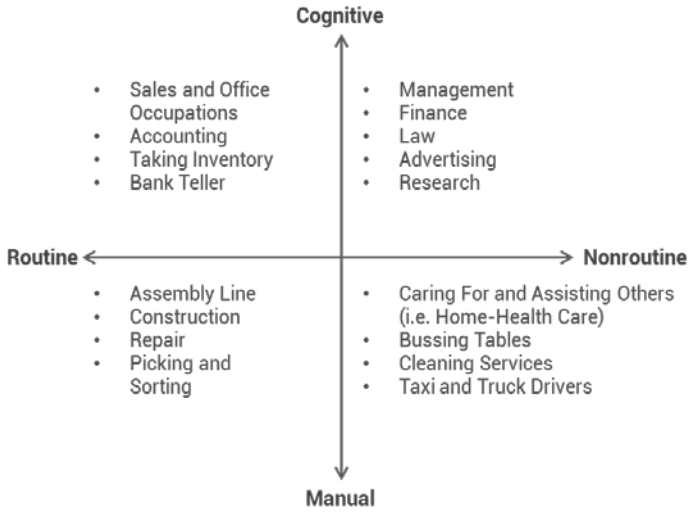
Data science will redefine virtually all jobs in the future, and nearly all work will require some level of digital capability. This process is transforming urban planning and urban design into a new field known as *urban science*. It combines information data and technologies, such as geographic information systems (GIS), simulation, real-time and historic data, and computational methods to identify data-driven solutions.[61] New York University began offering the first urban science degree program in 2012.

Digitization has downside risks. These include data breaches, social media blunders, increasing political unrest, legislative and regulatory uncertainty, greater

[59] Ibid.
[60] Marshall, *The Surprising Design of Market Economies*.
[61] President's Council of Advisors on Science and Technology, *Technology and the Future of Cities* (Washington, DC: February 2016), https://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/pcast_cities_report___final_3_2016.pdf.

risk of economic upheaval, a worsening of the digital divide, placing sensors where they are not needed or are unhelpful, digital remorse (once something is put on the Internet, it is hard to remove it), and loss of personal privacy.[62] The jobs cost of digitization is a particular area of concern. IBM's Watson has already bested Garry Kasparov at chess, and 74-time winner Ken Jennings at Jeopardy!.[63] Amazon already employs 30,000 robots in its fulfillment centers. A typical way to classify jobs is into routine and nonroutine, and cognitive versus manual categories, see Figure 6. The highest paying jobs fall into a cognitive nonroutine classification.[64] The lowest paying ones are manual nonroutine.[65] In between are routine jobs that tend to pay middle-class wages—in factories or in office administration—that outsourcing and automation have been replacing, see Figure 7.[66]

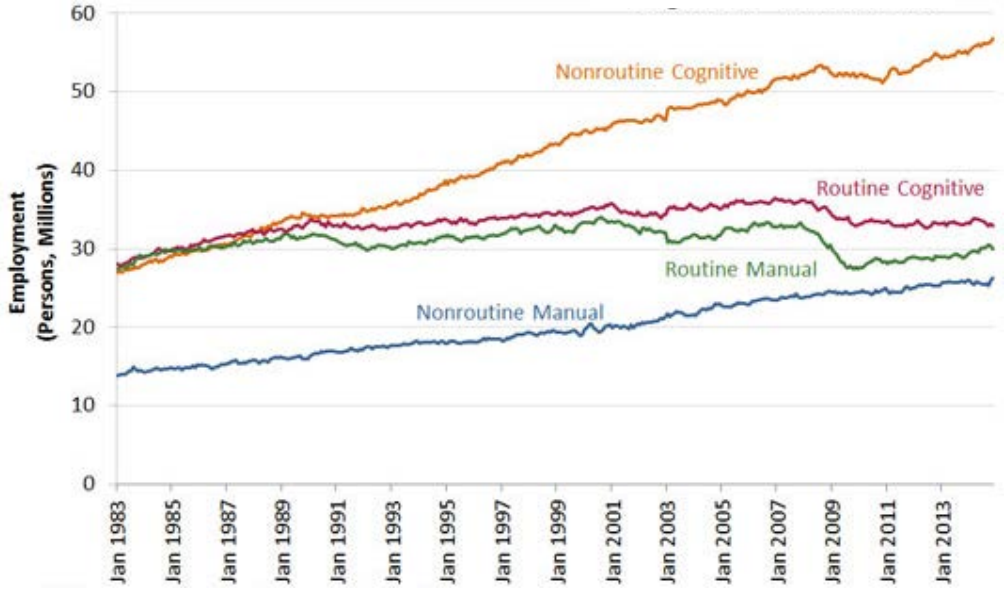
Figure 6. Jobs and Skills



Source: Adapted from Paul Krugman 'Autor! Autor!,' New York Times, March 6 2011, https://krugman.blogs.nytimes.com/2011/03/06/autor-autor/ (accessed February 24, 2017); and Elizabeth Kolbert, 'Our Automated Future,' The New Yorker, December 19 & 26, 2016 Issue, http://www.newyorker.com/magazine/2016/12/19/our-automated-future (accessed February 24, 2017).

[62] Dubravac.
[63] Elizabeth Kolbert, 'Our Automated Future,' *The New Yorker*, December 19 & 26, 2016 Issue, http://www.newyorker.com/magazine/2016/12/19/our-automated-future (accessed February 24, 2017).
[64] Ibid.
[65] Ibid.
[66] Ibid.

Figure 7. Job Growth: Nonroutine vs. Routine and Cognitive vs. Manual



Source: Maximiliano Dvorkin, "Jobs Involving Routine Tasks Aren't Growing," Federal Reserve Bank of St. Louis, January 4, 2016, https://www.stlouisfed.org/on-the-economy/2016/january/jobs-involving-routine-tasks-arent-growing (accessed February 24, 2017).

HAVs show how AI can eventually begin to replace nonroutine and cognitive job functions in areas that were previously seen as safe from automation and outsourcing. This reflects the growing concern over what kinds of work we will all perform in the future. Historically, technological innovation has displaced lower skill manual and routine jobs with new higher skill job opportunities. Thus, future jobs may be in industries that haven't yet even been thought of today. Dubravac has noted that all jobs in the future may have more of a data science component, but will otherwise largely be the same. This would indicate that quantitative skills will continue to be important. Likewise, the ability to work with technology and robotics is likely to be valuable. Social and creative skills may still be difficult to automate. Security is likely to be an ongoing and growing concern. More research is needed into understanding the future of work in a fully digitized world.

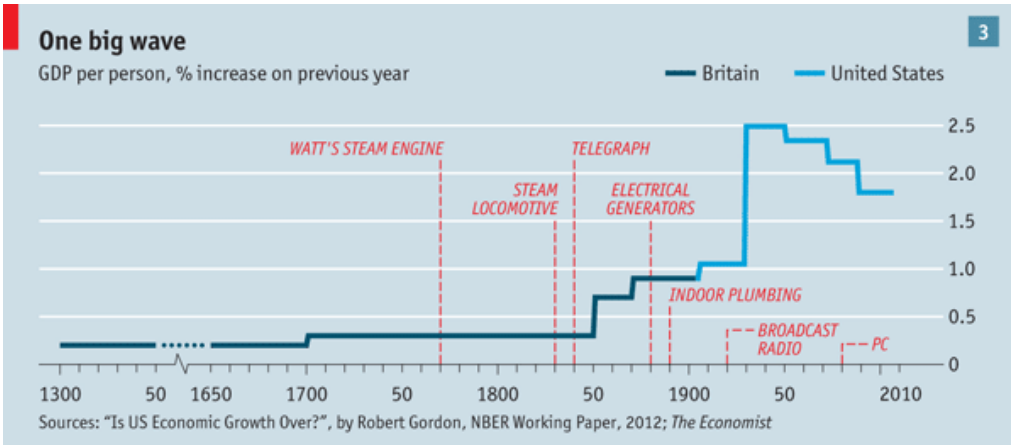
How the process of automation and robotics plays out can be complicated and unpredictable. In other industries, automation and robotics must be cheaper than hiring someone to perform a task. Outsourcing to countries with lower labor costs can be less expensive than applying automation. In periods of economic downturns, automation becomes hard to justify if someone could simply be given the job instead.[67] Toyota is returning some of its automated processes back to humans, as machines cannot yet make process improvement recommendations as well as

[67] Tod Newcombe, "Scaling Up Sensor-Based Smart Cities Proves Difficult," *Government Technology*, June 3, 2014, http://www.govtech.com/data/Scaling-Up-Sensor-Based-Smart-Cities-Proves-Difficult.html (accessed January 22, 2015).

humans.[68] This also allows workers to develop skills beyond picking parts from an assembly line.[69]

Some counter-narratives to a high-growth digital future come from secular stagnation theory and the law of diminishing returns. There are a variety of theories as to why growth may be stagnant in the future, including: the low capital and employee needs for digital companies; growing income inequality and rent seeking; long-term underinvestment in education and infrastructure; increasingly difficult to extract energy resources; aging population; globalization; and high consumer and government debt levels.[70] Twitter has a market cap of around $10 billion, and employs 3,600 people. In comparison, a traditional manufacturing company, such as Ford, has a market cap of $50 billion, five times more than Twitter, but employs 200,000 workers, more than 55 times as many. As for diminishing returns, HAVs, the IoT, smart cities, and clean energy may generate new efficiencies and yield economic benefits. However, these technologies may not be as dramatic as going from horses to cars or from no electricity to readily available electricity. This perspective expects that future innovations will not have as big of an impact as previous ones, because the base from which they are driving growth is much higher.

Figure 8. Pessimistic View of Innovation and Economic Growth



Source: Robert Gordon, "Is U.S. Economic Growth Over?," NBER Working Paper, 2012; and "Innovation Pessimism: Has the Ideas Machine Broken Down?," The Economist, January 12, 2013, http://www.economist.com/news/briefing/21569381-idea-innovation-and-new-technology-have-stopped-driving-growth-getting-increasing (accessed September 9, 2014).

The next section considers how digitization is reshaping transportation in Greater Philadelphia and around the world.

[68] Craig Trudell, Yuki Hagiwara, and Ma Jie, "Humans Replacing Robots Herald Toyota's Vision of the Future," *Bloomberg News*, April 7, 2014, https://www.bloomberg.com/news/articles/2014-04-06/humans-replacing-robots-herald-toyota-s-vision-of-future (accessed September 2, 2016).
[69] Ibid.
[70] "Secular Stagnation Theory," *Wikipedia*, last updated March 2, 2017, https://en.wikipedia.org/wiki/Secular_stagnation_theory (accessed March 14, 2017).

DIGITAL TRANSPORTATION TECHNOLOGIES

"The future of transportation is information."

- Richard McKinney
Former Chief Information Officer,
U.S. Department of Transportation

Digital transportation is working to find new efficiencies within the existing system. In a digital world, mobility is more about efficiently reaching a destination using the best available mode, rather than relying solely on the automobile.[71] Digitization and the IoT are connecting people, objects, and data and information in real time. Access to data, information, and real-time communications is helping new on-demand modes—such as ridesourcing and microtransit—to emerge. These are already expanding options in moving about the region but are also creating oversight challenges, and they could potentially disrupt existing taxi and paratransit services. Other technological advancements, such as CVs and AVs, could further revolutionize how we get around. A digitized transportation future promises new modes, a wider array of options for getting around, and potential disruption of dominant market players. Today's major transportation providers can reinvent themselves and thrive in this new future if they are flexible and adaptable, understand how change is occurring, and react to it accordingly

The 20th century physical infrastructure of roads, bridges, and transit systems remains critical to our ability to travel about the region. These facilities are too often in a state of disrepair, and much of the region's transportation infrastructure will need to be reconstructed and brought up to modern standards over the next 30 years. This is an opportunity to digitize these facilities by incorporating technologies like dedicated short-range communications (DSRC), which can talk with CVs and infrastructure; connecting traffic signals to the Internet; and using sensors to track infrastructure condition and better time repairs. DSRC may be necessary to achieving fully self-driving vehicles in the future. Already, private-market-driven digital services are causing transportation systems to be used in new and different ways, without being widely regulated or taking their wider impacts into consideration.[72] Navigating and regulating new technologies and services will provide many challenges to federal, state, and local governments going forward.

Digital transportation, as it is presently understood, consists of:

- 3-D printing;
- Artificial Intelligence;
- automated vehicles;
- Big Data;
- connected vehicles;
- digital mapping;

[71] U.S. Department of Transportation, *The Smart/Connected City and its Implications for Connected Transportation* (Washington, DC: U.S. Department of Transportation, 2014). http://www.its.dot.gov/itspac/Dec2014/Smart_Connected_City_FINAL_111314.pdf

[72] Benjamin Freed, "Amazon Prime and Uber Are Changing the Map of Your City," *Washingtonian*, May 31, 2015, http://www.washingtonian.com/blogs/capitalcomment/transportation/amazon-prime-and-uber-are-changing-the-map-of-your-city.php (accessed June 9, 2015).

- intelligent transportation systems;
- the Internet of Things;
- real-time information;
- smart, connected cities;
- transportation network companies and other digital transportation providers;
- unmanned aerial systems; and
- virtual communications.

Many of these technologies are highly interconnected. For example, the IoT forms the backbone of smart cities and CVs and is a driver of Big Data. Smartphones provide a platform that helps to network these technologies together. The following sections of this chapter look at key emerging digital transportation technologies. New digital technologies could emerge in the future, potentially disrupting these disruptors. The discussion around these technologies focuses on those that are most directly related to transportation. Any number of other technologies could be included here. For instance, e-commerce alters how we shop, how much travel we do when shopping, and how goods are moved from production, to warehousing, and to the consumer, among other changes. In 2016, more people shopped online than in stores on Black Friday for the first time ever.[73]

Disclaimer

This section contains references to a number of private market companies to better illustrate the types of transportation technologies and service innovations currently available or in development. This list is far from comprehensive, and inclusion here is not intended to be an endorsement of any product or service.

3-D Printing

3-D printing, or additive manufacturing, produces digital designs by breaking them into individual layers and progressively "printing" a variety of materials in a layered production process to create the object.[74] The 3-D printing industry is led by companies that are producing a variety of component technologies combining 3-D printing with other robotic and machine capabilities, such as ultra-high-end industrial machines, liquid molten jet technology, large-scale production of 3-D printers, open-source desktop tools, and all-in-one multifunctional personal fabricators.[75]

3-D printing shifts manufacturing from a drawn-out, linear, and multiparty process into one where individual inventors can design, prototype, test, and refine on their own.[76] 3-D printing will most likely lower production cost and retail prices, reduce

[73] Phil Wahba, "About 10 Million More Americans Shopped Online than in Stores over the Black Friday Weekend," *Fortune*, November 27, 2016, http://fortune.com/2016/11/27/black-friday-nrf-shopping/ (accessed December 9, 2016).
[74] Abbas Mohaddes and Peter Sweatman, *Transformational Technologies in Transportation: State of the Activities* (Transportation Research Board, May 2016), http://www.trb.org/Main/Blurbs/174370.aspx.
[75] Ibid.
[76] Ibid.

inventory limits, increase customization levels, and allow for more local and regional production.[77] 3-D printers can combine design, production, and transportation, which may make the supply chain irrelevant with the ability to produce parts as needed.[78]

Dubravac notes that 3-D printers offer medieval craftsmanship with industrial production quality for products that can be individually customized.[79] 3-D printers have the potential to do away with economies of scale, reduce demand for both automation and labor, and eliminate trade-offs that exist in traditional manufacturing between complexity and cost.[80] 3-D printing may return more manufacturing back to the U.S. and make it more local in nature.

The LM3D is the world's first road ready 3-D printed car.

Source: Local Motors.

Several manufacturers have been experimenting with 3-D printed cars, such as the **Urbee 2**, various vehicles produced by **Local Motors**, and **Divergent**. 3-D printed cars can be designed and manufactured much faster with 3-D printers, while using less material and energy in the process. They are generally printed with carbon fiber and plastic composites. This makes them as strong as steel, but weigh 50 to 90 percent less than a typical car. Lighter weight combined with the electric motors used for propulsion could reduce energy use and greenhouse gas emissions, while also reducing roadway wear and tear. They can enhance safety by embedding shock absorbing materials into the vehicle frame and bumpers. Local Motors has developed several prototype vehicles, including the Strati, LM3D, Rally Fighter, and the Olli bus. Divergent has raised $23 million in venture capital.

A partnership between Advanced Paving Technologies and the University of California–Davis Pavement Research Center is crowdsourcing funding to create a 3-D printing asphalt machine. This machine will scan the road to be repaired with LiDAR, compact its existing pavement, and apply a new asphalt topcoat, all in a single pass.[81] MIT researchers have developed small interlocking 3-D printed composite material pieces that can be linked together to build structurally sound vehicles, airplanes, bridges, levees, or dams.[82] Much like Legos or other similar toys, they can readily be disassembled and reassembled, potentially enabling easy maintenance and repairs. **MX3D** plans to 3-D print a bridge over a canal in Amsterdam, Netherlands in the fall of 2017.

Artificial Intelligence

Artificial Intelligence (AI) is the development of computer systems that are able to perform tasks that would typically require human knowledge. Human abilities, such as visual perception, speech recognition, decision making, and language translation, are embedded into computer software and communicated through hardware.

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[77] Ibid.
[78] Ibid.
[79] Shawn Dubravac, *Digital Destiny: How the New Age of Data Will Transform the Way We Work, Live, and Communicate* (Washington, DC: Regnery Publishing, 2015).
[80] Mohaddes and Sweatman.
[81] Ibid.
[82] David L. Chandler, "How to Make Big Things out of Small Pieces," *MIT News*, August 15, 2013, www.web.mit.edu/newsoffice/2013/how-to-make-big-things-out-of-small-pieces-0815.html (accessed December 9, 2013)

AI development is the key to creating self-thinking autonomous vehicles, as opposed to computer-programmed, automated ones. The development of the AI technology needed for this may be years or even decades away.[83]

Nuato and **Nexar** are examples of how AI can improve vehicle safety in the present. Nuato uses a connected dashcam network and AI in the cloud to learn how to prevent crashes and reduce roadway risks. It tracks driver performance for professional drivers and fleets and uses it to provide coaching that improves performance and reduces false liability claims. Nexar is a smartphone app that tracks driver behavior by reading license plate numbers, along with vehicle location, velocity, and trajectory. This data is then crowdsourced to rate drivers and is used to identify dangerous ones.[84] Drivers can install a device—or use their smartphone—on their dashboard that will both track other vehicles on the road and alert its driver to nearby bad drivers. Sensors on the smartphone or dashboard device detect hard braking, slowdowns on the road, and are part of a connected vehicle network. The app will also record the driver and passengers, serving as an additional degree of safety for TNC drivers.

Automated Vehicles

Automated vehicle (AV) and highly automated vehicle (HAV) systems comprise hardware and software, both remote and on-board, which perform the functions needed to drive a vehicle. The key hardware components include an on-board computer that makes decisions; a global positioning system (GPS) signal system; an inertial measurement unit for when the GPS is out of signal; radar sensors that detect nearby vehicles; ultrasonic sensors that detect other vehicles and objects alongside the AV; light detection and ranging (LiDAR) that identifies lane markings; and video cameras that read traffic signals, road signs, and watch for pedestrians and obstructions.

The National Highway and Traffic Safety Administration (NHTSA) has adopted the Society of Automotive Engineers International vehicle automation level definitions in an attempt to standardize them. These definitions classify vehicles based on "who does what, when":[85]

- Level 0 – A human driver does everything.
- Level 1 – An automated system on the vehicle can sometimes assist the human driver conduct some parts of the driving task.

[83] Lee Gomes, "Driving in Circles: The Autonomous Google Car May Never Actually Happen," *Slate*, October 21, 2014, http://www.slate.com/articles/technology/technology/2014/10/google_self_driving_car_it_may_never_actually_happen.2.html (accessed October 22, 2014).
[84] Dyllan Furness, "Bad Drivers Beware: This AI Powered Dashcam App Is Watching You," *Yahoo Tech*, June 20 2016, https://www.yahoo.com/tech/bad-drivers-beware-ai-powered-181310085.html (accessed June 22, 2016).
[85] National Highway Traffic Safety Administration, *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety* (Washington, DC: The U.S. Department of Transportation, September 2016). https://www.transportation.gov/AV.

- Level 2 – An automated system on the vehicle can actually conduct some parts of the driving task, while the human continues to monitor the driving environment and performs the rest of the driving task.
- Level 3 – An automated system both actually conducts some parts of the driving task and monitors the driving environment in some instances, but the human driver must be ready to take back control when the automated system requests.
- Level 4 – An automated system can conduct the driving task and monitor the driving environment, and the human need not take back control, but the automated system can operate only in certain environments and under certain conditions.
- Level 5 – An automated system can perform all driving tasks, under all conditions that a human driver could perform them.

These definitions draw a key distinction for who is primarily responsible for vehicle control: between Levels 0 to 2 it is a human driver, and from Levels 3 to 5 it is an automated system.[86] NHTSA will require manufacturers to identify vehicle automation class using these definitions. Vehicles fitting into the Levels 3 to 5 classifications are HAVs. Level 3 has particular concerns as to how readily a HAV occupant will be to take over driving when conditions warrant.

The Eno Center for Transportation's *Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations* identifies a number of potential benefits from an HAV future, including:[87]

- Enhanced safety can potentially reduce roadway fatalities with driver error as a contributing factor by up to 90 percent. This could lower insurance costs and allow vehicles to use lighter-weight materials.
- Platooning and closer vehicle spacing can increase road throughput capacity and relieve congestion. It is estimated that a 90 percent HAV fleet would increase road capacity by 80 percent.
- Reduced braking and smoother accelerating can further reduce fuel consumption and vehicle emissions.
- Vehicle sharing, which can lessen the need for parking and its costs.
- More mobility to the young, elderly, and disabled.
- Faster roadway speeds can lead to shorter travel times.
- Narrower road lanes can allow for more lanes in the same right-of-way.[88]
- More productive use of time while traveling.

Generally, autonomous and automated vehicle terms are used interchangeably. There is a difference in their meaning, however. Autonomous suggests independent operations, meaning that decisions are made without input from other vehicles or infrastructure. Instead of being connected, they rely solely on their internal sensors, cameras, and LiDAR to read and react to their operating environment. It can also

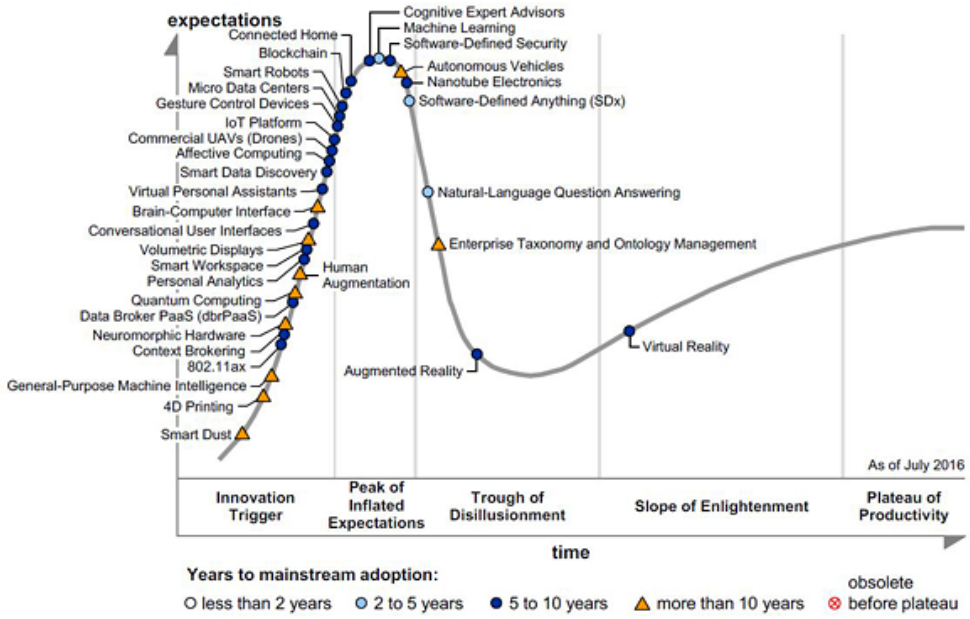
[86] Ibid.
[87] Daniel Fagnant and Kara M. Kockelman, *Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations* (Washington, DC: Eno Center for Transportation, 2013), https://www.enotrans.org/etl-material/preparing-a-nation-for-autonomous-vehicles-opportunities-barriers-and-policy-recommendations/.
[88] Mohaddes and Sweatman.

suggest the vehicle is controlled by AI, instead of human-programmed code. Autonomous vehicles will have greater risk from sensor failures and will not benefit from other connected technologies, but they may be less susceptible to hacking, particularly if they are not connected to the IoT.

The Federal Highway Administration's (FHWA's) CV requirements implies that vehicles will not be allowed to operate autonomously on the road. Cooperative AVs, which are connected to, and communicate with, other vehicles, are generally assumed to be the most likely future of self-driving vehicles.

HAVs are currently being funded with considerable research and development expenditures and are the subject of a daily barrage of news articles. As a result, they are currently near the peak of inflated expectations in the "Gartner Hype Cycle," which identifies a process of how thinking evolves about new technology and sets more realistic expectations for its development. Gartner pegs these technologies as being more than 10 years away from adding economic productivity.

Figure 9. July 2016 Gartner Emerging Technology Hype Cycle



Source: Gartner, 2016.

HAVs are likely to substantially affect travel choices, land use patterns, infrastructure investment, goods movement, and other activities. Once HAVs are deployed, complex feedback loops will reverberate throughout the economy. The next sections of this report consider HAV infrastructure implications, their technology and its challenges, the unknowns they present, and some thoughts on preparing for their eventual arrival.

HAV Infrastructure

HAVs will need to be able to operate within existing infrastructure facilities. Requiring some new or additional infrastructure would delay their rollout and

potentially create the chicken-and-egg problem that has plagued recent transportation infrastructure advances, such as EVs. Basic HAV infrastructure needs are the same as those for human-driven vehicles: well-maintained and modernized roads, safe bridges, clear and readable road signs, and consistent lane markings. There are two generally recognized paths to how AVs will operate in the future. The first is a gradual evolution in HAV capabilities using mixed traffic facilities. The second is through the development of HAV-only facilities.

Given that the average age of a vehicle on the road today is around 11 years, the fleet turnover period to reach a fully HAV fleet will likely take 20 to 30 years once these vehicles become commercially available. This suggests a shared facilities future for some period of time, during which HAVs are unlikely to achieve the significant safety, congestion, reduced energy use and emissions, or road capacity expansion benefits that they are touted to provide.[89] Assuming HAVs will be automated, and not autonomous, it will be very difficult to prepare them for every possible situation that may arise, particularly those involving poor drivers whose bad actions may or may not be intentional.[90] Initial deployment of HAVs in shared facilities could be limited to Level 4 vehicles where at least two of these three conditions are in place: "well-mapped urban areas, slow speeds (under 25 mph), and good weather conditions."[91] Limited access highways are also seen as likely early HAV deployment areas.

Options for developing HAV-only infrastructure include building new facilities for HAVs, converting portions of existing facilities to HAV use only, or outright banning human drivers. Developing new infrastructure will be very expensive but could benefit HAVs by simplifying the technological challenges.[92]

Infrastructure conditions become even more critical in a driverless world. The most widely recognized infrastructure and maintenance needs in preparing for HAVs are improving pavement conditions and creating up-to-date road lane marking, rumble strip, and sign management databases. If a pothole jars LiDAR or other electronic HAV equipment out of place, then the technology may not be able to properly read its surroundings.[93] HAVs use lane markings and rumble strips to guide themselves. Missing, dilapidated, and unclear markings or rumble strips may create confusion and safety risks. HAVs also need clear, readable signs, while older and outdated signs need to be removed from the right-of-way. Additional infrastructure needs may arise as more is understood about the technology. Most likely, these needs will be for CV and infrastructure technologies, particularly if the future of self-driving vehicles is connected and automated vehicles (CAVs), as is widely forecast.

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[89] Steven Schladover, "Progress toward Automated Driving," *Halmstad Colloquium* (video), February 12, 2012, https://www.youtube.com/watch?v=4wfpUSTG9zU (accessed June 7, 2016).
[90] Ibid.
[91] Joe Cortright, "The Price of Autonomous Cars: Why it Matters," *Strong Towns Blog*, October 4, 2016, http://www.strongtowns.org/journal/2016/10/3/the-price-of-autonomous-cars-why-it-matters (accessed October 12, 2016).
[92] Ibid.
[93] Jeffrey Short and Dan Murray, *Identifying Autonomous Vehicle Technology Impacts on the Trucking Industry* (American Transportation Research Institute, November 2016), http://atri-online.org/wp-content/uploads/2016/11/ATRI-Autonomous-Vehicle-Impacts-11-2016.pdf.

Highways in an HAV future could have truck-only lanes with thick, reinforced pavement that is needed to support them.[94] Other lanes could be car only, allowing for reduced pavement thickness and cost savings. Speed limits could dramatically increase, and HAV-only lanes will not need to be as wide as current roads, as HAVs are capable of much more precise driving.

HAV Technology

There are two probable paths for HAV technology to develop. The first is a gradual *evolution* of consumer vehicles performing more and more automated functions. The second is a *revolution*, where HAVs jump straight to full Level 5 autonomy.

Cost remains a potential stumbling block. Analysts estimate HAVs will be marketable when their technology costs are less than $10,000 per vehicle, and mass marketable at $3,000 to $5,000 per vehicle. One recent media analysis pegged their current component costs at $250,000.[95] Assuming these costs decrease by 50 percent every two years, in line with Moore's Law, it would take 10 years to get under the $10,000 marketability threshold, and another two years to achieve the mass production target. In addition, industry will look to recoup the substantial research and development expenses that have gone into creating HAVs.

HAVs are expected to have electric powertrains. This is largely due to the fact that many predict they will be used in on-demand shared mobility applications. This means they will travel considerable distances each year, and the much lower operating costs for electrical vehicles will pay for the higher up-front capital purchase costs.[96] However, this would mean more down time for recharging.

Initial HAV deployments may focus on trucks and buses.[97] In the United States, automated technologies have focused more on trucks. There may be a stronger business model for automated truck deployment. There is a driver shortage already, and many long-haul drivers are nearing retirement. The industry is having a hard time recruiting new, younger drivers to replace them.

Both **Daimler** and **Mercedes** have test-driven automated trucks.[98] Uber made headlines when its automated truck, Otto, made a 120-mile delivery of 50,000 cans of beer between Fort Collins and Colorado Springs, Colorado.[99] The automated hardware and software on the truck cost $30,000 and only operates at Level 4 autonomy on highways.[100] **Peloton** is developing connected and automated truck

[94] Mohaddes and Sweatman.
[95] Steve LeVine, "What it Really Costs to Turn a Car into a Self-Driving Vehicle," *Quartz*, March 5, 2017, https://qz.com/924212/what-it-really-costs-to-turn-a-car-into-a-self-driving-vehicle/ (accessed March 8, 2017).
[96] Chris Mooney, "These Researchers Think We're Nearing 'Peak Car'—and the Consequences Could Be Dramatic," *The Washington Post*, September 22, 2016, https://www.washingtonpost.com/news/energy-environment/wp/2016/09/22/these-researchers-think-were-nearing-peak-car-and-the-consequences-could-be-dramatic/ (accessed September 23, 2016).
[97] Schladover.
[98] Bollier.
[99] Alex Davies, "Uber's Self-Driving Truck Makes its First Delivery: 50,000 Beers," *Wired*, October 25, 2016, https://www.wired.com/2016/10/ubers-self-driving-truck-makes-first-delivery-50000-beers/ (accessed January 12, 2017).
[100] Ibid.

platooning technology, which can improve safety and fuel efficiency. The technology uses wireless links to reduce spacing between the vehicles and always-on radar to warn drivers to brake or initiate braking if needed. In a two-truck platoon, the lead truck can reduce fuel use by 4.5 percent and the trailing truck by 10 percent. Both trucks still need a driver, and the technology does not currently perform any steering. **Dispatch** is developing automated shipping vehicles designed to operate on sidewalks and in pedestrian areas to help with last-mile delivery issues.

The Olli is a 3-D printed self-driving shuttle.

Source: Local Motors.

A number of companies are developing automated buses around the world.

- **CityMobile2** has completed a test in Trikala, Greece, and is undertaking additional trials in Europe.[101]
- **WEPods** are circulating in mixed traffic between Ede-Wageningen railway station and Wageningen University in the Netherlands. Ligier Group, a French automobile company, makes the **EZ-10** vehicles being used in this pilot project and others in Europe and California.
- A two-year trial of autonomous buses has been launched through a partnership between **BestMile** and **PostBus** in Sion, Switzerland.
- The **Olli** is a 3-D printed automated bus that has been developed by Local Motors.[102] The city of Las Vegas, Nevada has purchased two of these vehicles.
- The **Lutz Pathfinder** is a system of driverless pods operating on pedestrianized streets serving the city of Milton Keynes, in the United Kingdom.
- The **Hitachi Ropits** is a single-seat, tablet-controlled self-driving pod that is intended to drive on sidewalks with a maximum speed of 3.7 miles per hour.[103]

Mobileye is developing safety technologies that are both connected and automated through its Advanced Driver Assistance Programs (ADAS). Connected technologies provide driver warnings such as lane departure warning and forward collision warning. On the automated end, ADAS can take control of the vehicle and perform automatic emergency braking, and other applications such as adaptive cruise control, lane keeping assist, lane centering, and traffic jam assist. Other ADAS functions help with traffic sign recognition and intelligent high-beam control. The company offers aftermarket products that can be used to retrofit existing vehicles.

Uber began testing Level 3 HAVs in the City of Pittsburgh, Pennsylvania, in September 2016. These vehicles will have both a standby driver and engineer monitoring their travel. The cars will operate under the same model as regular ridesourcing, with users summoning self-driving vehicles through their smartphones. This is the first time the public has had access to HAVs on public

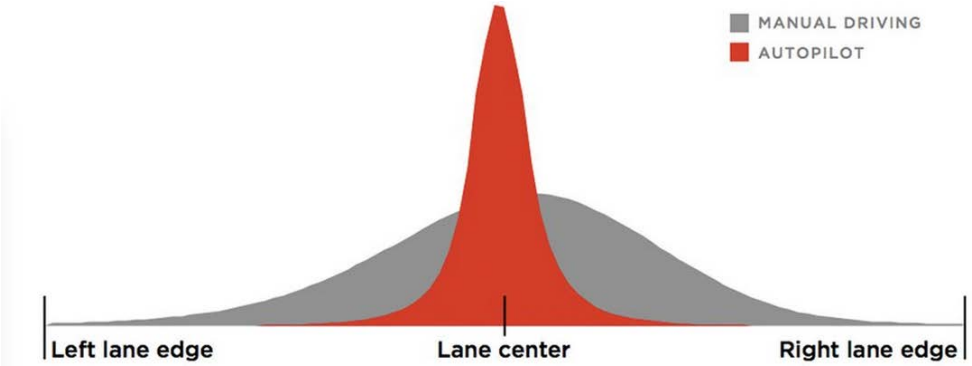
[101] Chuck McCutcheon, "Part 2. How Transit Is Looping in TNCs to Plan Integrated Transportation Networks," *Passenger Transport* 74, no. 4 (2016), http://www.apta.com/passengertransport/PublishingImages/PT_02-22-16_Connecting%20the%20Sectors_Part%20II_in-depth_integrated%20mobility_McCutcheon.pdf (accessed June 29, 2016).
[102] Rob Lever, "Olli, a 3D Printed, Self-driving Minibus, to Hit the Road in US," *Phys.org*, June 16, 2016, http://phys.org/news/2016-06-olli-3d-self-driving-minibus-road.html (accessed June 22, 2016).
[103] Jason Falconer, "Hitachi's ROPITS Tablet-Controlled, Self-Driving Urban Vehicle," *New Atlas*, March 20, 2013, http://newatlas.com/hitachi-ropits-self-driving-urban-vehicle/26727/ (accessed October 28, 2016).

roads. Pittsburgh was specifically chosen for the challenges it provides HAVs: hills, narrow streets in poor condition, trees that can hide signs and traffic signals, a number of tunnels and bridges, blinding summer sun, slippery conditions from leaves falling in the fall, and lots of snow in the winter.[104] Uber has also recently announced a $300 million alliance with Volvo to supply vehicles and technology, and the acquisition of Otto, the aforementioned automated semi-truck startup in San Francisco.

Alphabet Inc., the parent company of Google, is developing and marketing its self-driving car technology through a new subsidiary, **Waymo**. Since 2009, the company's AVs have driven more than two million miles, and is currently testing the technology in Kirkland, Washington, Mountain View, California, Phoenix, Arizona, and Austin, Texas. In October 2015, Waymo conducted the first driverless vehicle trip on a public road.

Tesla's autopilot is an example of a Level 2 AV. Its lane-centering technology benefit compared to human driving can be seen in Figure 10. Tesla is one of the most aggressive movers in vehicle automation. Elon Musk has indicated that the Tesla Model 3 will achieve Level 3 autonomy by the end of 2017, but actual use of this technology in vehicles will be rolled out more slowly.[105] The HAV program will record driver actions for the time being and compare them with what the software would have done in order to test its safety.[106] Autopilot currently relies only on radar.[107] However, its next version will add cameras and sensors, but no LiDAR.[108]

Figure 10. Tesla Autopilot Lane Centering Compared to Manual Driving



Source: Tesla via Philip E. Ross, "Tesla Reveals its Crowdsourced Autopilot Data," IEEE Spectrum, May 26, 2016, http://spectrum.ieee.org/cars-that-think/transportation/self-driving/tesla-reveals-its-crowdsourced-autopilot-data (accessed October 11, 2016).

[104] Heather Somerville, "Uber Debuts Self-Driving Vehicles in Landmark Pittsburgh Trial," *Reuters*, September 14, 2016, http://www.reuters.com/article/us-uber-autonomous-idUSKCN11K12Y (accessed September 21, 2016).
[105] Jack Stewart, "Elon Musk Says Every New Tesla Can Drive Itself," *Wired*, October 19, 2016, https://www.wired.com/2016/10/elon-musk-says-every-new-tesla-can-drive/ (accessed October 20, 2016).
[106] Ibid.
[107] LeVine, "What it Really Costs…"
[108] Jonathon Ramsey, "The Way We Talk About Autonomy is a Lie, and That's Dangerous," *Fortune*, March 8, 2017, http://fortune.com/2017/03/08/the-way-we-talk-about-autonomy-is-a-lie-and-thats-dangerous/ (accessed March 10, 2017).

While HAVs may initially closely resemble the vehicles we drive today, their ultimate form is likely to change substantially in order to accommodate more passenger comfort, changing vehicle functionality, aerodynamics, and other aspects of this technology. This is similar to how cars initially resembled horseless carriages, but their ultimate form evolved over time, shaped by technology, design needs and styling, safety improvements, and other innovations.

HAV Technological Challenges

Beyond the legal liability and regulatory challenges, a number of technological issues remain. Testing is currently being conducted by trial and error. It is very difficult to test all the possible paths that are programmed into the vehicle.[109] The vehicle must be able to detect when there is a fault right away and respond to it.[110] It cannot fail to detect a fault but must also minimize identifying faults that are not there (false positives).[111] The vehicle needs to be able to switch over and operate immediately in a degraded mode.[112] It must be able to distinguish between any object in the road that could cause harm and those that are innocuous.[113] Since no single technology can satisfy all environmental detection needs, a combination of sensors and other devices are needed, which adds complexity and cost.[114] Remote sensors are slower and more uncertain than on-board vehicle sensors in determining other vehicles' speed, acceleration, and actions.[115] Data collected by sensors needs to be filtered, which creates a lag in taking action.[116] AVs have a hard time detecting subtle cues from other vehicles, pedestrians, and bicyclists like experienced drivers can.[117] Manually driven cars travel about 50,000 hours between crashes and two million hours between fatalities; HAVs will need to do better than these figures.[118] However, computers and cellphones crash much more frequently than this, and the computers in AVs will be exposed to more extreme temperature and weather than personal and mobile systems are.[119]

Work zones create a particular problem for AVs because they take precedence over all the other detailed road information that these vehicles are programmed to read.[120] Each location can have a variety of methods of blocking of construction sites: cones, orange barrels, signs or trucks with blinking arrows, workers holding placards, and others.[121] Most work is done by private companies which are given

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[109] Ibid.
[110] Ibid.
[111] Ibid.
[112] Ibid.
[113] Ibid.
[114] Ibid.
[115] Ibid.
[116] Ibid.
[117] Ibid.
[118] Ibid.
[119] Ibid.
[120] Aarian Marshall, "Why Self-Driving Cars *Can't Even* With Construction Zones," *Wired*, February 10, 2017, https://www.wired.com/2017/02/self-driving-cars-cant-even-construction-zones/ (accessed February 13, 2017).
[121] Ibid.

much leeway in the timing of when they start work.[122] Very few state DOTs maintain a database detailing when and where construction activity will occur.[123]

HAVs are widely predicted to greatly enhance safety. However, a system that is safer 99 percent or more of the time can lull people into a false sense of security during periods when it is less safe. The transition to Level 3 HAVs is fraught with risks. Errors will come from a variety of factors, but the transition between humans and computers will be one of the major challenges. As computers do more driving, skills may atrophy due to disuse. This means individuals may be less able to respond to emergency situations. AVs being tested on roads today are very cautious drivers, having been programmed to follow all rules of the road.[124] This has led to them being involved in crashes twice as frequently as the average human driver, although none have been their fault.[125] Many of these crashes have been the result of computer reactions being much faster than human responses, leading often to low-speed, rear-end variety crashes.[126]

Wireless Internet connections and other connected technologies become potential cybersecurity risks whereby hackers can gain access to vehicles. Hackers have been able to access any vehicle that used the "Uconnect" vehicle navigation technology.[127] Once publicized, FHWA and Chrysler acted quickly to fix this flaw. As vehicles are increasingly connected through multiple different pathways, CV manufacturers will need to be more responsible for digital security.

HAVs are often portrayed as potentially harassing pedestrians, bicyclists, and other street users. However, recent research from the University of California-Santa Cruz on human behavior suggests it could be the other way around. The safety and law abiding implications of HAVs suggest that humans increase their risk taking around them.[128] For instance, if a pedestrian knows an HAV will stop when they step into the street, then they are much more likely to do so.[129] A recent test by a taxi driver in Manhattan to follow all the rules of the road and cede right-of-way to nonmotorized users significantly slowed travel speed, and took two to three times the normal amount of time required to get around.[130]

HAVs operate through human-generated computer code, which tells them what to do and must plan for any potential situation that can occur. They will be coded to

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[122] Ibid.
[123] Ibid.
[124] Keith Naughton, "Humans Are Slamming into Driverless Cars and Exposing a Key Flaw," *Bloomberg*, December 17, 2015, http://www.bloomberg.com/news/articles/2015-12-18/humans-are-slamming-into-driverless-cars-and-exposing-a-key-flaw (accessed December 21, 2015).
[125] Ibid.
[126] Ibid.
[127] Andy Greenberg, "Hackers Remotely Kill a Jeep on the Highway, With Me in It," *Wired*, July 21, 2015, https://www.wired.com/2015/07/hackers-remotely-kill-jeep-highway/ (accessed July 5, 2016).
[128] Shankar Vedantam, "Humans Worry About Self-Driving Cars. Maybe it Should be the Reverse,' *National Public Radio Morning Edition*, January 10, 2017. http://www.npr.org/2017/01/10/509086451/humans-worry-about-self-driving-cars-maybe-it-should-be-the-reverse (accessed February 9, 2017).
[129] Ibid.
[130] Ibid.

potentially make life–and–death decisions. Computer programmers will make these ethical choices, taking away control from transportation users.[131]

Due to the challenges of relying solely on a computer to react to all real world conditions, Nissan has stated it will never achieve Level 5 automation.[132] Instead, the company currently plans on using remote human operators to guide HAVs through overly complex areas beyond the program's ability to comprehend.[133]

HAV Unknowns

There are a variety of unknowns about HAV deployment. When will they be commercially available? How fast will their uptake be? How much will they cost to buy and to operate? Will they be shared or individually owned? What will their impact be on transit, biking, walking, and other forms of transportation? Will they promote more urban development patterns or unleash a new form of megasprawl? Will they reduce traffic and congestion or greatly increase it? What is the failsafe mode for HAVs? How will they behave if the system crashes? How will people change the way they value time and distance? What about jobs, what is the value proposition of HAVs when there is already a shortage of low-skill employment opportunities?

The provision of Level 5 HAVs could drastically reshape land use and development patterns. There remains a key question as to whether the digital revolution, which seems to be drawing people together by generating network effects, or HAVs which have the potential to spread people farther apart (this has been the result of most previous transportation technological advances) will play a larger role in determining future land use patterns. HAVs may yield denser development patterns if they are shared. If an individual can be whisked to wherever they need to go in an HAV on uncongested highways with significantly higher speed limits due to increased vehicle safety, then there are more choices in where to live, which can be made more independently of where one works.[134] Since HAVs are likely to make many trips with no occupants in them, measure of travel activity may need to shift from vehicle miles traveled (VMT) to vehicle miles driven (VMD).

There are major concerns that HAVs will eventually cost driver jobs.[135] There are millions of driver jobs—trucks, taxi, transit vehicle, and others—at risk from vehicle automation. Nationwide, the trucking industry alone employs 3.5 million drivers, with another 5.2 million indirect support jobs.[136] When new technologies disrupt jobs—think blacksmiths and saddle-makers from the pre-automobile era—they also create many new ones—such as mechanics to repair all the vehicles now on the road. There is a need to identify what will be the new jobs created by HAVs and then help the region's workforce to acquire the skills needed for them.

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[131] Test out what you would do with MIT's Moral Machine: http://moralmachine.mit.edu/.
[132] Marshall, "Why Self-Driving Cars *Can't Even* With Construction Zones."
[133] Ibid.
[134] Dubravac.
[135] Laura Bliss, "A Denver Suburb Bets Big on Free Lyft Rides to Light Rail," *The Atlantic CityLab*, August 9, 2016, http://www.citylab.com/commute/2016/08/centennial-lyft-transit-partnership/495080/ (accessed August 11, 2016).
[136] Bollier.

HAVs may lower transit ridership and fare revenue. There is no guarantee that pollution, greenhouse gases, or congestion will decrease as a result of their application. Lower transportation costs and increased road capacity suggest that traffic will increase, perhaps substantially due to the rebound effect. A handful of early travel demand model analyses have estimated that a 100 percent AV fleet will increase VMT by 12 to 68 percent.[137] At a presentation to the 2016 Association of Metropolitan Planning Organizations conference, Mike Wallace of Fehr and Peers estimated that a 100 percent AV fleet could double a region's VMT. Another rule of thumb may be to assume a one-for-one percentage of growth with how much AVs increase road capacity. This is in line with the rebound effect identified in *The Fundamental Law of Road Congestion*.

Shared mobility is not an inevitable outcome of HAVs. While Uber is investing heavily in this technology, its application would radically shift the asset-light TNC business model of today. The current model uses a driver's personal vehicle to provide transportation services. A future where TNCs own, operate, and maintain HAVs would require a considerable change.[138] However, Uber CEO Travis Kalanick has said that the company does not necessarily need to own vehicles in order to operate in an HAV world.[139] In fact, any individual HAV owner could send the vehicle out to provide on-demand transportation when they are not using it, potentially generating additional income at little personal expense. In a microtransit-style HAV service, there would be personal safety concerns for individuals who do not know each other when sharing a vehicle.[140] Such a service may need security monitoring, adding to its cost.[141]

A critical, but often overlooked issue about potential HAV use is what will be the price to use HAVs, where price is based on demand for the service and is not the same thing as the cost to operate it.[142] Transportation demand varies throughout the course of the day. The size of a shared-HAV fleet is unlikely to be based on peak-period demand, as many vehicles would be in use for only a few hours each weekday.[143] Even if the vehicle fleet is large enough to meet demand, it is not clear that there will be enough road capacity to meet it.[144] During off-peak periods, HAVs may be less expensive than transit and could steal its ridership.[145] Most experts expect that shared HAVs will charge per mile, and their price will fluctuate considerably based on demand. This will send much stronger signals to consumers

[137] Mike Wallace, "Planning for Automated Vehicles," Fehr and Peers: Presentation at 2016 Association of Metropolitan Planning Organizations Conference, Fort Worth, TX, October 26, 2016.
[138] "Uber's Mega Ambitions," *The Economist Radio: Money Talks*, September 7, 2016, https://soundcloud.com/theeconomist/money-talks-ubers-mega-ambitions (accessed October 5, 2016).
[139] Ibid.
[140] Todd Litman, *Autonomous Vehicle Implementation Predictions: Implications for Transport Planning* (Victoria, Canada: Victoria Transportation Policy Institute, 2013), http://www.vtpi.org/avip.pdf.
[141] Ibid.
[142] Cortright, "The Price of Autonomous Cars."
[143] Ibid.
[144] Ibid.
[145] Ibid.

about true costs of their travel.[146] It also means the calculus of each trip will vary based on the supply and demand of each mode.[147]

Preparing for HAVs

The future end state is relatively easy to envision. The challenge will be in navigating what will likely be several decades of transition, where vehicle behavior will be extremely difficult to predict and one will not know whether a particular vehicle is being operated by a human or a computer. This mixed state needs to be examined rigorously.

NHTSA plans to update its AV guidance annually, in reflection of the speed at which this technology is predicted to develop. It plans to further research AV technology applications in areas such as human factors, cybersecurity, performance metrics, and objective testing.[148]

The Commonwealth of Pennsylvania has set up an Automated Vehicle Task Force that has developed an initial report on regulating HAVs. This task force includes a wide range of representatives from the automotive industry, TNCs, academia, the Pennsylvania Department of Transportation (PennDOT), trucking associations, AAA, local government, trial lawyers, FHWA, and others. The report recommends that oversight be handled through PennDOT policy rather than the use of regulatory authority, which can take years to implement. Currently Title 75 in the Commonwealth's regulations does not include any mention of AVs. State Bills 1412 and 2203 have been drafted to allow for testing of HAVs—including shuttles, truck platoons, and completely driverless vehicles—on public roads under PennDOT's auspices. These bills require HAV operators to carry five million dollars in insurance liability coverage.

The *New York Times* recently published an op-ed that was critical of the push to develop HAVs without asking citizens if these vehicles are something they desire in their aspirational vision for the future.[149] The costs of developing this technology will largely be placed on individuals as consumers and taxpayers. While HAVs are touted to provide safety benefits, it is not clear they will reduce fatalities at the rate often cited, as existing crash data is incomplete. It also overlooks the possibility that new risks could emerge. With the considerable risks HAVs pose to transit and urban areas, the public should have more say in whether or not this is the right technology to invest in.

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[146] Ibid.
[147] Ibid.
[148] National Highway Traffic Safety Administration.
[149] Jaimie Lincoln Kitman, "Google Wants Driverless Cars, but Do We?," *New York Times*, December 19, 2016, http://www.nytimes.com/2016/12/19/opinion/google-wants-driverless-cars-but-do-we.html (accessed January 4, 2017).

Big Data

"Big Data is a broad term for data sets so large or complex that traditional data processing applications are inadequate."[150] Big Data sets are often mined or use other advanced methods to extract value and/or develop predictive analytics. Accuracy can help Big Data improve decision making, which in turn can enhance operational efficiency, reduce cost, and decrease risk. The steadily decreasing cost of computing power—storage, memory, processing, bandwidth—is enabling Big Data.[151]

Big Data sets come from a variety of sources, such as financial transactions, sensors, Internet searches, and social media.[152] Big Data has many potential transportation applications. A number of state departments of transportation (DOTs) are developing real-time, performance-measure dashboards on infrastructure condition, system operations, environmental, and weather factors.[153] CVs and AVs will generate and quickly process considerable amounts of real-time data.[154] Real-time parking information can help drivers quickly locate nearby available spaces and compare prices to find the best deal. This can reduce traffic congestion from drivers circling the block looking for on-street spaces.

The IoT is already capturing significant amounts of real-time data. Indexing, storing, and processing all this data will create a major challenge.[155] Data standardization is essential to ensuring compatibility across a variety of uses and platforms.[156] For example, The North American Bikeshare Association has adopted an open-data standard—the general bicycle service feed—that makes real-time data feeds available in a consistent format so that data sets can be readily incorporated into smartphone apps.[157]

Many public agencies are working to better, and more openly share, the data they collect. This opens it up to countless numbers of citizen analysts who can dive deeper into and provide their own unique perspectives to finding new solutions to the myriad of problems that cities and regions face. Beyond citizen analysts, there are a growing number of open-source and private-market resources that municipalities can turn to. Services in **orange** font identify Big Data applications in the Greater Philadelphia area:

- **The Center for the Management of Information for Safe and Sustainable Transportation** is a data center that aggregates and analyzes a variety of data sets to better understand and enhance transportation safety and sustainability in a cost-effective manner.[158]

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[150] Mohaddes and Sweatman.
[151] Ibid.
[152] *New Mobility*.
[153] Mohaddes and Sweatman
[154] Ibid.
[155] Ibid.
[156] Federal Highway Administration, *Shared Mobility: Current Practices and Guiding Principles* (Washington, DC: U.S. Department of Transportation, April 2016), http://www.ops.fhwa.dot.gov/publications/fhwahop16022/fhwahop16022.pdf.
[157] Ibid.
[158] Ibid.

- **cKan** is an open-source data management system. It provides tools to streamline publishing, sharing, finding, and using data.
- **Datahub.io** is a free, data management platform based on the cKan data management system.
- **ForCity** provides decision support for companies and cities, using complex systems modeling and 3D-visualization.
- **Fuel Buddy** is an app that tracks one or more vehicle's fuel mileage and maintenance history.
- **Fulcrum** offers a suite of apps related to traffic counting, infrastructure maintenance and inspection, and other transportation functions.
- **Junar** is a cloud-based, open-data platform.
- Xerox's **Mobility Analytics Program** presents visual real-time regional transportation information, such as on-time transit performance, car parking rates at transit stations, passenger load levels, etc. In addition, it provides analytics to predict future traffic flows or estimate the effect of adverse weather.
- **Open Data Philly** is a regional open-data platform, run by the nonprofit Azevea.
    - **Parkadelphia** is an online tool developed by Open Data Philly. It maps all of Philadelphia's parking regulations, including district boundaries, residential parking blocks, metered corridors, and 30-day use trends.
- **OpenDataSoft** is a tool to explore and turn data into information using easy-to-implement application program interfaces.
- **Placemeter** is a data-gathering system that counts the number of people, along with gender and age in a public space, using a video feed.[159]
- **PlannerStack** is an international multimodal transportation information-sharing effort. It is an open-source community based in the Netherlands that is working to make public transit more accessible. The effort brings together data owners, content brokers, content aggregators, and application integrators and is building a multimodal real-time trip planning and mobility ecosystem that can be used with plug-and-play dynamic travel information services and apps.
- **Spallian** is a French Big Data analytics firm. It supports smart governance analytics through services such as TellMyCity, Stat', Corto, and Memento.
    - TellMyCity allows anyone with a smartphone or computer to send a message to the appropriate city agency to report a problem or congratulate an initiative. This can be put on the city's main website and integrated with social media. It can also push notifications from the city out to users.
    - Stat' is an online platform that integrates complex data sets from various sources with real-time interaction and visualization.
    - Corto is cartography software that aids with decision making.
    - Memento is a real-time database for collecting, requesting management, and projecting results. It can be used on smartphones, tablets, and all web browsers.
- **Socrata** provides a cloud-based data platform for digital governance.
- **Uber Movement** provides anonymized GPS-based traffic data from vehicles operating for the company.

[159] Bollier.

- **Urban Engines** is a private company that has built what it calls a space-time engine that provides Big Data and analytics systems to better understand the flows of traffic over time.

While there are many privacy and ethical concerns around digital data collection, Placemeter warrants particular attention due to its facial recognition technology.[160]

New York City is a leader in using data to enhance its services. The Mayor's Office of Data Analytics (MODA) pairs operations staff and data scientists. This combines specialized knowledge of how the city functions internally with individuals who can access and read Big Data sources. The data sets that the MODA teams develop help to better understand the city's metabolism, find correlations, and identify emerging trends.[161]

Figure 11. Urban Engines Big Data Analysis

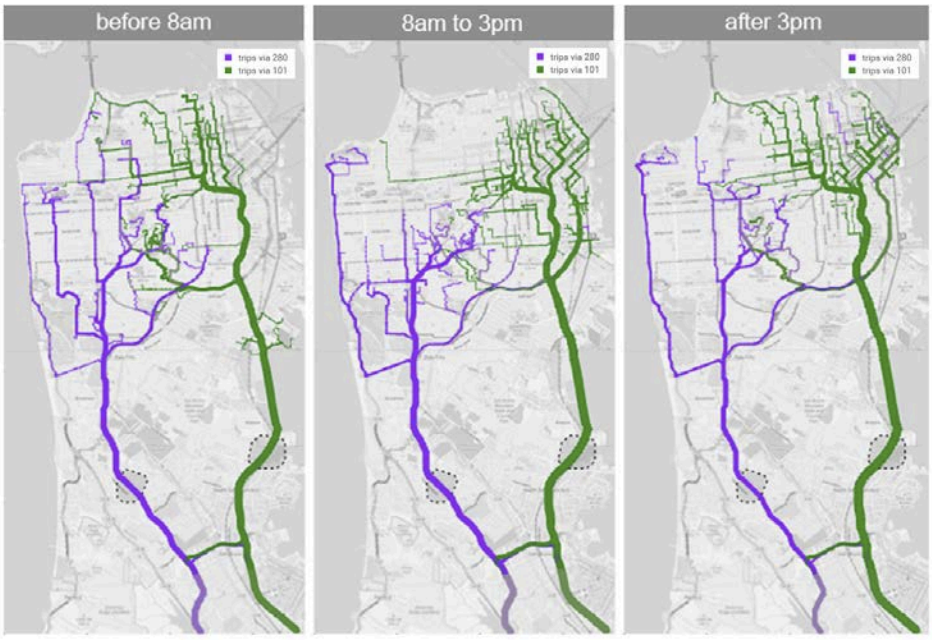

Figure 3. Route choices from San Francisco to Palo Alto at different times of day. Each trip is colored purple if it goes via 280 and green if it goes via 101, and the trips are superimposed on the map. The overall traffic on 101 and 280 is balanced at each time of day, but the "watersheds" change.

Source: Urban Engines.

PennDOT has recently developed an Endeca data discovery system that combines a variety of databases, including the Transportation Improvement Program, bridge management system, and others.

While using data to drive policy and investment is a laudable and highly recommended goal, it does leave some risk in decision making. In some cases there may not be enough, or relevant, data available; in others it may be unclear what the

[160] Bollier.
[161] Stephen Goldsmith, "How NYC Is Mainstreaming Data-Driven Governance," *Governing*, September 16, 2015, http://www.governing.com/blogs/bfc/gov-new-york-city-data-driven-governance.html (accessed December 1, 2015).

data is saying. The first risks solving for the wrong problems, while the second can lead to paralysis by analysis.[162]

Connected Vehicles

Connected vehicles (CVs) use DSRC through licensed wireless networks, cellular technologies, satellite, the Internet, and telematics to connect cars, trucks, buses, motorcycles, bicyclists, pedestrians, and infrastructure.[163] Telematics integrate telecommunication and information technologies for enhanced vehicle safety and mobility.[164] Connected systems create machine awareness with other CVs, infrastructure, and other objects. This can provide the driver warnings about safety hazards, such as curves, intersections, and nearby vehicles. CVs can overcome range, sight, and data interpretation problems with sensors, while enabling more coordination and traffic flow management.[165] By cooperating with each other, CVs are anticipated to reduce crash and fatality rates for nonimpaired drivers by up to 80 percent.[166] Some connected vehicle technologies include:

- approaching emergency vehicle warning;
- blind spot warning;
- connection protection;
- cooperative adaptive cruise control;
- curve speed warning;
- "do not pass" warning;
- dynamic ridesharing;
- dynamic speed harmonization;
- dynamic transit operation;
- eco-approach and departure at signalized intersections;
- eco-traffic signal timing;
- eco-traffic signal priority;
- electronic parking;
- emergency electric brake light;
- enhanced maintenance decision support system:
- freight signal priority;
- intelligent traffic signal system;
- intersection movement assist;
- in-vehicle signing;
- lane change warning;
- left turn assist;
- mobile accessible pedestrian signal system;
- motorist advisories and warnings;
- pedestrian in signalized crosswalk warning;

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[162] Tanya Menon and Leigh Thompson, "How to Make Better Decisions with Less Data," *Harvard Business Review*, November 7, 2016, https://hbr.org/2016/11/how-to-make-better-decisions-with-less-data (accessed November 9, 2016).
[163] Mohaddes and Sweatman.
[164] Peter Jin, *Emerging Transportation Technologies White Papers* (Austin, TX: The University of Texas at Austin Center for Transportation Research. May 2015), http://library.ctr.utexas.edu/ctr-publications/0-6803-P2.pdf.
[165] Schladover.
[166] Ibid.

- Pikalert® vehicle data translator;
- queue warning;
- red light warning;
- rollover warning;
- toll payments;
- traffic and travel condition data;
- transit bus stop pedestrian warning;
- transit signal priority;
- vehicle safety inspection; and
- weather-responsive traffic management.

These applications do not drive the vehicle in any way; the driver will always be in full control of a CV.

DSRC uses the 5.9 GHz bandwidth and enables drivers to see through extreme weather conditions—fog, rain, and snow—and around buildings, large vehicles, and sharp curves.[167] It can provide real-time alerts to imminent hazards such as vehicles stopping suddenly ahead, collision warnings to merging vehicles, sharp curves, veering to close to the road's edge, or slippery roads.[168] More road information will move to CV dashboards. This will make many roadside infrastructures—speed limit signs, exit signs, traffic signals, dynamic message signs, and others—unnecessary, though this will take time as the vehicle fleet will need to fully turnover.

As a digital technology, CVs will likely have a network effect. This means their overall effectiveness increases with the number of CVs on the road and devices embedded into road infrastructure. It will take considerable public and private investment in connected technologies to fully realize CV benefits. Applying connected infrastructure technologies, particularly at intersections and along sharp curves, may be challenging due to the lack of a clear business case for doing so.[169] CV costs can be reduced if agreement can be reached on a standardized platform, as opposed to the current myriad of devices that are included in connected technologies.[170] This standard should ensure that CVs can talk with each other.[171]

Connected trucks could run in tightly spaced platoons, increasing road capacity and draft off each other and save fuel. Testing has shown these benefits decrease with four or more vehicles in a platoon. Pennsylvania is working on draft regulations for connected and automated vehicles (CAVs) that would limit truck platoons to two vehicles. Larger platoons could increase the weight put onto bridges and increase wear and tear on roadways, shortening the lifespan of transportation infrastructure.

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[167] Research and Innovative Technology Administration, "Dedicated Short-Range Communications (DSRC): The Future of Driving," U.S. Department of Transportation, n.d, http://www.its.dot.gov/factsheets/pdf/JPO-034_DSRC.pdf (accessed January 9, 2017).
[168] Ibid.
[169] Mohaddes and Sweatman.
[170] Tiffany Fishman, *Digital-Age Mobility: The Future of Urban Transportation* (Westlake, TX: Deloitte University Press, December 2012), http://dupress.com/articles/digital-age-transportation/.
[171] Ibid.

CAVs

AVs are currently developing as a separate technology from CVs. Over the long term, many analysts expect there to be a convergence of them. CAVs will communicate with each other (V-2-V) and infrastructure (V-2-I), while also using on-board sensors to understand their operating environment. This communication and coordination will give a broader array of real-time info. CAVs help to overcome issues with sensors, which currently have limited ranges and require unblocked sightlines. Connected technologies are seen as critical to achieving higher levels of vehicle automation.

FWHA released a notice of proposed rulemaking (NPRM) for CVs in December 2016. Automobile manufacturers have indicated that they can have the necessary equipment to connect new vehicles within three years of the completed regulatory action; the additional cost is estimated to be around $350 per vehicle.[172] The NPRM will require all new vehicle-to-vehicle (V-2-V) technology in all new light-weight vehicles.[173] It mandates the use of DSRC to transmit data on location, direction, and speed.[174] It sets standards for V-2-V communications to ensure that all vehicles can communicate with each other.[175] And it creates regulations for strong cybersecurity protections and personal privacy.[176] FWHA plans to release a separate vehicle to infrastructure (V-2-I) NPRM.

The Federal Communications Commission (FCC) set aside the 5.9 GHz spectrum for CV technologies in 1999. The slow deployment of these technologies caused the FCC to consider allowing other devices to access the spectrum in 2016, but ultimately the commission chose to continue to reserve the spectrum to DSRC use only. However, with the growing number of devices connected to the IoT, at some point the spectrum may need to be shared.[177]

PennDOT is developing a connected infrastructure pilot program as part of the I-76 integrated corridor management project between US 1 in Philadelphia and the Pennsylvania Turnpike in Montgomery County.

Veniam is an example of a company that is developing CV technology. It is working to build "the Internet of Moving Things" by turning municipal (buses, trash trucks, and others) and private vehicles into mobile Wi-Fi hotspots, generating high-

[172] Office of the Assistant Secretary for Research and Technology, "20 Questions about Connected Vehicles," U.S. Department of Transportation, n.d, http://www.its.dot.gov/cv_basics/cv_basics_20qs.htm (accessed January 9, 2017).
[173] National Highway Traffic Safety Administration "U.S. DOT Advances Deployment of Connected Vehicle Technology to Prevent Hundreds of Thousands of Crashes," U.S. Department of Transportation, December 13, 2016, https://www.nhtsa.gov/press-releases/us-dot-advances-deployment-connected-vehicle-technology-prevent-hundreds-thousands (accessed January 9, 2017).
[174] Ibid.
[175] Ibid.
[176] Ibid.
[177] "US: FCC Commissioners Confirm Plans to Free Up 5.9 GHz," *SBDautomotive*, n.d, https://www.sbdautomotive.com/en/us-fcc-commissioners-confirm (accessed January 9, 2017).

definition vehicle data that is put into the cloud and can be used for smart city applications. It generates robust goods movement data that allows for real-time tracking, productivity improvements, safer and lower-cost operations, and intelligent insights through its LiveFleet and LivePort applications.

Digital Mapping

A number of efforts have focused on developing up-to-date, open-source street maps. These digital maps are widely used in other applications for wayfinding and research and analysis. They can offer side-by-side, real-time comparison of driving, transit, walking, and biking travel options. This information allows individuals to determine the mode and route that best suits their needs, while also balancing demand across transportation facilities.

- **OpenStreetMap** is an open-source community that creates and maintains road, trail, café, railway, and other geospatial data. **UMap** is a tool that creates maps using OpenStreetMap layers.
- **Google Maps** offers street maps, satellite images, panoramic street views, real-time traffic info, and point-to-point travel directions for driving, transit, bicycle, and walking.
- **Google Earth** is a virtual model of the Earth and uses satellite images to offer a variety of vantage points and 3-D views of cities and geographies around the planet.
- **Here** is an open-source, multisided platform to collect, process, and analyze locational data.
- **CollabMap** is a platform to share plans and designs.

Detailed and continuously updated digital maps are critical to AVs' ability to drive themselves. Most auto manufacturers are now developing their own digital mapping applications to avoid relying on a third party for them.

Tectonic shifts in Australia have moved the actual landmass by five feet from where the digital maps thought things were.[178]

Intelligent Transportation Systems

Intelligent Transportation Systems (ITS) represent the first generation of digital transportation infrastructure. ITS includes variable message signs, CCTV cameras, adaptive traffic signals, incident management programs, ramp metering, variable speed limit signs, and other technologies designed to improve information about traffic conditions; provide real-time route alternatives; enhance safety; and smooth the flow of traffic. In the longer term, CAVs will probably mean the phasing out of some forms of ITS infrastructure.

[178] Rick Noack, "Maps of Australia Are All Five Feet Off. Would You Be Brave Enough to Use a Self-Driving Car There?," *Washington Post*, August 2, 2016, www.washingtonpost.com/news/worldviews/wp/2016/08/02/maps-of-australia-are-all-five-feet-off-would-you-be-brave-enough-to-use-a-self-driving-car-there/ (accessed September 22, 2016).

The Internet of Things

The Internet of Things (IoT) uses physical objects and sensors embedded in electronics, software, and other devices to capture and exchange data.[179] The IoT was made possible by the convergence of multiple technologies, including wireless communications, the Internet, embedded systems, and microelectronics.[180] A number of technologies are driving the IoT, including: wearable devices, smart homes and buildings, smart cities, and smart enterprises. Smart buildings can reduce energy use and cost, and provide pricing signals to shift demand.[181] Smart enterprises use the IoT to enhance manufacturing, logistics and distribution, health care, manage energy, and automate operations.[182] The IoT can gather environmental data, such as air and water quality, atmospheric conditions, soil conditions, wildlife movement, seismic activity, and tsunami warning systems.[183]

A portion of the IoT is being applied to digital transportation services. It is variously called the "mobility Internet," "the Internet of cars," "the Internet of moving things," and other similar names. The mobility Internet will collect and share information with and between vehicles, drivers, and infrastructure.[184] As a result, vehicles, roads, traffic signals, and transportation authorities will all be receiving and able to react to data in real time.[185] Full realization of the mobility Internet could mean:

- dynamic signals that optimize traffic flow;[186]
- variable priced parking;[187]
- better travel directions and time estimates;[188]
- dynamic real-time information using intervehicular and intravehicular communications, smart traffic signals, smart parking, electronic tolling, fleet management, vehicle control and safety, and roadside assistance;[189]
- enhanced goods movement through real-time logistics, information sharing between enterprises, and tracking package location to ensure the right product is in the right place at the right time;[190]
- V-2-V and other machine-to-machine information sharing increases efficiency and accuracy;[191] and
- rethinking of business models.[192]

One major challenge for the IoT is that numerous devices with different manufacturers and uses must be able to interact with each other, but there is no

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[179] Mohaddes and Sweatman.
[180] Ibid.
[181] Ibid.
[182] Ibid.
[183] Ibid.
[184] Ibid.
[185] David Zax, "A World without Car Crashes," *The Atlantic CityLab*, February 11, 2014, http://www.citylab.com/commute/2014/02/world-without-car-crashes/8353/ (accessed August 12, 2015).
[186] Ibid.
[187] Ibid.
[188] Ibid.
[189] Mohaddes and Sweatman.
[190] Ibid.
[191] Ibid.
[192] Ibid.

central agency that is overseeing standardization (known as the "basket of remotes" problem).[193] Cybersecurity is another major concern, as billions of devices are connected to the Internet often with little regard for security. Many devices, and even infrastructure systems, are secured with a simple, easy-to-guess password. Security researchers have been able to gain access to traffic control systems, license plate readers, stadiums, car washes, hockey rinks, water plants, Olympic arenas, and even the Lawrence-Berkeley National Lab. Anyone with some degree of skill and interest could find ways to access and even take control over unsecured or weakly secured devices. [194] For example, Iranian hackers gained access to a dam in Rye Brook, New York, in 2013 and could have opened the gates to flood a wealthy suburban neighborhood.[195] Other challenges include: privacy, autonomy, control, design, and environmental and social impacts.[196] Increasingly connected, complex, interdependent systems of systems create risks that could lead to cascading failures.[197]

Smart, Connected Cities

One way in which the digital urban platform is being built upon is through "smart," "connected," "digital," "platform," or "intelligent city" movements. These efforts typically have several key components:[198]

- intelligent infrastructure that has sensors connected to the IoT, which it uses to monitor its surroundings and send and receive data and instructions;
- use of Big Data analytical techniques; and
- smart grid technologies that efficiently and dynamically transmit and distribute electricity in response to demand.

Smart, connected cities provide transparency, partnerships, and increased engagement with their residents.[199] They allow for experimentation and permission-less innovation.[200] In the digital economy, local government needs to become an enabler. Governments must do more to design with the end user in mind, while promoting social equity and inclusiveness. Local governments must build partnerships with stakeholders and residents through open data, crowdsourcing, prototyping, and trials. These partnerships can help generate new community activities and ideas, tap into citizen knowledge and expertise, and enhance local government services.

Smart cities are made up of smart buildings, which integrate systems into a common network that shares information and functionality in order to gain

[193] Ibid.
[194] Chris Francescani, "U.S. Infrastructure Can Be Hacked With Google, Simple Passwords," *NBC News*, April 3, 2016, http://www.nbcnews.com/news/us-news/u-s-infrastructure-can-be-hacked-google-simple-passwords-n548661 (accessed July 8, 2016).
[195] Ibid.
[196] Ibid.
[197] U.S. Department of Transportation, *The Smart/Connected City*.
[198] Ibid
[199] Bollier.
[200] Ibid.

efficiency.[201] Smart buildings enhance energy efficiency, improve operations, and increase occupants' comfort.

The smart, connected city is a way to develop connected communities for learning, by leveraging technology as an educational resource. Smart Connected Communities for Learning (SCCLs) aim to make more "livable, workable, sustainable,

Gamification

With rapid technological advancement many have envisioned "networked space" as a merger of the digital and physical worlds that will transform public spaces. In *The City as Interface*, Martjin de Waal argues that we are going to experience urban areas more and more through smartphones and other mobile devices.[a] Pokémon Go is the first popular outlet for creating network spaces.[b] By combining mobile device GPS and camera functions, users are able to view an augmented reality. Pokémon Go has been lauded for using a video game to encourage people and explore their community on foot.[c] Businesses are able to create their own "Pokéstop," encouraging local commerce.[d]

Ingress, like Pokémon Go, was developed by Niantic. It is a similar augmented reality mobile game based on the user's location with seven million players worldwide. The game is a real-time, story-driven alternative reality adventure that encourages players to go out and explore their community and the larger world. Ingress players are secret agents who must choose a side and determine the fate of the world. Players are given a map of the surrounding areas, and the game applies rich narratives to landmarks, buildings, public art, and other sites.[e] Most of the game occurs in portals, which are fixed locations in the physical world that draw players together.

Gamification has been applied to local transit through Chromarama in London and Project Sunset elsewhere in Europe. These games reward users with points for utilizing sustainable modes of transportation.[f] Certain levels of points deliver rewards such as discounted transit fares, museum admissions, and other benefits.

Gamification appeals to our competitive nature—through cooperation, status, and achievement—to cause behavioral change. The exploding popularity of Pokémon Go should act as an example for planners and cities to utilize gamification and augmented reality as a tool to improve city sustainability and quality of life, while also getting out into the community more and exercising.

[a] Jennifer Evans-Cowley, "Time to Try Pokémon Go: Augmented Reality Connecting People to Places," *Planetizen*, July 13, 2016, http://www.planetizen.com/node/87335/time-try-pokémon-go-augmented-reality-connecting-people-places (accessed July 27, 2016).
[b] Ibid.
[c] Ibid.
[d] Ibid.
[e] David Bollier, *The City as Platform: How Digital Networks Are Changing Urban Life and Governance* (Washington, DC: The Aspen Institute, 2016), http://csreports.aspeninstitute.org/documents/CityAsPlatform.pdf.
[f] Tiffany Fishman, *Digital-Age Mobility: The Future of Urban Transportation* (Westlake, TX: Deloitte University Press, December 2012). http://dupress.com/articles/digital-age-transportation/.

[201] "Smart Buildings," General Services Administration, Last Reviewed September 14, 2016, https://www.gsa.gov/portal/content/103965 (accessed February 28, 2017).

and connected communities."[202] SCCLs help citizens contribute to and improve their neighborhoods by thinking of the city as an ecosystem and using human and social capital to solve problems.[203] Connected learning uses technology to bring together people, classrooms, the community, and households. It better prepares individuals for the working world and enhances civil society, family, and community life.[204] Smart city efforts should tie in and work with other parts of this emerging educational ecosystem: maker labs, innovation challenges, interactive art installations, online experiences, universities, high schools, and middle schools.[205]

The rise of the Free Agent Economy, as highlighted in *Greater Philadelphia Future Forces*, suggests that a growing number of independent workers are more responsible than ever for training and educating themselves, as employers are less likely to do so. Today's workers must find ways to undertake challenging projects, learn where to find new business opportunities, and determine the best use of their capital resources: spend it on personal needs and wants, or invest it in growing their business. Educational portals could provide key financial advice to free agent workers, such as consulting with a financial advisor, setting up a limited liability corporation for their business, creating a separate bank account for it, and identifying the types of business expenses that are typically tax deductible.

Human actions can serve as leading indicators to anticipate demand through devices connected to the IoT. For instance, the time a commuter will depart for work may be predicted by the time he or she takes a shower or sits down for breakfast. Transit agencies could directly market to individuals stuck in traffic with incentives to try out the train or bus.[206] Intelligent infrastructure will be able to guide drivers searching for parking to the nearest available space, reducing the amount of time spent searching for one in traffic.[207]

Harnessing real city data can create possibilities for reducing traffic congestion, creating citywide Wi-Fi connections, enhancing pedestrian safety, generating economic development, making citizen engagement more proactive, and more. For example, General Electric's **Current** is an energy company that combines hardware and software technologies to provide an IoT platform for smarter cities. Current seamlessly integrates into all streetscapes by attaching to any light pole and providing power to any light fixture. It contains many sensors collecting data and provides real-time intelligence through the cloud, transforming the lighting network into an all-knowing digital infrastructure. Current's Intelligent Environment Platform, powered by Predix, is an open-source, secure platform for the Industrial Internet of Things, which has the power to analyze and interpret huge volumes of real-time sensor data, while keeping it secure, and making it actionable. With the ever-expanding ecosystem partners and the innovative developer community, thousands

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[202] Judi Fusco et al., "Smart and Connected Communities for Learning," *The Center for Innovative Research in Cyber Learning*, n.d., http://circlcenter.org/smart-and-connected-communities-for-learning/ (accessed May 18, 2016).
[203] Ibid.
[204] Ibid.
[205] Ibid.
[206] U.S. Department of Transportation, *The Smart/Connected City*.
[207] Ibid.

of applications can be built upon the open and secure Intelligent Environments platform to drive desired outcomes for cities.

Google's **Sidewalk Labs** is likewise building platforms that cities can use to apply data-driven solutions to urban problems. This company aims to bridge the gap between urbanists and technologists. It has developed technologies such as Link NYC, which uses kiosks to help bridge the digital divide; and Flow, which uses real-time data to better coordinate transportation modes and routing.

Hudson Yards in New York City and Songdo, South Korea, are often cited as model smart cities. Hudson Yards is being built with unparalleled fiber and Internet connections, which will quantify data from 120,000 workers and residents and use it to create new experiences.[208] Both Hudson Yards and Songdo are new builds, showing that it is easier to create a new smart city than to retrofit an existing city.

Real-Time Information

Traffic navigation tools and apps help to use the transportation network more efficiently in several ways. First, by mode optimization can determine the most efficient mode using information about travel time, cost, and available travel options. Once a mode is chosen, route optimization can identify the fastest and most direct route. Last, navigation tools route people and vehicles away from congested facilities and onto less congested facilities. This lets individuals make faster trip, while also benefitting society from reduced congestion. For vehicles, facility optimization can balance volumes throughout the system and can reduce congestion but may increase VMT, particularly on roads that have historically had lower traffic volumes. Real-time services in **orange** font identify applications that are currently operating in the Greater Philadelphia area.

- The Pennsylvania Department of Transportation operates a **5-1-1 system** that provides travel information about incident locations, construction, weather, special events, and roadway speeds.
- **Scout** provides real-time navigation information and sends notification updates on location to individuals whom the trip is for. The app lets users ask their friends to share rides.
- **Waze** offers crowdsourced, real-time travel conditions, maps, routing, and more.

Transit apps offer real-time information on bus and rail service. They are a core service of digital and shared mobility, which increasingly offer more information about connecting services, such as bikesharing, carsharing, and ridesourcing.

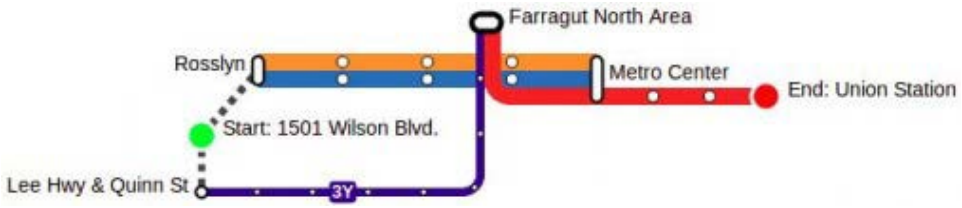
- **Beeline** is a Singapore app that crowdsources bus services. A user enters a trip they would like to make; then the app suggests the best available route and works with service providers to adapt existing routes in order to better suit user needs.
- **City-go-round** currently hosts 197 third-party transit apps using open-source data from 292 transit agencies.

[208] "The Future of the Smart City," The Takeaway Podcast, WNYC, July 4, 2016, http://www.wnyc.org/story/future-smart-city-070416/ (accessed July 4, 2016).

- Google Transit stores static, open data sets.
- Real-time transit information is available through Moovit, Transit App, and through regional transit authorities such as the SEPTA app and the NJ Transit mobile app.
- OneBusAway is an open-source platform offering real-time transit information in New York City, New York; York, Pennsylvania; Puget Sound (Seattle, Washington region); Tampa, Florida; and Rogue Valley (Medford and Ashland, Oregon).
- Swiftly is a data platform for transit agencies to enhance operational efficiency, make better infrastructure investments, and improve rider engagement. It includes real-time service information, multimodal trip planning, and a management dashboard.
- Transloc and TapRide help transit providers compete directly with TNCs by creating platforms that allow transit agencies to run on-demand shuttle services.
- TransitScreen provides information on a screen in a neighborhood or employment center. The information can be projected onto a sidewalk, so a screen is not necessarily needed.
- Transitive.js provides simplified transit network visualizations to aid with trip planning.

Moovit offers real-time transit information in Greater Philadelphia and more than 1,200 other cities. Moovit is a real-time transit planning app that features live arrival and departure times, updated line schedules, local station maps, service alerts, and advisories that may affect local transit trips. Moovit mixes existing transit and local rider data in order to efficiently plan a trip. These apps have network effects, where the more people use them, the more effectively they can direct users.

Figure 12. Transitive.js Network Rendering



Transitive.js rendering of the network options to travel from Mobility Lab's offices to Union Station in Washington, DC.

Source: http://mobilitylab.org/2014/04/16/the-technology-behind-a-new-kind-of-travel-planning/.

SEPTA's Trainview gives real-time transit information for regional rail service. Transitview transmits real-time bus, trackless trolley, and trolley data including current position every three minutes. It is a third-party-developed application that allows users to customize personal trips viewing arrivals, departures, length of trip, and route options. The NJ Transit Mobile App offers information to plan and travel with NJ Transit in one place, including: MyTix Mobile Ticketing, Trip Planning, Train Schedules, real train and light rail information with DepartureVision, real-time bus information by bus stop using MyBus, and contact information.

While many current real-time transit information platforms include both SEPTA and NJ Transit, smaller transit agencies, such as PATCO or Pottstown Area Rapid

Transit, may be missing. CityMapper does include PATCO in its trip-searching algorithm.

Ototo, previously known as NetBus, was an iPhone app that made transit route recommendations to provide the most efficient trips. It agglomerated user trip request data to resell to public transit agencies for their use in route planning. It was discontinued in October 2014.

The Impact of Real-Time Information on Bus Ridership in New York City, by Candace Brakewood, Gregory Macfarlane, and Kari Watkins at the City College of New York looked at real-time transit information in New York City. It found real-time information generated a 1.7 percent increase in ridership, with more occurring on high-frequency routes (+2.3 percent).[209] This generated $6.3 million in new revenue during a three-year study period and is in line with similar research in Chicago, which found a 2 percent increase in ridership thanks to real-time information.[210]

Multimodal apps use complex profile-routing algorithms to objectively discover the most efficient options across a variety of modes. There are no apps that currently plan for using multiple modes in a single trip. Applications in **orange** font identify multimodal apps that are currently available in the Greater Philadelphia area.

- **Citymapper** is a travel-planning app that allows users to navigate easily through a set of international cities. The app uses open transport data to link several modes in order to provide users with routes that people actually take.
- **Go LA** and **Go Denver** are municipally developed multimodal travel apps created by Xerox.
- **GoPhillyGo.org** is an Internet-based mapping tool for Greater Philadelphia. It identifies popular destinations and helps users navigate their way to them on transit, bicycle, or walking.
- **L'Agence Francaise pour l'Information Multimodale et la Billettique** is developing a multimodal trip planning search engine and payment system for the entire country of France, including planes, trains, cars, metros, tramways, buses, bicycles, carsharing, and taxis.
- **Moovel** uses publicly available government data combined with a technology platform to help users make the best travel decisions. Moovel gives trip options for multiple modes, including walking, biking, bikesharing, ridesharing, public bus, subway, taxi, and carsharing services like Zipcar.
    - **RideTap** is a developer tool provided by Moovel that adds transportation functionality into any app.
    - **Moovel Transit** conducts mobile sales, manages "smart-cards," and provides agencies with real-time analytics.
- **OMG Transit** provides real-time multimodal travel information for transit, carsharing, bikesharing, and ridesourcing in Minneapolis and Seattle.

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[209] Eric Jaffe, "The Best Evidence Yet That Real-Time Arrival Info Increases Transit Ridership," *The Atlantic CityLab*, March 9, 2015, http://www.citylab.com/commute/2015/03/the-best-evidence-yet-that-real-time-arrival-info-increases-transit-ridership/387220/ (accessed June 3, 2016).
[210] Ibid.

- **OpenTripPlanner** is an open-source platform for multimodal and multiagency trip planning. OTP Analyst dives deeper to understand transportation planning problems, incorporate public policy and social sciences to enable data-driven decision making, inform public outreach for route changes, and guide infrastructure development.
- **Quxsi**, **RideGuru**, and **UpHail** allow users to find the lowest possible fares between Uber, Lyft, available taxis, limos, and transit services.
- **SurgeProtector** identifies where TNC surge pricing is in effect. Users can walk to areas outside the surge pricing zone. TNC drivers can use it to find areas with high demand.
- Cisco's **Personal Travel Assistant** creates a travel opportunity map based on time and distance using real-time data, provides notifications, earn eco-points through low-carbon travel, and creates personalized travel itineraries that take into account transportation needs and preferences.[211] The Personal Travel Assistant collects user data and uses it for system analysis. The service was launched in 2009 in Seoul and Amsterdam. There have been no updates on it since.

HopStop was a publicly available static data tool that gave users step-by-step directions for a variety of modes based on user options like time, mode, more walking versus more transfers, etc. It calculated calories burned, as well as per passenger carbon emission savings. It was acquired by Apple in July 2013, which incorporated its real-time, door-to-door biking, bus, subway, taxi, train, and walking directions into iOS 9 Apple Maps transit directions. The HopStop app is no longer available. As part of its U.S. DOT Smart City Challenge application, the City of Portland proposed to develop a "UBMobilePDX" multimodal trip-planning app.

Digital Transportation Providers

Digital transportation providers offer services through digital networks. Some of these operations are shared mobility services that use real-time data to match supply and demand.[212] This section reviews some of the more noteworthy, interesting, and/or innovative efforts—although not entirely exhaustive—as the realm of digital transportation operations is vast, growing, and changing at an extremely rapid pace. Many of these companies are part of the shared economy, which works to use resources, especially time and assets, more efficiently. This can include unoccupied vehicle seats during trips, underused cars in a household, and other things. As digitization makes it easier to get around without having to own a car, car ownership rates are predicted to decrease.

Services that include vehicle sharing can vary by whether they are one-way, meaning the vehicle can be picked up in one location and dropped off at another; or round-trip, where the trip must end at the same location where it started. In Greater Philadelphia, Indego Bikesharing is an example of a one-way trip, which generally ends at a different station than where it started. One-way carsharing and bikesharing programs have been more successful in denser areas, where there are

[211] See also http://mobile.mit.edu/proj/connected-urban-development/mobility-opportunity-map.html.
[212] "Episode 2: Shared Mobility."

network effects from a critical mass of potential users.[213] Enterprise Carshare and Zipcar are examples of a round trip, where the vehicle must be returned to the same location where it was picked up. Free-floating systems break away from station infrastructure altogether and aim to move vehicles and bicycle pick-up and drop-off locations closer to trip origins and destinations.[214] In peer-to-peer networks an individual rents their personal vehicle (or bike, scooter, etc.) to someone else.

Table 1. Summary of Digital Transportation Providers in Greater Philadelphia

Type of TNC	Company	Service Provided
Bikesharing	Indego	One-Way Trips
	Spinlister	Peer-to-Peer Rentals
Carsharing	Enterprise Carsharing	Round-Trip Rental
	Zipcar	Round-Trip Rental
	Turo	Peer-to-Peer Rentals
Courier Network Services	BloomThat	On-Demand Flower Delivery
	Caviar/Trycaviar	On-Demand Restaurant Delivery
	Go Puff	On-Demand Cigarette Delivery
	Grubhub	On-Demand Restaurant Delivery
	Instacart	On-Demand Grocery Delivery
	Peapod	On-Demand Grocery Delivery
	Postmates	On-Demand Retail and Restaurant Delivery
	UberEATS	On-Demand Restaurant Delivery
Freight	Cargo Chief	Regional On-Demand Goods Movement
	Convoy	Regional On-Demand Goods Movement
	Transfix	Long-Haul and Regional On-Demand Goods Movement
Other	Honk	On-Demand Roadside Assistance
	Urgent.ly	On-Demand Roadside Assistance
Parking Apps	ParkMe	e-Payment and Parking Space Reservation
	ParkWhiz	e-Payment and Parking Space Reservation
	BestParking	e-Payment and Parking Space Reservation
	MeterUp	On-Street Parking e-Payment
Ridesharing	Atlas	Long-Distance Ridesharing
	RideAmigos	Transportation Demand Management Software
Taxi Apps	Curb	On-Demand Taxi Rides
	215 Get a Cab	On-Demand Taxi Rides
	Freedom Taxi	On-Demand Taxi Rides
	PHL Taxi	On-Demand Taxi Rides
	Way2Ride	Taxi e-Payment
	zTrip	On-Demand Black Car Service at PHL
Transportation Network Companies	Circulation	On-Demand Nonemergency Medical Transportation
	Go Go Grandparent	Phone-Call Based On-Demand Rides for Seniors
	Lyft	On-Demand Ridesourcing
	Lyft Line	Shared On-Demand Ridesplitting
	RoundTrip	On-Demand Nonemergency Medical Transportation
	Skedaddle	Group On-Demand Long Distance Trips
	UberPool	Shared On-Demand Ridesplitting
	UberX, UberBLACK, UberSUV, UberXL, UberWAV	On-Demand Ridesourcing
Transit Apps	Moovit	Real-Time Transit Information
	SEPTA App	Real-Time Transit Information
	New Jersey Transit Mobile App	Real-Time Transit Information and Virtual Ticketing
	City-go-round	Third Party Transit Apps

Source: DVPRC, 2016.

[213] "Ibid.
[214] *New Mobility*.

The range of digital transportation providers both in Greater Philadelphia, shown in Table 1, and around the world shows the breadth of creativity and experimentation brought by digitization. Digital transportation providers offer a variety of different services, including:

- bikesharing;
- carsharing;
- courier networking services;
- freight services;
- parking apps;
- ridesharing;
- taxi apps;
- transportation network companies, including ridesourcing, ridesplitting, and microtransit services; and
- virtual ticketing and e-tolling.

Bikesharing

Bikesharing services set up publicly accessible bicycles for short-term use. Modern bikesharing originated with the Vélo'v program in Lyon, France, in 2005. By 2015, bikesharing existed in 72 U.S. cities. Bikesharing services often fill in missing gaps in transit service and can serve as an overflow for peak-period transit ridership. Beyond citywide applications, bikesharing programs can be found on corporate and university campuses, residential properties, and hotels. **Orange** font identifies bikesharing services that are currently operating in the Greater Philadelphia area:

An Indego Bikeshare station in Center City, Philadelphia.

- Philadelphia's program, **Indego**, offers one-way bikesharing. Other well-known bikesharing programs include **Citibike** (New York City) and **Divvy** (Chicago).
- **Spinlister** offers peer-to-peer bikesharing. This service also lists other sporting equipment, such as skis, snowboards, stand-up paddleboards, and surfboards.
- **Social Bicycles** (or SoBi) has bikesharing technology built into each bike itself, allowing for free-floating service. Any bicycle rack can become a potential bikeshare stand. Users locate the nearest available bike through an app and have longer time limits than typically offered in bikeshare applications.

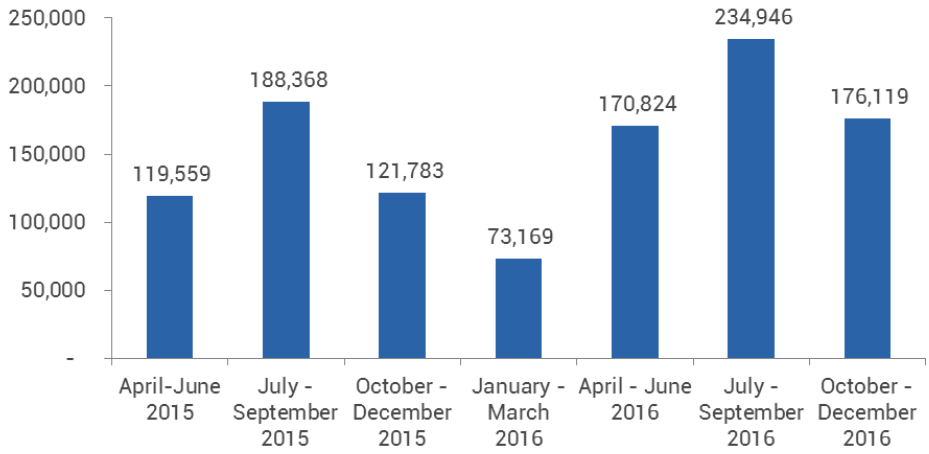
The City of Philadelphia launched Indego in the spring of 2015, mostly located in and around the Center City central business district. Independence Blue Cross is the official sponsor of the program, and BCycle manufactured the bikes and docking stations. BCycle has also built bikeshare infrastructure for cities around the United States, including Charlotte, Cincinnati, Denver, Houston, Madison, Miami, Milwaukee, Kansas City, Las Vegas, Los Angeles, and Oklahoma City, among others.

After expanding in the spring of 2016, Indego now features 1,000 bikes in 105 locations covering a larger portion of the City of Philadelphia, including several low-income neighborhoods. As of December 2016, users have logged more than one million trips. Locations in and near tourist areas have also had high visitor use. In Philadelphia, the Art Museum station near the Schuylkill River Trail is Indego's highest revenue and one of its highest ridership locations. For $15 a month the user has access to unlimited one-hour trips through a connected bank account or cash payment. For less frequent riders, the program offers a pay-per-trip option. To

encourage ridership, Indego also offers corporate and group memberships. Indego passholders have access to "passholder perks" such as Zipcar and Enterprise Carshare discounts, as well as special event and restaurant promotions.

In 2016, **Bluegogo** put 70,000 shared bikes on China's streets in just one month. Its bikes are free floating and users can find them through an app. It scaled back its expansion plans in San Francisco, when the local government feared that the service's bikes would litter the streets and fill bike racks.[215] Instead it is currently leasing space from private businesses, which serve as stations.[216] On its website, Bluegogo advertises a rate of 99 cents for 30 minutes, well below that charged by many public bike sharing systems.

Figure 13. Total Indego Bikeshare Trips by Quarter



Source: Indego Bikeshare, 2015-2016.

One-way bikeshare operators face a particular challenge in balancing across station docks. Each dock needs both available bikes and docking spaces in order to not inconvenience potential riders. A large portion of bikesharing operating costs from having people moving bikes from one station to another in order to keep docks balanced.[217] Certain stations in any system suffer from commute flows or being destinations where more people want to either pick up or drop off a bike, such as Central Park in New York or hilly Montmartre in Paris, France.[218] Various bikeshare programs have worked to design markets that incentivize pick ups or drop offs in order to get riders to help rebalance the system. New York has allowed riders to sign up for its Bike Angels program, where by picking up or dropping off bikes in a way that rebalances the system they can win prizes.[219] Paris gives riders a 15-minute

[215] Marisa Kendall, "Bike Share Service Caves to S.F. Demands," *East Bay Times*, January 23, 2017, http://www.eastbaytimes.com/2017/01/23/sf-bike-share-startup-caves-to-city-demands/ (accessed January 25, 2017).
[216] Ibid.
[217] Harry Grabar, "How New York's Bike-Share System Pays Riders to Make It Run Better," *Slate*, February 9, 2017, http://www.slate.com/blogs/moneybox/2017/02/09/new_york_s_citi_bike_pays_riders_to_make_it_run_better.html (accessed March 2, 2017).
[218] Ibid.
[219] Ibid.

credit for dropping off bikes at designated Vélib' Plus docking stations. [220] Indego is currently testing out a user-rebalancing program, called IndeHero, which gives reward points for returning bikes to specific stations.

Carsharing

Carsharing allows an individual to rent a car on an hourly or daily basis. Reservations are usually made in advance but often can be done with very short (30 minutes or less) notice. Round-trip carsharing requires the vehicle to be returned to the destination where it was picked up from. One-way carsharing allows the trip to be completed at any approved destination location, which is usually different from the trip origin. Each carsharing vehicle is estimated to replace 9 to 13 personally owned vehicles.[221] Companies in **orange** font identify carsharing services that are currently operating in the Greater Philadelphia area:

Priority parking for Zipcar at Ikea in South Philadelphia.

- Round-trip carsharing is available through **Zipcar** and **Enterprise Carshare** (previously PhillyCarShare).
- **Car2Go** offers free-floating carsharing, where users can pick up and drop off at on-street spaces throughout a city. Users are charged by the minute (currently $0.41), hour ($14.99), or day ($84.99) depending on what would work out to the lowest rate. Cars can only be reserved up to 30 minutes in advance. Car2Go has installed bicycle racks on some of its vehicles in order to facilitate vehicle-bicycle trip chaining.[222]
- Peer-to-peer carsharing with daily and hourly rates is available through **Turo** (formerly RelayRides), **Getaround**, **Silvercar**, and **Skurt**. Rental fees include insurance, and in some cases the owner delivers the vehicle to the renter. Silvercar only rents Audi A4s. Skurt agents pick up and drop off rental cars.
- **Carma** (formerly Avego) is a nonprofit carsharing service in San Francisco, California.
- **Maven** is GM's carsharing program.
- **Audi Unite** is a shared vehicle ownership model in Stockholm where up to 5 people can jointly share a vehicle through a smartphone app.

Car2Go is available in nine U.S. cities, as well as cities in Austria, Canada, China, Germany, Italy, Netherlands, Spain, and Sweden.

The Getaround website notes plans to launch service in Philadelphia soon. Flightcar offered rentals of vehicles that would otherwise be parked at the airport while its owner(s) are out of town. Its technology was recently bought out by Mercedes Benz and the service was discontinued.

Enterprise Carshare includes fuel, liability protection, and roadside assistance in addition to accessing the actual vehicle through a monthly, daily, hourly, or per mile rate. It offers individual and business plans in the region with cars available to be viewed and reserved in real time through the Enterprise Carshare app. Zipcar currently offers 450 vehicles in the Philadelphia area. Zipcar provides members with a Zipcard, which grants access to the vehicle.

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[220] Ibid.
[221] Transportation Research Board, *Special Report 319: Between Public and Private Mobility: Examining the Rise of Technology-Enabled Transportation Services* (Washington, DC: Transportation Research Board of the National Academies, 2015), http://www.trb.org/main/blurbs/173511.aspx.
[222] Federal Highway Administration.

Turo is a service in Philadelphia that provides a form of peer-to-peer carsharing. An individual can rent a vehicle when needed or list a personal vehicle for rent through the service to make extra money when not in use. Turo covers a car for up to one million dollars in insurance and provides 24/7 roadside assistance. Users are free to rent and list their vehicle to whomever they choose. The company's marketing materials include images of vintage, classic, and exotic cars rented by its members. This can create the opportunity for unique experiences that are not readily found in the traditional car rental market.

The Moovel Group, a subsidiary of Daimler AG, is quietly positioning itself to be a global leader in the new world of transportation. It is the parent company of Car2Go and recently acquired Ridescout, Globesherpa, and MyTaxi, creating an interesting blend of digital transportation assets.[223] The Shared Use Mobility Center refers to this type of service bundling as aggregators.

Courier Networking Services

These services offer on-demand pick-up and/or delivery of goods, groceries, and take out foods. By delivering needed, and potentially bulky or heavy, goods to a household, these services play an important role in helping individuals to live carfree or carlite if they choose. Companies in **orange** font identify courier networking services that are currently operating in Greater Philadelphia.

A Caviar bike delivery in Center City, Philadelphia.

- **Fresh Direct**, **Instacart**, **Peapod**, and **Good Eggs** deliver groceries.
- **Caviar/Trycaviar**, **Grubhub**, and **UberEATS** deliver restaurant foods.
- **Postmates** offers on-demand delivery for anything from a store or restaurant.
- **Rinse** offers on-demand dry cleaning and laundry service pick-up and return.
- **Sprig** delivers fresh, organic chef-prepared meals.
- **Shyp** is an on-demand service that finds the best available price for shipping, will pick up an item, and then package and ship it.
- **BloomThat** offers on-demand flower delivery. It has same day service in many major cities and next-day delivery throughout the United States.
- **Dolly** connects individuals to on-demand truck moving and delivery services.
- **Schlep** offers local logistics, delivery, and short-term warehousing.
- **GoPuff** delivers convenience store and tobacco goods.

UberEATS began service in Philadelphia in August 2016 and delivers food from over 100 restaurants in the city using the same model as UberX.

Washio was an on-demand laundry service that aimed to pick up dirty clothes, wash them, and then return them, all within 24 hours.[224] It shut down operations at the end of August 2016. SpoonRocket delivered freshly prepared meals on demand. It discontinued operations in March 2016, but its logistics platform has been relaunched in the iFood platform in Brazil.

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[223] Darrell Etherington, "Car2Go's Parent Company Moovel Acquired RideScout and MyTaxi," *TechCrunch*, September 3, 2014, https://techcrunch.com/2014/09/03/car2gos-parent-brand-moovel-acquires-ridescout-and-mytaxi/ (accessed July 18, 2016).

[224] Brian Solomon, "Washio, the On-Demand Laundry Startup, Washes Out," *Forbes*, August 30, 2016, http://www.forbes.com/sites/briansolomon/2016/08/30/washio-the-on-demand-laundry-startup-washes-out/ (accessed October 13, 2016).

Freight Apps

Freight apps are digital freight brokerages that replace conventional intermediaries for small trucking carriers to transact business with shippers. Companies in **orange** font identify on-demand freight services that are currently operating in the Greater Philadelphia area.

- **Convoy** , **Cargo Chief**, and **Cargomatic** book local and regional goods movement.
- **Transfix** books long-haul shipping and every distance in between. Services include dry, refrigerated, frozen, and flatbed full loads.

Drivers are paid automatically through these apps, dramatically speeding up their reimbursement, which can take weeks when using traditional intermediaries. Transfix's CEO estimates that commercial trucks needlessly drive 19 billion empty miles each year.[225] Real-time, on-demand routing programs can help to dramatically decrease empty trucking legs and reduce truck VMT.

New Jersey has a truck e-screening program, which puts a transponder on each participating vehicle that links to all federal trucking and safety databases. Companies with safe track records can sign up for the program and bypass weigh stations. This saves considerable travel time, while also reducing the problems of trucks backing up at weigh stations onto the highway mainline, causing further delay. Adopting this program in other states is more a business model decision than a technological issue. As it is, heavy regulations and outdated and poor-condition infrastructure makes Greater Philadelphia and the rest of the Northeastern United States undesirable for truck drivers. Trucking companies often advertise “no Northeast travel" in order to recruit drivers.

Mobility-as-a-Service

Mobility-as-a-service (MaaS) is sometimes called “Spotify for travel." These services intend to combine multiple transportation modes with monthly subscriptions or other payment plans. Companies either provide multimodal transportation services or partner with existing operators. These services are largely still in their infancy but may be the next big thing in shared mobility.

- **Whim** (formerly MaaS Finland) launched in Helsinki in the fall of 2016. It serves as a transportation broker offering a monthly mobility package. It does not operate any transportation service; rather, it negotiates between providers to sell different mobility options. The monthly pass costs about 100€, and includes unlimited transit ridership and limited taxi and car rental. A second option combines multiple modes into a single-trip ticket, and a third fuses a private car with a range of transit services.
- **Ubigo** was tested for six months by 70 households in Gothenburg, Sweden. Its app combined public transportation, carsharing, rental cars, taxis, and bikesharing options, paid for with a single monthly invoice. There are plans to launch Ubigo 2.0 in Gothenburg and one or two other Nordic cities. Users got

[225] Eric Jaffe, “How the Trucking Industry Could Be Vastly More Efficient," *The Atlantic CityLab*, January 21, 2015, http://www.citylab.com/tech/2015/01/the-trucking-of-tomorrow-is-here-and-its-a-huge-win-for-city-traffic/384672/ (accessed February 3, 2015).

bonus points for every trip that used less CO_2 than driving would have. These points can then be used for bike service, home delivery, health clubs, concerts, and other benefits.
- **CitiWay** is a French IT company that sells MaaS concepts by seamlessly combining multimodal trip planning and e-ticketing: personal vehicles, public transit, biking, bikesharing, carsharing, carpooling, ridesourcing, planes, ferries, etc. For transportation agencies it offers predictive trip planning, and fleet monitoring and supervising.

Shift (formerly Las Vegas 100) planned to offer an unlimited mobility on-demand service for a monthly fee in Las Vegas, Nevada. It intended to combine a smartphone app with a variety of transportation options it planned to provide: ridesource vehicles, carshare, bikeshare, and shuttles. The project was announced in 2013 with backing from Tony Hseih of Zappos.com, but was ultimately abandoned in July 2015.

Parking Apps

These apps aim to provide better space availability information or easier payment options to make parking in the region more efficient. Companies in **orange** font identify parking apps that are currently available in the Greater Philadelphia area.

- ParkMe, ParkWhiz, and BestParking allow individuals to compare parking costs at different facilities. ParkMe and ParkWhiz allow spaces to be reserved and paid for online ahead of time.
- **Luxe** is an app-based valet parking program, which will meet the driver (customer) at a specified location, park their car, and return it when needed again. This service has moved away from on-demand vehicle pick-up and now requests a scheduled pick-up of 15 minutes to one hour ahead of time.
- The Philadelphia Parking Authority's (PPA) MeterUp app allows parkers to pay for on-street parking and can extend their time using the app without having to return to the street.
- Pay-for-access parking apps:
  - **MonkeyParking** allows individuals to rent out underused, privately owned parking spaces.
  - **Haystack** allows users to sell their public on-street parking space when they are vacating it. This business model has been one of the most controversial parking apps as it attempts to profit off of a public good. Boston moved to quickly deem it illegal and shut it down when it commenced operations there.[226]
- Washington, DC, has begun charging for the use of curbside freight loading zones through the **goDCgo** website.

Valet Anywhere and Zirx are two former competitors of Luxe but have dropped the on-demand parking valet model. Valet Anywhere now targets residential parking needs, while Zirx has moved into a business-to-business model that helps park,

[226] Adam Vaccaro, "Parking App Haystack Banned in Boston," *Boston.com*, August 20, 2014, http://archive.boston.com/business/technology/2014/08/20/parking-app-haystack-banned-boston/S074MzUNYjWbJFSresmAIN/story.html (accessed July 6, 2016).

maintain, and wash other company-owned vehicles. Moving parked vehicles on demand has proven challenging. Workers need steady gigs, and on-demand parking companies also face uncertainties regarding worker employee status. These companies needed to book garage space in advance, but it was not always used, which would cause them a loss of money.

The PPA currently plans to allow MeterUp app users to extend parking beyond signed time limits, at a higher per hour expense. This brings a possible equity issue, as the people that will benefit from this have smartphones and credit cards.

Ridesharing

Ridesharing apps allow for real-time carpooling by connecting drivers and potential passengers. Companies in **orange** font identify services that are currently operating in the Greater Philadelphia area.

- **Blanc**, **Carzac**, **Duet**, **MüV**, **RideFlag**, and **Scoop** are publicly available real-time carpooling apps. Since these services match two or more people looking to make a similar trip, they can reduce vehicle travel. RideFlag allows drivers to set their prices for each trip. Carzac also sets up private networks for employers and universities.
- **Zimride** sets up private carpooling networks for employers and universities.
- **RideAmigos** is a transportation demand-management software program for local governments, schools and universities, businesses, and other institutions. It can track employee trips, provide information in dashboards, and give employees information on multimodal travel options.
- **Atlas** and **Blablacar** are apps that connect drivers and passengers for long-distance ridesharing trips, usually between cities. Atlas is based in Philadelphia.[227] Blablacar has 40 million users in 22 countries, but does not offer service in the United States.
- **La' Zooz** is an app that collects users' driving activity and mines it to ride share trips. Payments are done using a cryptocurrency (Zooz tokens), which attempts to reward all users, including the developers and backers.
- **Waze Carpool** is a project from Google that is conducting a trial ridesharing app using Waze technology. Google hopes to build the service from its millions of existing Waze users. Fees will be no more than the standard Internal Revenue Service (IRS) tax deductions for gas and vehicle expenses, currently 53.5 cents per mile. Safety could be an issue as Google is not screening drivers or passengers, instead relying solely on user ratings.[228]
- **UberCommute** is a ridesharing service operated by Uber.

Tripda was another long-distance ridesharing platform that operated in 13 countries, including the United States. It ceased operations in March 2016. Lyft

[227] Roberto Torres, "This Philly-Made Ridesharing App Is Gunning for the Long-Distance Market," *Technical.ly Philly*, September 2, 2016, http://technical.ly/philly/2016/09/02/philly-made-ridesharing-app-atlas/ (accessed October 13, 2016).
[228] David Dudley, "Can Google Make Carpooling Cool?," *The Atlantic CityLab*, September 1, 2016, http://www.citylab.com/commute/2016/09/can-google-make-carpooling-cool/498218/ (accessed September 21, 2016).

piloted a ridesharing program in San Francisco in 2016, but shut it down when it couldn't attract enough drivers to make the service worthwhile.

Taxi Apps

Taxi apps are similar to ridesourcing applications; however, they operate within the traditional taxi medallion framework. Users are able to access the technology through a handheld device to summon a licensed taxi driver. Applications in **orange** font identify taxi apps that are currently available in the Greater Philadelphia area.

- **Curb** (formerly Taxi Magic), **Flywheel**, **Hailo**, **iTaxi,** and **MyTaxi** are taxi apps that both hail and allow for electronic payment of trips. Curb is available in more than 60 cities.
- **CabCorner** app coordinates two or more people to meet and share a taxi at the same destination prior to hailing it.
- **Smartaxi** uses predictive analytics to help taxi drivers predict when and where demand for rides will be.
- **zTrip** (formerly Yellow X) is an app that allows for booking a black car or taxi on demand or at a scheduled time with electronic payment. It aims to work with independent taxi and limousine operators through the ExecuCar service. It is currently available in Greater Philadelphia only through black car service from PHL.
- Several local taxi-hailing apps are available in the City of Philadelphia. The **215 Get a Cab**, **Freedom Taxi**, and **PHL Taxi** apps allow a person to either electronically hail a cab or schedule a pick-up time.
- The **Way2Ride** app can e-hail and process mobile payments by tapping an enabled smartphone to the embedded reader. At its launch in Philadelphia in September 2014, the app was available in 1,400 of the city's 1,600 taxi medallion vehicles. The developer, Verifone Systems, is phasing out this app and embedding it into Curb, which it also owns.

Transportation Network Companies

Transportation network companies (TNCs) facilitate rides through a digital network. TNCs come in a few different forms, most prominently ridesourcing and microtransit. Ridesourcing operates much as traditional taxi services do, while microtransit services are more in line with public transportation. Ridesplitting is another form that combines aspects of ridesourcing and microtransit.

Microtransit

Microtransit services generally combine trips to move multiple passengers simultaneously on demand. Companies in **orange** font identify microtransit services that are currently operating in the Greater Philadelphia area.

- **Bridj**, **Chariot**, and **OurBus** use on-demand shuttles operating within a limited service area, often targeting underserved trip pairings in the transit network.
- **Loup** provides an optimized circular fixed route between neighborhoods with designated pick-up and drop-off spots using black cars or limos to provide the service.
- **Via** provides on-demand and demand-response transit within a specific zone.

- **Lyft Shuttle** is a pilot program in Chicago and San Francisco that operates a fixed route car service with designated pick up and drop off locations during peak periods. Fares will vary based on time and distance traveled, but will not surge based on demand.
- The **Big Blue Bus** in Santa Monica, California, is conducting a trial of an on-demand cab service from 8:00 PM to 3:00 AM each Friday and Saturday night. It has a flat rate cost of three dollars per trip within a service area, which must either originate or end at the 17th Street/SMC Expo Line Station.[229] The Big Blue Bus subsidizes the cost of the fare above three dollars.[230]
- **Skedaddle** helps groups of 10 to 54 make city-to-city or countryside getaway trips using professionally driven vans, shuttles, or buses. Private groups can book their own reservations, or individuals can join existing planned routes. Reservations can be made up to 48 hours in advance.

The Big Blue Bus service area around Expo Station.
Source: https://www.bigbluebus.com/Newsroom/News/Blue-at-Night-Your-Late-Night-Connection-to-Expo.aspx.

Kutsuplus was a municipally operated on-demand shuttle service that was in service for two years in Helsinki, Finland. It started with the ambitious goal of making car ownership unnecessary in the entire Helsinki region. The system was coordinated via a smartphone app that blended cars, small buses, bikeshares, and ferries into a trip planner and fare payment instrument. In its first year of operation, a fleet of 15 vehicles required a subsidy of 40€ per passenger trip. In its second year, the same number of vehicles required a 20€ subsidy per passenger. Its operators argued that the required subsidy would be reduced with a larger vehicle fleet and more passenger volume. The Ajelo software program that supported its operations was sold to Split. One of the reasons why it failed was that it did not do enough to market the service and spread word about it—in other words it didn't build a large enough network.[231]

Split provided shared, on-demand rides using shuttles in a 24-square mile area of Washington, DC. Despite growing an average of 30 percent per month after its May 2015 launch, the service was discontinued in October 2016. It still controls the Ajelo software and is refocusing its efforts to develop new products and services to help cities create the next generation of transportation solutions.

OurBus is operating a single, fixed-route bus route between New Jersey and New York City. It has plans to contract with charter bus companies to provide up to 75 new bus routes that will pick up passengers within walking distance of where they live. Charter company buses are in high demand for special occasions but are underutilized during peak commute periods. These companies will supply the buses,

[229] "Blue at Night Your Late Night Connection to Expo," Big Blue Bus, May 18, 2016, https://www.bigbluebus.com/Newsroom/News/Blue-at-Night-Your-Late-Night-Connection-to-Expo.aspx (accessed September 28, 2016).
[230] Nicole DuPuis, Cooper Martin, and Brooks Rainwater, *City of the Future: Technology and Mobility* (Washington, DC: National League of Cities, 2015), http://www.nlc.org/Documents/Find%20City%20Solutions/Research%20Innovation/City%20of%20the%20Future/City%20of%20the%20Future%20FINAL%20WEB.pdf.
[231] "What Killed Kutsuplus? 3 Takeaways for Cities Pursuing Mobility-on-Demand," *Shared Use Mobility Center*, May 3, 2016, http://sharedusemobilitycenter.org/news/killed-kutsuplus-3-takeaways-cities-pursing-mobility-demand/ (accessed September 20, 2016).

drivers, and insurance. OurBus will provide the digital ticketing platform and logistics technology.[232]

Bridj operates a pop-up bus service, with no fixed routes and aims to provide a one-seat ride. Riders summon the vehicle through the Bridj app and are directed to a nearby public bus stop. The stop is based on what is the closest stop where a vehicle can be dispatched most quickly. In Kansas City, it has entered into a partnership, called RideKC, with the local transit agency to provide on-demand bus service in place of a fixed route line (see TNC Partnerships section). Like OurBus, Bridj partners with charter bus jitney companies to provide the service. Bridj can profitably serve areas with a population density of 11,000 people per square mile without government assistance.[233] Bridj would look for subsidies to serve less dense areas, and places where transit service can be improved during off-peak hours. Bridj sees its role as providing trips and does not believe first-mile/last-mile connections are an issue that the public thinks about. Instead, it wants to provide what the public wants: one-seat rides. Bridj is exploring expansion into the city of Philadelphia.

Ridesourcing

Ridesourcing (or ridehailing) allows an individual to call a vehicle for a trip using a smartphone app. The cost of the trip is indicated before the request is finalized. The app guides a TNC driver with the service to pick up the passenger and then take them to their desired destination. Payment is handled electronically within the app, so the driver has no need to carry cash.

UberPool and Lyft Line are a hybrid of ridesourcing and microtransit, also known as ridesplitting. They pick up and drop off multiple passengers simultaneously for a discounted price. This increases occupancy rates and may help to alleviate congestion. Companies in **orange** font identify ridesourcing services that are currently operating in the Greater Philadelphia area.

- **Uber**'s primary ridesourcing service is called **UberX**. Uber has service in 561 cities worldwide.
  - **UberBlack**, **UberSUV**, and **UberXL** are luxury ridesourcing options.
  - **UberWAV** and **UberAssist** are services for individuals with disabilities. UberWAV is a wheelchair-accessible vehicle. UberAssist drivers come to the door to help the passenger into the vehicle.
  - **Didi Chuxing** is the largest ridesourcing provider in China, it formed from the 2015 merger of China's two largest TNCs, Didi Dache and Kuaidi Dache. Uber has recently merged its Chinese operations with this company.
- **Lyft** operates in more than 300 cities in the U.S. and is planning on expanding into international markets. General Motors has invested $500 million in the company.

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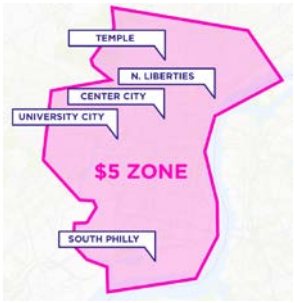
[232] Jen Kinney, "On-Demand Bus Service Arrives in New Jersey," *Next City*, September 22, 2016, https://nextcity.org/daily/entry/on-demand-bus-service-new-jersey-commute-new-york (accessed September 22, 2016).
[233] Matt George, phone call with author, July 5, 2016.

- UberPool and Lyft Line (these are also called ridesplitting and microtransit) match passengers leaving from similar origins and destinations to share a ride. These services are restricted to parties of one or two people; larger groups are requested to use ridesourcing options. Drivers use their personal vehicle.
- Juno is a ridesourcing startup that aims to give 50 percent of company ownership to its drivers.
- Fare, Instaryde, and GetMe are some of the larger ridesourcing operations that have emerged in Austin, Texas, following the decisions of Uber and Lyft to discontinue operations there.[234] Fare lets passengers choose their drivers and does not use surge pricing.[235] GetMe also delivers goods and food.
- Ride Austin is a nonprofit ridesourcing start up. It rounds up fares to the nearest dollar and donates the change to a local charity.
- WingzAround offers rides with a flat rate fare structure.
- Gett is an Isreal-based instant transportation service provider that has expanded into New York City. It operates in more than 100 cities around the world. It takes only a 10 percent cut of the commission from fares and does not use surge pricing.
- Fasten keeps only one dollar from each fare, letting the driver keep the rest. It has a unique pricing structure that lets passengers "boost" their fares in order to attract drivers.
- HopSkipDrive, Zum, and Kango all offer on-demand rides to unaccompanied minors. Drivers for these companies are almost exclusively female and often have a background in childhood education.
- Circulation and RoundTrip offer on-demand, nonemergency medical transportation services. Rides include both drop-off at the appointment and pick-up after it is complete.
- Go Go Grandparent offers on-demand rides via phone call, rather than an app, meaning no smartphone is required. The service sends text messages to family members or caregivers to update the status of the trip.



Lyft Line offers five-dollar rides anywhere within a zone from South Philadelphia to Temple University.

Source: https://blog.lyft.com/posts/lyft-line-philadelphia.

Sidecar was another well-known ridesourcing company. It ceased operations in 2015. GM purchased its intellectual property and hired 20 former employees.[236] Shuddle offered an "Uber for kids" service. It was unable to secure additional venture capital to keep operations going and had to shut down in April 2016. The timing was unfortunate, as the service had just reached a point of profitability on each ride it provided.[237]

Uber began operating in the City of Philadelphia in October 2014, without clear legal authorization. According to numbers obtained by the mobile news platform *Billy Penn*, the company provided 700,000 rides in its first year in the city, generating

[234] Michael Theis, "The Complete Guide to Austin's Ridesharing Apps," *Austin Business Journal*, updated August 31, 2016, http://www.bizjournals.com/austin/news/2016/06/07/the-complete-field-guide-to-austins-ridesharing.html (accessed September 21, 2016).
[235] Jiahui Jia, "Scottsdale-Based Ride Fare Dives into Ride-Sharing Business with a Focus on Drivers?," *AZ Central*, February 23, 2016, http://www.azcentral.com/story/money/business/contributor/2016/02/23/scottsdale-based-ride-fare-dives-into-ride-sharing-business/80219300/ (accessed July 17, 2016).
[236] Carolyn Said, "Shuddle 'Uber for Kids' Service Reaches End of Road," *San Francisco Chronicle*, April 14, 2016, updated April 15, 2016, http://www.sfchronicle.com/business/article/Shuddle-Uber-for-kids-service-reaches-end-7249450.php (accessed September 20, 2016).
[237] Ibid.

about $33 million in revenue.[238] Uber had approximately 1,250 drivers in January 2015, and by that October it had about 12,000: a 960 percent increase.[239] About 22 million trips are taken each day throughout the region. At that time, Uber in the City of Philadelphia represented just 0.01 percent of all regional trips. But the service has shown nonlinear, disruptive growth rates everywhere it has gone, as can be seen in the driver and revenue (income) growth rates in Figure 14. Before Uber was approved to operate in Philadelphia, several drivers were ticketed and some vehicles were impounded by the PPA.[240] DVRPC is unaware of any release of TNC ridership or driver data for any of the eight suburban counties in the Greater Philadelphia region.

Outside of Philadelphia (and Allegheny County), the Pennsylvania Utilities Commission (PUC) is responsible for regulating TNCs in Pennsylvania. Uber launched service in Bucks, Chester, Delaware, and Montgomery counties in May 2012.[241] Likewise, the PUC deemed the service as unauthorized when it launched in the four suburban counties. As a result of operating without permits in 2014, the PUC has fined Lyft $250,000, and Uber $11.4 million.[242] Lyft has paid its fine, while Uber is still negotiating a settlement on its fine. A two-year temporary authorization was granted in 2015, and made permanent with Act 164 of 2016.

Figure 14. Estimated Monthly TNC Revenue in the City of Philadelphia

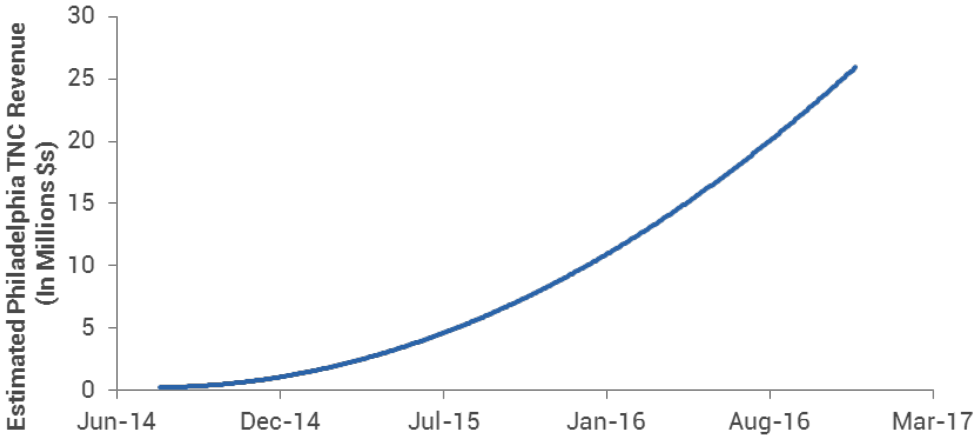


Chart shows a best fit polynomial curve based on limited available public information. It includes Uber only from April 2015 to June 2016, and Uber and Lyft from July 2016 to December 2016.

Sources: Anna Orso, "Uber in Philly: One Year In, How's the Not-Quite-Legal Ride-Sharing Service Doing?," Billy Penn, October 26, 2015, http://billypenn.com/2015/10/26/uber-in-philly-one-year-in-hows-the-not-quite-legal-ride-sharing-service-doing/ (accessed May 23, 2016); and "School District of Philadelphia Collects First Portion of Rideshare Revenue," School District of Philadelphia, February 2, 2017, https://webapps.philasd.org/news/display/articles/2371 (accessed March 28, 2017).

[238] Anna Orso, "Uber in Philly: One Year in, How's the Not-Quite-Legal Ride-Sharing Service Doing?," *Billy Penn*, October 26, 2015, http://billypenn.com/2015/10/26/uber-in-philly-one-year-in-hows-the-not-quite-legal-ride-sharing-service-doing/ (accessed May 23, 2016).
[239] Ibid.
[240] Ibid.
[241] Juliana Reyes, "Actually, UberX Has Been Operating in Philly's Pa. Suburbs for Months," Technical.ly Philly, October 28, 2014, http://technical.ly/philly/2014/10/28/uberx-has-been-operating-in-the-philly-suburbs-for-months/ (accessed February 21, 2017).
[242] Eleanor Klibanoff, "Uber. Lyft Get Green Light to Operate in Pennsylvania," *Newsworks*, updated October 26, 2016, http://www.philly.com/philly/business/Bill-to-legalize-UberX-and-Lyft-in-Philly-clears-last-legislative-hurdle.html (accessed October 27, 2016).

From July 14, 2016, until September 30, 2016, the ban on TNC operations in the City of Philadelphia was temporarily lifted as a result of 115 SEPTA Silverliner V regional rail vehicles needing to be taken out of service for emergency repairs. This caused service cutbacks right before the Democratic National Committee (DNC) convention was to occur in the city at the end of July 2016. During this time, UberX and Lyft paid a 1 percent tax on each ride, of which two-thirds went to the Philadelphia School District and one-third to the PPA. This tax required the companies to report their revenues, which were $42.1 million for UberX and $11.5 million for Lyft. UberX reported having 12,000 drivers in the Philadelphia region.[243] An unnamed insider said the two ridesourcing companies were providing about 59,000 rides per day in the city, but these numbers have not been verified by the companies and may have been inflated over normal expectations by the DNC convention and the regional rail service disruption.[244] The temporary authorization briefly lapsed before agreement was reached to permanently lift the ban on ridesourcing services statewide.

Governor Wolf signed Act 164 in late October 2016, legalizing TNC operations. The legislation includes a tax rate of 1.4 percent on ridesourcing service revenues in Philadelphia, with two-thirds going to the School District of Philadelphia and the remainder going to the PPA to oversee regulations; levies a $50,000 application fee for new entrants to the market; requires drivers to meet insurance and licensing requirements; specifies criminal activities that will disqualify drivers; and relaxes regulations on taxi operations.[245] The initial Philadelphia School tax payment from Uber and Lyft, covering the period from November 4, 2016 to December 31, 2016 was $411,381.12, which suggests these two TNCs are generating $23.5 million in fare revenues per month.[246] A news media report quotes the PPA as saying the two companies averaged 49,000 rides per day during this time.[247]

Prior to passing the "Transportation Network Company Safety and Regulatory Act," TNCs were not considered to be legal in the state of New Jersey. Newark Liberty International (EWR) Airport, in particular, was an area where many drivers were ticketed. Some vehicles were impounded according to posts on the Uberpeople forum for its drivers. In April 2016, Uber agreed to a 10-year, $10 million licensing agreement with the City of Newark to serve EWR.[248]

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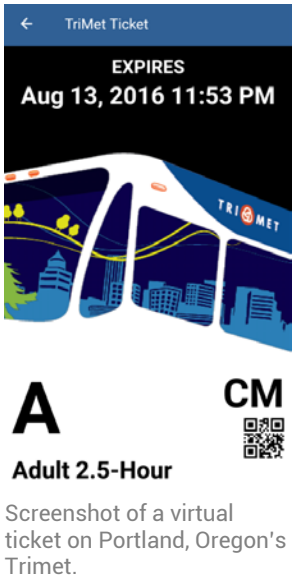
[243] Ibid.
[244] Ibid.
[245] Klibanoff.
[246] "School District of Philadelphia Collects First Portion of Rideshare Revenue," School District of Philadelphia, February 2, 2017, https://webapps.philasd.org/news/display/articles/2371 (accessed March 28, 2017).
[247] Jason Laughlin, "Uber and Lyft Made $44 Million Since Becoming Legal in Philadelphia," Updated February 16, 2017, http://www.philly.com/philly/business/transportation/Uber-and-Lyft-made-44-million-since-becoming-legal-in-Philadelphia.html (accessed March 28, 2017).
[248] "Uber Agrees to $10M Fee in Deal with Newark, New Jersey," *Insurance Journal*, April 20, 2016, http://www.insurancejournal.com/news/east/2016/04/20/405851.htm (accessed February 22, 2017).



Screenshot of a virtual ticket on Portland, Oregon's Trimet.

Virtual Ticketing and Electronic Tolling

New technology allows transit users to pay for fares, passes, or actual tickets for different transit options through their mobile device. Applications in **orange** font identify services that are currently operating in the Greater Philadelphia area.

- **Moovel Transit** (formerly Globesherpa) provides mobile ticketing options, often through partnerships with apps, such as Portland's **Trimet** and San Francisco's **MuniMobile,** allowing transit riders to buy, store, and use fares with a smartphone.
- Another well-known mobile ticketing company is **Bytemark, Inc**. Bytemark is a London-based mobile ticketing platform providing secure service for all modes of transit.
- **NS Business Card** is a multimodal fare payment card for the entire country of the Netherlands. It can be used on public transit, carsharing, taxis, parking, and bikesharing.
- The Chicago Transit Authority's (CTA) **Ventra** app allows riders to add money to their accounts by phone and buy digital tickets for travel on the CTA. Metra, and Pace systems.
- The MTA's **eTIX** app lets you purchase tickets and use the Long Island Rail Road and Metro-North Railroad in New York.
- **NJ Transit Mobile App**, MyTix, allows for the purchase of tickets for travel on the NJ Transit rail, light rail, and bus networks.
- **SEPTA Key** allows riders to use a reloadable, contactless chip card for transit fares and station parking. In the future, it may be possible to use SEPTA Key to make nontransit purchases. Riders can also now use bank-issued debit or credit cards that utilize the chip format to pay fares. Photo ID key cards will be issued to individuals who qualify for riders with disabilities, CCT customers, and senior citizen programs.
- **Cubic Transportation Services** offers integrated real-time payments and transportation management systems.

Several tolling authorities in the region (the Pennsylvania Turnpike, the New Jersey Turnpike, and the South Jersey Tolling Authority) are moving toward full electronic tolling on their facilities. These would mean the end of tollbooths and their workers (who will be reassigned). Instead, digital technologies use **E-ZPass** to read and collect tolls and will photograph vehicles without an E-ZPass and mail toll bills to those vehicle owners.

Miscellaneous Applications

Other applications are incorporating on-demand principles into niche transportation markets. Companies in **orange** font identify services that are currently operating in the Greater Philadelphia area.

- **Honk** and **Urgent.ly** are nationwide on-demand mobile roadside assistance apps that offer towing, tire change, jump starting, fuel, and lock-out services.
- **Scoot Networks** and **Zapp** (formerly Scootaway) offer on-demand scooter sharing services.
- Startups such as **Yoshi**, **WeFuel**, **Booster Fuels**, and **Filld** are aiming to be the "Uber" of gas delivery. These apps allow a car owner to request their car be filled

with gas via an app. The fueling company then comes to where the car is parked and fills it up. They are largely operating in a legal gray area with regard to fire codes.[249]
- Airbus and Uber are working to extend the ridesourcing concept to helicopters.[250]

There are related efforts to improve efficiency and the ability to find one's way around within the travel and tourism industry. Apps are increasingly being created to help visitors better understand the areas they are visiting or find better and lower-cost ways of reaching travel destinations.

- **WayBlazer** provides AI for travel and allows for trip personalization.
- **BD4Travel** provides real-time digital empathy and Big Data personalization for intelligent travel. The tool provides predictive user insights for each step of the travel process: inspiration, planning, choosing, and booking.

The Integrated Proactive Intermodal Travel Assistant (IPITA) is a travel industry vision for planning, booking, ticketing, and real-time updating travel within a single tool.[251] Such a tool would be personalized so the traveler could identify preferred modes of transportation and use AI learning to predict future preferences or responses to situations that arise. It would use smart devices, data glasses, or contact lenses for an information display.[252]

Integration with Nontransportation Apps

Many apps are now working to improve transportation by integrating with e-mail and social networks to provide better travel information and link people who potentially travel to the same destination.

- **Calendar42** combines calendar planning and travel routing needs to better match available resources by time and place. This app also includes route tracking and tracing, customizable business planning rules, and notifications.
- **SlideMail** is an intelligent e-mail service that enters appointments sent through messages into a calendar automatically. The event can be found on a map, or if a flight is necessary then it can bring up available schedules. It adapts to user behavior.
- **Google Now Cards** within the Google app deliver information without being prompted, such as weather, traffic, parking location, and messages from other apps.
- **Hitch** uses Facebook to connect friends and friends of friends in order to facilitate ridesharing. It has recently merged with Lyft.

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[249] Julia Carrie Wong, "Gas Delivery Startups Want to Change the World—but Will They Blow it Up First?," *The Guardian*, May 5, 2016, https://www.theguardian.com/technology/2016/may/05/gas-delivery-tech-startups (accessed May 6, 2016).
[250] Graham Warwick, "Airbus Reveals Urban Air-Transport Projects," *Aviation Daily*, August 2, 2016, http://awin.aviationweek.com/AWINLogin/tabid/1083/Default.aspx (accessed August 5, 2016).
[251] Boston Consulting Group, *Connected World: Hyperconnected Travel and Transportation in Action* (World Economic Forum, May 2014), http://www3.weforum.org/docs/WEF_Connected_World_HyperconnectedTravelAndTransportationInAction_2014.pdf.
[252] "IPITA," World Economic Forum, video uploaded February 14, 2013, https://www.youtube.com/watch?v=4KGNjAS7VkQ (accessed January 11, 2017).

Unmanned Aerial Systems

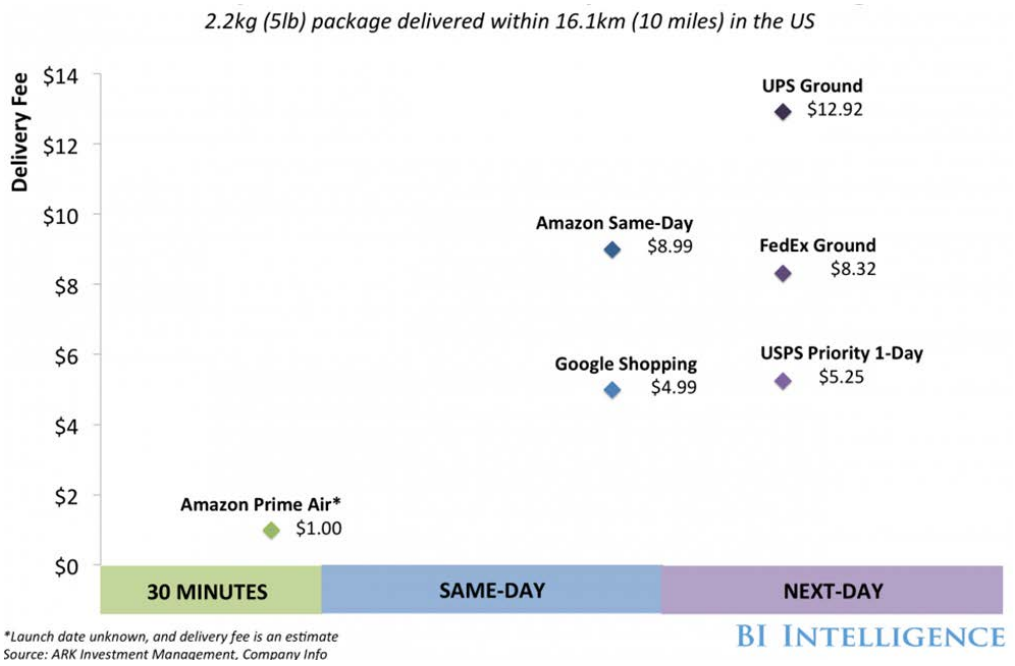
Unmanned aerial systems (UAS), more commonly known as drones, are remotely piloted aircraft. They can be used to inspect previously hard-to-reach facilities, such as bridges, tiers, towers, or windmills. Safety can be enhanced by not sending humans to inspect dangerous—such as first responders in disaster zones—and hard-to-reach spaces, and access can be gained to areas that were previously unreachable. UAS can save time and money in inspections, while recording data that can be retrieved later for reference. They can calculate volume of stockpiles, such as landfills, mines, and quarries, which are accurate enough for inventory purposes. They are able to fly and repeat these calculations under most weather conditions. At construction sites they can identify contours, orthographic projections, and help develop height models in the design phase. During construction they can document as-built conditions, such as utilities and underground services. Data can be fed into 3-D GIS for mapping. They were used to help map out Pope Francis' visit to Philadelphia in September 2015. There are many potential uses, such as:

- delivering food and goods (one London restaurant uses them as waiters);
- aerial photography;
- commercial photography;
- land surveying;
- agriculture (e.g. crop monitoring, spraying pesticides);
- communications;
- radio and TV broadcasting;
- firefighting;
- traffic monitoring;
- weather forecasting;
- journalism and reporting;
- tracking environmental conditions;
- infrastructure and building safety, security, and inspections;
- disaster response, including search and rescue;
- insurance claims;
- spectral and thermal analysis;
- aerial mapping;
- advertising; and
- moving passengers.

Amazon plans to launch a drone delivery service, Prime Air, by 2018. This service will aim to deliver packages under five pounds inside a 10-mile radius of any Amazon warehousing facility within 30 minutes of a purchase. While there are still many regulatory hurdles to overcome, it could offer both cost savings and greatly expedited shipping times, an estimated 80 percent price reduction compared to Google Shopping's current same-day delivery cost by 80 percent.[253]

[253] Eugene Kim, "The Most Staggering Part about Amazon's Upcoming Drone Delivery Service," *Business Insider*, June 15, 2016, http://www.businessinsider.com/cost-savings-from-amazon-drone-deliveries-2016-6 (accessed November 8, 2016).

Figure 15. Consumer Delivery Fee Comparison for Small Packages



Source: BI Intelligence via Eugene Kim, "The Most Staggering Part About Amazon's Upcoming Drone Delivery Service," Business Insider, June 15, 2016, http://www.businessinsider.com/cost-savings-from-amazon-drone-deliveries-2016-6 (accessed November 8, 2016).

Operating a UAS is much easier than flying a helicopter. So it is not surprising that different companies are working on UASs that can fly passengers.

- The Volocopter VC200 has 18 separate rotors but is operated with a joystick. Sensors, such as gyroscopes, accelerometers, and magnetometers are connected to an on-board computer that autonomously flies the drone.
- Ehang, a Chinese drone company, is developing a single-seat, eight-rotor drone. The rotors are in a square, with one facing up and the other facing down, both connected to a single engine. This ensures the UAS will still be able to fly, even if one engine fails. A passenger would enter their destination on a screen, and the drone would fly there at speeds up to 60 mph. It is battery powered, with a 23-minute maximum flight time.
- Malloy Aeronautics, a British company, is developing a "hoverbike" drone. It has two overlapping rotors in both the front and rear of the vehicle, which the passenger would sit on like a motorbike. The passenger would have control, through the use of a throttle grip and other command tools on the handlebar.
- Airbus's Silicon Valley subsidiary, A3, is developing an automated single-passenger drone.[254]

The next step in developing passenger-flying UASs is to convince aviation regulators that their automated features allow them to be flown by individuals with little training. While they will certainly be popular for recreational use, they may also become "flying taxis," shuttling people to destinations at the call of a smartphone app. This would create challenges for insurance liability, infrastructure, public

[254] Warwick.

safety, and other issues. It could, however, reduce the need for road infrastructure. A recent study about improving access to remote communities around the world estimated that a network of 50 base-stations and 150 drones would cost just $900,000, less than the one-million-dollar cost of a two-kilometer, one-lane road.[255]

Zee.Aero is developing a vehicle that is a combination of drones, flying cars, and aircraft with vertical takeoff and landing (VTOL) capabilities. It will fit into a standard parking space and can take off and land using eight four-blade rotors and two engines for thrust. Other companies, such as **AeroMobil** and **Terrafugia**, are working on flying cars that would need a short runway to take off and land. Terrafugia and Uber, through its Elevate program, are also working on VTOL concepts. Uber is envisioning an on-demand network of VTOLs to transport passengers within and between urban areas.[256]

The U.S. DOT and Federal Aviation Administration (FAA) have recently finalized rules for flying passenger-less drones. These new regulations work to harness new innovations safely, spur job growth, advance critical scientific research, and save lives.[257]

- A person actually flying a drone must be at least 16 years old and have a remote pilot certificate with a small UAS rating or be directly supervised by someone with such a certificate.
- Pilots need to keep an unmanned aircraft within visual line of sight.
- Operations are allowed only during daylight and at twilight if the drone has anti-collision lights.
- The maximum allowable altitude is 400 feet above the ground, higher if the drone remains within 400 feet of a structure. The maximum speed is 100 mph (87 knots).
- Small UASs cannot be flown over anyone who is not directly participating in the operation, nor under a covered structure or inside a covered stationary vehicle. No operations from a moving vehicle are allowed—unless flying over a sparsely populated area.
- Operations in Class G airspace are allowed without air traffic control (ATC) permission. Operations in Class B, C, D, and E airspace need ATC approval.
- External loads can be carried only when securely attached and do not adversely affect the flight characteristics or controllability of the aircraft.
- Transporting property for compensation or hire within state boundaries by drone—including its attached systems, payload and cargo—is allowed, as long as the drone weighs less than 55 total pounds and other flight rules are obeyed.
- Individuals are responsible for ensuring a drone is safe before flying. The FAA does not require small UASs to comply with current airworthiness standards or obtain aircraft certification.

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[255] Eoghan Macguire, "Road to Nowhere: Could Drones Be the New Highways of the Future," *CNN*, May 31, 2013, http://edition.cnn.com/2013/05/31/tech/innovation/matternet-drones-networks-gateway/index.html (accessed July 12, 2016)

[256] Uber, *Elevate: Fast-Forwarding to a Future of On-Demand Urban Air Transportation* (Uber, October 27, 2016), https://www.uber.com/elevate.pdf.

[257] U.S. Department of Transportation, "DOT and FAA Finalize Rules for Small Unmanned Aircraft Systems," *Transportation.gov*, June 21, 2016, https://www.transportation.gov/briefing-room/dot-and-faa-finalize-rules-small-unmanned-aircraft-systems (accessed July 12, 2016).

- Although the new rule does not specifically deal with privacy issues in the use of drones, the FAA strongly encourages all UAS pilots to check local and state laws before gathering information through remote sensing technology or photography.
- Individuals must make their drone available to the FAA for inspection or testing on request and must provide any associated records required to be kept under the rule.

Individuals must report to the FAA within 10 days any operation that results in serious injury, loss of consciousness, or property damage (to property other than the UAS) of more than $500.

Virtual Communications

Digital transportation could include virtual reality and near virtual reality devices, which lessen the need to travel by moving bits instead of atoms. In turn, communicating virtually can lower travel costs, reduce energy use, and make business operations more sustainable.

The Oculus Rift offers a virtual reality environment.

Source: Oculus.com.

Telecommuting is becoming more popular and frequent in the workplace due to improved communications technologies, such as video conferencing, instant messaging, virtual private networks, collaborative scheduling, screen sharing, and cloud computing.[258] Virtual communications now mean that home and work no longer needs to occur within commute distance. Individuals can now live and work anywhere in the world.

Virtual communications devices such as the Cisco TelePresence IX5000, Second Life, and virtual reality glasses and goggles (Oculus Rift, Google Glass, DVSR, Gear, HTC, etc) create new ways for people to communicate. Cisco's TelePresence IX5000 offers high-fidelity audio and video with seating for 6 to 18 individuals to create a rich multimedia platform for virtual communication.

The Cisco TelePresence IX5000.

Source: Cisco.

[258] Federal Highway Administration.

A CLOSER LOOK AT TNCS

The digital revolution is enabling new on-demand TNC services, as part of a wider technological reshaping of both the economy and transportation. TNCs offer a real opportunity to improve transportation for many individuals—elderly, young, low-income, and disabled—that are not well served by the existing system.[259] Digital transportation services and shared mobility companies are still in their infancy; business models and markets are still trying to figure out how to meet demand in a financially feasible manner.[260]

This section will take a closer look at issues faced by TNCs and the municipalities in which they operate: the opportunities and benefits provided by these new services, challenges they are facing, partnerships they are building, and how they can use advertising and other tools to grow their businesses. Specifically, these issues include transportation, employment, TNC operations, insurance and liability, municipal implications, and other challenges.

Transportation

TNCs can expand mobility around cities and regions. They can reduce the need to own a vehicle and demand for parking, provide flexible employment opportunities, and are a part of a more efficient, productive, and innovative transportation network.

Expanded Mobility and Reduced Congestion

Uber has a vision for "providing transportation that is reliable as running water." Reducing congestion is a major goal for the company and is needed to meet their vision. Both Uber and Lyft have carpooling options. By sharing rides, through carpooling or ridesplitting services such as UberPool and Lyft Line, the same number of trips can potentially be provided with fewer vehicles.

Only a few travel demand models have attempted to model HAVs in the U.S. to date. These limited runs have found that even when one shared mobility vehicle replaces 11 personally owned vehicles, VMT goes up by at least 10 percent.[261] These modeling runs assumed shared HAVs. Human-driven TNC vehicles would likely have a greater VMT increase. Whether ridesourcing vehicles are increasing traffic in central cities has been a subject of much debate. More information is needed to determine whether ridesourcing vehicles are creating traffic impacts in suburban

[259] Lindsey Hallock and Jeff Inglis, *The Innovative Transportation Index: The Cities Where New Technologies and Tools Can Reduce Your Need to Own a Car* (Washington, DC: U.S. PIRG and The Frontier Group, 2015), http://www.uspirg.org/sites/pirg/files/reports/Innovative_Transportation_Index_USPIRG.pdf.

[260] Michael Kodransky and Gabriel Lewenstein, *Connecting Low-income People to Opportunity with Shared Mobility* (New York: Institute for Transportation Development & Policy and Living Cities, 2014), https://www.livingcities.org/blog/740-how-can-shared-mobility-help-connect-low-income-people-to-opportunity (accessed April 27, 2015).

[261] Eric Jaffe, "How the Microtransit Movement is Changing Urban Mobility," *The Atlantic CityLab*, April 27, 2015, http://www.citylab.com/commute/2015/04/how-the-microtransit-movement-is-changing-urban-mobility/391565/ (accessed March 17, 2016).

areas. The data set is small and the conclusions drawn can be fashioned to fit different agendas.

In 2015, Uber released data showing it was having minimal traffic impact in Manhattan. It found an average of 1,904 Uber vehicles on the road at a time, a small number of the total vehicles in Manhattan. The report made the case that it is not responsible for the growing congestion in the city's core. Transportation analyst Charles Komanoff, using Uber's data, estimated the service has reduced traffic speeds in the central business district by 8 percent. However, Komanoff deems that the question is not whether Uber is the main source of congestion, but if they are making the traffic situation worse. Although Uber vehicles have a less significant impact on traffic (yellow taxis spend about 35 percent of their time "cruising" for fares), Komanoff notes, "Uber vehicles are perturbing a system that had a stable level of congestion for many years."[262] The data was only collected from May 31 to July 19, 2015, and only south of 59th Street. Mayor Bill de Blasio commissioned a *For-Hire Vehicles* study to assess the impacts of ridesourcing vehicles like Uber and Lyft on traffic in New York City. The completed report suggested that although Uber has added to congestion, it was not the main source for increasing it. Rather, slower traffic in Manhattan could be attributed to population growth, more tourists, and an increase in deliveries and street construction.[263]

One of the authors of *For-Hire Vehicles*, Bruce Schaller, released a follow up report in 2017: *Unsustainable: The Growth of App-Based Ride Services and Traffic, Travel and the Future of New York City*. Schaller's updated analysis found considerable changes since the publication of *For Hire Vehicles*. By the fall of 2016, TNCs were serving 500,000 passengers per day in New York City, which had tripled over the previous 18 months.[264] Growth in TNC ridership had reduced both taxi and transit trips.[265] After accounting for these declines, and an estimated 56 million fewer personal vehicle miles driven, TNCs generated an additional 31 million vehicle trips, carrying 52 million passengers between 2013 and 2016.[266] This contributed an increase of 600 million miles of travel after accounting for reduced taxi and personal vehicle driving during that three-year period.[267] TNC vehicles traveled 1.19 billion miles in 2016, increasing total VMT by about seven percent, and substantially worsening congestion.[268] Bus ridership was particularly impacted as TNCs served as both a pull factor, and slower road speeds created an additional push factor away from bus ridership.[269]

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[262] Stephen Miller, "Uber's Own Numbers Show It's Making Traffic Worse," *Streetsblog NYC*, July 22, 2015, http://www.streetsblog.org/2015/07/22/ubers-own-data-reveals-it-slows-manhattan-traffic-9-percent/ (accessed July 26, 2015).
[263] Emma Fitzsimmons, "Uber Not to Blame for Rise in Manhattan Traffic, Report Says," *New York Times*, January 15, 2015, http://www.nytimes.com/2016/01/16/nyregion/uber-not-to-blame-for-rise-in-manhattan-traffic-congestion-report-says.html (accessed July 26, 2015).
[264] Bruce Schaller, *Unsustainable: The Growth of App-Based Ride Services and Traffic, Travel and the Future of New York City* (New York City: Schaller Consulting, February 27, 2017), http://schallerconsult.com/rideservices/unsustainable.pdf.
[265] Ibid.
[266] Ibid.
[267] Ibid.
[268] Ibid.
[269] Ibid.

Schaller's study finds that ridesplitting options have not offset increased VMT to date. Impacts to total VMT depend on what mode riders are coming from and whether or not TNCs are generating new trips. Schaller suggests TNC growth necessitates reconsidering congestion pricing, particularly using new technologies to target the inefficient use of scarce road space. It also means transit needs to be made more competitive through the provision of bus only lanes, transit signal prioritization, preboarding fare payment, and other efforts to speed up service. Uber has come out in support of congestion pricing.[270]

While TNCs seem to be worsening congestion at the present moment, the debate seems to be focused on the wrong issue (to Schaller's credit, his study did estimate personal vehicle VMT reduction). TNCs will certainly continue to increase their VMT as long as they are growing. The ecosystem is still changing and rebalancing as a result of new services. TNCs ability to reduce congestion hinges on generating travel behavior change. Particularly they will need to reduce the expectation that individuals will make nearly all trips in a personal vehicle. TNCs cannot fulfill all travel needs on their own; instead they will need to be a part of an integrated, multimodal network that offers more options in how to get around and offers cost savings relative to automobile ownership.

Travelers have found TNCs to be a useful way of getting around when they are navigating a city or region they do not know as well as their own.[271] Optimized routing apps are increasing traffic on streets, particularly on local roads, that previously experienced much less vehicle activity. In Los Angeles, "Angelenos are already complaining that thanks to smartphone routing, and new modes such as Uber, once quiet streets between major thoroughfares are seeing more traffic."[272] Traffic-calming measures should be explored in areas that might not have received consideration in the past to ensure safety for pedestrians, as well as to prevent high-speed driving. Traffic-calming infrastructure can also preemptively prepare neighborhood streets for HAVs. With no human driver present, there is concern that HAVs will travel at speeds that enable passengers to simply "get there faster," making walking environments less pleasant. The configuration of HAVs may be quite different from the vehicles driven today. This may create some risk in the long-term effectiveness of traffic-calming infrastructure.

Reduced Vehicle Ownership Rates

TNCs reduce the need to own personal automobiles by essentially having a vehicle available at one's fingertips. Reduced vehicle ownership could mean less automobile-related costs for individuals. For TNC users there are no upfront vehicle expenses, no insurance bills, and no maintenance costs. In *TCRP Report 188: Shared Mobility and the Transformation of Public Transit*, Sharon Feigon and Colin Murphy coined the term *supersharer* for individuals who had used bikesharing,

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[270] Andrew Salzburg, "Road Pricing: A Solution to Gridlock," *Medium*, March 30, 2017, https://medium.com/uber-under-the-hood/road-pricing-a-solution-to-gridlock-b093b3f364f2 (accessed April 5, 2017).

271 Hallock and Inglis.

[272] Adam Rogers, "Welcome to the Metastructure: The New Internet of Transportation," *Wired*, January 4, 2016, http://www.wired.com/2016/01/the-metastructure-transportation/ (accessed May 31, 2016).

carsharing, and ridesourcing within the previous three months. Using nonscientific survey results of 4,500 people from seven major U.S. cities, they found supersharers own nearly 60 percent fewer vehicles per household (0.72 personal vehicles per household compared to the national average ownership of 1.72).[273] The survey also found that supersharers are more likely to use public transit, less likely to drive, more likely to walk, and save more on overall transportation costs.[274]

According to a Rockefeller Foundation survey supported by Transportation for America, millennials aspire to be less reliant on cars. Almost half (46 percent) of current vehicle owners surveyed agree they would seriously consider giving up their car if they could count on a range of transportation options. Only 27 percent of millennials in cities with "mature" public transportation systems (including Chicago, New York, and San Francisco) say it is very important to have regular access to a car or truck in their city.[275] Reduced vehicle ownership could also result in less need for parking in urban areas, allowing for increased densification and creating community support for converting parking spaces to other uses. This can then facilitate increased transit and active transportation options.[276]

Parking and Land Use

The average personal vehicle in Greater Philadelphia is driven just 1.1 hours per day, meaning it is parked more than 95 percent of the time.[277] If TNCs can reduce the need for vehicle ownership, there can be considerable savings in constructing fewer or smaller parking facilities, which may be as high as $30,000 to $40,000 per space.[278] The cost of providing parking is factored into the price of housing, office space, retail, and other development throughout the economy. While parking spaces are mandated by the zoning code, they often go unused even during peak periods.[279]

Every five years The Philadelphia City Planning Commission (PCPC) conducts an inventory of all publicly accessible parking facilities in Center City with more than 30 spaces. In 2015, the PCPC documented 46,400 public parking spaces, a decrease of 7.2 percent from 50,023 in 2010.[280] Occupancy rates for available spaces also dropped, from 76 percent to 74 percent, despite fewer available spaces in 2015.[281] There has likely been an increase in the number of private spaces due to the amount of redevelopment that has occurred in Center City over recent years. TNCs and other

[273] Sharon Feigon and Colin Murphy, *TCRP Report 188: Shared Mobility and the Transformation of Public Transit* (Chicago, IL: Shared Use Mobility Center and Transit Cooperative Research Program, June 2016), http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_188.pdf.
[274] Ibid.
[275] "Access to Public Transportation a Top Criterion for Millennials When Deciding Where to Live, New Survey Shows," *Rockefeller Foundation*, April 22, 2014, https://www.rockefellerfoundation.org/about-us/news-media/access-public-transportation-top/ (accessed June 26, 2016).
[276] Transportation Research Board.
[277] Based on data collected for *2012-2013 Household Travel Survey for the Delaware Valley Region*.
[278] Matthew Wheeler, "End of the Road: Uber and Millennials Help U.S. Cities Cut Car Addiction," *The Guardian*, May 31, 2016, http://www.theguardian.com/sustainable-business/2016/may/31/uber-millennials-us-cities-cars-austin-lyft (accessed June 13, 2016).
[279] Ibid.
[280] Mason Austin, David Kanthor, and Sarah Gates, *2015 Center City, Philadelphia Parking Inventory* (Philadelphia: Philadelphia City Planning Commission, 2016), http://www.phila.gov/CityPlanning/aboutus/planningservices/Documents/2015_Parking_Study.pdf.
[281] Ibid.

digital transportation providers will likely further this trend, decreasing need for both private automobile ownership and parking.

As a part of the digital revolution, TNCs are helping to drive network effects, generating demand for more dense, mixed-use center-based development patterns.

Efficiency

Efficiency is about doing more with less. On average, a vehicle in Greater Philadelphia carries just 1.58 persons. Some 85 percent of cars on the road have only one person in them, which is a huge, largely overlooked surplus of transportation capacity.[282] This results in millions of empty seats and innumerable amounts of wasted space. The sharing economy tries to find underutilized assets and put them to higher and better use. Shared mobility is an effort to better use these empty seats in vehicles and/or roadway space.[283] By increasing the load factor there is an opportunity to add one, two, three, four, or even more people to a vehicle, significantly expanding existing road capacity. On the flip side, if TNCs reduce the amount of walking, biking, and transit ridership, then they could lead to less efficient use of space. Norman Garrick, from the University of Connecticut, estimates that each car takes 10 times more space than a bike, 15 times more space than a train, and 30 times more space than a pedestrian.[284] Figure 16 further illustrates the space efficiency of active transportation modes, which also help to build beneficial network effects.

Figure 16. People-Moving Capacity of Street Designs

Source: NACTO via Private Mobility, Public Interest (New York: Transit Center, September 8, 2016), http://transitcenter.org/publications/private-mobility-public-interest/.

Safety

TNCs use technology to build safety into their service throughout each trip. Uber passengers can see their driver coming to get them on the app and wait in a safe place.[285] To ensure riders get into the right vehicle, they receive their driver's name, photo, make and model of their vehicle, and license plate number.[286] After being picked up, riders can see their location and route in real time, and they can share

[282] Paul Mackie, "Want to Start Carpooling? Pick up Your Phone and Get Going," *MobilityLab*, January 7, 2016, http://mobilitylab.org/2016/01/07/want-to-start-carpooling/ (accessed July 17, 2016).
[283] Lisa Nisenson, "Uber's New Wave of Urban Design. Are Cities Ready?," *MobilityLab*, September 8, 2015, http://mobilitylab.org/2015/09/08/ubers-new-wave-of-urban-design-are-cities-ready/ (accessed January 7, 2016).
[284] DuPuis et al.
[285] Shari Shapiro, e-mail message to author, December 15, 2016.
[286] Ibid.

this information with friends and family.[287] After reaching the destination, passengers and drivers rate each other and provide feedback on every ride.[288] If anyone is found to have violated company guidelines, they will lose access to their account.[289]

TNCs have a vested interest in reducing crash rates and insurance claims. A key feature of TNC apps is their capacity to use technology to help riders and law enforcement increase safety. TNCs know who the rider and driver are in the vehicle, the route taken, and other information. If there is an incident, TNCs can provide relevant information to the police.[290] Also, riders can share information about their rides with others to increase safety and convenience. Digital payments through smartphone apps reduce TNC drivers' need to carry cash, which makes them less vulnerable to theft.

TNCs offer convenience, and most importantly safety, during times when transit is generally infrequent. They often replace private vehicle trips for "nightlife, drinking, and entertainment."[291] A study conducted by Temple University and a similar report released by Uber have shown that driving under the influence (DUI) arrests decline after the ridesourcing company has entered the market. DUI arrests and alcohol-related crashes were both down 2 percent In Pennsylvania, and Allegheny County saw an 18 percent decrease in DUI arrests from 2014 to 2015. Peak periods for ridesourcing trips are between the hours of 10:00 P.M. and 4:00 A.M.

After launching in Philadelphia in October 2014, a media analysis of 2015 PennDOT data showed that DUI and related fatalities were surprisingly much higher than in the previous year. The earlier Temple University study found it usually takes 9 to 15 months after introduction of Uber and Lyft service for a decrease in alcohol-related traffic fatalities to show up in the data. However, the media analysis found that 19 of the 29 alcohol-related fatalities in Philadelphia occurred in the second half of 2015, which was during this 9- to 15-month period.[292] It is possible that until the temporary and then permanent approvals of TNCs in the city, the company experienced lower ridership, and more likely a lower number of drivers, during the period of this study. One year of data is also very little to work with in comparison to five years of data that is generally used in traffic safety studies. The lack of clear legal status for TNCs during this time in Philadelphia (the largest source of late-night ridesourcing trips) may be a factor in DUI-related fatalities increasing.

There is a need to ensure both TNC drivers and vehicles meet safety requirements—which means background and regular vehicle inspections. Taxis generally undergo more frequent and detailed inspections than the average vehicle.[293] TNC drivers turn

[287] Ibid.
[288] Ibid.
[289] Ibid.
[290] Ibid.
[291] Bruce Schaller, *Issues and Strategies for Cities on Transportation Network Companies* (National Association of Transportation Officials, draft January 12, 2016).
[292] Mark Dent, "What Happened with UberX and DUI in Philly? 'The Mind Reels,'" *Billy Penn*, May 17, 2016, http://billypenn.com/2016/05/17/what-happened-with-uberx-and-dui-in-philly-the-mind-reels/ (accessed June 2, 2016).
[293] Ibid.

over more frequently than taxi drivers. They receive less training and face less restrictive permitting requirements. This suggests that a larger number of less experienced and potentially less skilled drivers are on the road.[294] This makes TNC drivers a good audience for safety training, monitoring, and messaging.[295]

Carsharing users are charged by time and can be assessed a penalty fee if they return the car late. This can be especially problematic if someone has reserved the car immediately after it is due to be returned. Drivers may drive more aggressively in order to return it on time.[296] Lack of familiarity with a rental vehicle may create additional risks.[297] TNC drivers must coordinate ride connection, pick-up, and drop-off locations using their smartphones, potentially increasing distracted driving.[298]

TNCs are widely anticipated to reduce parking demand. Currently, on-street parking doubles to create a barrier that protects pedestrians on sidewalks in the event a car loses control. In transportation engineering lexicon, this is known as the clear zone. If there is less on-street parking, pedestrians may be more vulnerable to cars crashing into sidewalk areas. Lower speeds limits, bollards, fences, and other protective barriers are potential design options for protecting pedestrians.

Security

There is increasing risk from cascading failures within interconnected systems of systems. For instance, a power failure could also shut down connected vehicle or IoT infrastructure. If this were to occur during an emergency, communications lines could be cut and vehicle safety reduced during a critical situation.

Security and the level of information that TNC operators have access to are controversial, although perhaps no more than for many other consumer product companies. Cybersecurity breaches are becoming increasingly frequent. TNCs use passenger birth names and credit card information. A cybersecurity breach from an outside source could result in identity theft. In February 2015, Uber announced that a hacker had obtained names and drivers' license numbers of approximately 50,000 current and former drivers in a data breach.[299] In 2013, a Citi Bike software glitch mistakenly exposed sensitive personal and financial information, including credit card numbers, of nearly 1,200 bikeshare users.[300] Cybersecurity breaches can also occur from within. Employees often have access to information that should remain private. In 2014, two former Uber employees leaked to the media the existence of an

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[294] *Ride-Hailing Services*.
[295] *Ride-Hailing Services: Opportunities and Challenges for Cities* (National Association of City Transportation Officials, draft n.d.).
[296] Transportation Research Board.
[297] Ibid.
[298] Ibid.
[299] Megan Geuss, "50,000 Uber Driver Names, License Numbers Exposed in a Data Breach," *Ars Technica*, February 28, 2015, http://arstechnica.com/business/2015/02/50000-uber-driver-names-license-plate-numbers-exposed-in-a-data-breach/ (accessed July 17, 2016).
[300] Ted Mann, "Citi Bike Users' Data Exposed," *The Wall Street Journal*, July 23, 2013, http://www.wsj.com/articles/SB10001424127887323829104578624263439561672 (accessed July 17, 2016)

internal company tool known as "God View" which gives corporate employees wide access to track drivers and customers in real time.[301]

First-Mile and Last-Mile Transit Connections

TNCs realize that working with public transit is beneficial for both parties. TNCs are interested in opportunities to serve as the first-mile and last-mile transit connections. Lyft launched a "Friends with Transit" campaign in recognizing that 33 percent of their trips in Boston and 37 percent of their trips in New York City begin or end near transit. The company welcomes "transit agencies providing integrated digital trip planning, booking, and payment experiences for their passengers, leveraging Lyft as a first-mile/last-mile solution."[302]

Accessibility

TNC app technologies are an opportunity to vastly improve dial-a-ride programs for seniors and persons with disabilities. The existing programs often require individuals to make requests up to 24 hours in advance. Real-time, app-based technology can allow requests to be made as needed and reduce wait times.

Regulated taxis provide critical paratransit services for persons with disabilities. Taxis are mandated to serve all passengers equally, including those from low-income neighborhoods and those who use wheelchairs. Taxi companies are required to provide a specified number of accessible vehicles. If TNCs disrupt these services, low-income and individuals with disabilities may suffer undue burden if the private market is left to its own devices.[303] The PPA recently created 45 new wheelchair-accessible taxi medallions, which confer the right to legally operate a taxi within Philadelphia city limits. For each of the next seven years, the PPA will allow 15 new wheelchair-accessible vans to join the fleet.[304] Prior to this addition, there were only eight handicap-accessible taxis in the city.

The city of Dallas, Texas, has a clause in its general transportation ordinance that states TNCs cannot deny service to anyone needing special assistance. The clause requires that any company unable to render the needed service must direct the individual to another company that can provide it.[305]

UberAssist is a service that partners with the Open Door organization to specially train highly rated drivers to transport riders with additional assistance needs.

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[301] Maya Kosoff, "Uber's Top New York Executive Is Being Investigated after Using Uber's 'God View' Tool to Track a Journalist's Location," *Business Insider*, November 19, 2014, http://www.businessinsider.com/ubers-new-york-manager-investigated-for-using-god-view-2014-11 (accessed July 17, 2016).
[302] Rachel Kaufman, "Why Lyft is Making Friends with Transit Agencies," *Next City*, November 9, 2015, https://nextcity.org/daily/entry/lyft-transit-agency-partnership-first-mile-last-mile-goals (accessed July 6, 2016).
[303] *Ride-Hailing Services*.
[304] Jon Geeting, "How Many Taxis per Person Should Philadelphia Have?," *PlanPhilly*, July 14, 2014, http://planphilly.com/articles/2014/07/14/how-many-taxis-per-person-should-philadelphia-have (accessed May 6, 2016).
[305] Center for City Solutions and Applied Research, *Cites, the Sharing Economy, and What's Next* (Washington, DC: National League of Cities, 2015), http://www.nlc.org/Documents/Find%20City%20Solutions/City-Solutions-and-Applied-Research/Report%20-%20%20Cities%20the%20Sharing%20Economy%20and%20Whats%20Next%20final.pdf

Drivers come to the door to meet the passenger instead of waiting in the vehicle. Lyft is partnering with National Medtrans in New York to offer nonemergency medical appointment trips for seniors. However, both Uber and Lyft have been sued over Americans with Disabilities Act (ADA) access.

Pennsylvania's Act 164 of 2016 requires a nondiscrimination policy, including a notice of nondiscrimination, and procedures to report a complaint to a regulatory authority. Drivers must transport service animals free of charge, unless the driver has a documented medical allergy on file with the company. The legislation does not allow a TNC to impose additional charges for providing service to an individual with a disability. TNCs must provide the opportunity to indicate in their digital app whether a passenger requires a wheelchair-accessible vehicle (WAV). The TNC then must do one of the following:

- Connect the passenger to a TNC driver or other available driver with a WAV.
- Direct the passenger to an alternative provider with the ability to dispatch a WAV to the passenger.

The combined class of TNCs must make a minimum of 70 WAVs available in Philadelphia by June 30, 2017. Each year, all TNCs must report to the regulatory authority the programs and best practices it has implemented in order to improve the accessibility and availability of WAVs. If the regulatory authority deems not enough progress is being made each year, it can require up to an additional 10 aggregated WAVs each year through December 31, 2022. Uber is already providing WAVs in Greater Philadelphia.

Taxi Service Decline

TNC operations have led to declining use of taxis throughout the country, with typical decrease in use of about 30 percent.[306] Taxi companies are at a disadvantage in competing with unregulated ridesourcing services, as they have to pay business taxes and workers' compensation, and they are not allowed to increase prices when demand rises.[307] However, the taxi industry may be overregulated, and some of its requirements discourage new entrants to the market.

In Philadelphia, taxi revenues were $30 million from July to September 2014, before Uber commenced operations.[308] Over the same period in 2015, revenues fell to $21.5 million, even though TNCs were operating in a legal gray area.[309] From October 2014 through July 2016, the number of taxi trips declined by 40 percent, from around 1 million to just over 600,000.[310] In that same time period, the number

[306] Schaller, *Issues and Strategies for Cities on Transportation Network Companies*.
[307] Andrew Seidman, "Cabdrivers Press N.J. Lawmakers to Rein in Ride-Sharing Services," *Philadelphia Inquirer*, February 11, 2015, http://www.philly.com/philly/business/homepage/20150210_Cabdrivers_press_N_J__lawmakers_to_rein_in_ride-sharing_services.html (accessed February 11, 2015).
[308] Jason Laughlin, "UberX and Lyft Brought in $53 Million While Legal in Philly," *Philadelphia Inquirer,* updated October 18, 2016, http://www.philly.com/philly/columnists/jason_laughlin/UberX-and-Lyft-brought-in-53-million-while-legal-in-Philly.html (accessed October 18, 2016).
[309] Ibid.
[310] Todd Bookman, "Uber, Lyft Leaving many Philly Cabbies in the Dust," Newsworks, September 16, 2016, http://www.newsworks.org/index.php/local/philadelphia/97118-uber-lyft-leaving-many-philly-cabbies-in-the-dust (accessed March 28, 2017).

of taxi drivers in the city decreased by 42 percent, from 6,000 to 3,500.[311] In other cities:

- Taxi rides in Manhattan were 1.1 million lower in June 2015 than they were in June 2014.[312]
- The Washington, DC, taxi commission reported a 10 percent decrease in taxi trips in the first of year of TNC operations.[313]
- From fiscal year 2013 to fiscal year 2014 San Francisco taxi trips declined by 11 percent.[314]
- After three years of TNC operations in Los Angeles, California, the total number of taxi trips fell by 30 percent, with the steepest drops in popular tourist and night-life destinations. There has been a 14 percent (586 drivers) decline in the number of taxi drivers in this period. Taxi rides are decreasing in locations like Downtown and Hollywood; however, they are increasing (by 6 percent) in South Los Angeles. Taxi drivers are now serving these areas that have not been historically served as well, due to perceptions of danger, to compensate for revenue loss. Taxi trips have increased by 41 percent at Los Angeles International Airport.[315]
- Three of Madison, Wisconsin four taxi companies saw ridership declines in 2014. Green Taxi, the newest company, increased (by 26 percent), while Union Cab declined from 614,000 rides in 2011 to 514,000 in 2014. Badger Cab had 600,000 riders in 2012, which decreased to 458,000 in 2014.[316]

Pennsylvania's Act 164 of 2016 authorizing TNCs also eased some taxi regulations. Annual taxicab assessments where changed from $1,819 per medallion vehicle each year to 1 percent of gross operating revenue, not including tips or tolls. This is expected to lower the cost burden on taxi companies but increase the encumbrance on regulators. Annual vehicle inspection fees will be reduced to $25. Services will no longer be required to have a certified dispatcher office, in recognition of the wide variety of new technologies that facilitate two-way communication. Log sheets and manifests can be stored digitally. Taxi authorities can no longer stipulate the use of a specific meter. Instead, meters must meet certain standards: credit card processing capability, ability to produce reports, and compute distance and time. Vehicle standards and mileage are changed, including those for WAVs, to allow for up to 350,000 cumulative miles of driving or up to eight years of age. The authority is restricted from setting other service mileage requirements. Vehicles must meet quality standards and comply with environmental, cleanliness, safety, and customer service requirements. Authorities have no right to subject taxicab markings or

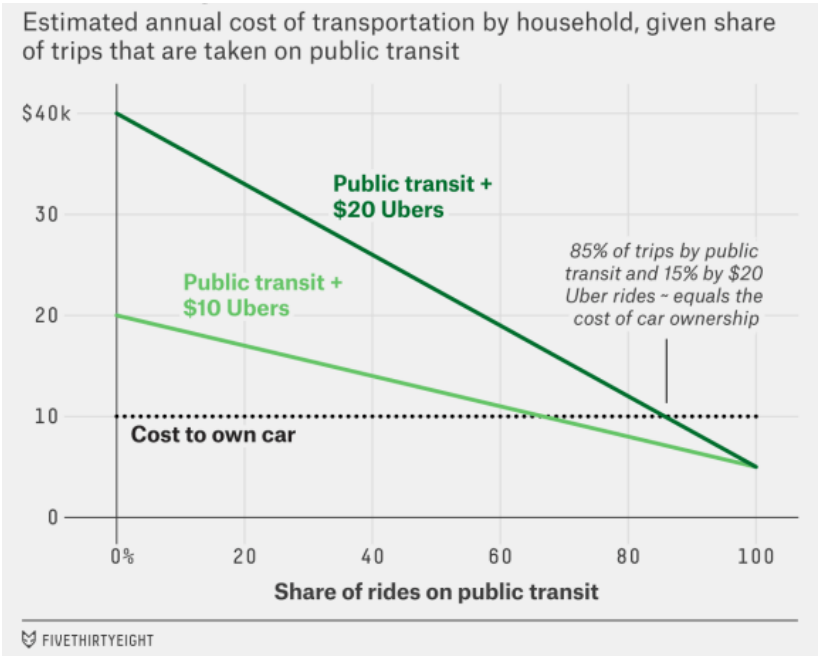
[311] Ibid.
[312] Todd W. Schneider, "Analyzing 1.1 Billion NYC Taxi and Uber Trips, with a Vengeance," November 17, 2015, http://toddwschneider.com/posts/analyzing-1-1-billion-nyc-taxi-and-uber-trips-with-a-vengeance/ (accessed June 27, 2016).
[313] Transportation Research Board.
[314] Ibid.
[315] Laura Nelson, "Uber and Lyft Have Devastated L.A's Taxi Industry, City Records Show," *Los Angeles Times*, April 14, 2016, http://www.latimes.com/local/lanow/la-me-ln-uber-lyft-taxis-la-20160413-story.html (accessed June 29, 2016).
[316] Steven Elbow, "Fare Fight: Uber Delivers a Wake-Up Call to Local Cab Companies," *The Capital Times*, December, 23 2016, http://host.madison.com/ct/news/local/writers/steven_elbow/fare-fightuber-delivers-a-wake-up-call-to-local/article_bcfbc765-7ea0-5131-9538-667c9a772c24.html (accessed June 24, 2016).

advertising to approval. Taxis operating in cities of the first class must have either a partition or a safety camera, which is turned on and operated at all times while the motor is running. Safety camera videos must be stored and kept for no less than 30 days. Taxi driver background checks are the same as those for TNCs, but do not require a third party to conduct.

Transportation Cost

In general, it is anticipated that digitally networking transportation will offer the opportunity to lower travel costs by making it easier to live either carfree or carlite (a household that has more driving-age adults than vehicles). According to an analysis by Nate Silver and Rueben Fischer-Baum, an individual or household that completes 85 percent of trips by public transit, and 15 percent by Uber rides with an average price of $20, will equal the cost of owning and maintaining a private vehicle.[317] The $20 Uber price seems high, particularly for Greater Philadelphia where trip lengths are much shorter than the average in the United States. If the average cost of a ridesourcing trip goes down to $10, than some 35 percent of trips can be completed with this mode. Walking and biking trips are even lower-cost options than transit, which can help make a multimodal network much less expensive than car ownership.

Figure 17. Uber Can Be Cheaper than Car Ownership, If You Mostly Use Transit



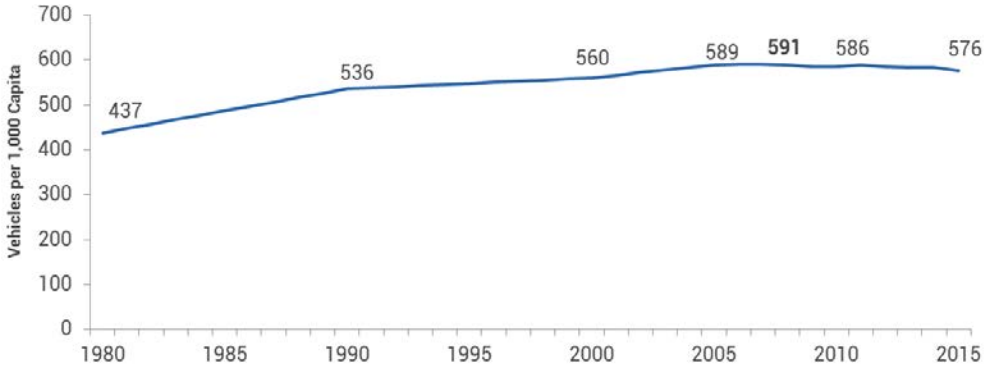
Source: Nate Silver and Rueben Fischer-Baum, "Public Transit Should be Uber's New Best Friend," Five-Thirty-Eight, August 28, 2015, http://fivethirtyeight.com/features/public-transit-should-be-ubers-new-best-friend/ (accessed June 28, 2016).

[317] Nate Silver and Rueben Fischer-Baum, "Public Transit Should Be Uber's New Best Friend," *Five-Thirty-Eight*, August 28, 2015, http://fivethirtyeight.com/features/public-transit-should-be-ubers-new-best-friend/ (accessed June 28, 2016).

TNCs are growing fast thanks to enormous venture capital investments. Uber is the most valuable TNC, with a market cap approaching $70 billion in early 2017.[318] To maintain these high valuations, TNCs will need to continue to grow very fast. They won't be able to meet growth targets by just stealing transit riders, instead they will need to change travel behaviors and convince people to use more shared mobility services. The long-term growth strategy will need to combine TNC use with lower cost options such as walking, biking, and transit. In addition, a future where TNC services grow along with personal vehicle use is a recipe for growing congestion and risks increasing backlash against ridesourcing.

Lower costs, significant growth, and TNC marketing, may lead more individuals to forego car ownership, or at least live in a carlite household. This may require a generational change, where more millennials than previous generations have shown interest in alternative transportation and living carfree. However, the millennial generation is still buying cars in large numbers, accounting for 27 percent of all new car sales in 2014.[319] Nevertheless, regional per capita car ownership has decreased by nearly three percent since peaking at 591 per 1,000 people in 2007, as shown in Figure 18.

Figure 18. Regional Car Ownership per 1,000 Residents



Source: U.S. Census, 1980, 1990, and 2000; American Community Survey, 2005 (1-year estimate), 2007 to 2015 (5-year estimates).

TNC drivers can keep more of their fares by lowering vehicle operating costs. One way for TNC drivers to do this is to switch to electric vehicles (EVs) or hybrids. For the average household that uses a vehicle one hour per day, lower EV operating costs are not currently offset by the higher capital costs. A TNC driver using their car 40 or more hours per week may find the higher upfront cost to be worth it with the lower operating costs of a hybrid or EV, although charging time is a potential issue with the latter.

[318] "The Investors, Investments, and Acquisitions of Top Ride-Hailing Companies," *CBI Global Insights*, March 3, 2017, https://www.cbinsights.com/blog/most-well-funded-tnc-ride-hailing-investor-graph/ (accessed March 6, 2017).
[319] Steve LeVine, "Investors Have Placed a One-Way Bet on Uber—Which Made Us Want to Find a Way to Short It," *Quartz*, August 5, 2016, http://qz.com/707947/investors-have-placed-a-one-way-bet-on-uber-which-made-us-want-to-figure-out-a-way-to-short-it/ (accessed August 5, 2016).

Employment

By at least one estimate, all employment growth in the U.S. since 2005 has been in the gig economy.[320] The gig economy provides on-demand services that are usually one-off events that may last a few minutes, hours, days, weeks, or longer but do not offer long-term employment or the benefits that come with it. This growth in independent contracting raises concern that all workers will face downward pressure on wages and benefits.[321] It is worth noting that the vast majority of people working as independent contractors in "The Free Agent Economy" are not on-demand workers but rather contingent workers in the traditional economy serving as day laborers, temporary help, taxi drivers, truck drivers, construction workers, salespeople, and others.[322] Characteristics of independent contractor employment include: [323]

- no benefits (insurance, retirement accounts);
- no overtime pay;
- no minimum wage;
- freedom to set their own work schedule;
- provide their own supplies and pay their own business expenses;
- paid only for work done (no vacations, sick time, holidays, etc.); and
- freedom to pursue other work.

Independent contracting has been on the rise throughout the economy and is an issue that goes well beyond TNC operations. Some reasons for increasing independent contracting rates include:[324]

- demographic changes;
- employment misclassification to avoid paying benefits, providing legal protection, and reducing rent sharing;
- using technology to cut out the middleman;
- the Great Recession; and
- reducing volatility for core employees by smoothing out labor demand shifts.

Flexible Employment

TNCs are competing with taxis and other employers for drivers. More flexible work hours have proven to be a benefit in attracting new drivers.[325] A Stanford University student survey of TNC drivers and other on-demand workers found that they:

- are more likely to be a minority, with 43 percent of workers being non-white, compared to 23 percent of the total population; and
- tend to be younger, with 39 percent of workers between the ages of 18 and 24.

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[320] Rob Wile, "Harvard Economist: All Net U.S. Job Growth Since 2005 Has Been in Contracting Gigs," *Fusion.net*, March 29, 2016, http://fusion.net/story/285543/krueger-katz-gig-economy-forthcoming-paper/ (accessed June 29, 2016).
[321] Ibid.
[322] Ibid.
[323] Noam Scheiber, "Employees, Contractors and Those in Between," *New York Times*, December 10, 2015, http://www.nytimes.com/2015/12/11/business/a-middle-ground-between-contract-worker-and-employee.html (accessed June 20, 2016).
[324] Wile.
[325] Elbow.

Respondents to the Stanford student survey indicated that schedule flexibility was their top reason for working on demand. This survey confirms other findings that TNCs are providing employment opportunities for young adults.[326] A media analysis of Uber's drivers found one-third of those living in the City of Philadelphia are located in census tracks with a greater than 9 percent unemployment rate, and one-quarter are female.[327]

Drivers, however, have complained about TNC use of gamification and goal setting to control their behavior and extend the amount of time they drive.[328] These practices have been developed with social and research scientists, such as offering the next fare before the current trip is complete, and offering noncash incentives to get drivers to work more, sometimes in areas that may be less lucrative.[329]

Employee Status

A major issue is whether TNC and other on-demand company workers (or drivers) are considered employees or contractors. If drivers are considered employees, TNCs will have to reimburse them for wear and tear on their vehicles, pay a minimum wage, and provide benefits. These costs would likely be passed on to customers and potentially make TNCs less cost competitive with personal vehicles. An on-demand home-cleaning service, Homejoy, shut down its operations rather than allow its workers to be reclassified as employees.[330]

Uber has recently paid out $84 million in settlements from two lawsuits brought forth by drivers in Massachusetts and California. In both suits, the drivers sought to be reclassified as employees. Another $16 million will be paid out to the plaintiffs if and when Uber reaches 1.5 times its $62 billion valuation at the time, the company goes public, or is sold.[331] The company made major concessions to drivers as part of the settlement:[332]

- Drivers will be warned and be given an opportunity to correct problems before their account is deactivated.
- Frequently turning down rides will no longer be a reason for deactivation.
- Uber will create appeal panels and form a drivers' association that contests termination.
- Uber will pay for an arbitrator where drivers can appeal the deactivation.

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[326] John Hall and Alan Krueger, *An Analysis of the Labor Market for Uber's Driver-Partners in the United States,* January 22, 2015, http://dataspace.princeton.edu/jspui/bitstream/88435/dsp010z708z67d/5/587.pdf.
[327] Orso, "Uber in Philly: One Year In, How's the Not-Quite-Legal Ride-Sharing Service Doing?,"
[328] Noam Scheiber, "How Uber Uses Psychological Tricks to Push its Drivers' Buttons," The New York Times, April 2, 2017, https://www.nytimes.com/interactive/2017/04/02/technology/uber-drivers-psychological-tricks.html (accessed April 3, 2017).
[329] Ibid.
[330] Ellen Huet, "Homejoy Shuts Down, Citing Worker Misclassification Lawsuits," *Fortune*, July 17, 2015, https://www.forbes.com/sites/ellenhuet/2015/07/17/cleaning-startup-homejoy-shuts-down-citing-worker-misclassification-lawsuits/ (accessed March 6, 2017).
[331] Tracy Lien, "Uber Will Pay up to $100 Million to Settle Suits with Drivers Seeking Employee Status," *Los Angeles Times*, April 21, 2016, http://www.latimes.com/business/technology/la-fi-tn-0422-uber-settlement-story.html (accessed April 25, 2016).
[332] Ibid.

- Uber will clarify that tips are not included in fares, and drivers will be able to request them. However, Uber will not add a tipping feature to its app.

Allowing drivers to turn down rides more frequently may be problematic from TNC goals of reducing racial bias and inequality in their services.

At least one on-demand company, The Munchery—a food preparation company in New York City—has benefitted from making its workers direct employees through reduced turnover, improved customer service, and more productivity. While the change in employee status raised costs by 20 to 30 percent, the bottom line increased by far more.[333] In the United Kingdom, Uber drivers recently won an employment tribunal case which granted them direct employee status that will provide holiday pay and paid break periods and ensure they earn the national minimum wage.[334] Uber will appeal the ruling, which will impact all companies with on-demand independent contractor business models in the United Kingdom.[335]

On-demand companies currently avoid doing anything, such as training, that is common in the employer–employee relationship that would automatically cause them to be considered direct employees with benefits in the eyes of the law.[336] There are concerns that there are not enough protections for independent contractors in the current employment law and worries that on-demand employment is being used to decrease the safety net.[337] Assuming the status quo does not hold, three alternatives to independent contractor status for workers in the on-demand economy have been widely proposed:

- Make on-demand workers direct employees.
- Consider on-demand workers as joint employees.
- Create a new dependent contractors category.

Direct employment is the traditional employee–employer relationship. Many on-demand companies do not classify themselves as traditional employers. However, these companies fill various traditional employer roles such as:

- controlling the employee–employer relationship, everything from hiring to termination;
- setting wages through fares;
- providing drivers with work and pay through the app;
- receiving payment from the driver's labor; and
- providing the app technology that makes the driver's work possible.

Some believe that TNCs are resisting granting direct employee status in order to escape some of the requirements that come with the traditional employment model, including insurance, overtime wages, and civil rights protections. While drivers value the autonomy of being an independent contractor (setting their own schedule,

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[333] Scheiber.
[334] "Uber Drivers Win Key Employment Case," *BBC News*, October 28, 2016, http://www.bbc.com/news/business-37802386 (accessed October 28, 2016).
[335] Ibid.
[336] Ibid.
[337] Scheiber.

spending more time with their family, etc.), many are calling for employment rights that are guaranteed to workers in the traditional employer–employee model.

Joint employment focuses on placing higher levels of responsibility on staffing agencies, classifying them as joint employers. As a joint employer, staffing agencies would share the same control and supervision responsibilities and face the same noncompliance violations as contracting companies. Misclassification of an employee as an independent contractor is a large issue that joint employment hopes to solve. The most typical form of joint employment is a vertical arrangement with one company hiring another. However, it can also be horizontal, where a worker may be employed by two subsidiaries of the same company but not be paid overtime because work hours are tracked separately. More attention is being paid to these issues because higher rates of wage theft have been documented in outsourced labor providers.[338] This is probably not an appropriate classification for TNC drivers. A driver with both Lyft and Uber apps open at the same time could be considered a joint employee. However, if drivers were to be considered employees, which company would compensate them for their time? These companies are competitors in the market, so it is not a co-employment situation.[339]

A *dependent contractor* has been proposed as a potential option, although one that requires new legislative designation. A dependent contractor would enjoy the benefits of being their own boss, while also receiving some traditional employment benefits such as a legal notice and pay severance in event of termination. However, the dependent contractor is not considered an employee because the hiring party has no legal need to withhold income tax payments. In addition, unlike the independent contractor, a dependent contractor maintains this individual working status as the main source of income. Only 24 percent of Uber drivers rely on driving revenue as the sole source of income.[340] The issue of liability is the same whether the contractor is independent or dependent. In this sense a dependent contractor would be a hybrid between a traditional employee and an independent contractor.

Another option could be to encourage the formation of TNC c*ooperatives* or *nonprofits*. A cooperative is a type of business where workers are also its owners, users, or managers, depending on the arrangement. Cooperatives aim to bring together producers, buyers, sellers, and workers in order to align goals and efforts more efficiently. This alternative view on capitalism applies democracy to the market.[341] There is still capital and profit, but unlike a corporation, it serves the co-op's members rather than business owners. Cooperatives also benefit from network effects, where the more members are involved, the stronger their market power

[338] Lydia DePillis, "Department of Labor Sends Warning Shot to Clients of Temp Staffing Agencies," *The Washington Post*, January 20, 2016, https://www.washingtonpost.com/news/wonk/wp/2016/01/20/department-of-labor-sends-warning-shot-to-clients-of-temp-staffing-agencies/ (accessed June 29, 2016).
[339] Seth D. Harris and Alan B. Krueger, "A Proposal for Modernizing Labor Laws for Twenty-First-Century Work: The 'Independent Worker,'" *The Brookings Institute Hamilton Project*, December 2015, http://www.hamiltonproject.org/papers/modernizing_labor_laws_for_twenty_first_century_work_independent_worker (accessed April 15, 2016).
[340] Hall and Krueger.
[341] Marshall, *The Surprising Design of Market Economies*.

becomes.[342] This helps to make them more inclusive, compared to how associations, unions, and guilds work to restrict membership. Their structure makes them an effective tool in the battle against income inequality.[343]

TNC Operations

TNCs offer improved customer service, enhanced safety, and opportunities for better first-mile and last-mile transit connections. Uber has had considerable success in the on-demand economy, and has become the business model that many other companies are trying to match, "by becoming the Uber of 'X.'" However, it may be that Uber has filled a unique niche in market demand, and no other on-demand company has been able to replicate its success to date.[344]

More Customer Service

TNCs are much more customer focused than traditional transportation modes.[345] Ease of payment, which is conducted digitally using the app, is one of the top reasons why customers say they use TNC services.[346] Many TNCs offer user and driver ratings so both individuals involved in the transaction can rate each other. Drivers whose ratings drop below a certain threshold are then at risk of being removed from the service. Uber initially did this automatically, but a recent lawsuit settlement requires more steps. The company now issues a warning and gives an opportunity to appeal before the driver is removed from the system.

Fare allows its users to save their favorite drivers in a preferred driver menu within the application. This as an untapped niche in the ridesourcing market, where parents feel more comfortable with drivers they know. The app lets passengers schedule rides up to seven days in advance.[347]

TNCs have identified an unserved market and capitalized on taxi industry weaknesses, such as unreliability, a limited number of vehicles, uncompetitive prices, and poor customer service. A recent Seattle taxi survey found that:

- Around 70 percent of TNC drivers arrived within five minutes of being requested, while under 40 percent of taxis did.
- About 80 percent of TNC customers rated the service as "very good," while only 10 percent of taxi customers rated the service that highly.

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[342] Ibid.
[343] Jon Liss, "Uber and the Taxi Industry's Last Stand: What the Rise of the App-Based Cab Service Says about the Future of Work in America," *The Nation*, January 27, 2015, https://www.thenation.com/article/uber-and-taxi-industrys-last-stand (accessed June 28, 2016).
[344] Josh Zumbrun, "The Entire Online Gig Economy Might Be Mostly Uber," *Wall Street Journal Real Time Economics Blog*, March 28, 2016, http://blogs.wsj.com/economics/2016/03/28/the-entire-online-gig-economy-might-be-mostly-uber/ (accessed April 6, 2016).
[345] Susan Shaheen, Adam Stocker, and Abinav Bhattacharyya, *Multimobility and the Shared Economy: Shaping the Future Market through Policy and Research* (Transportation Research Board, April 25, 2014), http://www.trb.org/Main/Blurbs/174624.aspx.
[346] Lisa Rayle et al., *App-based, On-Demand Ride Services: Comparing Taxi and Ridesourcing Trips and User Characteristics in San Francisco* (Berkeley, CA: University of California Transportation Center, 2014), http://www.uctc.net/research/papers/UCTC-FR-2014-08.pdf.
[347] Jia.

More than 90 percent of ridesource customers rated ease of payment as “very good," compared to just 10 percent of taxi customers.[348] In response to reports and similar customer feedback, taxi services are working to improve their service.

Pricing

TNCs are creating new markets through their driver payments and use of surge pricing. The structure of these markets is benefitting consumers, with more travel options and lower costs; and drivers, who are generally paid 80 percent of each fare, which allows them to provide rides as their schedule permits. In comparison, taxi drivers must rent their vehicle by the day, and earn no income until they have generated enough fares to pay this fee. There are some days where taxi drivers work long days and actually lose money because they have not collected enough fares to pay for the vehicle rental cost.[349]

TNCs are not subject to pricing controls, and some have used surge pricing as a way of balancing supply and demand in real time. Economists see this as a best practice.[350] There is little evidence of price gouging; customers are able to see the cost of the trip beforehand and have been willing to pay it.[351] Properly pricing the use of goods and services, including transportation, can make it more efficient. The price surge signals additional drivers to hit the road. However, there are concerns that surge pricing can make TNCs even more unaffordable for low-income individuals and can lead to ethical dilemmas during emergency situations, such as the use of surge pricing during Hurricane Sandy.[352] TNCs have pledged to limit surge pricing during emergencies. Pennsylvania's Act 164 of 2016 further restricts surge pricing during emergencies. Some of the new startups in the ridesourcing market are vowing not to use surge pricing.[353]

TNCs have experimented with monthly pass options that create flat fares within a designated service area. In February 2017, Uber launched a pilot monthly pass to some of its customers in Philadelphia.[354] The pass options offered 10 rides for $5 or 40 rides for $20 plus a flat per ride rate.[355] All rides had to be used within 30 days, with a rate of $4.49 on UberX and $2.49 on UberPool for trips completely within a designated 389-square mile zone.[356]

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[348] Shane Phillips, “Uber and Lyft Are Dragging Traditional Taxi Companies into the 21st Century," *Planetizen*, January 5, 2015, http://www.planetizen.com/node/73096/uber-and-lyft-are-dragging-traditional-taxi-companies-21st-century (accessed January 9, 2015).
[349] Transportation Research Board.
[350] Ibid.
[351] Ibid.
[352] Liss.
[353] Daniel C. Vock, “When Uber Leaves, What Happens?," *Governing*, June 15, 2016, http://www.governing.com/topics/transportation-infrastructure/gov-uber-lyft-austin-ride-sharing.html (accessed June 17, 2016).
[354] Jason Laughlin, “Uber Gives Subscriptions a Test Drive in the Philly Region," *Philadelphia Inquirer*, Updated February 14, 2017, http://www.philly.com/philly/business/transportation/Uber-subscriptions-finance-ride-share-philadelphia.html (accessed February 24, 2017).
[355] Ibid.
[356] Ibid.

"TNCs have created something not seen in modern times—competition from a nimble and aggressively customer-focused private-sector competitor with deep wells of capital for expansion and marketing."

- Bruce Schaller

Flexible Operations

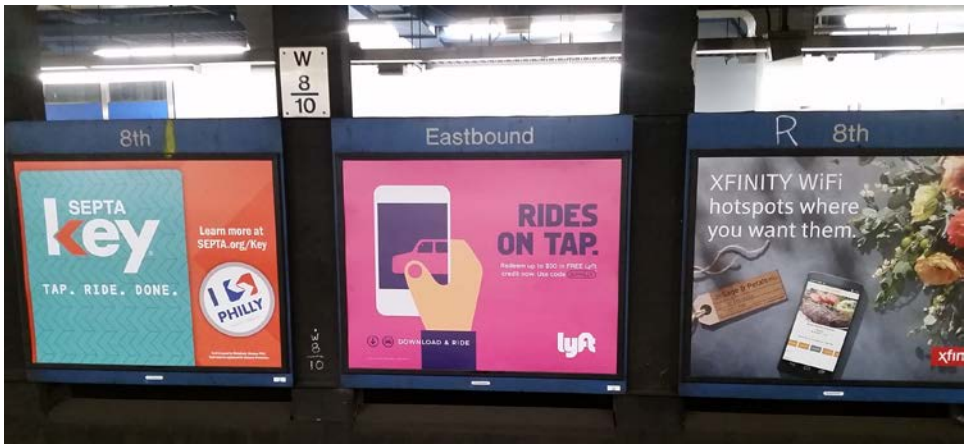
Private-market operators have the flexibility to respond quickly to shifting conditions. A TNC can change a route, or even service, in a day if it offers a better and more attractive opportunity, while a public entity would need months of study and political clout to move through the bureaucratic process.[357]

TNCs are not restricted to specific service areas. This helps them more efficiently move people when they pick up a person in one area of the region, dropping them off at a distant destination. They can then potentially pick up another rider nearby. When a taxi company drops off someone outside their service area they cannot pick someone else back up and must drive a passenger-less vehicle back to their designated zone.[358]

Since TNCs are not restricted to a specific fleet size, like taxis are, their dispersed and flexible employment model allows them to have a pool of drivers in reserve at all times.[359] This means they can readily scale up service to match increasing demand, especially when surge pricing sends a signal to drivers to get on the road.

Marketing

Private companies are able to effectively separate themselves from public transportation and the taxi industry due largely in part to strategic marketing campaigns that paint these companies as sleek, modern alternatives. Mass advertising is distributed through e-mail, print, and word of mouth months before service begins.



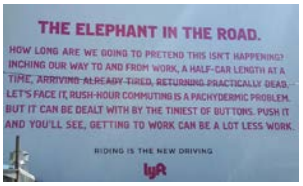
Lyft and other digital service advertisements in the Market-Frankford Line's 8th Street Station.

TNC companies often send a "street team" to a city scheduled for future service. This group is responsible for generating a buzz within the city through posters, handouts, and word of mouth. The group also acts as a liaison between the city and TNC ownership during the negotiation/legislation process.

- Uber spends around $80,000 to $120,000 per month on "pay-per-click" (PPC) advertising, while Lyft spends $19,000 to $29,000. Uber has spent twice as

[357] Shaheen et al.
[358] Transportation Research Board.
[359] Ibid.

much in the last year, with approximately $1.6 million spent on PPC advertising.[360]
- Uber is currently distributing free breathalyzer cards in Russia that show if someone is above the legal alcohol limit to drive.
- A "Get there with Uber" national campaign is being distributed through traditional radio and out-of-home advertising. Photos and stories of "real-life" Uber drivers will act as inspiration for new drivers, as well as allowing the service to tell its story.



Lyft Mural in Portland, Oregon.

Transit vehicles out and about in the community do serve as a form of advertising for themselves. This is another reason to ensure vehicles are kept clean, graffiti free, and well maintained. SEPTA Pass Perks gives passholders discounts at arts and entertainment, fitness, bars and restaurants, museums, shopping, sporting events, transportation, and other service and entertainment venues. SEPTA receives very little usable rider data from a program such as this. However, the future of transit rider data will be vastly improved with the full implementation of the SEPTA Key digital transit fare payment card.

Insurance and Liability

Pennsylvania's Act 164 of 2016 includes language reflecting the national compromise for TNC insurance coverage. In December 2016, the New Jersey Senate and General Assembly passed the "Transportation Network Company Safety and Regulatory Act" (Assembly Bill 3695 of 2016, Senate Bill 2179). The bill requires TNCs to carry $1.5 million in commercial insurance coverage for passengers, drivers undergo state background checks, and levels the playing field between TNCs and taxi and limousine services.[361]

The National Association of Insurance Commissioners and 20 state insurance departments have issued consumer alerts encouraging TNC drivers to understand their exposure.[362] According to the Property Casualty Insurers Association of America, there are five things every TNC driver should know:

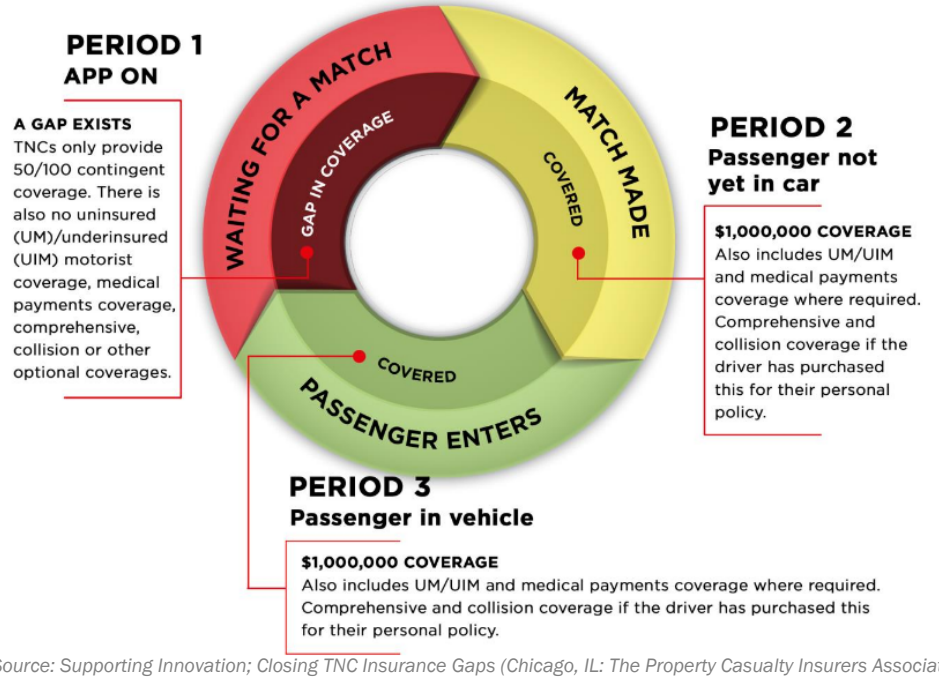
- An insurance gap exists. While TNCs claim they have insurance, it is not always clear when insurance is activated.
- Drivers could end up paying for damages if their vehicle hits another one whether or not it is their fault, or if an uninsured driver hits them.
- If TNC coverage is not primary, and personal insurance does not provide coverage, there could be a battle of litigation over who pays for damages.
- There are no clear guidelines to ensure vehicles used are properly insured.
- There are reports that ridesource drivers have been encouraged to lie about how they use their vehicles. Since TNC drivers are not provided insurance, they are in

[360] Joe Putnam, "Uber Vs. Lyft: Who's Winning the PPC Battle?," *ISpionage: A PPC Marketing Blog*, August 28, 2015, http://blog.ispionage.com/uber-vs-lyft-ppc.html (accessed September 7, 2016).
[361] Phil Gregory, "Uber, Lyft Face Regulation in New Jersey," *Newsworks*, December 20, 2016, http://www.newsworks.org/index.php/local/item/99846-uber-lyft-face-regulation-in-nj (accessed January 9, 2017).
[362] *Supporting Innovation; Closing TNC Insurance Gaps* (Chicago, IL: The Property Casualty Insurers Association of America, 2014), www.pciaa.net/docs/default-source/default-document-library/tncq-a091614.pdf (accessed June 29, 2016).

a difficult position when describing to their primary insurance agencies how they use their vehicles.

The insurance gap is not about how much insurance there is, but when it applies. Personal coverage does not apply when a car is in commercial use. Ridesourcing trips are often divided into three periods. In the first period, where the driver has the app on and is waiting for a rider, they are not covered by TNC commercial insurance. In addition, drivers are not covered if they are hit by an uninsured driver, and there is no coverage to repair a vehicle if it is damaged while in use for TNC operations. TNC drivers are recommended to purchase supplementary commercial coverage to fill this insurance gap. In the second period, the driver has a rider match and is in route to pick the passenger up. The third period reflects the time where the rider is in the vehicle until being dropped off. TNC commercial insurance provides driver coverage during the second and third periods.

Figure 19. The Three TNC Driver Insurance Periods



Source: Supporting Innovation; Closing TNC Insurance Gaps (Chicago, IL: The Property Casualty Insurers Association of America, 2014), www.pciaa.net/docs/default-source/default-document-library/tncg-a091614.pdf *(accessed June 29, 2016).*

Insurance companies have expressed a number of concerns about shared mobility's risk implications. Shared mobility seems likely to increase VMT, leading to greater risk exposure.[363] Many trips travel through dense urban centers, which have higher risk hazards.[364] Both carsharing and ridesourcing potentially mean more drivers on roads they are unfamiliar with.[365] Higher vehicle occupancy rates mean more people who can be injured in the event of a crash.[366] TNC drivers may be pressured to

[363] Federal Highway Administration.
[364] Ibid.
[365] Ibid.
[366] Ibid.

respond quickly to accept matches and rush to pick up passengers in order to keep wait times short.[367]

Pennsylvania's Act 164 of 2016 mandates TNC insurance coverage. TNC drivers must maintain primary coverage that recognizes the vehicle is used to transport passengers for compensation and covers the driver when they are logged into a ridesourcing app, is engaged in a prearranged ride, or is otherwise required to be covered by regulations.

New Jersey's recently enacted TNC authorization legislation requires the driver, the TNC, or both maintain a minimum level of primary automobile liability insurance coverage for: death or bodily injury per person of $50,000, death or bodily injury per accident of $100,000; property damage while the driver is logged into the TNC app and waiting for a rider of $25,000; for death or bodily injury and property damage while the driver is providing a ride of $1,500,000; and driver coverage per person per incident of $10,000. This closes the insurance gap identified in Figure 19.

Vicarious liability protections have insulated manufacturers and rental agencies from being responsible for covering damages when an individual harms another person or property while using their product. In addition, companies can purchase additional insurance protections at the time of a motorized vehicle transaction.[368] Bikesharing programs, in particular, are not covered by statutory protections and are subject to risks from vicarious liability lawsuits.[369] General commercial liability insurance can protect bikesharing operators from direct or indirect actions that cause bodily harm or property damage.[370]

Municipal Implications

Municipalities will need to react quickly to fast-moving trends and changes in their operating environment. They also need to focus on developing platforms and enabling others to further build upon them.

Innovation

TNCs and their supporters have helped brand their operations as forward-thinking, progressive entities. TNC popularity is being driven by technological advances and the demographic trends of young adults and empty nesters moving to urban areas. These trends are challenging transit agencies' ability to be nimble and flexible enough to respond to them. This can make municipalities and governments that oppose TNC operations appear to be backwards. Welcoming TNCs can give a municipality a bit of a “cool” factor, which is important for attracting young, highly skilled workers who have a choice in where they live. In low-income communities, TNCs are seen to be spurring entrepreneurship, while also providing improved job access in areas that may be underserved by traditional taxis and transit.[371]

[367] Ibid.
[368] Ibid.
[369] Ibid.
[370] Ibid.
[371] Center for City Solutions and Applied Research.

The City of Pittsburgh has clearly benefitted from rolling out the red carpet to innovative transportation companies. The city was a finalist for the U.S. DOT's Smart Cities competitive grant program, which ultimately went to Columbus, Ohio. Pittsburgh has let Uber test out its AVs on its streets, leading to significant—and positive—media attention. The company employs some 500 people at its Advanced Technology Center in Pittsburgh and is expected to double that number within a few years.[372] As a result of this effort and many others, the city is reinventing itself as a technology hub: companies such as Apple, General Motors, Google, and Intel are growing their presence in Pittsburgh.

Sustainability efforts lead to significant organizational and technological innovations that yield both bottom-line and top-line returns. Becoming environmentally friendly lowers costs because companies end up reducing the inputs they use.[373] Partnerships between TNCs, transit agencies and local governments have sought to improve services all over the country (see "TNC Partnership" section).

Equity

TNCs can offer new equity opportunities by improving transportation and job access in urban and suburban areas that have traditionally been underserved by transit and taxi services. TNC coverage areas extend throughout the Greater Philadelphia region, reaching into suburban areas that often lack transit access. As demographic trends have shifted more poverty to the suburbs, TNC services can serve as a lifeline to those without access to a personal vehicle.

A recent study by the transportation research labs at Stanford, MIT, and the University of Washington tested ridesourcing and taxi passenger discrimination by race and gender. It was conducted by research assistants requesting rides in Boston and Seattle and found that:[374]

- In Boston, African American males were three times more likely to have UberX rides canceled than white males.
- In Seattle, African American riders had wait times that were 16 to 28 percent longer on average than those of white riders. However, it may be worth noting that the difference between these services was generally one minute.[375]
- When hailing taxis, the first taxi stopped for whites nearly 60 percent of the time and stopped for African Americans less than 20 percent of the time. African American passengers were passed by six or seven taxis 20 percent of the time. In comparison, white passengers never had more than four taxis pass them by.

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[372] Gary Shapiro, "A Tale of Two Cities—Where Only One Supports Innovation: Gary Shapiro," *PennLive*, November 16, 2016, http://www.pennlive.com/opinion/2016/11/a_tale_of_two_cities_-_where_o.html (accessed December 19, 2016).
[373] Ram Nidumolu, C. K. Prahalad, and M.R. Rangaswami, "Why Sustainability Is Now the Key Driver of Innovation," *Harvard Business Review*, September 2009, https://hbr.org/2009/09/why-sustainability-is-now-the-key-driver-of-innovation (accessed May 28, 2015).
[374] Megan Geuss, "Race, Gender Discrimination Persist with Uber, Lyft—and Cities Need to Know," *Ars Technica*, November 7, 2016, http://arstechnica.com/cars/2016/11/race-gender-discrimination-persist-with-uber-lyft-and-cities-need-to-know/ (accessed November 10, 2016).
[375] Shari Shapiro, e-mail message to author, December 15, 2016.

- Female ridesourcing passengers were treated differently from men. They often were taken on substantially longer routes by "talkative" drivers, increasing fares, causing a loss of time, and putting them in an unpleasant situation.

The study did find the new ridesourcing companies are no worse than taxis for discrimination and notes that they are reducing total wait times for everyone across the board. However, this study does reveal the risk in potentially using TNCs in place of transit.[376] Any service with consistently longer response times or a higher frequency of canceled trips for different racial groups risks violating the Civil Rights Act.[377] Many shared mobility services receive either direct monetary and/or nonmonetary support from federally funded agencies, such as reduced parking costs from transit agencies. As a result, any shared mobility operation that receives such support could be required to meet all federal nondiscrimination guidelines.[378]

Uber is using studies such as this to improve its app and services to reduce discrimination.[379] The driver app does not show a potential passenger's photo and will not show the rider's name until the trip has been accepted.[380] The final destination is only shown after the rider is picked up.[381] Each city has a maximum cancellation rate (based on the average cancellation rate in that area), after which point a driver may be barred from using the app.[382] The community guidelines state that racial or gender discrimination "can result in permanent loss of access to the Uber platform."[383]

In the longer term, the movement toward transportation on demand could lead to a future where mobility is auctioned off to the highest bidder, particularly if taxis and transit services are disrupted.[384] Operators of carsharing, ridesharing, ridesourcing, and microtransit services are often private or nonprofit companies that must recoup their costs in order to be financially viable. Serving low-income populations may not be a major business objective.[385] There are a number of barriers that must be overcome in order for low-income individuals to use TNC services:[386]

- TNCs and other digital transportation providers not locating in or serving low-income neighborhoods;
- accessing and paying for the service if a credit card, debit card, or a bank account is needed, which low-income individuals are less likely to have;
- access to information and ability to comprehend how the service works, particularly for non-English and English-as-a-second-language speakers; and
- logistics such as Internet access, smartphones, or a driver's license (particularly for undocumented populations).

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[376] Guess.
[377] Ibid.
[378] Federal Highway Administration.
[379] Shari Shapiro, e-mail message to author, December 15, 2016.
[380] Ibid.
[381] Ibid.
[382] Ibid.
[383] Ibid.
[384] Jaffe, "How the Microtransit Movement Is Changing Urban Mobility."
[385] Kodransky and Lewenstein.
[386] Ibid.

If TNCs harm transit service, they may widen the digital divide.[387] Low-income and other individuals without a smartphone could have a harder time accessing transportation. In response to this issue, Uber has been experimenting with a call-in dispatch system called UberCentral in Pinellas County, Florida.[388]

If people and jobs continue to flock back to downtown areas, lower-income populations may be pushed out to the peripheries of major towns and cities, areas that are seldom served by transit. This could exacerbate a spatial divide that disconnects low-income populations from jobs, education, and opportunity. TNCs can potentially benefit these communities by providing additional low-cost transportation options.

Public Finances

Most local governments are already underfunded. Taxi fees, along with parking and motor vehicle tickets, are sources of revenue that are at risk if TNCs become the dominant mode. In FY 2015, the PPA was responsible for $79.9 million in funding to local Philadelphia governments, including the city's municipal fund, the school district of Philadelphia, the city's Division of Aviation, and PennDOT.[389] Reduction in transit ridership could increase the subsidy needed to cover its cost. Roads are largely financed by a flat per gallon gasoline tax. As vehicles become more fuel efficient, or start to use new fuel sources, such as battery electric vehicles, less revenue is likely to be collected. With public finances stretched thin, municipalities, DOTs, and transit agencies may need to seek out PPPs and other creative financing arrangements to help deliver new digital infrastructure and maintain and increase the resiliency of existing physical infrastructure.

As part of Act 164 of 2016 in Pennsylvania, TNCs will pay 1.4 percent on every ride originating or ending in Philadelphia, and 1.3 percent for other rides. Two-thirds of the fees generated in Philadelphia will go to the School District of Philadelphia, with the remainder going to the PPA to oversee TNC regulations.

Regulating TNCs

TNCs operate at an international scale and are considerably larger than any local taxi company. TNCs and other on-demand services can emerge and scale quickly before a local government can react. They have successfully used advertising, social media, and other outreach to build public support. This creates major regulatory challenges for municipalities.

Driver background checks have been a major sticking point in the debate over TNCs. There are some who consider FBI fingerprint background checks to be the best in class. However, former U.S. Attorney General Eric Holder has noted that the FBI

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[387] Schaller, *Issues and Strategies for Cities on Transportation Network Companies*.
[388] Spencer Woodman, "Uber Wants to Take over Public Transit, One Small Town at a Time," *The Verge*, September 1, 2016, http://www.theverge.com/2016/9/1/12735666/uber-altamonte-springs-fl-public-transportation-taxi-system (accessed September 21, 2016).
[389] Baker Tilly, *Financial Statements, Required Supplementary Information and Other Financial Information for the Years Ended March 31, 2015 and 2014 & Independent Auditors Report* (Philadelphia: The Philadelphia Parking Authority), http://www.philapark.org/wp-content/uploads/2015/09/PPA_Issued_Financial_Statements_FY_15.pdf.

database is not intended for background checks, and using it for this purpose can harm minorities and other individuals who may have been charged for but not convicted of a crime.[390] Holder's firm is a client of Uber.[391] Fingerprinting is more expensive than the screening processes that TNCs currently use. Uber's background checks are conducted by Checkr, which is accredited by the National Association of Professional Background Screeners. The screens are checked against the U.S. Department of Justice National Sex Offender Public Website, the PACER database for federal crimes, and terrorist watch lists.[392] Checkr also conducts a Social Security trace to identify an applicant's past residences, and it will verify any criminal records in those locations—including an in-person check at the local courthouse if needed.[393] They also check an applicant's driving history, which will flag violations that did not necessarily result in an arrest and would not be found in other screens, such as a fingerprint check.[394]

Newark, New Jersey cab and limo companies have filed a federal lawsuit against the city under the Takings and Equal Protection Clauses of the U.S. Constitution.[395] The complaint stems from heavy regulations of the taxi industry, including $500,000 medallions, while TNCs operate with few restrictions.

In May 2016, Austin, Texas became the first U.S. city to put TNC regulations to a vote. The referendum resulted in passing an ordinance that requires fingerprinting as part of a driver's background check. The ordinance bans anyone from driving for a TNC who has more than three driving violations or been charged with driving without insurance or on a suspended license.[396] The City of Austin will process the background checks. Each violation of the ordinance is subject to a fine of up to $500 per offense. Uber and Lyft have since left the city, claiming that the new ordinance essentially prohibits ridesourcing. Since the Austin measure was enacted, a half-dozen startup TNCs have begun operations there. They are seizing an opportunity to expand in a city where people are used to using TNCs.[397] Houston, Texas has required TNC drivers to be fingerprinted since August 2014. Uber stayed—but has threatened to leave—while Lyft ended its service in the city.[398] New York City requires fingerprinting, and both Uber and Lyft have continued their operations there.[399] Atlanta has considered establishing TNC driver fingerprinting requirements.

Until recently, Miami had placed strict regulations on ridesourcing companies. Miami-Dade County required a ride service to be booked at least one hour in advance and have a minimum $80 fare. This effectively kept TNCs from

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[390] Josh Cornfeld, "Eric Holder Weighs in for Uber against Fingerprint Checks," *Associated Press*, June 8, 2016, https://www.yahoo.com/news/eric-holder-weighs-uber-against-fingerprint-checks-182643765.html (accessed November 22, 2016).
[391] Ibid.
[392] Shari Shapiro, e-mail message to author, December 15, 2016.
[393] Ibid.
[394] Ibid.
[395] Harriet Taylor, "Uber and Lyft Are Getting Pushback from Municipalities All over the US," *CNBC*, September 2, 2016, http://www.cnbc.com/2016/09/02/uber-and-lyft-are-getting-pushback-from-municipalities-all-over-the-us.html (accessed September 21, 2016).
[396] Vock.
[397] Vock.
[398] Taylor.
[399] Ibid.

commencing ridesourcing operations. After nearly three years of negotiation, Miami-Dade commissioners passed an ordinance authorizing ridesourcing services in the area contingent on factors such as regular vehicle inspections.

Some examples of existing TNC regulations in various cities:

- Taxes and fees that help pay for other municipal services: Washington, DC, requires TNCs to collect a tax of 1 percent of all fares; Seattle has a flat rate of 10 cents per ride originating in the city limits.[400]
- The California Public Utilities Commission (CPUC) requires TNCs to conduct criminal background checks for all drivers, have driver training programs, maintain zero tolerance on drugs and alcohol, maintain a minimum one million dollars per incident insurance coverage, $5,000 medical payment coverage, $50,000 comprehensive and collision coverage, and one million dollars uninsured/underinsured motorist coverage per incident.[401]
- Colorado SB 125 establishes a framework for ridesourcing company commercial liability insurance coverage for when a driver logs into the app and is available for hire.[402]
- Chicago, Illinois city council substitute ordinance 2014-1367 requires ridesourcing companies to provide one million dollars in liability coverage and one million dollars of coverage for drivers from the time a ride is accepted until completion.[403]
- North Carolina's General Assembly has prohibited local government regulation of "digital dispatching" services.[404]
- Seattle, Washington city council has an ordinance that requires commercial insurance coverage for ridesourcing companies whenever a driver is "available" to drive.[405]
- California is requiring all ridesourcing companies participate in the Motor Vehicles Employer Pull Notice program. This will give them notice any time there has been a change to a driver's record: drivers' license revoked or suspended, conviction of a crime, failure to appear in court, crashes, or other action taken on driving privileges.[406]
- Houston, Texas is conducting a pilot project to track ridesourcing driver behavior with GPS for safety. Telematics will report speed, hard stops, and unsafe acceleration rates.[407]
- New York City limits TNC driver shifts to 12 hours. The California Vehicle Code limits TNC drivers to 10-hour shifts within any 15-hour period.[408]
- San Francisco requires new ridesourcing drivers to take a safe driving training course. New York City makes new drivers watch a video, "Drive Like Your Family Lives Here," telling the stories of different families whose lives have been shattered by fatal crashes.[409]

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[400] Center for City Solutions and Applied Research.
[401] Rayle et al.
[402] Ibid.
[403] Ibid.
[404] Ibid.
[405] Ibid.
[406] *Ride-Hailing Services*.
[407] Ibid.
[408] Ibid.
[409] Ibid.

- Austin, Texas's ridesourcing ordinance states that drivers cannot refuse service or charge higher fees to disabled passengers.[410]
- Denver, Colorado has required carsharing companies to locate vehicles in census tracts where more than 30 percent of the population lives in poverty.[411]

Some proposed TNC regulations:

- Baton Rouge, Louisiana has proposed an ordinance allowing TNCs to operate without following the rules set by the Taxicab Control Board.[412]
- California's legislature approved Assembly Bill 2293, which would separate personal and commercial TNC auto insurance, establish requirements of $50,000 per individual and $100,000 total primary liability coverage during periods when a driver is using the app but not picking up or dropping off a passenger, reaffirming the CPUC as the TNC oversight board, and providing an expedited approval process for TNC insurance policies.[413]
- Columbus, Ohio has proposed an ordinance to amend the city's for-hire vehicle regulations to include peer-to-peer services.[414]
- The District of Columbia's Taxi Cab Commission has proposed rules to regulate TNCs by establishing minimum commercial insurance requirements and new regulations on inspection and licensing of for-hire vehicles.[415]
- Illinois House Bill 4075 would require drivers working more than 18 hours a week to obtain a special license and vehicle registration, TNC vehicles to be less than four years old, and that vehicle dispatchers insure drivers without insurance.[416] House Bill 5331 decreases the required insurance coverage to $350,000 to match Chicago taxi regulations.[417]
- New Jersey Assembly Bill 3362 would mandate that the New Jersey Motor Vehicle Commission establish insurance and safety requirements for TNCs.[418]
- In August of 2016, New York City introduced legislation proposing a "three-strikes-you're–out" policy for for-hire drivers. This legislation prohibits drivers from receiving a license from the Taxi and Limousine Commission (TLC) if they have had three suspensions in the past 10 years on either their Department of Motor Vehicles-issued or TLC-issued licenses for traffic-related infractions.[419]

Pennsylvania's Act 164 of 2016 has a number of driver requirements. Each driver must have a valid state driver's license, from any state, district, or territory in the United States. Drivers must be at least 21 years old and not have had a limousine or taxi driver certificate revoked by the authority due to a violation within the previous five years. The authority will make this list available to TNCs upon request. Each applicant must undergo a background check using local and national databases.

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[410] Federal Highway Administration.
[411] Ibid.
[412] Rayle et al.
[413] Ibid.
[414] Ibid.
[415] Ibid.
[416] Ibid.
[417] Ibid.
[418] Ibid.
[419] David Meyer, "Garodnick Proposes Three-Strikes Suspension Policy," *Streetsblog NYC*, August 16, 2016, http://www.streetsblog.org/2016/08/16/garodnick-proposes-three-strikes-suspension-policy-for-tlc-drivers (accessed August 17, 2016).

The check must use a multistate or multijurisdictional criminal records locator or similar commercial nationwide database and review the U.S. Department of Justice's National Sex Offender public website. An applicant that has been convicted of any of the following crimes within the given timeframe must be disqualified:

- Driving history in the past three years:
  - more than three moving violations; or
  - one major violation.
- Conviction in the past seven years:
  - driving under the influence of drugs or alcohol; or
  - a felony conviction involving theft, fraud, or possession of a controlled substance.
- Conviction in the past 10 years:
  - burglary or robbery; or
  - use of a motor vehicle to commit a felony.
- Conviction at any point in time:
  - a sexual offense under current or former laws in Pennsylvania or similar offense under the law of another jurisdiction;
  - a crime of violence (defined in 18 PA. C. S. Section 5702); or
  - an act of terror.

Each driver must be reviewed for continued eligibility at their one-year driving anniversary, and every two years thereafter. Companies must enforce and maintain a zero-tolerance policy on drug and alcohol use. A driver who is subject to a passenger complaint for drug or alcohol use must immediately be suspended until an investigation on the matter is completed.

TNCs are divided into classes based on the number of drivers that were registered at the time of license issuance, or its most recent license renewal:

- Class A companies have more than 10,000 active drivers.
- Class B companies have between 1,001 and 10,000 active drivers.
- Class C companies have between 1 and 1,000 active drivers.

Based on the TNCs classification, the regulatory authority can randomly request a certain number of random vehicle inspections within a set period of time. The Pennsylvania legislation puts limits on the vehicles that can be used in TNC services. Vehicles can seat no more than 10 passengers, including the driver. Vehicles cannot ever have had a “Salvage, Rebuilt, Junk, Total Loss," or equivalent title class issued. They cannot be more than 10 years old, or 12 years for alternative fuel vehicles. Lastly, they cannot otherwise be used as a taxi or limousine.

TNC drivers are prohibited from soliciting potential passengers, prearranging rides for cash payment, soliciting or accepting street hailing or phone calls for

transportation service. A fee of $0.40 must be collected each time a passenger is picked up or dropped off at an international airport. Fees collected will be distributed in whole or part to the county in which the airport is located. There is no limitation to the right of an Amtrak station to collect reasonable fees, but it may not contract with a TNC to provide a lane or lot dedicated exclusively to TNC vehicles. During a state of emergency, a TNC is limited in how high it can set its surge pricing multiples. This limit for service class is defined as the next highest multiplier below that set on the three highest multiple days in the previous 60 days prior to the emergency.

Act 164 of 2016 also grants the regulatory authority approval for supplemental training programs, which can be taught by a qualified third party for the following topics:

- the geography of the city;
- the provision of safe TNC service;
- providing courteous service;
- statutory or regulatory requirements for TNC drivers; and
- providing service to individuals with disabilities.

New Jersey's "Transportation Network Company Safety and Regulatory Act" authorizes the New Jersey Department of Transportation to collect and retain data on pre-arranged rides that occur entirely within New Jersey, creates a $25,000 annual permit fee, impose a $500 daily penalty for each day a TNC operates without a permit, vehicle inspections, and driver background checks. The New Jersey Motor Vehicle Commission is responsible for issuing and revoking TNC permits. The Office of the Attorney General will review and approve the method in which a TNC conducts driver background checks. Each driver must maintain a valid personal vehicle inspection that meets the state's requirements. This inspection is already required for vehicles operating on the state's roads. The legislation requires a zero tolerance policy to alcohol and controlled substances while the driver is logged into a digital TNC app. Digital records must be kept for at least six years, and an additional five years after any driver is terminated. The bill restricts the ability of local governments to develop taxes specifically targeted at TNC services (any tax liability must also be imposed on all other businesses and residents within the jurisdiction).

Other Challenges

TNCs and other digital transportation technologies rely more and more heavily on ubiquitous wireless technologies. There are still some areas of the region, and many parts of the country and the world, that lack reliable wireless connectivity. Wi-Fi 'Loons is a project by Google to launch helium-filled balloons over much of the world that still lacks Internet access. These solar powered 'Loons will fly in the stratosphere, filled with electronics to beam Wi-Fi down to the Earth's surface.[420]

[420] Tom Simonite, "Project Loon," *MIT Technology Review*, n.d., https://www.technologyreview.com/s/534986/project-loon/ (accessed February 27, 2017).

Scaling up globally is difficult for any expanding company, especially in overcoming bureaucratic legislation on a case-by-case basis. TNCs prefer statewide and national regulations so they can reliably plan on serving wide areas and do not have to worry about meeting each individual local government's requirements within regional operating areas. One of the biggest challenges for TNCs to date is the opposition from countries outside of the United States. Italy and Spain have both disputed the legality of TNC services, and these companies have had legal problems in France and South Korea as well.[421] In addition to legality issues, there is competition. Uber has recently entered a business agreement with Chinese rival Didi Chuxing. The business deal creates a new company worth $35 billion dollars, which is 20 percent owned by Uber. The company had already spent billions of dollars in the market. It is not yet clear whether Uber's business deal with Didi is a win or a loss for the company, but this deal does indicate the difficulties TNCs face expanding in large international markets.

It has been reported that some TNC drivers have used “rigging" to spark surge pricing. A number of drivers simultaneously turn the app off, wait for fares to rise due to lower vehicle availability, and then jump back in when the price increases.[422]

Nationwide, carsharing services are taxed at 1.7 to 2.2 times the rate of other goods and services.[423] In Philadelphia, a one-hour carshare rental is subject to a nearly 40 percent effective tax rate: $7.25 per hour with $2.89 in taxes.[424] The source of these taxes are the 8 percent sales tax rate in the city (6 percent state and 2 percent city), a 2 percent state vehicle rental tax, and a $2 per day state rental fee.[425] Excess taxation of socially desirable services leads to inefficiency and underutilization.

The Toronto city council recently refused to let Car2Go try a floating on-street parking pilot for its carsharing vehicles.[426] The council was afraid that it would take too many spaces away from parking permit holders. This decision prioritizes car owners over carsharing residents, who more efficiently use urban space.[427]

Cars serve as mobile storage containers, particularly for families with young children. Tradesmen use them to haul their tools. The multitude of ways people use their cars creates a challenge for TNCs if their goal is to replace car ownership.

TNC Partnerships

Partnerships between TNCs and others can help to grow services and promote more efficient transportation and carfree or carlite lifestyles. Partnerships and data sharing between TNCs and public agencies can help to better understand the economic and travel impacts of new shared services. TNCs and public agencies can develop metrics, models, planning platforms, and methodologies to measure the

[421] Steven Greenhouse, “Uber: On the Road to Nowhere,” *The American Prospect*, Winter 2016, http://prospect.org/article/road-nowhere-3 (accessed June 29, 2016).
[422] Liss.
[423] Federal Highway Administration.
[424] Ibid.
[425] Ibid.
[426] *New Mobility*.
[427] Ibid.

economic and travel impact of shared mobility, such as VMT; person miles traveled; commute travel time; and other indicators that local, state, and federal public agencies can incorporate into land use and transportation planning.[428]

SEPTA and Uber launched a 14-week pilot program in May 2016 to provide a 40 percent discount, up to $10, on Uber trips to and from 11 SEPTA stations. The stations in this pilot were Glenside, Jenkintown-Wyncote, Elkins Park, Melrose Park, Warminster, Doylestown, Lansdale, Woodbourne, Swarthmore, Wayne, and Exton. They were chosen based on existing parking shortages and location in suburban areas outside the City of Philadelphia—where ridesourcing operations were fully legal at the time the partnership began. No money was involved; instead, SEPTA gave advertising space to Uber in stations and on trains. The hope was that more people would turn to Uber and SEPTA to get them to the city, rather than driving. Unfortunately, shortly after announcing the partnership 115 SEPTA Silverliner V regional rail vehicles had to be taken out of service for emergency repairs. Despite the Silverliner recall and the resulting decrease in SEPTA ridership, Uber trips increased at every station involved in the pilot. Both reported satisfaction with the results of the pilot and intend to pursue additional partnership opportunities.

Some interesting government and transit agency partnerships with TNCs and other digital transportation providers from around the nation include:

- The landlord of a new, large development, Parkmerced, in the Silicon Valley plans to subsidize renters $100 per month in transportation credit to go carfree. $30 of this must be spent with Uber each month.[429]
- In the summer of 2016, the Florida Department of Transportation gave interested individuals a $100 credit to try out carpooling with RideFlag.[430]
- Ride KC was a one-year pilot project between the Kansas City Area Transit Authority (KCATA), Bridj, and Ford Motor Company.[431] The goal was to fill gaps in the public transit network, provide first-mile and last-mile solutions, and improve service in low-income communities. The shuttles could be hailed using a smartphone app, with a flat charge of $1.50, the same as the existing bus fare. Service is from and to the nearest existing KCATA bus stop. Ford has provided the vehicles, which are locally built and will serve as on-demand shuttles. KCATA provides the drivers and subsidies for the service beyond fare revenue. Bridj provides the app, routing information, and support.[432] Unfortunately, the service attracted less than 1,500 riders during the trial period.[433]

[428] U.S. Department of Transportation, *The Smart/Connected City*.
[429] Andrew J. Hawkins, "Uber and a Bay Area Landlord Will Pay New Tenants $100 a Month to Go Car-Free," *The Verge*, May 18, 2016, http://www.theverge.com/2016/5/18/11691904/uber-parkmerced-maximus-real-estate-stipend-san-francisco (accessed May 19, 2016).
[430] Paul Mackie, "Is 'On-Demand' the Missing Ingredient in Carpooling?," *MobilityLab*, May 11, 2016, http://mobilitylab.org/2016/05/11/on-demand-carpooling-rideflag/ (accessed June 6, 2016).
[431] Mary Ebeling, "Transportation Network Companies, Public Transit Eye Steps toward Integrated Mobility," *State Smart Transportation Initiative*, February 29, 2016, http://www.ssti.us/2016/02/transportation-network-companies-public-transit-eye-steps-toward-integrated-mobility/ (accessed June 28, 2016).
[432] George, phone call with author, July 5, 2016.
[433] Aarian Marshall, "How a Failed Experiment Could Still be the Future of Public Transit," Wired, March 6, 2017, https://www.wired.com/2017/03/failed-experiment-still-future-public-transit/ (accessed March 7, 2017).

- The Suncoast Transit Authority (STA) in Pinellas County, Florida, has partnered with Uber and a local taxi company, United Taxi, to provide rides between transit stations and a designated catchment area. STA will cover 50 percent of the trip cost, up to $3.[434]
- Divvy Bikesharing and Zipcar are exploring joint membership options in Chicago.[435]
- Chicago's joint fare card between the CTA and Enterprise Carshare (formerly IGO) is the first integrated shared mobility-public transportation fare card in North America.[436]
- Hourcar and Metro Transit in the Twin Cities have integrated their fares.[437]
- There is a partnership between BCycle and RideTap and its Moovel App mobile payment subsidiary in 28 cities across North America, including Philadelphia.[438]
- Capital Bikeshare, in Washington, DC partnered with United Bank and the District Government Employees Federal Credit Union to allow users to open a bank account and obtain a debit card. New account holders received a $25 gift card good toward the cost of annual Capital Bikeshare membership.[439]
- Centennial, Colorado has a trial agreement with Lyft to enhance its Dial-a-Ride service. Citizens residing within a designated service area will be able to summon a free ride to and from the Dry Creek light rail station. The partnership is anticipated to save significant revenue compared to the existing system, which costs $21 per ride, even with forecasts of triple the ridership demand.[440]
- Uber and WageWorks, a transit commuter benefit program, are teaming up to offer riders commuter tax breaks using UberPool service with UberXL vehicles in order to meet the IRS requirements of the law, which is not intended to subsidize carpooling.[441] This program launched in Philadelphia.
- Summit, New Jersey is partnering with Uber to subsidize fares to and from its commuter rail station. The annual cost of this subsidy is projected at $167,000 per year and will avoid the township spending $10 million building a new parking facility at the station.[442] It is not clear how parking revenues, which could help to repay the capital cost, factored into this decision. As it is a densely developed community, it may have needed to tear down one or more ratable properties, which could have a larger impact on its tax base.
- Altamonte Springs, Florida, near Orlando, is partnering with Uber to run part of its transit system. Uber's app offers “Altamonte Cars," which are subsidized at 20 percent of their regular fare by the city, and 25 percent for any trip starting or

[434] Ibid.
[435] McCutcheon, “Part 2."
[436] Federal Highway Administration.
[437] Feigon and Murphy.
[438] Regina R. Clewlow, “Three Ways Mobile Transit Payments Will Change How We Move in Cities," *Planetizen*, November 23, 2015, http://www.planetizen.com/node/82353/three-ways-mobile-transit-payments-will-change-how-we-move-cities (accessed February 9, 2016).
[439] Federal Highway Administration.
[440] Bliss.
[441] Andrew J. Hawkins, “You Can Now Use Pretax Dollars to Pay for UberPool, Which is Huge," *The Verge*, August 31, 2016, http://www.theverge.com/2016/8/31/12727908/uber-pool-wage-works-pretax-dollars-transit-benefits (accessed September 26, 2016).
[442] Andrew J. Hawkins, “New Jersey Town Decides to Pay Uber Instead of Building a Parking Lot," *The Verge*, October 3, 2106, http://www.theverge.com/2016/10/3/13147680/uber-new-jersey-free-ride-parking-lot-train-commute (accessed October 14, 2016).

ending at its Sunrail commuter station.[443] In the first weeks of this partnership, Uber ridership increased tenfold.[444]

- Uber and Caltrain created a partnership called POOLtrain to enhance transit service during Super Bowl 50, played at Levi's Stadium in Santa Clara, California.
- Uber has partnered with the Westside Transportation Alliance (WTA), in Portland, Oregon, to promote more sustainable transportation operations. The promotion includes a $20 discount on the first Uber ride. For each new Uber rider, the TNC will donate five dollars to the WTA to fund future sustainable transportation programs.
- Uber and Metropolitan Atlanta Rapid Transit Authority are teaming up on the "Last Mile Campaign" to promote Uber as a first-mile/last-mile to transit solution. Uber is offering first-time riders a free first ride, up to $20.
- Uber and La Salle University in the City of Philadelphia have a partnership that offers students a flat $1.99 fare to travel between SEPTA's Olney Station and the campus. Riders must use UberPool, and the trip is less than one mile.[445]
- Washington, DC has proposed having Uber respond to some 911 ambulance calls.[446]

There is a risk with any transit and TNC partnership that the private company could cut the public sector out of the equation. [447] For instance, rather than taking a passenger to a transit station, the company could encourage a one-seat ride straight to the destination.[448]

Partnerships can be made more challenging by the nondisclosure agreements that TNCs prefer to operate with. Among Uber's initial request to Altamonte Springs, Florida, was a far-reaching requirement to keep any proprietary technical or business information about Uber secret.[449] Failure to do so could lead to a lawsuit where the city would be required to pay attorney fees and civil damages.[450] The city refused to sign this agreement, fearing it would violate state transparency laws.[451]

[443] Woodman.
[444] Ibid.
[445] Anna Orso, "Uber's First College Partnership in Philly is with La Salle," *Billy Penn*, February 22, 2017, https://billypenn.com/2017/02/22/ubers-first-college-partnership-in-philly-is-with-la-salle/ (accessed February 22, 2017).
[446] Ibid.
[447] Luke Upton, "Public Transit! Your Uber Has Arrived, Please Proceed with Caution," *Smart Rail World*, January 27, 2016, http://www.smartrailworld.com/public-transit-your-uber-has-arrived.-please-proceed-with-caution. (accessed February 10, 2016).
[448] Ibid.
[449] Woodman.
[450] Ibid.
[451] Ibid.

FUTURE SHARED MOBILITY SCENARIOS IN GREATER PHILADELPHIA

The digital revolution is creating a new and very different view of transportation engineering, as shown in Table 2. Traditionally, transportation engineering has focused on the movement of automobiles, which is represented in the Auto-Oriented column in Table 2. With the push in recent years for more sustainable transportation and building livable communities, a new generation of transportation engineers has advocated for more active transportation. Digital transportation provides more information about different options to get around and uses technology to promote safety and efficiency. It has enabled new fast growing private market, shared mobility providers such as TNCs.

The biggest uncertainties around TNCs and other digital transportation service providers seem to be the rate of their future growth and whether or not they will help to build cooperative partnerships, or act individually, leading to a more fragmented transportation system. Four scenarios for TNC growth were developed and analyzed to better understand how digital transportation could evolve:

- **Filling a Niche:** TNC operators do not grow beyond specialized trips. Transit and regional transportation largely remain in status quo.
- **A Tale of Two Regions:** TNCs and transit agencies build partnerships to create an integrated, multimodal transportation network in the region's core. In lower-density areas, traditional auto-oriented transportation remains dominant. The two systems do not allow for easy movements between them.
- **TNCs Take Off:** TNCs operate independently and are quickly able to respond to changing market conditions. This has led to a significant scaling down of transit operations, and a worsening of congestion.
- **Moore Growth:** MaaS and partnerships between TNCs and transit agencies blur the line between them, enabling rapid growth. Convenient motorized options, and increasing traffic volumes and vehicle speeds reduce walking and biking.

Figure 20. Future Shared Mobility Scenarios for Greater Philadelphia

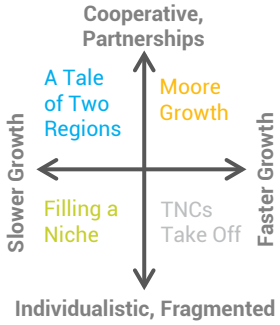
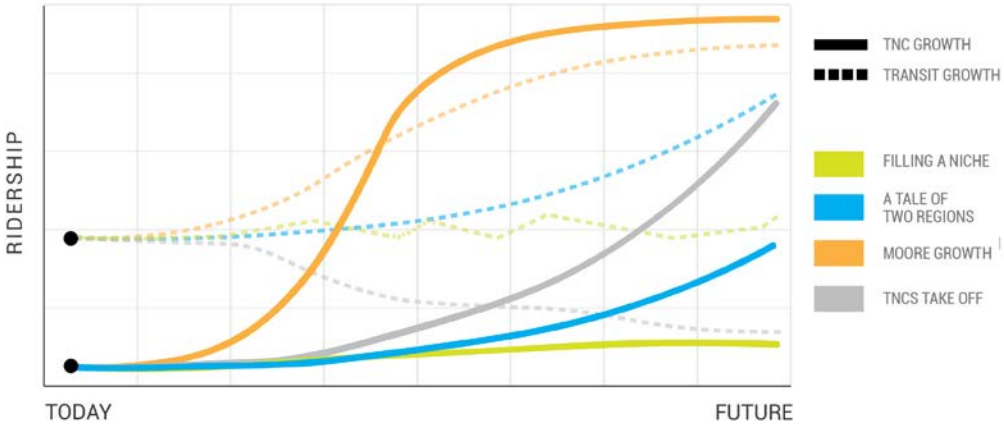


Table 2. Different Transportation Engineering Systems

	Auto-Oriented	Active Transportation	Digital Transportation
Overall Goal	Increase mobility	Increase accessibility	Increase information
Land Use	Separation of uses	Mixed use, high density	Live /work where you want; recognition that size and density have network effects
Trip Priorities	High speed	Short trips, getting exercise	Customization, cost, reliability, use time other than for driving
Safety	Safe mobility	Vision Zero	Connected technologies, warning systems, feedback loops, and data enhance safety
Key Metrics	Level of service, vehicle hours of delay, travel time index/savings	Bike/Ped level of service, trip length, total travel time, vehicle miles traveled, greenhouse gas emissions, transit trips	Real-time data, person throughput, wait time, personal ratings, Big Data, and analytics
Investment Priorities	New and wider roads	Connections between modes; walking, biking, and transit facilities	Multimodal smart roads that increase safety and efficiency
Rationale for Investment	Fight congestion; reduce delay	Build livable communities; sustainability; improve health	Create an integrated, multimodal network; profit (private market)

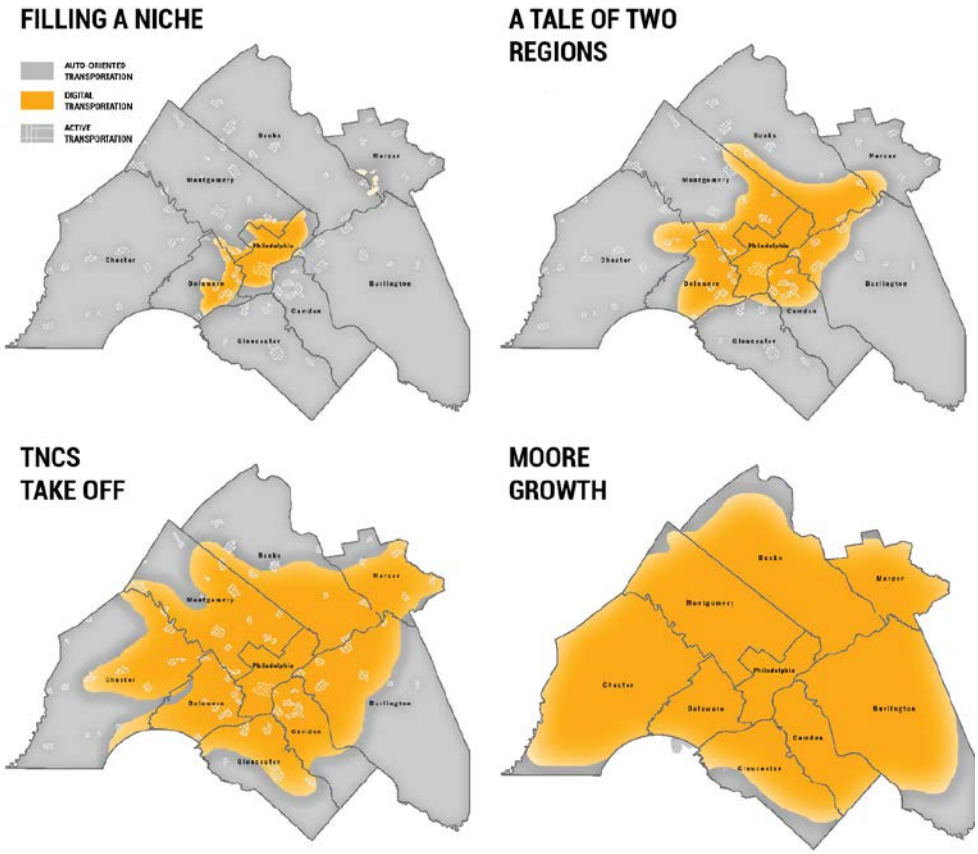
Source: DVRPC, 2016, adapted from Ian Lockwood, "Livable Traffic Engineering," CNU Orlando, video published November 17, 2012, https://www.youtube.com/watch?v=o7IXblXNOPk (accessed June 4, 2015).

Figure 21. Four Scenarios for the Future of Shared Mobility



Source: DVRPC, 2016.

Figure 22. Geographic Distribution of Different Transportation Engineering Systems in Each Shared Mobility Scenario



Source: DVRPC, 2016.

Each scenario estimates a different level of geographic spread of a digital transportation network around Greater Philadelphia. Shared mobility ridership on TNCs and transit are shown as key indicators of some potential outcomes from the evolution of digital transportation networks are shown in Figure 21. The following sections consider how the scenarios may impact the transportation system and people using it in the future, with a series of "contingent" priority actions specific to each. The actions are pulled from the larger list of recommendations identified later in this report. These scenarios are exploratory, and develop a range of plausible futures. They are not normative expressions of things the region would like to see happen. Instead, they consider what the region should do if something happens. They focus on key uncertainties in the future of TNC and other digital service provider operations.

Table 3. Future Shared Mobility Growth Scenarios Summary

	Filling a Niche	A Tale of Two Regions	TNCs Take Off	Moore Growth
Demographic Trends	Well-educated young people more likely to live in other regions that are seen as more innovative	Intraregional migration into region's core; more of the region's population living in poverty is being pushed away from the digital network, which has lower costs and more travel options	The ongoing evolution of transportation technology and new business models leads to fast-changing locational preferences	Intraregional migration away from the region's core; those with preferences for active transportation options may move away or not relocate to the region
Development Patterns	Mix of high-density development in the core and low-density development throughout the region	Very high-density development in region's core	High-density development in and around the region's core	Mostly low- and medium-density development spread throughout the region
Travel Demand Shifts	No significant change	Move to shared mobility in region's core; auto-oriented transportation remains in lower-density areas	Significant declines in transit and taxi service, growing use of private-market shared mobility	Significant declines in walking and biking trips.
Transportation Infrastructure	No significant change	Significant digital infrastructure investment and resulting network effects in the region's core	Efforts to serve increasing traffic volumes have led to roadway expansions that have further worsened congestion and the condition of existing facilities; decline of transit service	Significant reduction in car ownership and parking demand; expansion of transit service
Miscellaneous	Missed opportunity to improve transportation options	Lack of travel options in lower-density areas creates challenges for those aging in place or living in poverty	Growing concerns that a private-market monopoly may arise in shared mobility services; need to enhance pick-up and drop-off circulation at rail stations	Regional transportation is highly dependent on complex systems of systems and external energy sources, thereby increasing risks from disruption

Source: DVRPC, 2016.

Filling a Niche

TNCs continue to offer a convenient service for certain groups of individuals, particularly those that do not own a car, or who frequent nightlife venues. However, they fail to capture a wider audience due to the continued popularity of the private automobile. Political challenges and ongoing battles with taxi operators and regulators have harmed the reputations of TNCs. Their inability to gain a larger foothold in terms of service area has also slowed their development, as TNC trips work best in the 4-to-10 mile range, where walking and biking are less feasible alternatives. Attracting and retaining drivers has also proven problematic, serving as another limit to growth. Drivers often quit working for TNCs after accounting for a major out-of-pocket expense.

Transit service remains in status quo, experiencing little effect from surrounding TNC operations. Ridership fluctuates from year-to-year, but shows a stable pattern overall. Taxis continue to operate in the densest developed areas of the region, having scaled back their service due to lagging demand.

Lack of growth in the TNC market has meant a number of missed opportunities to improve transportation service in Greater Philadelphia:

- TNC trips cost more than in a higher-growth scenario, limiting their appeal in general and keeping their services largely out of reach for low-income residents and those living in EJ communities who are seeking better job access.
- Slow TNC growth has meant missed employment opportunities and improving work conditions for those who do drive for on-demand services.
- Transportation service for the region's growing elderly population has not been improved. These individuals are trying to age in place in the communities where they have always lived and raised their children. However, many of these areas lack transportation alternatives for getting around when they can no longer safely drive a vehicle.
- There have been little energy- or space-efficiency gains, or reductions in greenhouse gas emissions, as the system remains largely based around the personal automobile.

Land use decisions are little affected by digital transportation, TNCs, and transit service. Most new development is locating in areas where a wide range of digital transportation services have little or no operations. Lack of growth in transportation alternatives means the personal vehicle has remained the mode of choice for most trips. There has been no reduction in parking demand. The failure to grow these service options makes Greater Philadelphia appear to be less innovative and appealing as a location for young and well-educated individuals seeking out carfree or carlite lifestyles. The region may also be less competitive than other areas that are building lower-cost and more efficient transportation networks.

Filling a Niche
Biggest Challenges

- Perception of, and improvements to transit;
- Fairly regulating TNCs and taxis; and
- Building partnerships between transit agencies, taxi services, and TNCs.

Filling a Niche Contingent Recommendations

- Clearly define the process for licensing and regulating new digital and shared mobility services.[452]
- Do not create barriers to entry. Are additional regulations necessary? Is there data to demonstrate that they increase safety, access, or mobility?
- Increase access to jobs for low-income individuals, create income-based subsidies, and spread awareness on the growing menu of transportation options such as ridesharing, ridesourcing, and microtransit that reduce the need for vehicle ownership.[453]
- Transit agencies should find opportunities to cooperate and work with TNCs and other digital service providers, seeking mutually beneficial partnerships.[454]
    - Start small by opening dialogue with TNCs and conducting integrated trials that can build trust and lead to wider collaboration.
    - Partnerships should extend beyond traditional transportation and infrastructure realms, seeking better connections with travel and tourism, goods movement, education (with a support of co-learning), and other industries.

A Tale of Two Regions

A Tale of Two Regions Biggest Challenges

- Adapting physical infrastructure to changing demand, particularly in the region's core;
- Improving transportation options in lower-density areas of the region; and
- Geographic equity.

Increasingly, there are two transportation systems that operate in Greater Philadelphia in entirely different fashions. In the region's core, TNCs and shared mobility providers continue to experience beneficial network effects by concentrating growth in dense, walkable areas. Outside the core, traditional auto-oriented transportation patterns remain, and there has been little change in these areas of the region. For the most part, individuals choose where to live based on their transportation preferences, with many younger and well-educated individuals choosing to live where they have more options in how to get around and not needing to own a car. Older generations that have always owned vehicles generally still prefer to live in auto-oriented settings.

The two systems function very differently and have a hard time integrating with each other. Lack of options in the lower-density portions of the region make them difficult to access for those living in the region's denser core. With reduced car ownership, and increasing demand for denser development in the core, many former parking lots are being redeveloped. A reduction in parking in the core has made it more difficult to access for people in the auto-oriented suburban areas of the region. However, improved real-time digital information about available parking space locations and transit options—along with less overall demand for parking—has helped to somewhat ameliorate this concern.

Much of the demand for new development is occurring in the region's core area, where there is a multitude of transportation options. Individuals in this part of the region are relying less on the personal automobile. As a result, car ownership rates are declining, and total personal transportation costs are lower. Commercial and

[452] *Ride-Hailing Services*.
[453] Federal Highway Administration.
[454] McCutcheon, "Part 2."

residential development focuses in the region's core areas with increasing density in order to be located near the wider array of less expensive transportation modes afforded by the digital transportation network. However, demand for housing in the core has led to equity challenges as low-income individuals and families have a hard time affording housing in this area. More and more, low-income individuals are left with no option but to locate in the auto-oriented suburbs, increasing their transportation costs. As people continue to age in place in lower-density portions of the region, they lack access to the myriad of digital transportation services that could improve their mobility and quality of life.

While change often occurs more slowly than many expect, those who have continued to prefer car ownership are slowing down transportation digitization in lower-density areas. However, younger generations living and/or working in these areas of the region see things differently and call for more networked transportation throughout the region. There is a need for regional leaders to develop a comprehensive plan to digitally network lower-density suburban areas to the region's core. A key question is whether or not there is enough density throughout the auto-oriented suburbs to feasibly support TNCs and other digital transportation providers.

Tale of Two Regions Contingent Recommendations

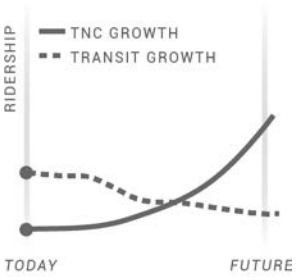
- Create data sharing agreements with private transportation operators to obtain data at a level that will inform transportation and city planning. Access to data must be balanced with the need to maintain personal privacy and for private companies to protect competitive information.
- Ensure all modes to operate together as one seamless system. Form partnerships with TNCs to supply difficult-to-fill public services, such as first-mile/last-mile transit trips.[455]
- Develop a singular regional fare payment and real-time information app that allows individuals to use and pay for transit, bikeshare, ridesharing, microtransit, ridesourcing, and taxi services. It should give real-time travel information for all modes, including use of multiple modes in a single trip, and include cost, wait time, time to complete, calories burned, and the trip's greenhouse gas emissions.

TNCs Take Off

TNCs have become a primary form of transportation, both in the region's core and inner-ring suburban areas. TNC services that bundle more passengers together have drastically lowered their prices and attracted many former drivers and transit riders. As the economy and technology evolve, travel patterns and needs routinely shift. The ability to respond more quickly and nimbly to these shifts has helped TNCs grow fast.

TNCs also surpassed governmental agencies in data collection and analysis.[456] They were better able to use data to tailor mobility solutions for different ridership

[455] Jaffe, "How the Microtransit Movement Is Changing Urban Mobility."
[456] *New Mobility*.



TNCs Take Off
Biggest Challenges

- Equitable access to digital transportation services;
- Transportation infrastructure investment allocation;
- Public and private sector cooperation; and
- Preventing private-market transportation service monopolies.

groups, and their employees were more skilled in creating algorithms that are able to respond to demand in real time.[457] There remains generally robust competition between private-market TNCs. This makes them less amenable to building PPPs in order to protect propriety information. However, private-market transportation service companies are beginning to consolidate as the field has matured. With transit and taxi alternatives in decline, the region is increasingly at risk of a monopolized transportation service market. Growing private market strength is giving TNCs more influence over public policy.

Transit bus service has seen a sharp decrease, notably due to long waits and slow travel speeds associated with fixed bus routes. On-demand, one-seat microtransit services have largely filled the role of fixed-route buses. While rail service remains viable, it is losing ground to options provided by TNCs. Rail stations are often poorly configured to meet changing access needs.[458] Today's passengers arrive by being dropped off, but poor circulation patterns make this overly difficult; meanwhile station parking facilities increasingly sit empty.[459] A lack of funding and demand for transit-oriented development makes it difficult to remedy these problems.

Traffic is increasing due to additional vehicle service on the roads, although real-time routing information has helped to keep congestion from becoming even worse than it has. However, there is now more traffic on formerly quiet local and neighborhood roads in primarily residential areas. Denser regional development centers are facing severe gridlock with on-street pick-up and drop-off being compounded by rising traffic volumes. The region tried to ameliorate congestion by expanding roads, at the cost of repairing existing infrastructure. The rebound effect from new roads and dilapidated infrastructure conditions have both led to even more congestion.

Pricing for mobility services in this future is largely based on private-market competition, with little regard for societal or network impacts.[460] The most negatively affected individuals are also the most vulnerable. Low-income and EJ communities have struggled with job access, as TNC services require smartphones and credit cards, which these individuals do not always have. TNCs are more costly than transit. Attempts to remedy this situation and improve access for those without smartphones or credit cards have centered on prepaid transportation cards, placing interactive kiosks around the region that can hail a vehicle, and smart buttons at participating retailers that allow passengers to hail and pay for TNC services.

Commercial and residential development spreads around the region's core and nearby areas in order to be located near the wider array of less expensive transportation modes afforded by the digital transportation network. Rural areas of the region still lack significant TNC service and other digital infrastructure.

[457] Ibid.
[458] Ibid.
[459] Ibid.
[460] Ibid.

TNCs Take Off Contingent Recommendations

- Optimize services in order to better compete in the new transportation market, while improving service to transit-dependent populations.
  - Pursue transit-first strategies, such as: transit signal priority, off-board fare payment, and dedicated bus lanes.
  - Use Big Data, on-demand, and automated technologies to optimize bus routes in ways that better meet demand by time and location.
  - Improve pick-up and drop-off circulation at rail stations.
- Incorporate TNC passenger collection point 'nodes' into existing communities and new transit-oriented development. TNCs may make urban and denser suburban areas that currently lack transit access more appealing to new development.
- Avoid regulatory capture and ensure competition. Avoid exclusive contract problems—such as Coke and Pepsi—by limiting fare and compensation structures that lock consumers into a particular service. [461] If drivers remain independent contractors, they should remain free to use any network and should be able to determine their own prices. For example, one TNC in New York City has offered rides for one cent to consumers who purchase a monthly pass. This can help to build a monopoly by shutting competitors out of a market.[462] The trade-off, however, may be less beneficial financial deals, due to lack of exclusivity.
- Ensure that data and information about these shared mobility services is freely open and available since ridesourcing companies use a scarce public resource: street space. This can provide a comparison to other cities, make sure that consumers are getting a good deal, and deter price discrimination and other anti-competitive practices. [463]
- Use digital technologies to price roads for efficiency, helping to balance supply and demand.

Moore Growth

New MaaS companies have helped to further blur the distinction between public transit and private shared mobility companies through convenient multimodal monthly subscriptions and seamless, real-time travel information. Partnerships between TNCs and transit helped both to grow substantially. TNCs were able to double their trip rates on a routine basis, slowing down only once they became the dominant mode of transportation. However, the convenience offered by TNCs and transit, along with growing traffic, has reduced the amount of trips conducted by walking and biking. Individuals in this future have proven quite adaptable to new money-saving lifestyles that do not require car ownership. Car ownership has substantially decreased as a result. Declining car sales have created major challenges for auto manufacturers and a whole host of offshoot industries, particularly auto liability insurance and auto repair and maintenance services.

Moore Growth Biggest Challenges

- Maintaining walkable, bikeable, and livable communities;
- Regulating TNCs; and
- Data sharing.

[461] Ibid.
[462] Ibid.
[463] Joe Cortright, "A To-Do List for Promoting Competitive Ride-Sharing Markets," *City Observatory*, August 2, 2016, http://cityobservatory.org/a-to-do-list-for-promoting-competitive-ride-sharing-markets/ (accessed August 3, 2016).

Reduced expenditures on transportation have provided some regional economic benefit, as residents have more disposable income to spend at local businesses.

Some transit agency and TNC partnerships have led to cost savings for transit services that were used to strengthen its operations in other areas.[464] Transit agencies themselves now provide first-mile and last-mile connections, sometimes connecting passengers to new private-market carriers. Small, on-demand shuttles and automated fixed-route buses feed existing rail service or new demand responsive, amenity-laden bus rapid transit services provided by new private companies. Partnerships with TNCs have been the key to transit agency growth and have helped to stretch limited public funds.

TNCs are able to size vehicles to meet ridership needs. This reduces energy use and allows for a more efficient use of space within the roadway network. The seamlessness of the system enables commutes to be easily completed in any direction: from the city to the suburbs, the suburbs to the city, or suburb to suburb; even without owning a personal vehicle. Increasing use of virtual communications technology has also reduced the need to commute or make other trips. TNCs are making areas that currently lack transit access more appealing to new development. Slightly denser, mixed-use, and more pedestrian-friendly locations in these areas are becoming new transportation nodes. [465] The struggle to pay for new digital infrastructure and maintain the existing physical infrastructure has led to calls for more taxes and fees on TNC services.

Commercial and residential development spreads around, with lower density outside the core and higher density inside the core, as the wider array of less expensive transportation modes afforded by the digital transportation network covers the entire region. The region's towns and cities have declined in their relative importance, as the spread of digital infrastructure has diluted its network effects.

Public health has been a mixed bag. A decrease in single-occupant commuting has reduced stress for many individuals. However, the decline in walking and biking has reduced activity levels. The reduced walkability and bikeability in the region's centers has slowed economic activity within them and weakened the region's ability to grow agglomeration economies. This has also harmed the environment with more open-space development and increased greenhouse gas emissions.

Even greater reliance on connected technology and external energy sources has increased the region's risk of disruption, whether from severe weather, network outages, or cyberattacks.[466] As the world continues to be more interconnected, it matters less where these events occur. Network disturbances as far away as Australia can impact the ability of Greater Philadelphia residents to get food delivered, access carsharing vehicles, and even purchase virtual transit tickets.[467]

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[464] *Private Mobility, Public Interest* (New York: Transit Center, September 8, 2016), http://transitcenter.org/publications/private-mobility-public-interest/.
[465] Nisenson.
[466] *New Mobility*.
[467] Ibid.

A reduction in active transportation has made the region less resilient, as walking and biking do not require external energy sources or advanced communications.[468]

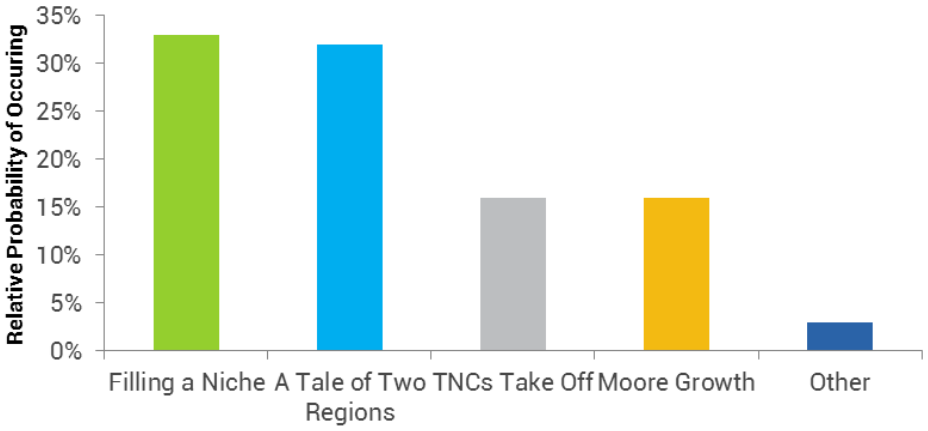
Moore Growth Contingent Recommendations

- Integrate shared mobility into long-range transportation plans—particularly using ridesourcing to better connect low-income communities and jobs, extend transit coverage, and find ways to better integrate transit with new shared mobility services.[469]
- Ensure that sustainable and active transportation remains a part of the vision and its implementation is funded. Invest in a diversified transportation network with traffic calming on local roads to deter neighborhood street use by through-traveling vehicles, and protected bike lanes to safeguard nonmotorized users.
- Conduct research into shared mobility business models, particularly cross-sector partnerships, focusing on how to be more inclusive of low-income communities, based on real identified transportation needs of low-income populations.[470] Employ pilot projects to test and develop comprehensive and collaborative approaches to digital transportation barrier reduction and work with intermediaries to address barriers and increase demand for shared mobility.

Leading Indicators

The Futures Group was surveyed on the relative probability of each scenario occurring. Given information on hand, members felt the lower growth Filling a Niche and A Tale of Two Regions scenarios were about twice as probable as the faster TNC growth scenarios, The TNC Takeover and Moore Growth.

Figure 23. Futures Group Future TNC Growth Scenarios Probability Assessment



Source: DVRPC, 2016.

In contrast, Uber averaged 2,000 rides per day in its first year of operations in the City of Philadelphia in 2015; while Uber and Lyft combined, recently were estimated to average 59,000 trips per day over the summer of 2016. This suggests an

[468] Ibid.
[469] Kodransky and Lewenstein.
[470] Ibid.

exponential growth rate more in-line with TNCs Take Off and Moore Growth. A recent report from Bruce Schaller, *Unsustainable*, found that TNC ridership in New York City had tripled over the past 18 months. This is an even faster growth rate than would be predicted by applying Moore's Law to TNC services.

The primary leading indicators that can be used to tell what scenario is occurring are total TNC trips and transit ridership. Other relevant indicators may include: total carsharing and bikesharing memberships, active TNC drivers and passengers, percentage of people with or without drivers' licenses, solo-driving trips, linked multimodal trips, number and percentage of zero-car households, and vehicles per household.

The Potential for Disruption

It is worth noting that a weakness in scenario planning may be that each scenario envisions what appears to be an end state. The reality is the world goes through a series of transitions, and there is no "end state" to be reached. Often the transition into a new era can feel like a step back, as change filters through the economy causing old firms to fail as new ways of conducting business emerge. New technologies need time to be adopted and may go through a curve where they are initially very expensive but see declining costs as production or consumption increases. The shared mobility scenarios presented here could alternatively be seen as a series of transitions as digital transportation services arise and spread throughout the region.

The next transition, which has not been addressed in these four TNC scenarios, is the possibility that HAVs, or another technology, disrupt driver-based TNC operations. A key question for HAVs is whether they will operate similar to TNCs, i.e., cars ferrying people around on demand; or be owned, serving one owner and perhaps more frequently running errands, or even driving long distances to a parking space in between trips. The shared HAV option may require drastic restructuring of the TNC business model (see the "HAV Unknowns" section of this report).

HAV disruption is another study altogether. Some additional potential indicators to track related to AVs and their implications could include: hyperlong commutes (taking 90 or more minutes) and percentage of the vehicle fleet that are HAVs, NHTSA Level 3 and above.

DIGITAL TRANSPORTATION INFRASTRUCTURE IMPLICATIONS

"In lieu of large civil infrastructure projects, transportation systems are increasingly being augmented with a range of information technologies that make them smarter, safer, more efficient, more integrated."

- Anthony Townsend, PhD *RE-PROGRAMMING MOBILITY: The Digital Transformation of Transportation in the United States* (New York: Rudin Center for Transportation Policy & Management).

Tiffany Fishman of Deloitte suggests the future of transportation is "massively networked, dynamically priced, user centered, integrated, and collaborative."[471] Digital transportation aims to provide new efficiencies through the provision of better information. Individuals can use travel information to choose the mode and route that best suits their needs for each trip, while routing optimization can help to balance loads throughout different facilities in the network.

The region's transportation system faces many challenges. Our transportation system is aging and too often in a state of disrepair. Climate change will require upgrading infrastructure to be robust, repairable, resilient, and responsive.[472] There are considerable implications for different forms of transportation and infrastructure systems: which will require incorporation of new technologies, new ways of efficiently and safely using space, improving the connections between modes, building around efficient public transit systems, and making infrastructure more multifunctional. The end goals of investments should promote increased efficiency and strive for beneficial network effects, which provide for diversity and options in getting around.

Incorporate New Technologies

Transportation infrastructure will increasingly need to be connected to the Internet and be able to capture and share information in real time. Networking infrastructure can enable remote management and operations, particularly for infrastructure such as traffic signals, speed limit signs, dynamically managed traffic lanes, and roadside CV warning devices. Multimodal real-time travel information needs to be readily available by all possible means, conveniently integrated into a single communication medium.

DSRC and other connected technologies will enable communication between vehicles and infrastructure. This will improve safety and transportation flow, both of which can help to reduce congestion.

Sensors installed in parking spaces can determine if they are occupied or available. These sensors can be connected to real-time travel apps, and help drivers more easily find available parking spaces. This can reduce how much circling vehicles do in search of parking. There is some concern that parking sensors may not be necessary in an HAV world, where parking demand is drastically reduced. They could become a stranded investment in the future.

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[471] Fishman.

[472] Jonathan F. P. Rose, "5 Crucial Principles for 21st Century Transportation Systems," *The Atlantic CityLab*, May 29, 2014, http://www.citylab.com/commute/2014/05/5-crucial-principles-for-21st-century-transportation-systems/371782/ (accessed August 5, 2015).

Efficient and Safe Use of Space

Digital transportation aims for increased efficiency, moving people in space-efficient modes. This can include increasing vehicle occupancy rates, and increasing use of modes that take less room, such as walking, biking, and transit. Space efficient transportation is critical to building network effects and agglomeration economies through increased density.

Digital transportation technologies are already changing the landscape of Greater Philadelphia. Bikesharing stations require sidewalk, parking, and road space. Carsharing needs visible parking spaces. TNCs need curbside space for pick-ups and drop-offs, resulting in new, de facto parking lots. Regulations must ensure the public can safely and equitably access these areas. However, shuttles and cars picking up and dropping off along curbs could increase congestion and lead to conflict over access to curb space. In general traffic terms, assuming pick-up and drop-off issues are resolved, more shared vehicle mobility could reduce overall congestion levels, particularly if it is combined with increasing transit, biking, and walking trips. Plans for future infrastructure should look to mitigate pick up and drop off concerns through design.

A recent Center for Neighborhood Technology study found that one-third of available parking spaces required by code went unused, even during peak demand for space.[473] If digital transportation services reduce demand for parking, as anticipated, then even more spaces will go unused. This will create opportunities to reuse parking spaces, both on- and off-street. Unnecessarily wide roads can be given road diets to improve their multimodality. Road lanes can be narrowed to enhance safety, and new uses can be found for the existing right-of-way. Some ideas for repurposing road space, parking lots, and on-street parking spaces include:

- pick-up and drop-off zones for new modes: microtransit, ridesourcing, and eventually HAVs;
- transfer stations between modes;
- electric vehicle charging stations;
- widening of sidewalks;
- green infrastructure;
- protected bike lanes;
- pedestrian plazas;
- street furniture;
- bus or shared mobility only lanes; and
- returning land to the private market.

Where it is warranted, CAVs can allow more lanes to be put into the same right-of-way. For instance, a 36-foot-wide road with three 12-foot lanes today could be transformed into a facility with four 9-foot lanes in the future.

[473] Wheeler.

In 2015, Washington, DC, began charging for curbside loading zones with location, reservation, and payment through the truck and bus map on the **goDCgo** website. The website provides routing directions to access loading zones, and is intended to keep trucks on designated freight routes. There are day and annual pass options. For those that pay by the hour, the tool creates considerable data about who is using these zones and when they are using them. It has also helped to identify unauthorized vehicle use, which is otherwise very difficult to regulate.

Connections between Modes

In the digital age, the focus needs to be on transportation networks—not systems. The entire transportation network should be seen as an ecosystem that consists of a variety of modes: walking, biking, bikesharing, transit, intercity buses and rail, ridesourcing, microtransit, personal vehicles, goods movement, and airports. [474] Viewing transportation as an ecosystem can help to resolve whether TNCs are complimentary to or competitive with transit.[475] To date, many of the new shared modes are serving particular niches in the transportation market. Ridesourcing is most often used for social trips, late at night, and when alcohol consumption is involved.[476] Carsharing is used for running errands and noncommute trips that lack good transit service and are over five miles long.[477] Bikesharing is used for last-mile connections and to reduce overcrowding on peak-period transit routes.[478] France is placing EVs, called Wattmobiles, at railway stations to make first- and last-mile transit connections.

Citypost kiosks in Kansas City, Missouri, offer access to city services, current events, local business information, digital public art, local history, and entertainment options.

A key way of networking transportation is to create seamless connections between all modes, facilities, and vehicles. Trips can be made more customizable to meet individual and freight needs and priorities. The ultimate goal is to better connect these modes, giving people an expanded range of options and new efficient ways to get around by building an integrated, multimodal transportation network. Network integration will help people get around using the most convenient mode and operator by time of day.

Integrated, multimodal transportation networks use digital devices to collect data in order to provide real-time information about how to best move people and goods, more efficiently use existing transportation facilities, and employ a variety of modes to get around an area or region quickly.[479] Public transportation may need to evolve, but it will need to be the backbone of an integrated network. An integrated network would provide lower-cost transportation options and improved service in urban areas, as well as in suburban areas where transit service is currently not frequent or cost effective. Connections between modes are critical for enabling easy transfer. Creating multimodal transportation hubs that combine a transit station with

[474] Rose.
[475] "Episode 2: Shared Mobility."
[476] Feigon and Murphy.
[477] Ibid.
[478] Ibid.
[479] Chuck McCutcheon, "Part 1. Connecting the Sectors," *Passenger Transport* 74, no. 3 (2016), http://www.apta.com/passengertransport/Documents/PT_02-08_16_Connecting%20Sectors_Part%20I_in-depth_integrated%20mobility.pdf (accessed June 30, 2016).

carsharing, bikesharing, and TNC and taxi pick-up and drop-off areas can enhance connections. Transit station circulation will need to enable easy kiss-and-ride opportunities. Pick-up and drop-off areas will become more important to accessing the final destination than parking lots.

Placing digital kiosks around a city for hailing a TNC was a common component in the U.S. DOT Smart City Challenge applications. Such kiosks could have a wider community use: as a community message board, educational tool, information for tourists, etc. Another idea is Bttn's, which is a simple button with wireless Internet connection. It has many potential uses, whether pressing it to request a service (such as hailing a taxi or on-demand transit vehicle), sending information, or pressing it to confirm something has been accomplished (such as taking one's medication). Outdoor-rated models are not currently available, but are coming. Concierge or phone services, where someone is available to help book a ride for an individual without the use of an app, are another possibility.[480]

Bttn describes itself as the world's simplest Internet interface.

Source: https://bt.tn/.

Transit Opportunities

TNCs and other digital transportation services and innovations offer opportunities for transit systems. Public transportation remains critical to the efficient use of space and building agglomeration economies. Transit systems across the country suffer from a challenge where peak-period service operates at 120 percent of capacity, while off-peak service operates at 20 percent of capacity.[481] New services, such as TNCs and bikesharing, can help to shave peak-period demand, thereby reducing crush loads.[482] While new business models and technologies can help increase efficient use of space during the off-peak hours, state and local transportation departments will need to shift their view away from building transportation assets, and toward a broader vision of managing the transportation network.[483]

In a digital world, people value unique and customizable experiences. For companies, competitive advantage is now based on understanding customer needs and meeting them better than anyone else does.[484] Ways to personalize transit need to be found in order to make it more appealing to use.

TNCs can offer a way to improve Dial-a-ride mobility programs for seniors and persons with disabilities. The real-time, app-based technology has helped to reduce wait times for these individuals and freed them from having to make ride requests up to 24 hours in advance. Even as this service improves, it could also generate cost savings that can then be applied to other improvements.

In low-density, suburban areas, on-demand bus service may be more cost effective for transit agencies and efficient for riders than the current fixed-route services.

[480] "Episode 2: Shared Mobility."
[481] Shaheen et al.
[482] Ibid.
[483] Ibid.
[484] Frank Van Den Driest, Stan Sthanunathan, and Keith Weed, "Building an Insights Engine," *Harvard Business Review*, September 2016, https://hbr.org/2016/09/building-an-insights-engine (accessed December 12, 2016).

Transit agencies can set up on-demand services and eventually purchase automated shuttles.

Multifunctional Infrastructure

In order to gain more efficiency, infrastructure in the digital age aims to be multifunctional. It integrates not just transportation, but also water, waste, energy, and other infrastructure into an efficient network. Plug-in EVs can help regulate energy demand in a vehicle-to-grid system by becoming energy sources during peak daytime hours and recharging to smooth demand curves during low-demand overnight periods. This can help to smooth energy flows within an increasingly interdependent system.[485] Pervious pavements can reduce the need for stormwater systems. Cogeneration plants use waste heat from electricity production to heat and cool (through the use of chillers) homes and can even capture carbon emissions for use in other manufacturing processes, such as beverage carbonization. Copenhagen's Enghaveparken manages stormwater through underground water storage tanks and a sports field that becomes a large water holding tank during heavy rainfall events.[486] A nearby children's playground uses bouncy pads to power pumps that water the park's landscape.[487] Waste flows are seen as an opportunity for repurposing. Waste Management Inc. estimates their trash hauling services pick up nine billion dollars' worth of reusable materials each year.[488]

Governmental Role in the Digital Age

Government's role is to integrate all transportation modes into an efficient network.[489] This will require designing streets using a software programming approach, where different modes—walking, biking, TNCs, personal vehicles, fixed guideway transit, CVs, and eventually HAVs—will need to be accommodated within the existing transportation network.[490] Transportation network users will need to be able to quickly and easily transfer between different modes. Austin, Texas is creating a new multimodal transportation system around a planned Metro Rail stop that incorporates bus transit, bikesharing, carsharing, and hiking and bike trail connections.[491]

Governments at all levels need to recognize and plan for a much more uncertain future. Lack of funding and aging infrastructure will make implementing digital technologies and designing more resilient infrastructure very difficult. Digital transportation will likely need to be funded in one of two ways. A more private-market approach will require building partnerships with a diverse group of public, private, and nonprofit organizations; and government oversight to build, finance,

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[485] U.S. Department of Transportation, *The Smart/Connected City*.
[486] Athlyn Cathcart-Keays, "Why Copenhagen Is Building Parks That Can Turn into Ponds," *Citiscope*, January 21, 2016, http://citiscope.org/story/2016/why-copenhagen-building-parks-can-turn-ponds (accessed July 5, 2016).
[487] Ibid.
[488] Nidumolu.
[489] DuPuis et al.
[490] Ibid.
[491] President's Council of Advisors on Science and Technology.

operate, and maintain transportation infrastructure. However, an increasing role for the private sector will potentially pit shareholder demands for profit against community desires to serve the public good. Alternatively, a more public approach will finance improvements through new revenue collection mechanisms—such as congestion pricing or VMT fees—which digital technologies will make more feasible by flattening transaction costs and enabling easy transactions that cause less inconvenience, such as having to slow down at toll booths. Congestion pricing uses economic principles to encourage more efficient use of transportation facilities. The cost to use the facility increases when demand is high during peak periods, which can help to balance supply of and demand for transportation infrastructure. Other local funding sources could possibly be identified. Public support and political will is necessary for any additional revenues.

Digitization will add a few new layers around connecting modes with each other and providing more real-time information through the Internet. Governments need to be transparent in the digital age by opening data and unleashing citizens to be problem solvers. Digital technologies offer a key opportunity to rethink transportation around how we can make our communities more efficient, sustainable, equitable, and economically competitive. This will not happen on its own, and the regions that best leverage digitization's potential benefits will be guided by careful government planning, implementation, and oversight of new technologies and partnerships.

The regions that invest in transportation infrastructure and make land use decisions which centralize major destinations and create dense, mixed-use communities that reduce the need to travel long distances will be more desirable. These investments will help to reduce carbon emissions and attract talented individuals who can live anywhere they choose as a result of the digitized global economy. The most competitive regions will prioritize short walking, biking, and transit trips over long trips in their investments. Areas where more people can walk or bike to work—and fewer have long drives—have a competitive advantage by providing a less costly infrastructure network to maintain.[492] This remains true regardless of whether the trip maker, a for-hire driver, or a computer is behind the wheel.

Housing

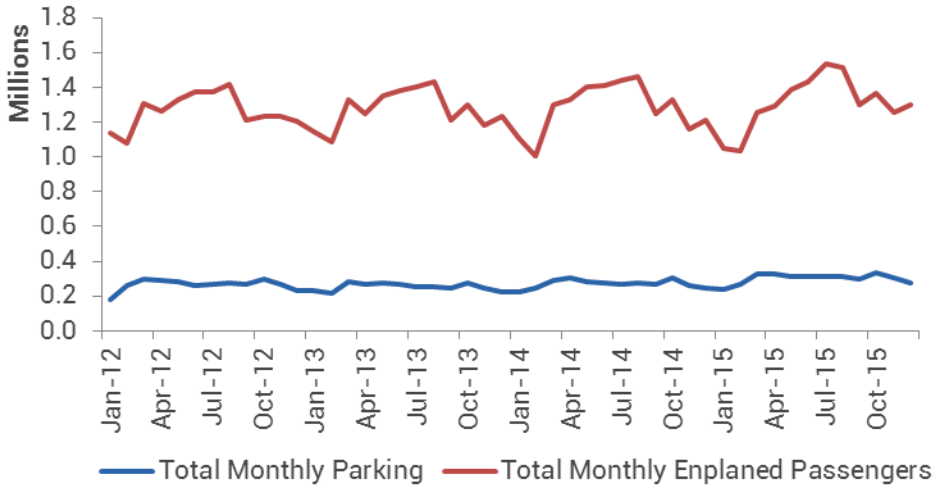
Dynamic, globally connected economies produce more population movement. As jobs and situations change, people may prefer to be able to move quickly to be closer to work or build more business contacts. Housing a more mobile digital population will require more rental units with a variety of sizes, from micro apartments to serve singles, to three-plus bedrooms for families. This unattached style of living can evolve in different ways. For instance, “apartment timesharing" could allow individuals to buy a unit that they can effectively move about as needed.[493]

[492] Ian Lockwood, “Livable Traffic Engineering," *CNU Orlando*, video published November 17, 2012, https://www.youtube.com/watch?v=o7lXblXNOPk (accessed June 4, 2015).
[493] Conner Clark, “The Great Reset: Urban Theorist Richard Florida Explains Why Recession Is the Mother of All Invention," *The Atlantic*, March 2009, http://www.theatlantic.com/magazine/archive/2009/03/the-great-reset/307303/ (accessed February 22, 2016).

Digital Transportation at PHL

Changing transportation technologies potentially impact major planned investments at PHL. Expansion plans at the airport currently include building new parking structures. Amtrak recently completed a Tier I Environmental Impact Statement (EIS) to plan for improvements to the Northeast Corridor rail line over the next 30 years. Three proposed alternatives were reviewed, two of which would add a new station stop at PHL. The locally preferred alternative (LPA) identified at the completion of the Tier I EIS included a new Amtrak stop at PHL. Adding a new airport stop is consistent with the region's vision to create an integrated, multimodal transportation network. The goal of such a network is to provide seamless movements between all modes of transportation, including commercial aviation.

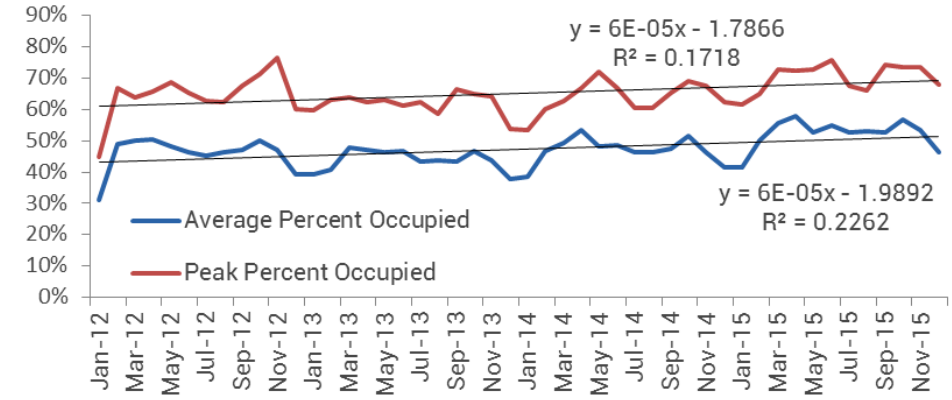
Figure 24. Monthly PHL Enplaned Passengers and Overnight Parking, 2012 to 2016



Source: Philadelphia Parking Authority, 2012–2016.

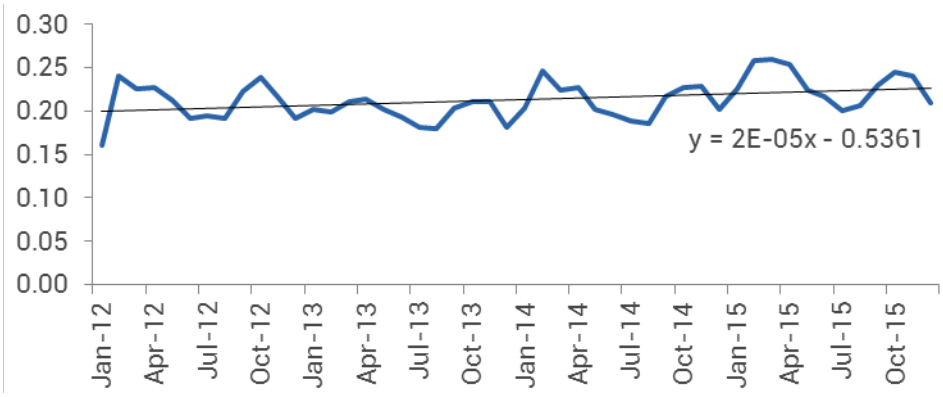
Parking demand at PHL has been growing over the past four years, along with increased passenger activity. The number of nights of parking per enplaned passenger is increasing. In 2012, just under 3.2 million nights of overnight vehicle parking were recorded by the PPA in the PHL long-term parking lots. About 15.2 million passengers departed from PHL that year, for an average of 0.21 vehicle parking nights per enplaned passenger. In 2015, more than 3.6 million nights of overnight vehicle parking were recorded in the long-term parking lots. Over 15.7 million passengers departed from PHL that year, for an average of 0.23 nights of vehicle parking per passenger. Overall, the peak night and average nightly occupancy over the course of each month is showing signs of increasing. This is occurring even as lower cost private off-site airport parking facilities have also been significantly expanding.

Figure 25. Percentage of Monthly Overnight Parking Spaces Occupied



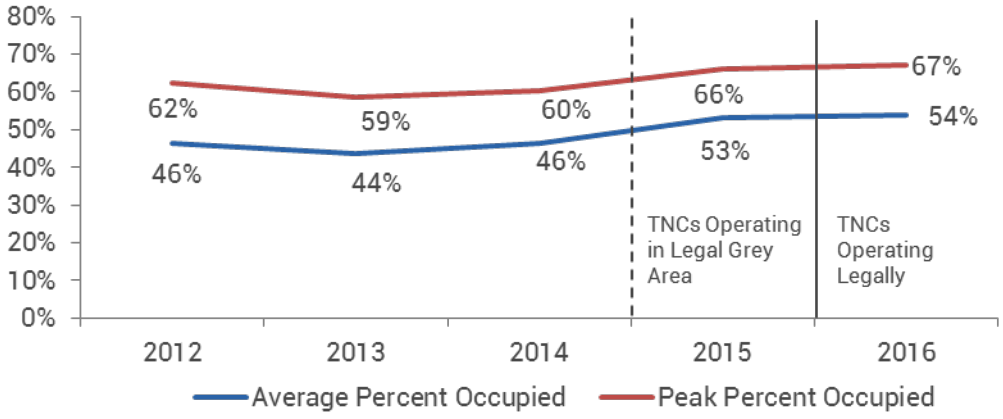
Source: Philadelphia Parking Authority, 2012–2016.

Figure 26. Nights of Parking per Enplaned Passenger



Source: Philadelphia Parking Authority, 2012–2016.

Figure 27. Parking Rates for August 2012 to 2016

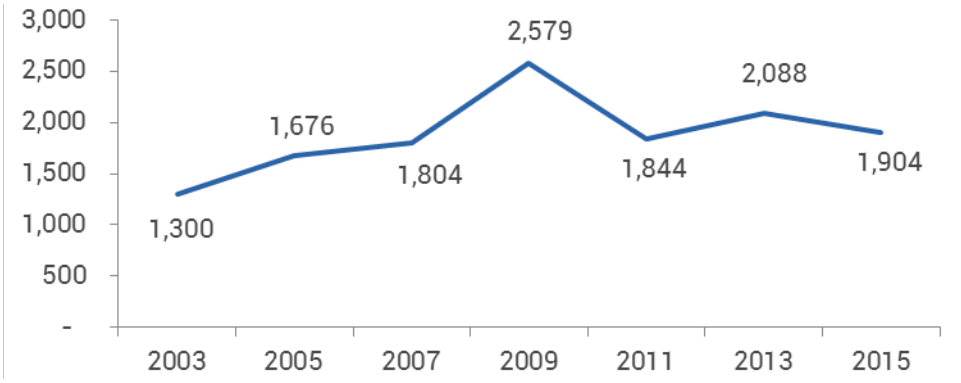


Source: Philadelphia Parking Authority, 2012–2016.

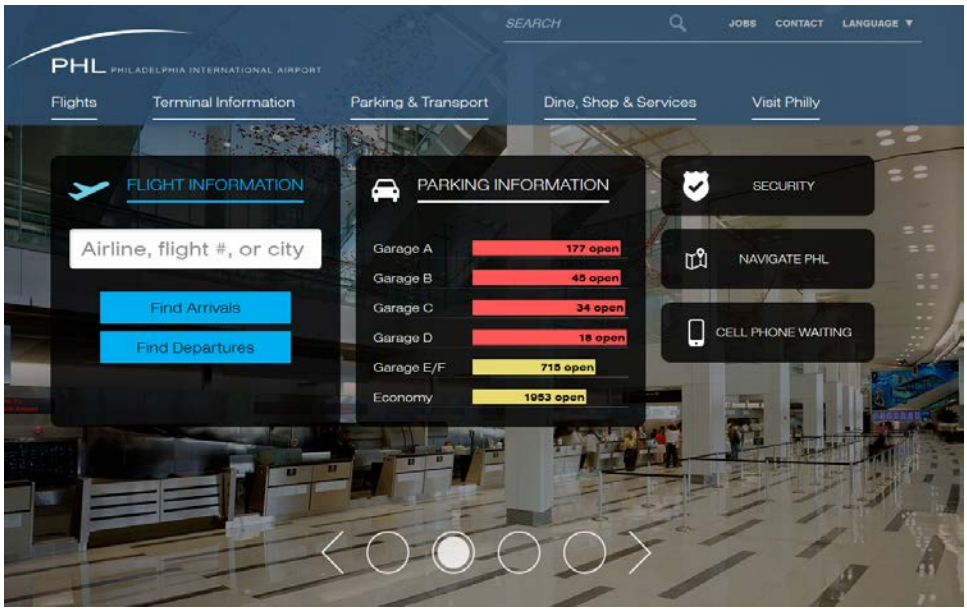
TNCs may be having an effect on SEPTA ridership. Figure 28 indicates SEPTA riders alighting at the four PHL stations (Terminal A, Terminal B, Terminals C & D, and Terminals E & F), based on the biennial regional rail census. Ridership is down by 26

percent since peaking in 2009. While these figures estimate station level ridership, they are not adjusted for factors such as the weather, which may have a ridership impact when counts are being conducted. Other factors, such as low gas prices, have also contributed to this decline.

Figure 28. SEPTA Airport Line Average Daily Ridership Alighting at PHL Stations



Source: SEPTA, 2003–2015.



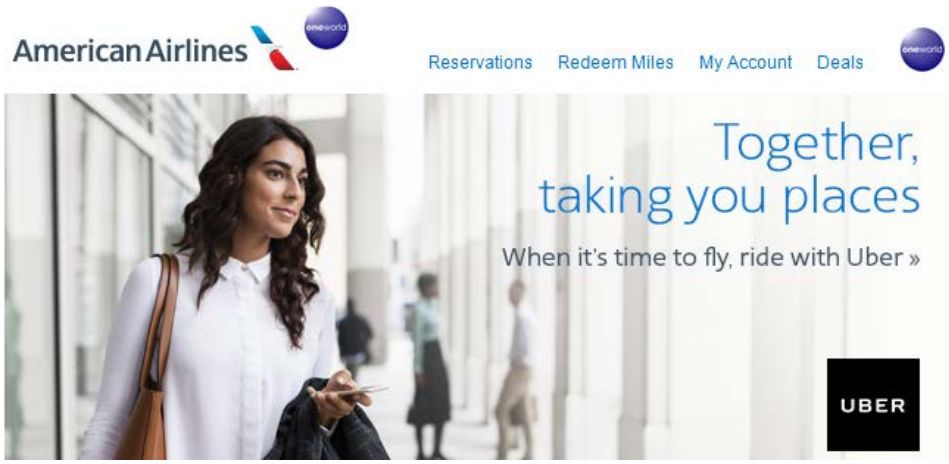
PHL is already providing real-time parking information on its website and has parking information in each garage.

Source: Philadelphia International Airport.

Even though TNC's do not appear to be impacting PHL parking patterns so far, whether or not to further expand parking facilities will need to weigh the risks of future parking demand decreasing from new options in a fragmented, digital transportation system. Although a current financial analysis may point to building additional parking space, the City of Philadelphia and PPA should explore other options and encourage new means of accessing the airport facility. One such option is a new station stop along Amtrak's Northeast Corridor line, as planned in the LPA selected from Amtrak's Tier I EIS. This option would increase the daily number of intercity and regional trains stopping at PHL from 72 in the no-action alternative to

332 in the LPA.[494] It would reduce daily travel in the Northeast by an estimated four billion VMT annually and save travelers 70 million hours of travel time each year.[495] It would reduce travel times between Philadelphia and Boston's South station by 55 minutes, while increasing job accessibility—the number of jobs within 45 minutes of travel time from Philadelphia—by 89 percent.[496]

A second option is to work with TNCs to provide additional service that helps fill gaps in the transit network. Similar to how municipal partnerships around the country are subsidizing access to commuter rail stations, PHL-TNC partnerships could aim to provide lower-cost ground access. Such partnerships should also include taxi services and transit in order to be more equitable. Looking into the future, this option may be the less risky business proposition. Subsidies could be paid for through parking surcharges in PHL facilities or ground transportation fees added to each ticket purchase. Land that would be used for parking facilities can then potentially be put to higher and better use. Such investments could generate wider economic benefits throughout the region by strengthening an integrated, multimodal transportation network. These benefits won't show up in a cost-benefit analysis for parking expansion conducted solely from the vantage point of PHL.



Uber and Lyft have already partnered with airports and airlines to advertise services directly to and from various airports.

Source: Uber & American Airlines.

Alternatively, if plans are made to go ahead with new parking facilities, PHL officials should consider potential future reuse options for them. New facilities should then be designed and constructed with the potential reuse at a later date if parking demand does decline.

With legalization of TNCs throught Pennsylavania, wayfinding signage at PHL is needed to help passengers access their services.

[494] "Preferred Alternative: Description," NEC Future, n.d., http://www.necfuture.com/alternatives/ (accessed January 16, 2017).
[495] Ibid.
[496] Ibid.

TNC Wayfinding at Portland International Airport.

Key Findings

Future infrastructure investment in Greater Philadelphia should focus on building an integrated, multimodal transportation network and supporting a dense, mixed-use, centers-based land development pattern. Transit should serve as the backbone to this transportation network, and is complemented by other services such as TNCs.

New technologies, policies, and business models can help to relieve transportation problems, but they cannot fully solve them. Instead, communities need to be structured so that living and working spaces are closer together, and there is less need for motorized transportation to begin with. This requires walkable, high-density, mixed-use "livable" neighborhoods where most daily needs can be found within a 20-minute walk. Pricing and markets need to ensure efficient use of the system. Successfully achieving the systemic change envisioned from these technologies will not simply happen on its own. Challenges include finding first adopters to ensuring the supporting infrastructure is in place. For example, increasing EV market share requires setting a wide network of charging stations.

While digitization is a force that will bring much change with it, it will not change the basic fundamentals of how successful and competitive regions function.[497] As an example, growing use of computers—and later cellphones—had many people convinced that they meant a decreased need for cities and dense, mixed-use neighborhoods. If anything, though, digital devices have strengthened urban areas through network effects, as people continue to want to be near other people. Cities have experienced considerable growth, reversing decades of population decline, concurrent with the digital revolution. In a globalized world where capital and labor are ever more mobile, and competition for them is growing ever more fierce, transportation investments need to contribute to the attractiveness of a place to live, work, and play.[498] The next section lays out recommendations for how the region can bring about the vision of an integrated, multimodal network.

[497] "The Future of the Smart City."
[498] Rod Eddington, *The Eddington Transport Study. The Case for Action: Sir Rod Eddington's Advice to Government* (London: HM Treasury, 2006), http://www.hsr.ca.gov/docs/about/business_plans/BPlan_2012LibraryCh1_Edngton_Study.pdf.

Creating a Safe, Equitable, Integrated, Multimodal Transportation Network

The following is a menu of potential actions that the region can take to help build an integrated, multimodal transportation network. From this menu, state and local governments, transit agencies, and DOTs can together work with DVRPC, the public, and key stakeholders, to build a shared mobility action plan. Successfully incorporating these new technologies will require collaboration and discussion between municipal officials, planners, engineers, and technology experts.

Shared mobility requires building transportation networks in the digital world and supporting infrastructure in the physical world. New technologies won't solve all transportation problems on their own. The future of transportation is multimodal, with a variety of options in how to most efficiently make a trip. Even Anthony Foxx, U.S. DOT Secretary of Transportation under President Obama, and one of the biggest proponents of AVs, has recognized that the future holds more "bike lanes, pedestrian-only areas, driverless rideshares, high-speed trains, and buses."[499] The region will need to be flexible in determining how to achieve this vision; rapid technological change can quickly outdate rigid master plans, regulations, infrastructure investments, and institutional practices. [500]

The analysis does not attempt to calculate the benefits and costs of these recommendations. It is worth noting that the benefits are likely to be far reaching, and any attempt to quantify them will largely undervalue second- and third-order benefits.[501] These are changes that cannot readily be captured or fully understood by existing travel demand models.

Infrastructure Recommendations

Transit, walking, and biking should continue to be prioritized, due to their more efficient use of land, as well as encouragement of denser development, network effects, and agglomeration economies. Design and strategy should focus on the network, not individual lines. TNCs may help make denser, walkable, mixed-use communities in areas that previously have lacked transit service become more attractive to development. These underutilized areas can become flexible transportation nodes within the network.[502]

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[499] Leanna Garfield, "Uber Has a Plan to Completely Transform Your City," *Business Insider*, December 16, 2016, http://www.businessinsider.com/how-driverless-cars-might-change-cities-2016-12 (accessed January 5, 2016).
[500] Anthony Flint, "Is Urban Planning Having an Identity Crisis?," *The Atlantic CityLab*, July 17, 2015, http://www.citylab.com/housing/2015/07/is-urban-planning-having-an-identity-crisis/398804/ (accessed June 13, 2016).
[501] David Roberts, "Sometimes a Driverless Car Is Not Just a Driverless Car: Thoughts on Widgets and Systems," *Grist*, February 1, 2013, http://grist.org/business-technology/sometimes-a-driverless-car-is-not-just-a-driverless-car-thoughts-on-widgets-and-systems/ (accessed August 12, 2015).
[502] Nisenson.

Transportation projects should revolve around connecting modes, enhancing safety, and managing infrastructure. The region has a long way to go in rebuilding the existing system, which remains the top priority for investment. Decision making should refer back to the major goals that guide the regional vision; these include: affordability, safety, mobility, accessibility, reducing congestion, promoting active modes and improving health, decreasing energy use and reducing greenhouse gas emissions, and improving transportation infrastructure conditions, among others.

Improve Connectivity

The region needs to be reimagined as a digital platform. This platform can help to move people and goods more efficiently and serve as a learning tool that can support the knowledge economy. Physical and digital connections need to be improved both within the region and with the outside, global world.

- Develop a standardized digital payment platform using near-field communication and real-time information apps that allows individuals to use and pay for transit, bikesharing, ridesharing, microtransit, ridesourcing, taxi services, and tolling.[503]
    - It should give real-time travel information for all modes, incorporating the use of multiple modes in a single trip, and include cost, wait time, time to complete, calories burned, and the resulting greenhouse gas emissions. Such an app could build off the existing GoPhillyGo platform, or a similar effort.
    - Create alternative payment arrangements using cellphones, money orders, prepaid credit/debit cards; and partner with banks and credit unions to bring people into the banking system. It could alternatively serve as a banking mechanism for those who do not have access to a credit card or bank account.
    - Wi-Fi kiosks, Bttns, phone calls, or other Internet-connected devices and concierge services can allow individuals without a smartphone to e-hail a ride, while providing educational and tourist information, citizen engagement, and other opportunities.
    - Fare payment instruments could experiment with “MaaS” prepayment or monthly payment options that integrate multiple modes, such as transit, bikesharing, carsharing, microtransit, and ridesourcing.
- Create multimodal transportation hubs that work as a one-stop alternative transportation shop, by blending a transit station or stop with carsharing, bikesharing, microtransit, ridesourcing, ridesharing, and taxi pick-up and drop-off points.
    - Replace some on-street parking spaces with curbside pick-up and drop-off points.
    - Incorporate TNC passenger collection point ‘nodes' into existing communities and new transit-oriented development.[504]
    - Improve kiss-and-ride circulation patterns at transit stations.

[503] Fishman.
[504] Nisenson.

- Create partnerships to help develop the 'Mobility Internet.'
- Invest in digital technologies and ITS to improve access to real-time information for transit and roads.
    - Install DSRC along highways and major arterials.
    - Apply smart technologies to roads, such as connecting adaptive traffic signals to regional Transportation Operations Centers to enable more remote, real-time traffic management.
- Improve domestic and international mobility connections to the nation and world, which are critical in the global market.[505]
    - Expand domestic (outside the Northeast Corridor megaregion) and international connections at PHL.
    - Improve rail connections within the Northeast Corridor megaregion.
- Rethink paratransit services by integrating them with new mobility options and as a way to improve first-mile/last-mile connections. This can reduce costs for both agencies and passengers, while enhancing operations and customer service.[506]
    - Modernize paratransit reservation systems to provide same-day or real-time rides.[507] Integrate paratransit trip planning into mainstream transit agency trip planning and real-time information apps and platforms.
    - Use paratransit to feed into an accessible fixed route public transit system.
    - Work with the private market to innovate ADA transportation by providing incentives for accessible vehicles and services.
    - Require TNCs to let passengers indicate if they need a WAV, and refer the passenger to another service if they cannot offer a ride. As an alternative to requiring WAV operations, impose a tax or fee on TNC operations to subsidize other private or public WAV services.[508]
    - Blind individuals need voice-instruction technologies to be incorporated into shared mobility services to ensure accurate location information.[509] Service animals need to be allowed to ride in accessible shared mobility vehicles.
- Expand New Jersey's truck e-screening program into Pennsylvania and other Mid-Atlantic and Northeast states.

SEPTA has applied for competitive federal funding to help overcome barriers to mobility on demand by adding a data integration platform to the SEPTA smartphone app. The proposal included a web-based version of the app that would enable transportation providers to connect and share their service information to potential customers, including economically disadvantaged populations. The data integration platform would allow for a one-stop shop for travel information equipping travelers with useful tools to complete door-to-door trips using a variety of transportation

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[505] Clark.
[506] McCutcheon, "Part 1."
[507] Shared-Use Mobility Center, *Shared Mobility and the Transformation of Public Transit* (Chicago, IL: American Public Transit Association, March 2016), http://www.apta.com/resources/reportsandpublications/Documents/APTA-Shared-Mobility.pdf.
[508] *Ride-Hailing Services*.
[509] Shaheen et al.

services. The SEPTA app and data integration platform would produce a uniquely deep and broad dataset to analyze gaps in the regional transportation network and identify opportunities for multimodal service optimization. While this grant application was not successful, it shows that serious thinking about creating an integrated, multimodal network is already underway in Greater Philadelphia.

DVRPC's Equity Through Access planning is identifying gaps and bridges in service for low-income and individuals with disabilities. It aims to enable more people to use transportation to find ladders of opportunity.

Enhance Safety

Municipal regulations must protect the safety and general welfare of citizens.

- Incorporate TNCs and other digital transportation providers into Vision Zero plans.[510]
    - Some local and residential streets will see increasing through traffic volumes due to real-time information and TNC use. These streets may need additional traffic calming measures and protected bike lanes to safeguard nonmotorized users and reduce vehicle speeds.
    - Use requirements for TNC driver training as an opportunity to educate about safety.
- Create regulations to either prohibit or ensure safe on-demand mobile refueling of vehicles through digital services.
- Consider whether current digital rating systems are adequate for the safety of drivers and passengers using on-demand ridesharing apps. These services generally do not conduct background checks.
- Prepare evacuation plans to move larger numbers of carless households.
    - Use digital technologies and social networks to improve the reach of emergency communications.

Manage Infrastructure

Managing infrastructure includes better parking management and making roads more efficient. Decisions should prioritize and reward the efficient use of space. Transit and shared mobility services should receive preferential treatment over personally owned vehicles.

- Update parking policies for shared mobility services.
    - Create a “Floating Parking Permit" category for one-way carsharing.
    - Develop on-street parking policies for carsharing.
- Set a goal to increase the use of off-street parking facilities and use pricing to ensure on-street spaces are available.
    - Use sensors to track parking space use and availability in real time. The resulting data can dynamically price on-street parking, ensuring each block

[510] Bollier.

always has one or two available spaces. Mobile apps can be used to locate the best available parking spot and price.
    - Develop uniform signs for all off-street facilities with hourly and daily rates more prominently displayed, along with a real-time count of available spaces.
- Include real-time parking information in a visitor-friendly, multimodal transportation app that tells both the city's story and history, and provides easy-to-understand transportation wayfinding for nonresidents.
- Use digital technologies to price roads for efficiency, helping to balance supply and demand.
- Infrastructure should aim to increase efficiencies by providing a variety of benefits rather than having only one single purpose.
    - Build out EV infrastructure in order to use EVs in the energy grid to smooth out demand over the course of the day. EVs can provide excess energy during peak daytime demand and recharge overnight while demand is low.
    - Pervious pavements allow roads to reduce stormwater runoff.
- Build connected infrastructure through traffic signal upgrades, and adding roadside warning devices in high-crash locations and areas with poor visibility locations or with elevated risk of fog, wind, flooding, ice, or other extreme weather risks.
    - Ensure interoperability of connected technologies across jurisdictional boundaries.
- Optimize bus service in order to better compete in the new transportation market, while improving service to transit-dependent populations.
    - Pursue "transit first" strategies to make surface transit as efficient as possible and improve convenience and travel times relative to motor vehicles (whether private or shared). These may include: transit signal priority, off-board fare payment, multidoor bus boarding, and dedicated bus lanes with enforcement.[511]
    - Pursue funding to pilot on-demand and/or automated shuttles in lower-density, suburban areas of the region that either complete a trip or link to fixed-route service. Potentially use this service to replace existing low-passenger-volume, fixed-route buses.
    - Be more adaptable by using Big Data to better determine travel demand by location and time of day and adjust service as necessary.
- Prioritize pavement, bridge, and other transportation infrastructure state-of-repair investments.
    - Create and use management system databases to enhance signs, lane markings, construction activities, and other key infrastructure needed for the safe operation of HAVs.

[511] Schaller, *Unsustainable.*

- Improve or require coordination during major reconstruction and resurfacing projects to reduce or eliminate instances of tearing up roadways to access below-grade water, communications, and other infrastructure.

- Manage curb space, including for pick-up/drop-off zones, loading zones, and other relevant short-term uses of curb space.

  - Microtransit services may be particularly interested in curbside space for pick-up and drop-off "station stops." Depending on demand, municipalities may consider charging for use of this space.

Regulatory Recommendations

Municipalities and transit agencies need to work toward integrating TNCs into a multimodal network that gives patrons and residents new and improved options for how to get around. Local governments can enhance shared mobility in low-income communities using incentives. In general, TNCs will prefer consistent regulations across states, or at least within distinct regions. Having to comply with multiple random municipal regulations creates challenges in providing service and decreases its potential efficiency.

The pace at which digital technology is driving change can mean that laws and regulations are continuously outdated, ineffective, or even harmful shortly after they are implemented.[512] Public policy approaches will need to be made more fluid and market based to keep up with a new normal of fast-changing economic paradigms.[513]

Build Competitive Transportation Markets

While the region is building a cooperative transportation system between public and private entities, it must also ensure that no single private provider grows so large that it monopolizes transportation services. Nothing about the future of TNCs is preordained. How cities design marketplaces—rules, regulations, and taxes—will determine if TNCs or other digital transportation providers can effectively serve an area, become monopolies, or allow for new firms to enter and disrupt established operators by offering better or more efficient options. Governments need to determine if pricing should be set by each company to compete in a market or if it should reflect social benefits or community goals.[514] Increasing vehicle travel may necessitate congestion pricing or VMT fees to reduce traffic jams. Any change in pricing mechanism should anticipate opposition. The current underpricing of transportation will make any attempt to more fully capture the cost of services look like a tax increase.[515] To design competitive transportation markets, set ground rules (such as driver certification) to assure rider safety, transparent pricing, and a level playing field:[516]

"In the long run, the social benefits of a new technology will depend in large part on whether the technology is controlled by a monopolist or is subject to dynamic competition."

- Joe Cortright

[512] Dubravac.
[513] Ibid.
[514] Fishman.
[515] Ibid.
[516] Ibid.

- Ensure that data and information about shared mobility services are freely open and available, since TNCs and other digital transportation providers use a scarce public resource: street space. This can be used to compare with other cities, make sure that consumers are getting a good deal, and deter price discrimination and other anti-competitive practices. [517]
- Encourage bidding through services similar to Kayak for airfare or eBay, with simple one-stop shopping that allows consumers to find the best deal. This would make it easier for new companies to enter the marketplace and grant more clout to consumers.[518]
- Do not create barriers to entry. Nearly any regulation will create a higher cost for small firms, which then benefits the larger, established ones. For example, if providing WAVs is restricting new entries to the TNC market, create a per-ride fee that can be paid in lieu of operating WAVs.[519] This fee can then be used to subsidize other private or public WAV operations.
    - Ensure one-time and/or annual TNC licensing fees don't price out new startups or otherwise restrict competition.
    - Create a per-ride fee option that can subsidize WAV services.
- Ensure competitive markets by avoiding exclusive agreements with singular service providers and regulatory capture.
    - Municipalities and transit operators should stipulate that multiple options be available when making deals to improve connections between transit and TNCs.[520]
    - Limit fare and compensation structures that lock consumers into a particular service. If drivers remain independent contractors, they should remain free to use any network and should be able to determine their own prices. For example, one TNC in New York City has offered rides for one cent to consumers who purchase a monthly pass. This can create a monopoly by shutting smaller competitors out from a market.[521]
- Determine where and if technology can provide customer service protections—such as driver and passenger rating information—that formerly required government oversight.[522]

Building a robust shared mobility market now can help the region be more prepared for a shared HAV future.

Equity

Equity, in this case, means that transportation operations do not unfairly burden or exclude low-income, minority, or other disadvantaged communities. There can be difficult trade-offs between protecting societal interests and not stifling innovation. States, regions, and municipalities need to ensure widespread and equitable access

[517] Cortright, "A To-Do List."
[518] Ibid.
[519] Ibid.
[520] Ibid.
[521] Ibid.
[522] Transportation Research Board.

to infrastructure and the services that traverse it.[523] Shared mobility services need to work for all people regardless of age, income, and mobility needs.[524] At the same time, building competitive transportation markets means that the network must be equitable across operators and modes and does not necessarily pick winners between individual service providers or modes of transportation.

- Guide expansion by requiring companies to serve low-income communities in return for operating rights, or alternatively, tie carsharing to use of curbside space. [525] This will ensure that vehicles or services are located in low-income neighborhoods, particularly in parts where a specified percentage lives below the poverty level.
- Develop comprehensive and collaborative approaches to reduce barriers to access and work with intermediaries to address barriers and increase demand for shared mobility.
    - Conduct research into shared mobility business models, particularly cross-sector partnerships, focusing on how to be more inclusive of low-income communities, based on real identified transportation needs of low-income populations, such as 'reverse commute' access to suburban employment.[526]
    - Employ pilot projects to test and develop comprehensive and collaborative approaches to digital transportation barrier reduction and work with intermediaries to address barriers and increase demand for shared mobility.[527]
    - Increase access for low-income individuals to jobs by subsidize to fill the gap between the ability of low-income individuals to pay for and the cost of providing TNC services;[528] and spreading awareness on the growing menu of transportation options such as ridesharing, ridesourcing, and microtransit, that combined with transit, walking, and biking reduce the need for vehicle ownership. [529]
    - Ensure that new transportation technologies and services are accessible to individuals in EJ communities and those who have disabilities, and are friendly to families with small children.
- Municipal and regional decision-making processes should more heavily weigh the benefits from investments that aid low-income and EJ communities.

Regulating Shared Mobility Companies in a Digital Age

Municipalities, DOTs, and transit agencies should welcome new transportation modes and business models, along with the innovation and entrepreneurship that develops them.[530] As TNCs and other digital transportation services are just starting up, municipalities should work with them rather than trying to compete with or ban

[523] Bollier.
[524] Shared-Use Mobility Center.
[525] Kodransky and Lewenstein.
[526] Ibid.
[527] Ibid.
[528] Kodransky and Lewenstein.
[529] Federal Highway Administration.
[530] McCutcheon, "Part 1."

them.[531] They should ensure legal status of and provide clear, consistent and reasonable regulations for TNCs to pick up passengers who have prearranged travel and cost through a smartphone app.

State regulations for TNCs are generally more concerned with establishing legality and basic operating parameters. They allow for more flexibility and less direct accountability for things such as background checks and commercial insurance that are often included in local oversight.[532] Even so, regulations should largely occur at the state level for consistency. Municipal and other governmental agency actions should focus on protecting public safety and general welfare, and promoting healthy competition. More research is needed on the cost effectiveness and efficiency of different background check and vehicle inspection systems.[533] Given what is known about the use of mobile phones while driving, more research is needed on the safety implications of TNC operations.[534] Where local actions are taken, regulators should strive for regional consistency in order to limit regulatory interference in TNC operations.

- Provide public oversight of new shared mobility services to maintain safety even while working through regulatory issues.[535]
- Clearly define the process for licensing and regulating new TNCs and other digital transportation provider operations.[536] To get started, a municipality should review existing regulatory frameworks that digital transportation providers could fall under, such as those for taxis or livery services.
    - Ensure new digital transportation services have adequate and appropriate insurance coverage.
    - Conduct high-level background checks on drivers.
    - Limit the number of hours TNC drivers can operate within a given period.
    - Regulate demand-based pricing to ensure equitable treatment of riders, if deemed necessary. Standardize pricing only if needed to ensure that no company gains a monopoly.
    - Provide safety training, or at a minimum require watching a video on safe driving, before allowing new TNC drivers on the road.
- Reduce or remove rental car taxes on carsharing.
- Government agencies and municipalities should begin to prepare for passenger and delivery UAS services.

Taxi companies' need to purchase medallions and pay for commercial insurance, tolls, and taxes puts the industry at an unfair competitive advantage compared to TNCs.[537] Medallions were created to restrict supply and ensure fair wages to drivers. This model needs to be rethought in a world of unlimited TNC vehicles. Standard economic theory suggests that price controls, location and quantity restrictions, and

[531] Joseph Stromberg, "These Startups Want to Do for Buses What Uber Did for Taxi Rides," *Vox*, July 7, 2015, http://www.vox.com/2015/7/7/8906027/microtransit-uber-buses (accessed July 21, 2015).
[532] Center for City Solutions and Applied Research.
[533] Transportation Research Board.
[534] Ibid.
[535] McCutcheon, "Part 1."
[536] *Ride-Hailing Services*.
[537] Center for City Solutions and Applied Research.

a monopolistic structure create inefficiency and poor service.[538] Taxis should retain the sole ability to be hailed from the street without the use of an app and thereby serve a different market than TNCs.

There are questions for cities that are attempting to regulate taxis.[539] What are the impacts among other modes—such as transit—while working to level the playing field?[540] If local governments are not willing or able to regulate TNCs and other digital providers, it may be better to deregulate taxis.[541] If this is the more feasible response, how much deregulation is needed?[542] How strong is the local government desire to protect or regulate taxi service in a changing economy?[543]

Regulatory requirements for taxis need to be updated to equalize those for TNCs, while maintaining passenger and driver safety to the greatest extent possible.

- Driver background checks and vehicle inspection requirements should be the same as those for TNCs.
- Regulations should allow taxis to set their fares at rates that let them compete with TNCs, and if needed increase their fares to attract more drivers during peak demand periods.
- Lessen restrictions on the ability of taxi companies to pick up passengers beyond their designated service zone.

Institutional Recommendations

Digitization and rapid innovation are driving change, and create considerable risk in any governmental investment, particularly in technology becoming obsolescent far more quickly than anyone may think possible.[544] TNCs are a part of the digital revolution and will move forward with or without governmental partners.[545] The good news is that these companies have successfully built partnerships and are working with universities, transit agencies, and cities all over the country.

The region will need flexible planning, design, procurement procedures, operations, and funding for transportation to ensure its ability to act on new technologies and other emerging trends.[546] Rather than being tied to a rigid plan or policies, organizations need to adapt to continuously changing circumstances. Governmental and agency silos need to be broken down. Local government must see itself as an enabler in the digital economy, recognizing that some of the best

"How do we leverage and harness innovation and technology to help empower people to improve their own lives?"

- Andrew Ginther

Mayor of Columbus, OH; winner of the U.S. DOT Smart Cities Challenge.

[538] Transportation Research Board.
[539] *Ride-Hailing Services*.
[540] Ibid.
[541] Ibid.
[542] Ibid.
[543] Ibid.
[544] Felix Salmon, "How Roads Could Beat Rail," *Reuters Blog*, January 24, 2013, http://blogs.reuters.com/felix-salmon/2013/01/24/how-roads-could-beat-rail/ (accessed August 10, 2015).
[545] Nisenson.
[546] Ibid.

parts of a community emerge spontaneously.[547] Transit agencies and DOTs need to see themselves as shared mobility agencies.[548]

Civic participation should borrow concepts from open-source software philosophy: make it open and modular, and avoid complex and custom units.[549] Interchangeable parts can be used to offer new and creative approaches to engagement methods that help to tame urban problems.

Data

Digital transportation technologies are creating new datasets that are essential to future planning and policy development.[550] Open data needs to be the default choice, with recognition that certain data sets will need to be restricted for privacy or proprietary purposes. What is, and is not, restricted needs to be openly discussed in more depth. In some cases, governments may find it is not worth trying to maintain every possible data set, particularly those that contain sensitive personal information that can put it at risk of hacking, and sensitive disclosure agreements. Instead, it may be better to focus on key data sets that have less of the personal data that is coveted by hackers. Data interoperability and standards must be maintained across platforms. Data itself creates a risk that everything may appear to be a technical problem with a technical solution. Municipalities should be sure to consider potential nontechnological options.

- Adopt open data and open-source software policies.[551]
- Create data agreements with private transportation operators to expand publicly accessible schedule and real-time open data for transit operations, and encourage open data and data sharing with TNCs and other private transportation companies. This must be balanced with the need to maintain personal privacy and for private companies to protect competitive information.
    - Basic data generally desired for sharing includes: when and where trips are being made, geographic service area, availability and use of WAVs, and trip mileage and duration.[552]
    - More advanced data includes: speed; volume; travel time; vehicle occupancy; non-revenue miles traveled; vehicle dwell time; number, date, and time of unfulfilled rides; number, date, and time of declined rides; number, date, and time of canceled rides; vehicle availability by type; crashes; severity of crashes; rapid acceleration (location and time); rapid deceleration (location and time); AV operation disengagement.[553]
    - Potential solutions to concerns over driver and customer privacy include: anonymizing sensitive and personal information, nondisclosure agreements with each private company that spell out what can and cannot be shared

[547] Flint.
[548] Feigon and Murphy.
[549] Bollier.
[550] *City Data Sharing Principles: Integrating New Technologies into City Streets*, (New York: National Association of City Transportation Officials, January 2017), http://nacto.org/wp-content/uploads/2017/01/NACTO-Policy-Data-Sharing-Principles.pdf.
[551] Hallock and Inglis.
[552] *Ride-Hailing Services*.
[553] *City Data Sharing Principles: Integrating New Technologies into City Streets*.

with third parties, or having an intermediary, such as a university or research institution, keep the data.[554]

- Create interdisciplinary regional or local data coordination team(s) to centralize and analyze data sets in a single, shared platform to guide decision making and enhance government programs. The teams should regularly meet to discuss and interpret the data.
    - Appoint municipal and transportation agency chief innovation officers to direct public data analytics and technology-related efforts.
    - Adjust service models using feedback loops and real-time data, and customize services for individual needs.[555]
    - Conduct more research and document the impacts of TNC regulations and other transportation investments and policies so that future decisions can be better informed by data.[556]

In nearly all instances, there will be trade-offs between data collection and sharing, and maintaining personal privacy.[557] Sensor-based data in cities, and possibly in HAVs, should be used for informing travelers and decision making, and not for enforcement or surveillance purposes.

Cybersecurity

Transportation has not been a focus of cybercriminals to date, but increasing use of connected and automated systems, along with mobile devices, could make the field more of a target in the future.[558] Increasing data in the cloud, the IoT, mobile devices, and wearable technologies all create a variety of potential hosts and networks that cybercriminals can hack into.[559] Rather than compromising entire systems, hackers today are stealthily stealing data sets through embedded spy software that tracks touch-screen fingerprint movements, eavesdrops on conversations, and uses malware to scrape point-of-sale systems.[560] For large organizations, firewalls, antivirus programs, and tool-based security programs are no longer considered to be adequate for ensuring cybersecurity.[561]

There are concerns about personal privacy in digital data collection. While privacy is possible, over-vigilance can compromise the usefulness of some data sources. Digital city policies need to build public trust, particularly for cybersecurity and personal privacy. They need to develop ethical guidelines for data use, and prevent data-profiling discrimination and/or predictive interference.

- Appoint a digital risk officer.
- Use up-to-date cybersecurity strategies. Currently, these include: testing security measures with crowdsourcing, improving mobile device protections, enterprise networks, placing smart devices inside the IoT, user interface web

[554] Ibid.
[555] Episode 2: Shared Mobility."
[556] Ibid.
[557] Dubravac.
[558] Mohaddes and Sweatman.
[559] Ibid.
[560] Ibid.
[561] Ibid.

protections, next-generation endpoint security, and cloud-based data security.[562]

- Protect passenger and customer privacy by safeguarding sensitive data and reviewing and revising open records statutes and policies to ensure personal data is kept private.

Building Partnerships

With limited funding, building successful partnerships with the private sector will be the key to getting new digital technologies in place and efficiently managing the demands placed on the transportation network.[563] Municipalities, DOTs, and transit agencies will need to seek out new business markets and partnerships that can help to enhance transportation service and infrastructure.[564] The goal of any new partnership is for all modes to operate together as one seamless network, and for both sides to be made better off as the result of the agreement.

- Incentivize the private sector, nonprofits, and PPPs to participate in infrastructure development, which can speed up project delivery and better respond to new technologies.
- Transit agencies should find opportunities to cooperate and work with TNCs and other digital transportation providers, seeking mutually beneficial partnerships.[565]
    - Start small by opening dialogue with TNCs and conducting integrated trials that can build trust and lead to wider collaboration.
    - Use new shared modes as last-mile-to-transit connectors, particularly in suburban areas. [566]
    - Partnerships can extend beyond traditional transportation and infrastructure realms, and should seek better connections with travel and tourism, goods movement, education (with a support of co-learning), and other industries.
- Encourage mobility-as-a-service opportunities to create a multimodal monthly pass or ticket options.

Partnerships could expand well beyond the traditional transportation field, into areas such as technology, energy production and distribution, education, tourism, and others.

Planning and Zoning

Develop a vision and expectations that respond to the digital revolution. Regions working with counties and municipalities need to consider what role each existing and future mode of transportation plays in a unified, multimodal network.

- Develop an economic vision for the digital age, which considers a municipality's or region's strengths, weaknesses, opportunities, and challenges.[567]

[562] Mohaddes and Sweatman.
[563] "Episode 2: Shared Mobility."
[564] McCutcheon, "Part 1."
[565] McCutcheon, "Part 2."
[566] Jaffe, "How the Microtransit Movement is Changing Urban Mobility."

- The vision should identify appropriate technology applications; address resilience, inclusivity, and productivity; and not rely on federal government assistance.[568]
- Decision-making processes may need to be reformed to include sustainability, technological development, and with a focus on advancing the vision.[569]
- Research into the future of economic growth and identify and train for the labor skills needed to participate in the digital economy.

- Integrate shared mobility into long-range transportation plans—particularly to better connect low-income communities and jobs, extend transit coverage, and find ways to better integrate new services with transit.[570] Ensure that sustainable and active transportation remains a part of the vision and is funded for implementation.

  - Increase regional funding allocation for new transportation technologies in long-range plans. These investments should aim to create smart roads and highways that can communicate with CAVs throughout Greater Philadelphia. Investments should improve access to real-time transit information and consider building regional multimodal travel applications.
  - Make transportation affordability a planning goal.[571]
  - Pay more attention to the eras and transitions that may occur in between the base year and horizon year of the plan.
  - Conceptualize a transportation planning philosophy that blends the best of digital and active transportation practices.
  - Update regional travel demand models to incorporate new ridesourcing services, the effects of real-time information, route optimization, changing costs and travel behaviors, and the impacts of other digital technologies, as well as the possibility of HAVs.
  - Complete The Circuit regional trail network and then focus on better connecting it to transit and other modes.

- Set goals and indicators to track performance and progress toward attaining them. Set targets and identify concerns about the risks of not achieving the goals. Use competitive funding to develop innovative projects and financial incentives to reward agencies for helping to achieve the vision.
- Develop expectations for equity, data sharing, and public asset use.[572]
- Revise building regulations and zoning codes to enable more density for developments that incorporate shared mobility: bikesharing, kiosks, TNC pick-up/drop-off zones, or carshare parking spaces.[573] Potential options include:

  - Reduce the number of required parking spaces in new development when shared mobility provisions or partnerships are built into the design.[574]

"If you plan cities for cars and traffic, you get cars and traffic. If you plan for people and places, you get people and places."

- Fred Kent
Founder and President,
Project for Public Spaces.

[567] David Thorpe, "Can We Design Cities that Don't Need Cars?," World Economic Forum, February 2, 2015, https://www.weforum.org/agenda/2015/02/can-we-design-cities-that-dont-need-cars/ (accessed June 27, 2016).
[568] Ibid.
[569] Ibid.
[570] Kodransky and Lewenstein.
[571] Litman, "Affordability as a Transportation Planning Objective."
[572] Nisenson.
[573] Clark.

    - Incentivize parking substitution for shared mobility space.[575]
    - Allow greater floor-area ratios for development that incorporates shared mobility or is accessible to transit.[576]
- Reduce parking minimums in zoning codes. Next City has created a crowdsourced map that has identified 93 U.S. cities (including Philadelphia and Phoenixville, Pennsylvania) that have eliminated, or are thinking about doing away with, parking minimums.
- Conduct research into best practices in digital infrastructure development and partnerships; use cross-industry dialogue to better understand equity impacts and lessons learned.[577]
- Ensure that federal/state regulations around AVs reflect and respond to the specific needs of dense, urban areas.
- Improve communication between municipalities within a metropolitan area. Smart city investments can help to build in and formalize this communication. Find ways to spread the risks and rewards of smart city investments.

Procurement

New thinking needs to be done in the procurement and research and development realms, where avoiding tech "lock-ins" will be critical.[578] Public procurement will need to be sped up in order to more quickly respond to emerging trends. Uber has had a hard time building partnerships with transit agencies when they need to respond to 300-page requests for proposals.[579] Innovation requires ongoing dialogue and flexibility to try out different potential solutions, which are not easy to spell out in advance. Conduct more experimentation and testing of short-term pilot projects to determine if a proposed solution can work before committing to major investments.[580]

- Changing technologies will require local governments and governmental agencies to purchase and maintain new equipment, such as sensors, mobile payment technologies, traffic signals, and digital signs.
- Undertake low-cost, short-term pilot projects to test out new ideas before making significant new investments in major capital projects. Use low-cost, short-term trials to gauge public response before making larger investments for permanent physical change in the built environment.

[574] Federal Highway Administration.
[575] Ibid.
[576] Ibid.
[577] McCutcheon, "Part 1."
[578] Bollier.
[579] McCutcheon, "Part 2."
[580] Bollier.

Looking to the Future

The next generation of transportation digitization will likely bring about HAVs and/or other new technologies, such as using UASs for goods delivery and passenger movement. Further study should be undertaken to identify the infrastructure implications of this transition and lead to a CV and HAV action plan. Legislation seems likely to support their deployment, particularly if they prove to be as beneficial for safety as anticipated. Initial regulations on HAV use may include vehicle and occupant licensing, reporting incidents, and restrictions on operating without passengers. Such a study should involve the public in a general discussion about how and even if this technology (and paying for it) fits into an aspirational vision for the future. Too often HAVs are presented as an end in themselves. In reality, HAVs are unlikely to be the answer to all transportation problems. Rather, HAVs need to be seen as a means to an end, which is an aspirational vision for what kind of transportation system we want to build as a society. The current vision put forth here is a safe, integrated, multimodal network that provides more options for how to get around and improves safety in doing so.

CONCLUSION

The digital revolution is reshaping the economy and unleashing new forms of creativity and entrepreneurship. For transportation, this means there will be a continual evolution of new and innovative ways to move people and goods. TNCs and other emerging digital technologies are transforming and expanding the region's transportation network and are likely to continue to drive change. While TNCs are currently the focus, MaaS, followed by HAVs and UASs, may drive the next eras. Entirely new forms of transportation could arise after that.

Achieving the region's vision of an integrated, multimodal transportation network will mean using technologies to seamlessly network all modes together. This will not successfully happen by itself. Governments must take the lead in creating a vision and forging partnerships, and ensuring its own efforts support achieving that vision. This analysis has six key takeaways:

1. **Digital transportation and new shared mobility modes offer an opportunity to build a safer, more efficient, and less costly transportation network.** New mobility services are still in their infancy, and markets are trying to figure out how to meet transportation demand in a profitable manner. MaaS—where private-market companies either directly provide multiple multimodal transportation options or partner with existing providers to deliver a variety of transportation options for a monthly subscription or payment plans—may be the next big thing in shared mobility.
2. **The regions that best leverage digitization will use careful government planning and flexible oversight of new technologies, while building partnerships with the private market and other institutions.** They will create physical and digital platforms that others can build upon and open access to data—while recognizing proprietary, cybersecurity, and privacy limitations—to enable their citizens to be problem solvers. Lack of strong public leadership risks a more fragmented, inefficient transportation network in the future.
3. **Existing transportation providers can be successful in the new digital transportation realm if they are flexible and adaptable.** They may need to reinvent themselves by finding new niches in the marketplace. They will need to understand how and why change is occuring and react to it accordingly.
4. **Funding a digital transportation network may rely more heavily on partnerships with the private market.** However, new digital technologies will make funding options, such as vehicle miles traveled (VMT) fees and congestion pricing, more feasible. Enacting new payment methods can promote new system efficiencies, while also strengthening the public role in defining new mobility.
5. **Highly automated vehicles (HAVs) are likely to be the next major transportation disruption.** While they promise many improvements, realization their benefits may require HAV-only facilities. Redesigning cities and regions around HAVs is unlikely to be a panacea that solves all transportation problems. Instead, areas

should focus on developing a full range of digital technologies that help to build network effects and agglomeration economies.

6. **Digitization reinforces the basic fundamentals of good urban design.** Competitive regions will continue to prioritize dense, mixed-use communities that limit demands on the transportation network and reduce how much infrastructure is needed to meet travel needs. Doing so requires prioritizing space efficient walking, biking, and transit trips, using active transportation engineering philosophies, and centralizing major destinations within multimodal development centers.

Over-reliance on technology alone to solve the region's transportation problems and challenges will risk exacerbating the rebound effect. Instead, solutions must also come from market principles and sound community design. Doubling down on inefficient modes of transportation, or outdated business practices, will make the region or nation less competitive in a global, digital world.

Transportation is a marketplace where individual actions are based on the types of transportation facilities that are available, how much they cost to use, what incentives have been put into place, and what is most convenient. The way we design the marketplace through rules, regulations, pricing and incentives, infrastructure provision, and technological deployment all significantly shapes the use and outcomes of the transportation network. Digital transportation is a tool we can leverage to meet the region's goals. It is a means to building a more sustainable, efficient, and affordable transportation network. The basic vision and goals set forth in the region's Long-Range Plan should continue to guide policy and investment decisions, from the design of markets to the design of infrastructure. In addition, this report identifies a series of infrastructure, regulatory, and institutional recommendations to help build the region's vision for an integrated, multimodal transportation network.

When considering our shared values and vision of what we want to happen in the region, special consideration should be given to less-well-off members of our society and future generations. There are many opportunities for Greater Philadelphia to leverage technology and institutional change to meet our goals, including: a stronger economy; a safer, more sustainable, and equitable transportation system; a more engaged citizenry; and an improved quality of life. Instead of just trying to impose independent TNCs and eventually HAVs, onto an auto-oriented platform, we should all strive to reinvent the transportation system around a new connected, multimodal paradigm. This means ensuring that an active transportation philosophy and dense, mixed-use development centers are fully incorporated and embedded into the upcoming digital transportation network era.

APPENDIX

A. Other Transportation Technologies

Beyond digital, there are some other noteworthy transportation innovations, including:

- e-bikes;
- electric vehicles;
- gondolas;
- the Hyperloop; and
- other innovations.

This section further explores each of these innovations, and their potential impacts on transportation.

E-Bikes

E-bikes have an electric motor that assists with pedaling. Even with this help, they still provide a "meaningful" amount of exercise and could possibly open bicycle-commuting to people who would have never given it any thought previously.[581] E-bikes enable people to move around at a fraction of the cost of owning a private automobile. Today's standard e- bikes cost less than 50 cents in electricity for every 100 km traveled.[582]

E-bike popularity appears to be growing. Birmingham, Alabama launched Zip bikesharing in October 2015. It is the first e-bikesharing system in the United States. The Electric Bike Report projects 152,000 e-bike sales in the United States in 2016. This figure is small compared to projected sales of 1.6 million in Western Europe. Retailers in Holland are already selling more e-bikes than regular bicycles. In addition, there will be an estimated 300 million e-bikes in China by 2030.

In addition to e-bikes, another form of electric-powered cycling has emerged. Walking bikes are essentially a treadmill on wheels. With electric assist it takes no more effort than casual walking in order to travel at the speed of regular bicycles. The Lopifit is the first commercially available walking bicycle. It moves at four times the speed of the rider's walking pace.

Electric Vehicles

Electric vehicles (EVs) are powered by an electric motor using electrical energy stored in rechargeable batteries or other storage devices (such as a hydrogen fuel cell). EVs include plug-in hybrid electric vehicles—which have a supplementary internal combustion engine—and all-electric vehicles. EVs present an opportunity to

[581] Ben Coxworth, "It's Official—E-bikes Are Still a Lot Healthier than No Bikes," *Gizmag*, July 8, 2016, http://www.gizmag.com/e-bikes-fitness/44257/ (accessed July 12, 2016).
[582] Dana Sanchez, "Beyond Bicycles: Will E-Bikes Revolutionize Transport in Africa?," *AFKInsider*, July 11, 2016, http://afkinsider.com/127447/beyond-bicycles-are-e-bikes-the-future-of-transport-in-africa/ (accessed July 12, 2016).

serve a significant portion of Greater Philadelphia's mobility needs while simultaneously reducing energy use, petroleum dependence, fueling costs, and greenhouse gas emissions. Due to regional driving characteristics, EVs have the ability to meet the needs of many area residents. On a typical day, 82 percent of all passenger vehicles in the region travel 40 miles or less, and 97 percent travel 70 miles or less—well within the driving range of most EVs currently on the road.

In addition to vehicles, the region will need to plan for electric vehicle charging infrastructure. While most charging will take place at home or at the workplace, there remains a limited need for publicly accessible charging, both for emergencies and for those—such as residents of multifamily buildings—who do not have access to a dedicated private parking space. According to the U.S. Department of Energy's Alternative Fuel Data Center, as of November 2016 there are 310 publicly accessible EV chargers in the region, 228 in the five Pennsylvania counties and 82 in the four New Jersey counties.[583] Increased EV charging has implications for the electric distribution grid.

As battery prices drop, the range of electric vehicles continues to increase while their sales price continues to decrease. EV owners praise the vehicles' performance, low operating costs, and minimal maintenance. EVs are expected to comprise approximately 2.6 percent of total new vehicle sales in the region by 2020 (just over 17,000 vehicles).[584]

Gondolas

Gondolas are an option for transportation along steep slopes or across large geographic obstacles. The Metrocable in Medellín, Columbia, has acted as a catalyst for gondola construction all over the world, including Rio de Janeiro, Caracas, and London. Estimated costs of building a gondola are between $3 million and $12 million per mile. This is much less expensive than the $400 million per mile for subway systems and $36 million per mile for light rail systems.[585] Gondolas create a connection between city districts that would not have been able to be reached by public transit. These unreachable areas are often some of the poorest areas in the city, which was the case in Medellín. The Medellín Metrocable was recognized as a key factor in its winning the Urban Land Institute's "Most Innovative City of the Year" award in 2013. Formerly dangerous, poverty-stricken neighborhoods have seen economic prosperity and renewal. The Caracas "Teleferico" project has increased economic opportunity and lowered crime rates in similar poorer, previously disconnected areas. Portland, Oregon's Goby Tram connects downtown with the city's largest employee, the Oregon Health and Science University and its

[583] U.S. Department of Energy, "Alternative Fuels Data Center," last updated November 30, 2016, http://www.afdc.energy.gov/locator/stations/ (accessed November 30, 2016).
[584] Delaware Valley Regional Planning Commission, *Ready to Roll: Southeastern Pennsylvania's Regional Electric Vehicle Action Plan* (Philadelphia: Delaware Valley Regional Planning Commission, June 2013), http://www.dvrpc.org/reports/12055B.pdf.
[585] Eoghan Macguire, "Are Gondolas the Next Big Thing in Urban Transport?," *CNN*, September 8, 2014, http://www.cnn.com/2013/09/13/business/skypods-gondolas-urban-transport/ (accessed July 12, 2016).

main campus on Marquam Hill. This commuter tram offers aerial views of the city and beyond.

Like any other form of transit, gondola stations and routes should be planned to work with economic activity and centered on dense populations to support everyday trips. Washington, DC, is currently conducting a feasibility study to build a gondola between Georgetown and Rosslyn, Virginia, over the Potomac River.[586]

The Hyperloop

Elon Musk, the CEO of Tesla and Space-X, has proposed an entirely new mode of transportation based on large vacuum tubes connecting cities and propelling a windowless metal pod through them at speeds of up to 760 mph (1,220 kph). The Hyperloop is billed as broadband for transportation. **Hyperloop One** is a test facility that will try to prove the technology works and is feasible. The 99-mile system will connect Dubai and the United Arab Emirates. The project could potentially shorten the current 1.5 hour travel time from Dubai to Abu Dhabi to just 12 minutes.

Other Innovations

Research for this report unearthed a few other interesting innovations and partnerships. These are noted here, but not explored in further depth:

- **CityCar** is a foldable (for compact parking) electric, two-passenger vehicle for use in solving first- and last-mile transit trips.[587]
- **Mobil.Punkt** stations in Bremerton, Germany, combine a transit stop with carsharing and bikesharing stands.[588] Bremerton currently has 14 of these stations, with plans for 20 more.
- **MIT's CityScope** is a physical-scale, virtual-reality model using digital Lego blocks and 3-D projections.[589] It can display information layers, such as energy consumption, solar power generation, social media, real-time traffic, and other data. Users can model and see the likely outcomes from developing new buildings, roads, and other elements.
- A 26-square-mile experimental **Smart City** will be built in New Mexico by the Center for Innovation, Testing, and Evaluation.[590] This will be the world's largest urban testing facility, built to code with schools, roads, a downtown, suburban areas, rural areas, and even an airport for a simulated population of 35,000.

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[586] Perry Stein, "D.C. Has Taken a Step to Link Georgetown and Rosslyn via Overhead Gondola," *The Washington Post*, May 28, 2015, https://www.washingtonpost.com/news/local/wp/2015/05/28/d-c-has-taken-a-step-to-link-georgetown-and-rosslyn-via-overhead-gondola/ (accessed July 5, 2016).
[587] "City Car," *Wikipedia*, last updated July 30, 2016, https://en.wikipedia.org/wiki/CityCar (accessed October 17, 2016).
[588] Amanda Kolson-Hurley, "How Bremen, Germany, Became a Car-Sharing Paradise," *The Atlantic CityLab*, December 11, 2014, http://www.citylab.com/commute/2014/12/how-bremen-germany-became-a-car-sharing-paradise/383538/ (accessed December 16, 2014).
[589] President's Council of Advisors on Science and Technology, *Technology and the Future of Cities* (Washington, DC, February 2016), https://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/pcast_cities_report___final_3_2016.pdf.
[590] Mohaddes and Sweatman.

- **OWL** is a virtual reality prototyping device that allows users to see a visualization of an imagined future or a historical look back at a location.[591] This helps urban planners get reactions and feedback.
- **PayNearMe** is a Greyhound Bus payment service which allows transactions to be conducted at local convenience stores.[592]
- **The Chicago Regional Environmental and Transportation Efficiency** program is a PPP between the U.S. Department of Transportation, Illinois Department of Transportation, Chicago Department of Transportation, Metra, Amtrak, and six privately owned freight railroads that will make infrastructure investments to freight and passenger rail lines in order to reduce regional congestion.[593]

[591] David Bollier, *The City as Platform: How Digital Networks are Changing Urban Life and Governance* (Washington, DC: The Aspen Institute, 2016), http://csreports.aspeninstitute.org/documents/CityAsPlatform.pdf.
[592] Transportation Research Board, *Special Report 319: Between Public and Private Mobility: Examining the Rise of Technology-Enabled Transportation Services* (Washington, DC: Transportation Research Board of the National Academies, 2015), http://www.trb.org/main/blurbs/173511.aspx.
[593] Nicole DuPuis, Cooper Martin, and Brooks Rainwater, *City of the Future: Technology and Mobility* (Washington, DC: National League of Cities, 2015).

B. ACRONYMS

AAA	American Automobile Association
AI	Artificial Intelligence
ATC	Air traffic control
AV	Automated vehicle
CAFE	Corporate average fuel economy
CAV	Connected and automated vehicle
CPUC	California Public Utilities Commission
DOT	Department of Transportation
DSRC	Dedicated short-range communications
EV	Electric vehicle
EJ	Environmental Justice
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
GPS	Global positioning system
IoT	Internet of Things
ITS	Intelligent Transportation System
LiDAR	Light detection and ranging
MaaS	Mobility as a Service
NHTSA	National Highway and Traffic Safety Administration
NPRM	Notice of proposed rulemaking
PPP	Public-private partnership
SCCL	Smart, connected community for learning
TNC	Transportation network company
UAS	Unmanned aerial system
V-2-I	Vehicle-to-infrastructure
V-2-V	Vehicle-to-vehicle
VMD	Vehicle miles driven
VMT	Vehicle miles traveled
VTOL	Vertical take-off and landing

ABSTRACT

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The nine-county DVRPC region, which covers the counties of Bucks, Chester, Delaware, Montgomery, and Philadelphia in Pennsylvania; and Burlington, Camden, Gloucester, and Mercer counties in New Jersey.

Key Words:

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Abstract:

Networking Transportation looks at how the digital revolution is changing Greater Philadelphia's transportation system. It recognizes several key digital transportation technologies: Artificial Intelligence, Big Data, connected and automated vehicles, digital mapping, Intelligent Transportation Systems, the Internet of Things, smart cities, real-time information, transportation network companies (TNCs), unmanned aerial systems, and virtual communications. It focuses particularly on key issues surrounding TNCs. It identifies TNCs currently operating in Greater Philadelphia and reviews some of the more innovative services around the world. It presents four alternative future scenarios for their growth: Filling a Niche, A Tale of Two Regions, TNCs Take Off, and Moore Growth. It then creates a future vision for an integrated, multimodal transportation network and identifies infrastructure needs, institutional reforms, and regulatory recommendations intended to help bring about this vision.

Staff Contact:

Brett Fusco
Assistant Manager, Long-Range Planning
Phone: (215) 238-2937
Email: bfusco@dvrpc.org

190 N. Independence Mall West, 8th Floor
Philadelphia, PA 19106-1520
Phone: (215) 592-1800
Fax: (215) 592-9125
Web: www.dvrpc.org

DELAWARE VALLEY
dvrpc
REGIONAL
PLANNING COMMISSION

190 N Independence Mall West
8th Floor
Philadelphia, PA 19106-1520
215-592-1800
www.dvrpc.org