Future Trends and Forecasting

City of Cambridge New Mobility Blueprint

January, 2020

ARCADIS Design & Consultancy for natural and built assets

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Contents

Acronyms & Abbreviations

AV – Autonomous Vehicle

BMT – Bike Miles Traveled

EV – Electric Vehicle

ICE – Internal Combustion Engine

MaaS – Mobility as a Service

MPO – Metropolitan Planning Organization

PTDM – Parking and Transportation Demand Management

RHV – Ride-hail vehicle

SOV – Single Occupancy Vehicle

TDM – Transportation Demand Management

TMT – Transit Miles Traveled

VMT – Vehicle Miles Traveled

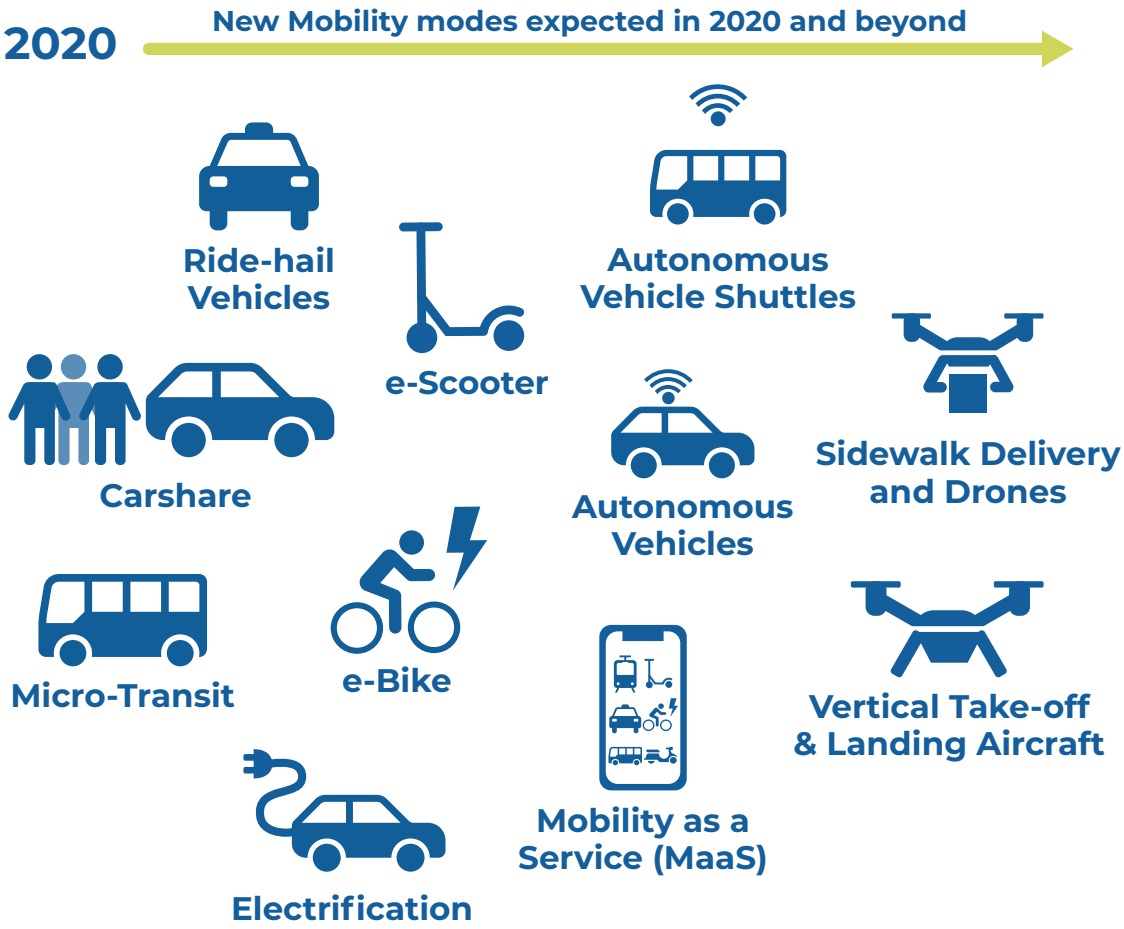
VTOL – Vertical Take Off and Landing Machine

WMT – Walking Miles Traveled

Executive Summary

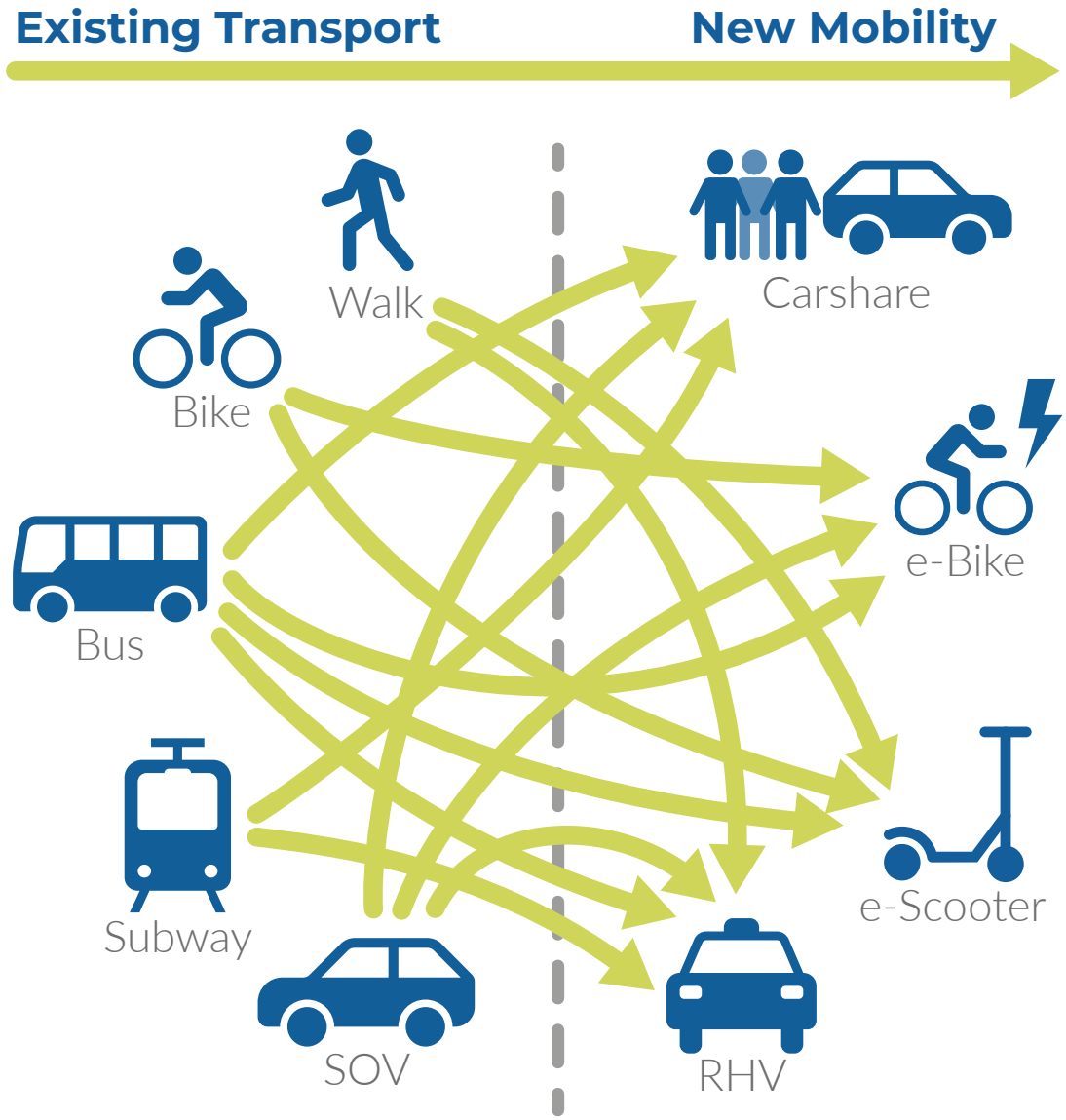
New Mobility, which includes a variety of transportation methods like ride-hail vehicles, e-scooters, e-bikes, and carsharing, is fast growing and evolving. It has increasingly changed the way residents and workers in Cambridge and throughout the region travel. The number of companies making, selling, or renting New Mobility technologies or devices continues to increase, and private sector investment continues to bring new technologies to the market. In the next ten years, more New Mobility technologies such as robotic delivery services, aerial drones, vertical take-off and landing (VTOL) vehicles, autonomous vehicles, and shared robo-taxis (autonomous vehicle taxi services) may be on streets in cities across the US.

While not all of these technologies currently exist in Cambridge, it is likely they may arrive in the near future. This will set the stage for continuing changes in the way that Cambridge residents and workers travel in the city. **The timeline of this forecast is from now through 2035 and onwards.** More imminent and/or longer term forecasts are specified as such.



As New Mobility options become available, more Cambridge residents and workers may choose these instead of existing methods. The chart below shows our estimations for likely shifts between different modes of travel. In addition to ridership shifts, it is likely that each new mode will also create new demand, as riders discover new uses. Ultimately, shifting

is difficult to predict, as it depends on many complex factors. However, it will impact how often people travel by current methods of transportation.



The chart above shows likely ridership shifts amongst new and established modes.

Impact on Current Transportation

As it grows in use and popularity, New Mobility will impact the use of existing transportation. However, we expect existing methods of transportation to remain popular due in part to the city's strong walking, biking, and transit culture as well as its willingness and track record of making transportation policy that aligns with its goals.

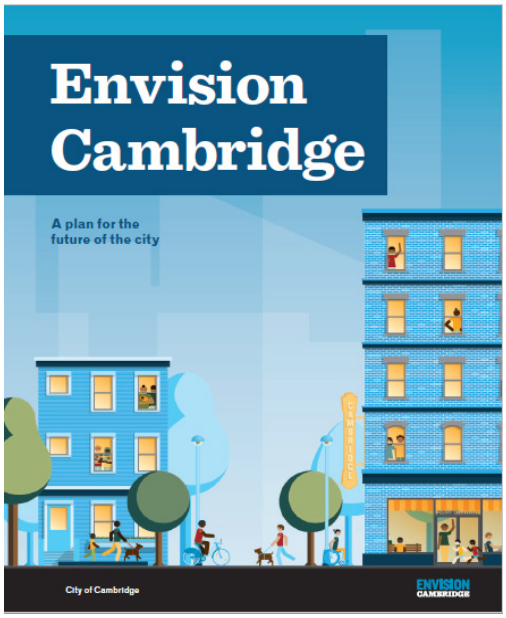
1. Purpose of Report

The goal of the New Mobility Blueprint is to develop concrete recommendations for policy, programs, and regulations that will help the City implement New Mobility options in a way that aligns with and advances existing City values and policies.

The goal of this report, Future Trends and Forecasting, is to better understand the potential impacts of New Mobility on the City's transportation system. By understanding likely changes, the City will have an opportunity to better prepare for the future. Results of this report will inform policy recommendations in a future report entitled The New Mobility Blueprint.

2. Cambridge Goals

Cambridge is a forward-thinking, welcoming, and diverse city. In 2019, the City released its citywide plan, Envision Cambridge - the culmination of a three-year planning and public engagement process. The citywide plan provides a blueprint for the city's growth and changes through 2030, incorporating the City's core values and shared vision to make Cambridge a sustainable, inclusive, and connected community for generations to come.



The Envision Cambridge plan recommends 55 strategies and 183 new, expanded, or modified actions related to six primary planning topics: climate and environment, community wellbeing, economy, housing, mobility, and urban form. The City of Cambridge New Mobility Blueprint is specifically focused on the Mobility goals and Climate and Environment goals.

Envision Cambridge: Mobility

Universal access to safe, reliable, efficient, and sustainable transportation is key to building

an inclusive economy, reducing greenhouse gas emissions, improving public health, and creating a high quality of life for all people in Cambridge. The City's mobility policies have restrained the growth of automobile traffic, despite significant population growth locally and regionally. Yet the city's transportation systems will need to adapt over time as the region continues to grow, technology advances, and the economy changes. Cambridge aims to address these challenges by upgrading, expanding connections to regional sustainable transportation, and advocating for creative transportation policies across the region.

Envision Cambridge Goals

- **Equity and Accessibility**: Ensure a diverse set of travel options that meet the access and mobility needs of people of all ages, abilities, and incomes.
- **Reliability and Efficiency**: Ensure people and goods can reliably move within Cambridge and around the region, and encourage space-efficient transportation choices like walking, biking, transit, and carpooling.
- **Safe and Active Transportation**: Eliminate traffic fatalities and serious injuries while encouraging active living and improving comfort for people of all ages and abilities.
- **Connectedness and User-Friendliness**: Create an easy-to-understand, integrated, continuous, and comfortable transportation network for all people.
- **Community Character and Vitality**: Ensure that the city's transportation system supports shared community spaces and enhances neighborhood streets.
- **Climate Mitigation and Resilience**: Achieve a carbon-neutral transportation system and adapt to climate change.

Envision Cambridge: Climate and Environment

The City is working to enhance environmental quality for all and decrease its impact on the climate. As the impacts of climate change become more apparent, the City must contend with the increased risk of flooding and extreme heat. These risks come from environmental changes, and social and economic factors will affect who is most impacted. While Cambridge works to address these issues, the task is more complicated by aging buildings and infrastructure, our regional role in driving economic growth, and the need for more regional and global coordination.

Cambridge understands connections between energy use, stewardship of natural resources, limiting the effects of extreme weather, and the health and wellbeing of its people. The City actively develops green infrastructure, sets environmental regulations, and favors action to create a sustainable environment for all.

Relevant Goals

- **Climate Action**: Achieve carbon neutrality by 2050.
- **Environmental Justice**: Ensure that all Cambridge residents are protected from environmental impacts and benefit equally from environmental resources.

3. Cambridge Transportation Today

With roughly 113,000 residents located within a 6.4-square-mile area, Cambridge is a unique city with a strong mix of cultural, demographic and social diversity. It is also an important transportation hub and connection within the greater Boston metropolitan region, which has roughly 5 million residents. Transportation planning in Cambridge is therefore directly linked to the movement of people entering, leaving, and passing through Cambridge every day. Approximately 3/4 of all trips within Cambridge start or end outside of city limits..

Trips within Cambridge are not just about commuting to work or school. Eighty percent of trips across all types of transportation options, or modes, are non-commuting. These trips could be for recreation, shopping, medical appointments, dining out, etc.

Transportation in Cambridge is also about more than just the movement of people. Cambridge has significant commercial activity, including package delivery or home improvement worker services, such as plumbing and electrical trades. Data on the number of trips and miles traveled by private delivery services is not available, but data from other cities and Boston regional estimates indicate commercial vehicles account for approximately 10 percent of miles

3/4
of all transportation within Cambridge starts or ends outside of the city limits

traveled every day. These factors were top of mind during the New Mobility Blueprint forecasting. The initial forecasting baseline was based on a review of available transportation data for the City of Cambridge. The snapshot was limited by available data sources, and certain types of activity like commercial vehicles do not have measurable data.

The following table summarizes this snapshot. The full document summarizing existing trends is entitled Cambridge New Mobility Blueprint Trends Assessment, July 2019. The trends assessment had two primary goals: (1) to determine a review of Cambridge transportation today; and (2) to identify ridership and usage trends that might impact forecasting.

Cambridge Trends Snapshot (2008 -2019)

Modes	Current Trends	Notes
Walking	↑	Cambridge ranks 1st among 178 medium-sized cities in the US for the number of residents who walk to work.
Biking	↑	The Cambridge workforce ranks 4th among 178 medium-sized cities in the US for the percentage of the workforce that commutes by bike. Bike commuting represents just 20% of overall bike trips in Cambridge.
Micromobility	↑	Privately owned scooters and electric skateboards appear to be increasing in use, although the data is limited.
Transit	→	Both bus and subway ridership are declining overall, though rush hour trips on the subway have remained mostly flat.
RHV	↑	Ride-hail vehicle trips have been growing significantly. Cambridge has the highest number of trips per capita in Massachusetts.
EV	↑	Electric Vehicle adoption in Cambridge is growing faster than in Middlesex County and the State of Massachusetts, overall.
All Vehicle Trips	↑	With an increase in population, the total number of vehicles owned by Cambridge residents will also grow. As job opportunities in Cambridge increase, it's likely that employees from surrounding communities will drive to work, increasing the overall number of vehicles on the road.
Vehicles per Households	↓	While the total number of cars owned in Cambridge is growing slowly due to housing construction, the number of cars per household is trending downward.

The snapshot relied on datasets including the American Community Survey (ACS), data from the City of Cambridge, anonymized GPS data, and others. A fuller discussion of trends is available online at:

https://www.cambridgema.gov/CDD/Projects/Transportation/~/media/E4A1EFA8FAC143C6A19F748A8C787E51.ashx

3.1 Daily Baseline Trips and Distances

The number of trips and the miles traveled for the main methods of transportation in Cambridge were used to create a baseline for forecasting. Walking Miles Traveled (WMT) and Bike Miles Traveled (BMT) were calculated using a combination of bike and pedestrian count data (TIS data) and cell phone data, which were combined to estimate citywide patterns. A detailed methodology can be found in the appendix.

Daily Baseline Trips in Cambridge

Walking Miles Traveled
270,600 trips
190,000 miles

Transit Miles Traveled
170,000 trips
510,000 miles*

Bike Miles Traveled
40,600 trips
24,500 miles

Vehicle Miles Traveled**
226,000 trips
1,236,000 miles

* Transit travel assumes an approximate trip distance of 3 miles per trip which is the average bus and subway trip in the MBTA area.
** Average Daily Vehicle Miles Traveled is based on estimates by the Boston Region Metropolitan Planning Organization and does not include public bus miles traveled.

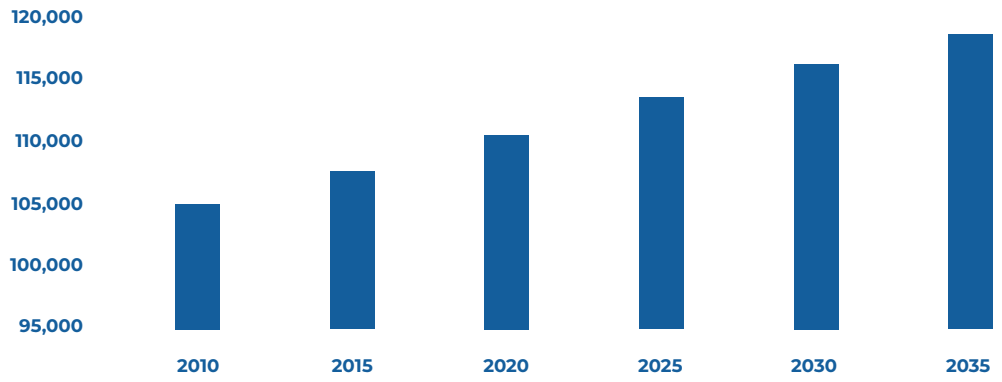
3.2 General Trends

Forecasting the impacts of New Mobility relies on monitoring general trends within the City of Cambridge. For example, the City's increasing resident population and workforce (both of which are reviewed at length below) might influence traffic patterns and create more congestion, adversely affecting modes like driving and buses. However, it might also result in more cyclists, making it safer to bike. The following paragraphs describe major trends that will influence New Mobility and existing transportation in Cambridge.

Demographics (Residents)

According to state-level planning research, which is based on regional growth patterns rather than Cambridge-specific conditions, the population in Greater Boston is expected to grow steadily, between 0.4 to 1% per year. In Cambridge, the population growth is expected to be similar, as shown in the figure below.

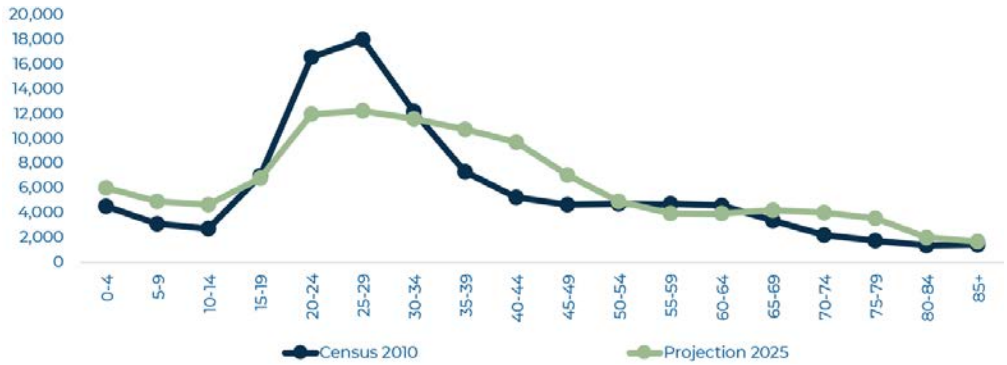
City of Cambridge Population Growth



Source: http://pep.donahue-institute.org/

In addition, state-level planning research suggested there will be a slight increase in the number of young residents (i.e. less than 25 years of age), coupled with a shift from the 20-30 age group to the 40-50 age group.

Population by Age, Cambridge, MA, 2010 & 2025



Source: http://pep.donahue-institute.org/

Employment

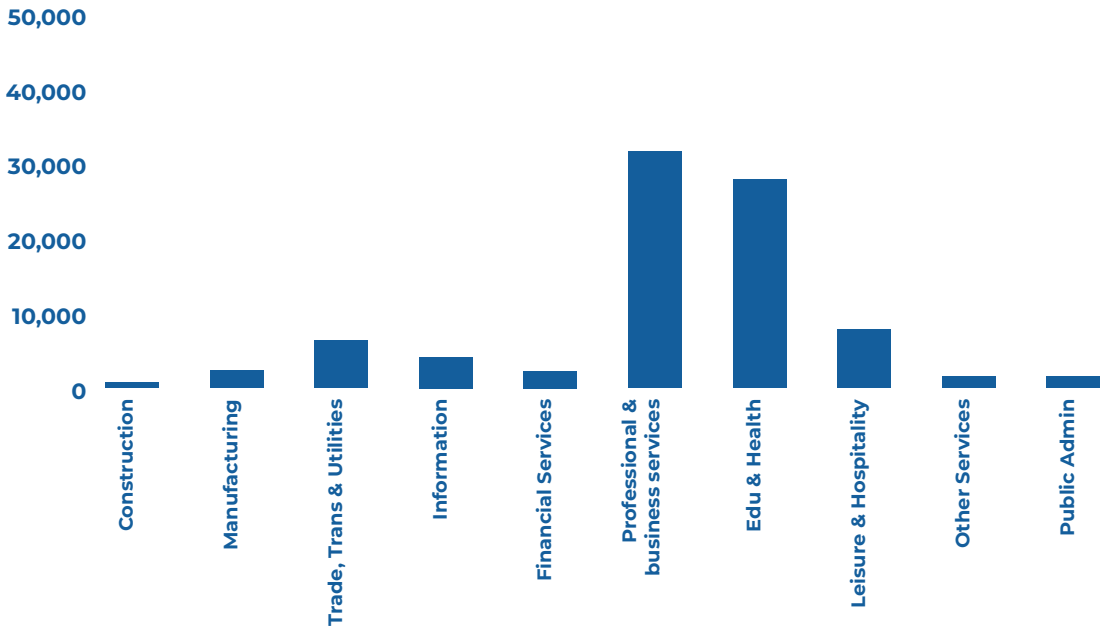
According to state-wide data, the overall employment and number of businesses in the greater Boston region will increase by about 50,000 jobs from 2016 to 2026, as shown in the graph below.

Job Growth: Boston Metropolitan Region

Source: Massachusetts Executive Office of Labor and Workforce Development (EOLWD) http://lmi2.detma.org/Lmi/projections.asp#Long-Term%20Occupational%20Projections

As of 2018, Professional and Business Services represents the largest employment sector in Cambridge. Professional and Business Services is a United States Bureau of Labor Statistics classification that includes employment in biotechnology and life sciences, high technology and consulting, all significant employers in Cambridge. The City also has a significant number of jobs in Education and Health.

Cambridge Employment by Job Sector



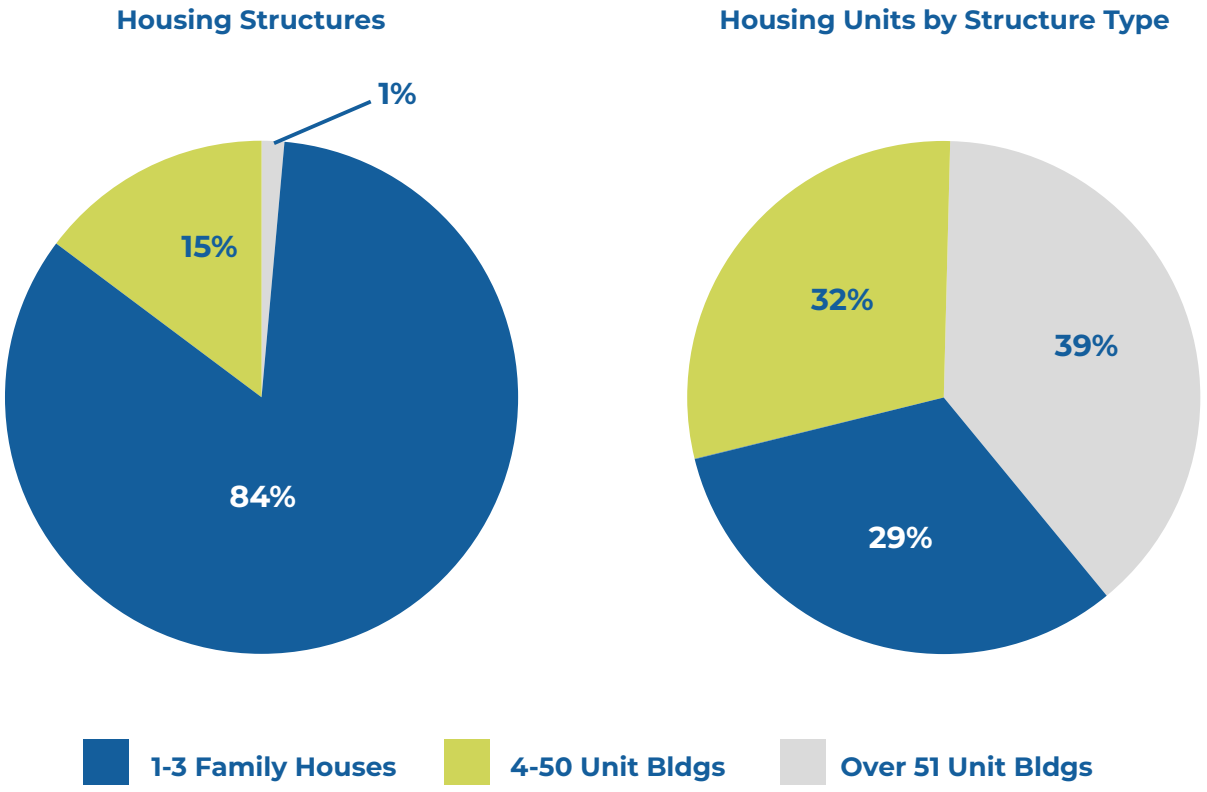
Source: https://data.cambridgema.gov/Economic-Development/Workforce-By-Industry-2001-2018/cmjx-t9pi/data

According to a 2016 report[1] from the City, 22% of Cambridge's workforce lives within the City of Cambridge. 49% of the workforce lives in the "Inner Core"[2] of the Boston Metropolitan region (but outside Cambridge), with 15% living in Boston. 24% reside in the greater Boston Metropolitan region[3], with the remaining 6% or so residing elsewhere in Massachusetts, in New Hampshire and in Rhode Island.

Housing

There are at least 15 current or future development projects that have broken ground or are scheduled to begin construction soon, according to City data. The large majority of housing structures in the City is 1- to 3-family homes, though housing units are relatively evenly split between all building types.

Housing Units & Housing Stock by Structure Type: 2016



https://www.cambridgema.gov/~/media/Files/CDD/FactsandMaps/profiles/demo_profile_housing_2016.ashx

1 https://www.cambridgema.gov/~/media/Files/CDD/FactsandMaps/profiles/demo_moving_forward_2016.pdf?la=en
2 The 21 cities and towns comprising the center of the metropolitan Boston area as defined by MAPC; this includes Boston and Cambridge."
3 The Metropolitan area is defined as Metro North, "The cluster of towns along the northern Massachusetts coastline between Boston and New Hampshire.", Metro West, "The cluster of towns west of Boston and east of Worcester, Massachusetts." and Metro South, "The cluster of towns south of Boston in Massachusetts' Southeastern region, including towns along the South shore and the Cape and Islands

4. Forecasting Methodology

The goal of forecasting is to provide a ballpark prediction for the likelihood of changes to come. New Mobility technologies like ride-hailing have already changed how people travel in Cambridge. Emerging New Mobility like e-bikes, e-scooters, e-skateboards and mopeds appear poised to further change travel patterns. It is these technologies, and other expected new ones, that will be forecast.

The forecast methodology is a 3-step process. First, a list of current and potential future New Mobility technologies was assembled in the "future trends." This list was based on the experience of project team Arcadis and Sam Schwartz, which is currently working in more than 20 different cities across the US on New Mobility policy. The list reflects a scan of the market in 2019, but it is understood this is a rapidly evolving market and it is very likely that in a few years a new cluster of New Mobility technologies will show up in US cities.

Second, a semi-qualitative short-term (i.e., in approximately 5 years) projection of the growth of each of these New Mobility technologies was made. The projection was based on low + (0-10 percent), medium ++ (10 – 20 percent), and high +++ (20-30 percent) growth from the current year, and was based on judgement considering the different "pressures" that might affect the specific technology. A list of pressures is included for each New Mobility technology. Also, a "forecast wild cards" section was included to highlight some of the more significant unknowns that could affect the adoption of each New Mobility technology.

Third, a slider scale that reflects whether a mode's introduction will be positive, negative, or neutral relative to City goals, assuming a scenario in which the City does not regulate the mode's introduction.

Forecasting is as much an art as it is a science. While each mode's forecast is based on actual current transportation trends, they represent just one future possibility, not a guaranteed outcome. These forecasts are meant to be a starting point for discussion about policies that will get us to our ideal future. The City will use this exercise to help prioritize new transportation policy.

5. Future Trends

The following sections present forecasting results for emerging, new, and future modes of transportation within the City of Cambridge.

5.1 Ride-hail vehicles

Forecast Summary

RHV companies have taken advantage of and complicated preexisting trends in which fewer young people are driving. These demographic shifts have contributed to RHV companies' success. Assuming the continuation of current levels of service and trends, and that RHV companies continue to subsidize the cost of their rides, we expect that ridership will continue to increase. However, increasing traffic congestion (ultimately caused in part by the companies themselves) could make RHVs less attractive, as could any move to end subsidies that would increase the cost of a ride. The State of Massachusetts is also contemplating imposing new fees on ride-hail companies, which might be passed on to riders and could also increase fares. So far, RHVs have not faced any competition from other modes. It's possible that new modes like e-bikes and e-scooters, both of which are useful at trip distances comparable to that of a typical ride-hail trip, could compete for ridership. However, ride-hail companies are aware of the comparable trip distances and are investing in those services to ensure they capture revenue from potentially competitive modes.

Ride-hail vehicles	
Forecast Change	**Forecast Community Impact**
+++	

Each "+" represents an approximate 10 percent increase in trip activity.

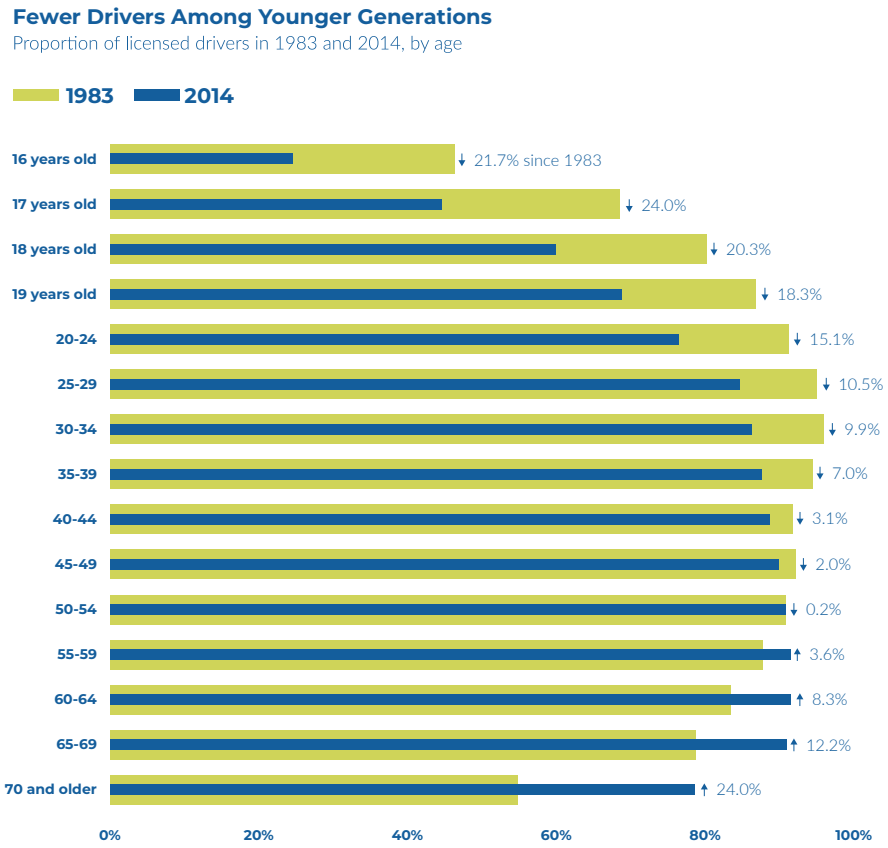
Forecast Wild Cards

The RHV companies' struggles to become profitable could ultimately become a wild card in terms of how they offer their services. Any change in cost will affect consumers' thoughts on service value. Regulation could also impact RHVs value and attractiveness for consumers: regulations that cap the number of RHVs in the Greater Boston area could impact pricing and vehicle availability. However, fewer RHVs could also mean less congestion and faster trips. If the State passes a labor protection law, in which the companies' drivers are considered employees, the cost of a ride could increase. If the companies are someday subject to accessible vehicle requirements and ADA compliance, like local taxis, the cost of RHV rides will also increase. If RHVs embrace autonomous vehicle technology, and that technology is available sooner than expected, RHV rides could become cheaper and more attractive.

Pressures and Trends

Demographic Impacts

The number of licensed drivers has declined dramatically since the early 1980's, especially among people between the ages of 15 and 29. This shift has led to other modes becoming more popular particularly ride-hail vehicles.



Source: University of Michigan Transportation Research Institute
Credit: Katie Park/NPR

Policy

Municipalities in Massachusetts do not have the authority to regulate ride-hail company services on local roads. There is no policy that guides or restricts ride-hail vehicle activities in Cambridge, the greater Boston region, or in Massachusetts at large. The City is reportedly working with the local taxi industry and other interested parties to draft a home rule petition that the City Council could submit to the state Legislature, giving the City the ability to regulate RHV companies.[4]

Relevant Policies

- State of Massachusetts Utilities Commission: TNC Regulations

Market

Ride-hail vehicles continue to grow at a tremendous pace in Cambridge, increasing 15% from 2017 to 2018, for a total of 7,827,584 rides in 2018[5]. However, despite growth, the companies themselves are facing pressure to reach profitability; this pressure might ultimately force them to change their business model, and their subsidization of rides. If that does happen, it will alter the landscape in terms of competition.

4 https://cambridge.wickedlocal.com/news/20190612/cambridge-looks-to-create-its-own-tnc-regulations
5 https://tnc.sites.digital.mass.gov/

Technology

Ride-hail vehicles were enabled by developments in GPS and smartphone technology. However, their technology has not evolved significantly since launching. At this point, it is their business models and suite of services that are most likely to evolve. As these companies strive to grow and find profitability, they are considering new technology in terms of modes of travel, or delivery of services, but not in terms of their ride-hail vehicle practice. Autonomous vehicles appear to be on the distant horizon but would represent the most significant opportunity to change their operation and services.

Infrastructure

According to a 2018 data report on Transportation Network Company (TNC --another name for ride-hail vehicles) usage by the State of Massachusetts, there were about 81.3 million TNC rides in 2018 across the state, representing a 25% increase from 2017. The largest increases in numbers of rides from 2017 to 2018 happened in Boston, Cambridge, and Somerville. However, many smaller towns with smaller numbers of rides saw a much larger percentage increase in rides when compared to 2017 ridership. Population density, which was once considered a main attractor for RHV usage, appears to no longer be a necessary factor. In fact, according to research by the City of New York, urban density might actually slow RHV ridership and growth, as RHVs become less attractive with increased congestion, which create mixed incentives for RHV users. If traffic congestion becomes so severe that RHVs are no longer a quicker option but take equal time and cost more, it's possible the riders will begin to turn to other means of travel.

Mode Shift

RHV trips and market share continue to grow. Recent impediments to RHV growth have arrived in the form of regulatory actions, but not from competition with other modes. Even with recent regulatory efforts in cities like New York and elsewhere, it remains to be seen whether decreases in ride-hailing following the passage of legislation are just temporary, standard seasonal variations.[6]

The RHV companies themselves are aware of potential modal competition and are striving to enhance accessibility through their apps. An article published by NASDAQ in advance of Uber's IPO sheds light on the company's real competitors: not other modes, but other RHV operators.[7]

Opportunities (Reasons to Support)

RHVs have become an important part of the way that people navigate Cambridge. The mere fact that RHVs serve such a significant portion of the population is reason enough to support their functioning in some form; if these services suddenly became unavailable, many people would have to seek alternative means of travel. RHVs offer door-to-door opportunities for travel by the elderly and mobility challenged, as well as the general population. RHVs, if used for shared rides and in place of privately owned vehicles, could contribute to a net decrease in congestion. Shared RHV offer the best of the technology,

6 https://www.bloomberg.com/news/articles/2019-07-15/uber-lyft-ride-totals-in-new-york-city-slow-as-fares-increase
7 http://www.nasdaq.com/article/who-are-ubers-biggest-competitors-cm860923

opening up door-to-door opportunities for riders and filling transit gaps, while also reducing traffic and promoting sustainable travel behavior.

Challenges (Reasons to Limit)

RHVs have upended the way that people get around, and in so doing have increased traffic congestion, as well as vehicle emissions and vehicle miles traveled. The vast majority of RHV miles traveled are between trips without any passengers. RHV companies have substituted for trips that would have otherwise been taken by transit and increased unequal provision of services—low income populations can't use RHV services to the extent that middle- and high-income individuals can[8]. Buses get stuck in traffic caused by ride-hail vehicles. As more people abandon public transit, the more the City and State will have to support it in order to maintain levels of service, or otherwise risk a spiral of diminishing service and ridership. RHVs are also not necessarily ADA compliant, which is discriminatory and limiting for people with disabilities that impact navigation.

RHV vehicles are creating additional obstacles by blocking access to crosswalks and bike lanes. They have been responsible for numerous bike crashes through "doorings," where cyclists crash into RHV car doors that are unexpectedly opened into bike lanes. RHV pick-up and drop-off behaviors are currently unsafe.

8 *https://www.mapc.org/planning101/report-release-fare-choices-on-ride-hailing-in-metro-boston/*

5.2 Micromobility

Micromobility includes e-scooters, e-bikes, e-skateboards, and mopeds, as well as other emerging personal, motorized devices, that are part of shared docked or dockless fleets, or individually owned.

Forecast Summary

The use of micromobility, such as e-scooters, e-skateboards, e-unicycles, and other light, electric devices that might be available on the market in coming years, will likely continue to grow. According to a report by McKinsey & Company, micromobility start-ups have raised more than $5.7 billion since 2015. The market has attracted a strong customer base more than 2 to 3 times faster than either carsharing or ride-hailing. Many of the companies are still seeking profitability and it remains to be seen whether their initial success is durable, but it appears likely that micromobility as a sector will only continue to grow in popularity and use. Expansion has been driven by adoption in primarily urban environments with residents already accustomed to New Mobility business models like carsharing, ridesharing and ride-hailing. Compared to other New Mobility, micromobility leads to quicker returns on investment. Whereas carsharing, for example, requires significant capital to start up, and then more rides per vehicle to profit on the initial investment, e-scooters and e-bikes make more money, faster, after fleets launch. The combination of user demand and massive investments into the industry seem guaranteed to grow micromobility use and popularity in coming years.[9]

Micromobility	
Forecast Change	**Forecast Community Impact**
+++	

Each "+" represents an approximate 10 percent increase in trip activity.

Forecast Wild Cards

The growth of micromobility is affected by a variety of wild cards given that the market is new and still developing, both in terms of technology and business model. Their recent arrival means that it remains to be seen whether adoption is just a fad. The City's ultimate regulatory framework for the technology is also still developing. In other cities, municipalities have significantly restricted or banned them outright in response to concerns about safety and maintaining order on sidewalks. For example, the City of Nashville banned all scooter companies following a crash involving an e-scooter user. However, if cities fully permit e-scooter and shared moped fleets to operate, they will help the services become established. On the other hand, if cities restrict their general use, or limit the eligible population in response to safety concerns (i.e. they enact licensing requirements for each rider), it will restrict their growth. Or the City might decide to enforce different kinds of industry requirements, for example, by creating specific parking zones, thus eliminating the

9 https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/micromobilitys-15000-mile-checkup

dockless nature of the fleets.

Pressures and Trends

Demographic Impacts

Population growth for key age groups in Cambridge, especially those younger and middle-aged, will continue to drive the popularity of these technologies. It's possible that, provided there is increasing comfort with any of these devices, older populations might also increase adoption. However, e-scooters, e-skateboards, and e-unicycles all require physical strength and balance that might be restrictive for certain populations and age groups.

Policy

Micromobility fleets aren't currently allowed in the City of Cambridge. The e-scooter fleets that have launched around the country, for example, do not meet the current standards for scooter operation as specified by Massachusetts state law, though changes to vehicle requirements are under discussion. Currently, scooters are only street-legal if they have brake lights and directional lights, and are only legally permitted to operate during daylight hours. The City is developing a common approach to permitting shared micromobility systems with regional partners in Boston, Somerville, Brookline, and Watertown through its coordination with the MAPC. Micromobility falls in a grey area policy-wise in terms of ridership. There is currently no clear agreed-upon guidance on the how/where these modes should be ridden: is it appropriate to ride an e-scooter in the bike lane, or are the vehicles not suitable for riding on city streets at all? If e-scooter users are instead encouraged to ride on sidewalks, what is the impact on pedestrian safety? Is it even possible to allow scooters in the streets, or does that present an unsafe condition? Should e-scooter riding be permitted on City sidewalks? Should there be designated areas for e-scooter parking? How can Cambridge design policy to ensure safety for riders, road users and pedestrians alike?

Relevant Policies

- Massachusetts State Law for Scooters and Personal Devices

Market

The market for micromobility is large and growing, including fleet operators like Bird and Lime, as well as a growing number of manufacturers selling personal micromobility devices. Given significant interest and investor capital, as well as fast improving battery technology, it's likely that the micromobility market will evolve significantly in the near future. Furthermore, given how new most of the devices are, their uses and users are still changing and evolving along with the technology itself. City policy and guidance is also still developing, which will ultimately influence the devices' popularity.

Technology

Micromobility, defined at its most basic as a manually powered device enhanced by the addition of a small motor, has existed in some form or another for quite some time. However, for the first time its current form is also viable for long-range travel. Battery technology has expanded how far people can travel on a single charge, making it possible

to navigate urban environments for long periods and longer distances. This, in combination with smart phone and GPS technology, has made dockless fleets possible. Technology continues to improve in both areas.

Infrastructure

There is little infrastructure for micromobility in Cambridge. Elsewhere, where micromobility fleets exist, they are usually dockless, with scooters, mopeds, and e-bikes simply left at their riders' destination point. There is a growing market for micromobility-focused infrastructure, including parking structures that are comparable to docked bike stations that charge the devices while they're parked. Some cities have also designated "corrals," or select areas either in the street or on sidewalks where e-scooters can be picked up or dropped off.

Mode Shift

Micromobility has the potential to shift ridership from other modes, based on how expensive a trip is, how long it takes and how far the destination. E-scooter trips, tend on average to be comparable in distance to walking, and it's possible that some portion of walking trips will shift to scooters. Given the recent emergence of micromobility, it's still unclear how popular they will become and how people will use them. It also remains to be seen whether these devices will act as pure ridership substitutes, or if they might in fact complement and support existing modes, like public transit. Finally, it seems likely that there will be mode shift amongst the various micromobility options as they continue improving their technology and competing with one another for market niches.

Potential Pros	Potential Cons
Substitute for RHV & SOV trips	Inhibit sidewalk movement for people with disabilities
Improved comfort and familiarity with micromobility modes	Substitute for sustainable modes like pedal-powered biking, walking, or transit
Improved connectivity for people lacking transit access	Cause tension to introduce motorized vehicles and higher speeds in bike lanes
First-mile/last-mile access to transit	Beginners can ride unpredictably; hard for other road users to anticipate rider movement and behavior; likelihood of crashes
Creates "critical mass" demand for non-auto infrastructure as usage increases	Generate new energy demands

Opportunities (Reasons to Support)

Micromobility is a potential substitute for auto trips by RHV or private SOV, and could help the City achieve its goal of reducing SOV trips. Devices could be a low-cost solution to improve connectivity for residents who are otherwise disconnected from transit as an origin-to-destination vehicle, or as a first-mile/last-mile connection to the T and buses. They could also help create more demand for non-auto infrastructure as usage increases, and make traveling by bike safer in the process.

Challenges (Reasons to Limit)

The possibility of widespread use of micromobility devices raises questions about safety, equipment sustainability, and equity. The extent to which shared micromobility fleets or the growing private ownership of these devices will benefit the City and its residents is still unclear. The key question is this: will these modes help achieve City goals, or impede them? If shared micromobility becomes expensive, lower income groups won't share in the benefits; if scooters are left on the sidewalks and in public spaces, they could impede movement by people with disabilities that impact navigation; and if micromobility doesn't account for mobility-impaired people by design, people won't necessarily benefit from this new mode. The ultimate impact will largely depend on how the City sets policy for operating regulations.

5.3 Carsharing

Carsharing services rent cars for hourly rates for as little as an hour at a time. In Cambridge, there are carsharing fleets and peer-to-peer models in operation.

Forecast Summary

Market forecasts indicate that carsharing businesses will continue to increase their membership. Cambridge, by virtue of its growing population, transit friendly policies, and efforts to reduce local commutes by car, will likely see an increase in carshare membership as a result. However, expectations for carsharing growth will be tempered by increasing competition amongst other modes like ride-hail vehicles.

Carsharing	
Forecast Change	**Forecast Community Impact**
+++	

Each "+" represents an approximate 10 percent increase in trip activity.

Forecast Wild Cards

Carsharing is subject to many of the same forecast wild cards as single occupancy vehicles in general. Congestion pricing and any other regulation targeting SOVs would also target carsharing vehicles, shaping the value they offer consumers. Furthermore, the advent of AVs could dramatically diminish, if not eliminate entirely, the underlying business model for carsharing.

Pressures and Trends

Demographic Impacts

Carsharing businesses rely on dense urban populations that don't generally rely on private cars to commute to work, and residents' lack of ready access to cars to make their businesses viable. As Cambridge's population continues to grow, carsharing companies will find a growing number of potential customers.

Policy

The City amended zoning in 2015 that clarified accessory parking space requirements for carsharing vehicles, formalizing the services' role and availability in the City. Furthermore, the City's sustainable transportation policies discourage people from driving alone to work, which makes carsharing an attractive option for when workers need access to a car during the day.

Relevant Policies

- City of Cambridge Off Street Parking Regulations: Carsharing Vehicles

Market

There are multiple carsharing businesses operating in Cambridge, including ZipCar, Turo and GetAround. ZipCar operates a fleet-based service: the company owns and offers members access to a fleet of cars parked at predetermined spots around the City. Turo is a peer-to-peer service through which car owners can rent out their personal vehicles. Getaround offers both a fleet-based and peer-to-peer service. Though data for Cambridge in particular is limited, carsharing has been steadily growing as a market since 2006 with over 1,837,854 members as of 2016.[10] According to market research published by P&S Intelligence, the market for carsharing is projected to reach $10,846.9 million by 2025, advancing at a compound annual growth rate of 11% during that time. Favorable government regulations for carsharing services, growing concerns over environmental emissions, increasing demand for more convenient and cost-effective mobility solutions, and advancements in technology are the key factors driving the growth of the market. But the rise of ride-hail vehicles has significantly affected carsharing in Cambridge. There were more than 300 carsharing vehicles in 2015, and there are now half that number in Cambridge.

Technology

The carsharing business model has been enhanced by advances in GPS technology and accuracy, and the prevalence of smart phones, making it much easier and simpler to reserve a vehicle compared to traditional car rental services. In addition, the sharing economy has created opportunities for car owners to rent their personal vehicles, creating value out of underused, preexisting assets.

Infrastructure

The City passed an ordinance in 2015 that specifically permitted and established a process for setting aside parking spaces for carsharing. Carsharing otherwise relies on the same infrastructure built for car ownership and driving in general.

Mode Shift

Carsharing competes directly with private vehicle ownership. However, it also competes with RHVs, bikes and emerging micromobility. The demand for carsharing decreases with the introduction of new modes and models that chip away at the value of carsharing, and by extension, private automobiles. For example, trips that require hauling (e.g. shopping for groceries or retail) can be accomplished by RHV and trips that might have otherwise been taken by car can be taken by e-bike. As the scenario for when carsharing is useful becomes more defined, it remains to be seen how new market entrants impact membership and growth in the use of carsharing.

Opportunities (Reasons to Support)

According to the City of Cambridge, carsharing increases mobility options for city residents,

10 https://escholarship.org/uc/item/49j961wb

employees, and visitors, and reduces competition for resident street parking by decreasing the number of cars searching for parking. National research shows that carsharing members tend to drive less because they think about whether they want to pay each time they use the car, and that carsharing members often get rid of their cars or delay buying one. Each carsharing vehicle is estimated to take 9 to 13 privately owned cars off the road.[11] By making cars available for those who might not be able to afford to own one, it opens doors for people with lower incomes to have access to a car when they need one.

Challenges (Reasons to Limit)

While carsharing supports people who want to live car-free or car-light lifestyles, it still supports vehicle trips and does not encourage shared trips. Current policy does not specify vehicle requirement for fuel efficiency or other measures of sustainability.

11 https://tsrc.berkeley.edu/research/shared-mobility

5.4 Micro-Transit

Micro-transit are small-scale, on-demand shuttle services, operated publicly or privately, that can operate in fixed zones, on fixed routes, or on flexible routes and on-demand scheduling. They are distinct from shared RHV rides like Uber Pool or Lyft Line. Example companies include Via, EZRide, and the Alewife TMA Shuttle.

Forecast Summary

Micro-transit ridership and usage in Cambridge will likely emerge and grow in the near and long term, as consumers seek the convenience of ride-hailing at a more affordable price. Near Cambridge, the City of Newton partnered with Via on a micro-transit service tailored specifically towards seniors. Cambridge riders are also comfortable with shared RHVs, which makes adoption of micro-transit likely. Future City policy passed to support micro-transit would be favorable, especially relative to private ride-hail vehicle trips, given that micro-transit is comparably sustainable, could help diminish emissions generated through ridesharing, and could ultimately offer equitable services to connect areas that would be difficult or costly to serve through fixed-route public transit. The value offered to riders in terms of affordability is key: as RHV companies seek profitability, it seems likely that the cost of private rides will increase, but that shared rides will remain largely affordable in order to maintain a broad spectrum of appeal across riders.

Micro-Transit	
Forecast Change	**Forecast Community Impact**
+++	

Each "+" represents an approximate 10 percent increase in trip activity.

Forecast Wild Cards

Micro-transit forecasting in Cambridge is dependent on the arrival of services. If either the City or MBTA supplement existing transit or replace under-utilized routes, either during certain hours or entirely, adoption would also increase. Finally, the introduction of autonomous vehicle services could have tremendous influence on micro-transit: shuttles might transition to AV fleets with low costs, or the costs for private AV RHVs might become so low that micro-transit loses market share.

Pressures and Trends

Demographic Impacts

There are no clear demographic trends that will conclusively influence the overall projections for micro-transit.

Policy

Other than requiring shuttle participation in some PTDM Plans and Special Permit conditions, the City of Cambridge does not have an official policy for micro-transit.

Market

The market for micro-transit continues to grow. Dynamic shuttles are cheaper to implement in partnership with software companies compared to fixed route buses. RHV companies have also stepped into the micro-transit market and are pursuing contracts with governments, in addition to running private services that offer the convenience of ride-hailing at lower cost.

Technology

Micro-transit has grown into a viable business as a result of advances in dynamic routing software that facilitates efficient pick-ups/drop-offs and rider pairing. Companies continue to work towards increasing the efficiency of their software as it pertains to operations by, for example, encouraging users to walk to a pickup point, in order to simplify vehicle routing.

Infrastructure

Micro-transit relies on existing infrastructure for operations, using advanced software to dynamically route shuttles and pair riders traveling similar routes or towards similar destinations.

Mode Shift

Micro-transit has the potential to both attract as well as lose ridership to mode shift in Cambridge. In instances where micro-transit services are private, they have the potential to attract ridership from what would have otherwise been public transit. However, micro-transit also competes directly with RHVs, transit, and micromobility. The result won't be winner takes all, but will depend on the user and the route, based on the time and cost for each.

Opportunities (Reasons to Support)

Micro-transit, offered as a private service or a publicly subsidized service is a more sustainable form of dynamic transit compared to RHVs. Micro-transit shuttles are typically high capacity, whereas shared RHVs are usually no more than just 2-4 passengers. Service is typically lower cost, as dynamic ride-matching ensures more riders in each vehicle, making micro-transit more equitable. Ride-matching should also reduce Vehicles Miles Traveled and generate less to traffic as a shuttle service than if each person drove alone or took a solo RHV. Services can reach areas that are otherwise underserved by traditional public transit, representing a lower-cost means of expanding access.

Challenges (Reasons to Limit)

Micro-transit, offered as a private service, can compete directly with public transit and cost more per ride: dynamically routed shuttles offer a premium version of public transit that shifts riders with expendable income off buses. The subsequent ridership loss from transit translates to less farebox revenue, which then raises the possibility of service losses on

bus routes due to lost ridership, creating a cycle of diminishing service that is most likely to impact lower income riders who depend on services. Micro-transit designed in partnership with City government is less subject to these concerns, as the government can ensure that services complement existing transit.

5.5 Electrification

Forecast Summary

Electrified vehicles (EV) will eventually be the dominant form of motorized street-based transportation in the US, as evidenced by the commitments of many major car companies to phase out internal combustion engines. Individually owned and RHV vehicles, as well as public buses, trains, and logistics providers will likely all gradually shift. The speed of adoption at the individual and fleet level in Cambridge relies on local infrastructure investments into electric charging stations, as well as regional and national charging stations.

Electrification	
Forecast Change	**Forecast Community Impact**
+++*	

Each "+" represents an approximate 10 percent increase in trip activity.
*The annual growth rate has exceeded 100 percent for the past 4 years and this is expected to continue.

Forecast Wild Cards

EV adoption depends on the availability of a wide-scale EV charging infrastructure network that can meet vehicle charging needs, as well as on being cost competitive to their Internal Combustion Engine (ICE) counterparts. Local, state, or national policy that makes ICE vehicles a better value, or slows the expansion of the EV charging infrastructure network, will ultimately dampen the market's development.

National policy and market development that influence upfront EV cost and availability of EV charging infrastructure are especially influential on the rate of EV adoption, and will impact vehicle owners' decision-making equally as much as local initiatives, given the variety of journeys consumers consider when buying new vehicles.

The regional electricity supply grid's ability to meet increased demand for the electricity needed to fuel EVs and the electricity rate structures that determine the cost to fuel EVs will also have significant influence on the rate of EV adoption.

Pressures and Trends

Demographic Impacts

As the EV market develops, leading to lower costs for new vehicles and an increasing number of available second-hand vehicles, a wider range of people from different socio-economic backgrounds will have the means to purchase electric vehicles. Electric vehicles in the form of micromobility will be accessible to larger segments of the population before

private electric automobiles. RHVs might also transition earlier, introducing residents to electric vehicles through those services.

Policy

City policy focuses on two primary areas: residents who drive EV's and the municipal fleet. For residents the City has a policy of promoting and building EV charging infrastructure to accommodate EV drivers who do not have access to a driveway for charging at home, offering public charing stations throughout Cambridge. The City is actively pursuing expansion of this program.

For the municipal fleet, the 2006 Green Fleet Policy requires that all new vehicle purchases requested by municipal departments identify three vehicle options, and compare them on the basis of fuel economy and emissions using the EPA Green Vehicle Guide. The policy does not explicitly require new vehicle purchases to be electric when possible, but it has supported the adoption of some full electric and hybrid electric vehicles. The City has added municipal electric vehicles and many electric vehicle charging stations.

Relevant Policies

- State of Massachusetts Zero-Emission Vehicle Programs
- City of Cambridge Green Fleet Policy
- State of Massachusetts: An Act Promoting Zero-Emission Vehicle Adoption
- State of Massachusetts Global Warming Solutions Act: Requirements for Transportation

Market

The EV market in the United States continues to mature, with increasing levels of adoption. Abroad, the EV market is far more competitive, especially in Europe and Asia. As such, the supply chain for EV parts and knowledge is being pushed forward by competition and developments in those regions. Adoption in the United States, Cambridge included, is constrained by vehicle cost and reliable access to charging across trip types.

Technology

EV technology developments are focused on increasing battery range while reducing battery cost and EV charging infrastructure, two of the primary issues slowing EV adoption. The battery is one of the most expensive components of an EV, so as battery technology improves and becomes less expensive per kWh of storage, the upfront cost of an EV becomes more competitive with the upfront cost of an ICE.

While there has been large public and private investment in developing and installing EV charging infrastructure to meet a wide range of EV charging needs, significant gaps still remain. For example, reliable and affordable EV charging solutions for urban car owners that do not have access to an off-street parking space at home have lagged behind other EV charging solutions.

Infrastructure

Electrification of motorized transportation will require significant public and private investment in EV charging infrastructure. Expansion of an EV charging infrastructure network should be strategic; it should be designed to include a variety of EV charging solutions that can meet the needs of different charging use cases, including daily driving for City residents, local and/or regional fleets, longer "destination" charging of private passenger vehicles, and RHV drivers, while also promoting charging behavior that optimizes the benefits and reduces the burden of EV charging. Though EV charging stations are growing more prevalent, development is largely private. The City has invested in public charging stations and is considering a residential EV charging pilot as part of the New Mobility Blueprint.

Mode Shift

Electrification will shift automobile ridership and dependence from gas-powered ICE cars. However, EV's are ultimately subject to the same mode shift as those vehicles. If policy discourages trips by automobiles, EV drivers will also be subject to that. Any policy targeting congestion, for example, will also target EV's. The electrification of pedal-powered bikes to e-bikes, as described in the micromobility section, could create new demand for energy. Mode shift will largely depend on City guidance.

Opportunities (Reasons to Support)

Policies and programs that enable replacement of motorized trips powered by fossil fuels with motorized trips powered by electricity is an important way to reduce GHG emissions from the transportation sector. Switching trips from ICE vehicles to EVs has a net emissions benefit when the electricity is generated primarily from natural gas, as is the case in New England. It also improves local air quality and reduces negative health impacts associated with localized air pollutants from transportation.

Challenges (Reasons to Limit)

EVs that have replaced ICE vehicles contribute the same amount of traffic to roads as an ICE vehicle does. The City's primary goal is to reduce the overall amount of vehicle travel, and vehicle ownership in Cambridge. Electrifying vehicle trips does not alleviate other problems caused by vehicle trips or help achieve Vision Zero goals like fewer car accidents.

Electrification of modes that have traditionally been non-motorized, for example a bicycle trip that is replaced with an electric bicycle trip, or a walking trip replace by an electric scooter or electric RHV trip, can have negative impacts by increasing the demand for electricity, and increasing GHG emissions if the electricity used to charge is primarily generated by fossil fuels rather than renewable energy.

5.6 Autonomous Vehicles

Forecast Summary

The AV introduction and adoption of AVs is subject to a wide variety of variables. Recent reports have indicated that the technology might be further from development than companies had at first anticipated, making introduction in urban areas with complex travel patterns in the near future less likely. However, competing reports have suggested that Waymo is inching closer to market readiness. AV use will largely depend on a mix of policy guidance and consumer perceptions in terms of trip cost and time.

Autonomous Vehicles

Forecast Community Impact

**Date of mode's market readiness is speculative. No forecast change included.*

Forecast Wild Cards

Virtually every aspect of AVs arrival to market is subject to unknowns. The technology itself is still developing, as are regulatory frameworks and business models for the industry. Ultimately, it remains to be seen whether AVs will launch as fleets, operating like ride-hail vehicles, or will be personally owned, in line with the current auto sales model. Consumer response and comfort with the new technology, especially regarding safety perceptions, will impact technology adoption. Government regulation and acceptance of safety assurances, insurance requirements, and other business aspects, will play a big role in the market's growth. The vehicles themselves could also be subject to restrictions on single occupancy vehicles and congestion pricing, which would affect their consumer value.

Pressures and Trends

Demographic Impacts

There are no demographic trends that can conclusively predict the launch of autonomous vehicles in Cambridge, or in general. For every demographic, there are elements and characteristics that would both encourage and discourage adoption. The elderly, for example, might be early adopters in order to increase independence. However, distrust of the technology and companies' assurances of safety might dissuade the same group, despite the potential benefits. Furthermore, if vehicles aren't wheelchair accessible, a portion of the elderly population might not be able to access the vehicles at all.

Policy

In 2018, the City worked with the Metropolitan Area Planning Council and the Metro Mayors Coalition of Great Boston, MassDOT, and the Governor's Office to develop and sign an AV testing Memorandum of Understanding. The testing program is subject to specific

guidance, focused on safe operation and testing. Beyond the MOU and testing application, however, the City does not have specific regulations for AVs. The State of Massachusetts issued guidance, but likewise has few specific regulations.

Relevant Policies

- State of Massachusetts Executive Order No. 572: To Promote the Testing and Deployment of Highly Automated Driving Technologies
- MassDOT Memorandum of Agreement and Application to Test AV Systems in the Public Ways

Market

Significant capital continues to be invested in the development of autonomous vehicles. It remains to be seen how the vehicles and technology will ultimately come to market: as robo-taxi fleets or for personally owned vehicles. The market is full of companies, including new entrants and well-established automakers, pursuing both methods. Reports indicate that Waymo has the edge in terms of technology at present and is likely to license its technology and/or vehicles to other providers. Should that ultimately prove true, it seems likely that the market for self-driving robo-taxis will emerge first, with subsequent business models arriving later.

Technology

The underlying technology for autonomous vehicles continues to advance in all vehicle areas, from software to the new suite of sensors required for operation. At this point, the technology is still changing, especially as companies strive to address any and all scenarios necessary for the vehicles to operate successfully in urban environments. Autonomous vehicles are more likely to be able to successfully navigate highways than complex urban environments in the short term.

Infrastructure

The prevailing notion across the United States is that autonomous vehicles should be capable of operating in urban environments without investments by local city governments. This runs in opposition to efforts globally, where national governments have invested heavily in communications technology to support the vehicles' successful development and deployment. The infrastructure that AVs will use will be the same infrastructure currently used by car owners and drivers. This represents a higher bar for entry compared to nations abroad, and demands more of the software up front. Vehicle software and hardware will need to be more sophisticated to operate correctly in the event of missing signs or road markings, or other unpredictable obstacles that are more likely in cities.

Mode Shift

AVs could cause mode shift across the board, introducing a great deal of change to the transportation system in Cambridge as it currently stands. Travel by an AV robo-taxi should cost much less than an RHV ride, since labor is a significant cost of each ride. If AV rides are cheap enough, they will compete with both RHVs and transit, as well as travel by other modes if they're sufficiently convenient. However, mode shift will also result from policy

decisions by the City and State, and might cool down any tension between AVs and transit, for example, turning them into complements instead of competition.

Opportunities (Reasons to Support)

AVs have the potential to increase road safety and eliminate traffic fatalities. They could vastly expand mobility options, likely at an affordable cost, for all age groups; open new doors for people with disabilities that impact navigation; offer low-cost travel locally and regionally for lower income populations; and meet family travel needs. Assuming promised improvements in traffic efficiency, they could eliminate the tremendous environmental impacts of traffic from gas-based automobiles. AVs could also free up space currently used for parking, as the vehicles could park at specific off site locations from a user's origin or destination.

Challenges (Reasons to Limit)

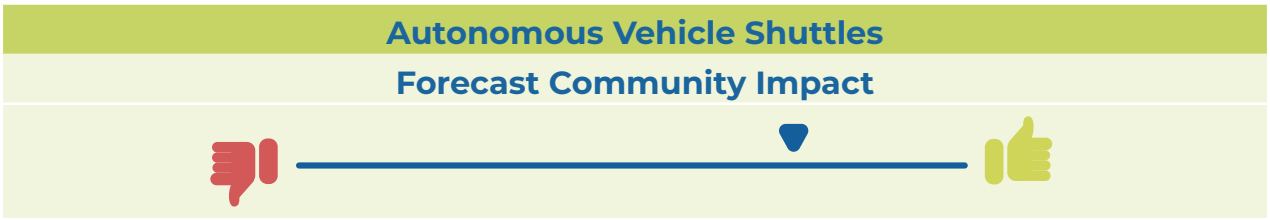
AV challenges are numerous and depend on systems and policy frameworks being in place at the technology's roll out. If vehicles and technology aren't properly vetted, both at their introduction and on a continuing basis, they could prove unsafe for riders, other vehicles, and other road users, like cyclists and pedestrians. Vehicles won't need parking, which will eliminate one of the most direct tools the City has at its disposal to mitigate car traffic. AVs from multiple companies, especially if they operate competing platforms, could worsen traffic congestion. Without municipal requirements, they might not be accessible, making them difficult for the elderly and people with disabilities that impact navigation. Without equity requirements, they could be cost-prohibitive for some people. If they compete with transit and shift ridership, it could be catastrophic for people who rely on transit, if the shift leads to worse transit service. They might make longer commutes viable, encouraging sprawl. If vehicles are petroleum based, the increased Vehicles Miles Traveled could increase pollution.

5.7 Autonomous Vehicle Shuttles

Autonomous Vehicle Shuttles are multi-passenger autonomous shuttle services that operate on-demand, publicly or privately, in fixed zones, and on fixed or flexible routes.

Forecast Summary

AV shuttles are subject to the same level of uncertainty as AVs themselves. It seems likely that robo-taxi companies will price private AVs at a premium and offer shuttle services at a lower cost. However, this is by no means a given; private services could ultimately become so affordable without the cost of a driver that existing shuttle services are rendered obsolete. If the market advantage for shuttle services isn't cost, as it has traditionally been in the case of a private taxi vs. bus, for example, there will have to be more compelling reasons for people to choose to ride shuttles



**Date of mode's market readiness is speculative. No forecast change included.*

Forecast Wild Cards

As AV technology matures and becomes generally available and commonplace, all buses (including public buses) will likely become autonomous vehicle shuttles. From a rider's perspective, this would eliminate any substantial difference between private and public autonomous shuttles.

Pressures and Trends

Demographic Impacts

Like autonomous vehicles in general, there are no demographic trends that will conclusively influence the deployment of autonomous vehicles shuttles in Cambridge, or in general.

Policy

In 2018, the City signed onto an AV testing program with the Metropolitan Area Planning Council and the Metropolitan Mayors Coalition of Greater Boston, along with the Massachusetts Department of Transportation and the Governor's Office. However, the program is not specifically focused on AV shuttles, as much as it is on AVs generally.

Relevant Policies

- State of Massachusetts Executive Order No. 572: To Promote the Testing and Deployment of Highly Automated Driving Technologies

- MassDOT Memorandum of Agreement and Application to Test AV Systems in the Public Ways

Market

The market for AV shuttles, at present, is very similar to AVs. The underlying technology needs to work before shuttles can be differentiated as a service or market opportunity.

Technology

The underlying technology for AV shuttles will be the same as it is for AVs, with perhaps tailored software that makes shuttle stops dynamic and efficient.

Infrastructure

Much like AVs, AV shuttles will have to operate seamlessly with existing infrastructure and obstacles. No new infrastructure is planned to support their operation.

Mode Shift

Assuming AVs deploy as robo-taxi fleets, it will remain to be seen how the market differentiates between shared and solo rides, in the manner that Uber and Lyft distinguish between their solo and shared services. Ultimately, mode shift will depend on the cost difference between services. If AVs, in general, are affordable, there will need to be a compelling reason, like cost, for consumers to choose shuttle options over a solo AV. If solo AVs are expensive, then it would be reasonable to assume that shuttles will compete with public transit and with buses in particular.

Opportunities (Reasons to Support)

AV shuttles could be an efficient, sustainable and affordable transportation option for Cambridge residents and employees, complementing existing public transit and offsetting SOV trips. If AV shuttles become the norm as opposed to solo AV services, it would reduce traffic in general and diminish congestion across the City. If AV shuttles are subject to requirements for equity and access, like lower fare guarantees for lower income users and ADA compliance for elderly people and mobility challenged populations, then they will benefit the entire community. AV shuttles are a far more preferable scenario for the City compared to private ownership of AVs, which could bring about more pollution, congestion and equity challenges.

Challenges (Reasons to Limit)

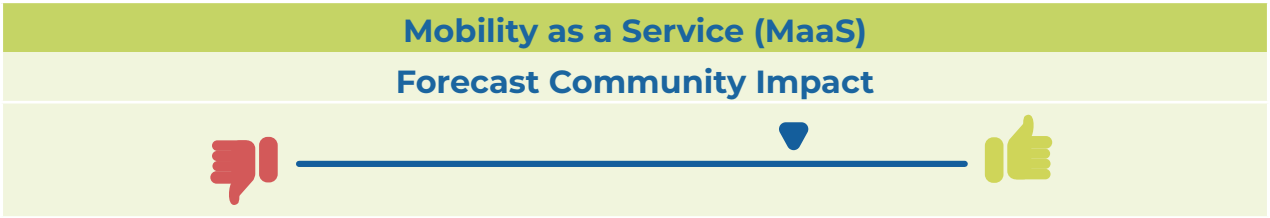
Like private autonomous vehicles, if vehicles and technology aren't properly vetted, both at their introduction and on a continuing basis, they could prove unsafe for riders, other vehicles, and other road users, like cyclists and pedestrians. If shuttles are cheap enough, they could compete with public transit services and deprive transit of ridership and fare box revenue. Unregulated shuttle services would not guarantee equity, either for the short- or long-term, putting lower income groups at risk of diminishing quality of service.

5.8 Mobility as a Service (MaaS)

Mobility as a Service, or MaaS, is an on-demand system where people use an app to request the use of or gain access to a variety of transportation modes operated by one or multiple companies. Typically, people pay a subscription fee to a MaaS provider on a monthly basis, and the fee includes use of buses, fixed-rail transit, and bicycles. More expensive monthly plans include access to ride-hail vehicles. MaaS platforms typically include a trip planning dashboard similar to Google Maps.

Forecast Summary

Due to the difficulty of gaining market share and becoming profitable, it is unlikely that MaaS platforms (as independent companies) will grow in popularity in the US. However, it is highly likely that RHV companies will begin to evolve into MaaS platforms, offering multiple modes, linking to public transit, and coordinating payment across all modes.



**Date of mode's market readiness is speculative. No forecast change included.*

Forecast Wild Cards

Successful MaaS platforms elsewhere have relied on subsidies to overcome significant losses. In the United States, creating a MaaS platform that includes competitors (like Uber and Lyft, for example), there would need to be an agreement and companies would need to be comfortable sharing some level of information about ride pricing, which is currently treated like a trade secret. Venture funding seems more likely than any agreement. The wild card then is whether individual companies can successfully create MaaS platforms, whether that actually ties together transportation in a given City or just a private segment of it, and whether venture capital will be sufficient to overcome initial losses.

Pressures and Trends

Demographic Impacts

The shift away from personal car ownership is creating opportunities for residents to select other forms of transportation such as public transit or ride-hail vehicles. MaaS is in many respects simply a coordinated system of transportation modes that doesn't involve personal ownership.

Policy

The City does not currently have specific policy on MaaS.

Market

The market for MaaS is emerging in the United States. It has grown fastest in areas like Northern Europe, like Helsinki and in Amsterdam, where there are subsidies available for commuting.[12] In the United States, MaaS platforms are less common because they have not demonstrated profitability in the absence of subsidies.

Technology

The underlying technology for MaaS is similar to ride-hail vehicles, except that it typically includes other modes such as bicycles and micromobility services and connects to a city's transit system. MaaS platforms in theory act as a single payment system; while it is technically feasible to coordinate payment between a MaaS provider and a public transit system, in practice this is normally difficult to implement because of public transit's outdated payment systems.

Infrastructure

No new infrastructure is required to support MaaS, except for the creation of an app by a private company.

Mode Shift

The success or failure of MaaS will likely come down to whether people are willing to pay a slight premium to have a simplified transportation experience. If so, MaaS will catch on in the US and gain market share. Also, RHV companies may seek to present themselves as MaaS providers further blurring lines between a single company, multi-mode, RHV platform and a separate MaaS platform.

Opportunities (Reasons to Support)

MaaS holds promise because it represents a simplified customer experience and door-to-door travel opportunities. In a MaaS platform, payment is simplified because the service is paid as a monthly subscription instead of individual trip transactions. Also, the MaaS platform allows the customer to consider a variety of modes that are best fit for a particular trip distance. Wheelchair accessible vehicles, if they are a part of the MaaS fleet, offer the opportunity for door-to-door service that might otherwise be difficult by public transit. MaaS can offer point-to-point travel for families, especially those without vehicles.

Challenges (Reasons to Limit)

MaaS still has implementation challenges, in the sense that the cost of the platform needs to be passed on to customers in some fashion. Assuming that the business model gets worked out in the US market, the other challenge will be how people will respond to the choices presented to them in a MaaS platform. For example, if people pay a monthly fee and have unrestricted access to a variety of modes, they may choose by convenience and less by a sense of value. This could translate into more RHV-like trips and fewer transit trips. Based on the current rollout of MaaS platforms, a platform service for low- income populations might need to be subsidized by the City.

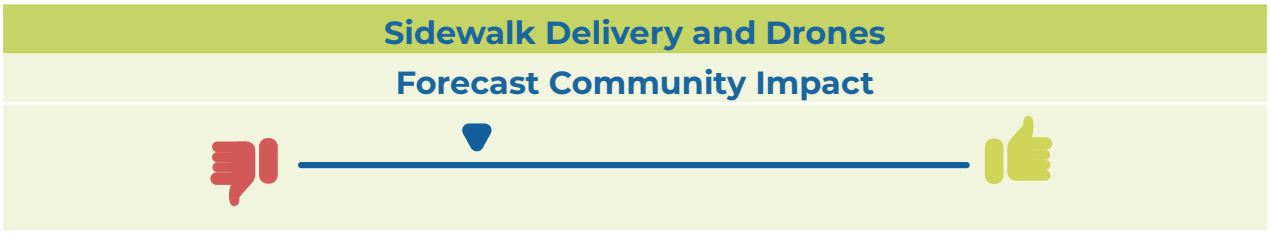
12 Source: https://whimapp.com/

5.9 Sidewalk Delivery and Drones

Robotic delivery is the automated delivery of goods via either on the ground or by air to a destination like a residential address or a commercial location. It is no longer an abstract concept, as many universities across the US are piloting robotic delivery to take advantage of the controlled campus environments. Companies such as Walmart, Amazon, and Uber are investing heavily in research on this future delivery approach.

Forecast Summary

Limited pilots of ground-based robotic delivery should be expected in US cities over the next 5 years, and those providers will want to also be operational in Cambridge. Aerial drone delivery is also starting to expand across the US, particularly led by big box retailers.



**Date of mode's market readiness is speculative. No forecast change included.*

Forecast Wild Cards

If significant technical advances in either ground-based or drone-based delivery methods occur in the next 5 years, the possibility of more widespread implementation in US cities will increase. Large online shopping platforms will likely be investing significant resources to advance the technologies involved and streamline the regulatory approval of aerial deliveries at the federal and state level.

Pressures and Trends

Demographic Impacts

The decline of brick-and-mortar storefronts and the rise of online retail over the past decade has resulted in additional parcel delivery activity in the City. The City's 2017 Retail Strategy Market Analysis found that 60% of Cambridge residents had made an online purchase in the past 30 days, compared with 42% nationwide.[13] Current trends in other cities show that online shopping delivery will continue to increase over time. Consumers are attracted to faster delivery and/or a reduced delivery cost.

Policy

The City does not currently have specific policy on ground-based robotic delivery. In addition, the legality of aerial drone deliveries has not yet been established by the federal government.

13 *https://www.cambridgema.gov/~/media/Files/CDD/EconDev/retailstrategy/loamarketanalysispresentationmay172017.pdf*

Market

The market for robotic delivery is fueled in part by the promise of greater delivery speed. Direct aerial delivery presumably would be the fastest method to deliver a parcel. the delivery cost per parcel could be reduced because the cost of human labor would be removed (although the cost of maintaining the robot delivery system may offset this savings).

Technology

The underlying technology for commercial robotic delivery is in its infancy. The ability of current drones to navigate complex real-life situations safely and repeatably is not yet demonstrated.

Infrastructure

No new infrastructure is required to support robotic delivery at a city-level. However, receiving stations for small parcels have not been integrated into residential or commercial buildings.

Opportunities (Reasons to Support)

If the technology becomes mature and the airspace regulations become established, aerialdelivery may offer benefits in delivery speed and potentially reduced cost for critical items such as medicines. By giving families subscription bundles that include multiple modes of transit, they enjoy a greater number of options that make trips of all kinds possible, for the family as a whole and for individual family members, without a family car or other personally owned vehicle.

Challenges (Reasons to Limit)

The prospect of robots driving around crowding our streets and sidewalks (or flying overhead) dropping off packages may meet with intense community resistance as it represents a significant cultural shift circa 2019. The noise pollution caused by aerial drones will be difficult to limit. Furthermore, the impact to delivery labor could be significant if those jobs are not transitioned into another related role such as robotic maintenance.

5.10 Vertical Take-Off and Landing Machines (VTOL)

Vertical Take-Off and Landing Machines are aircraft that can take off, hover, and land vertically. Commercial applications are under development for VTOL shuttle services as well as cargo delivery.

Forecast Summary

There is no policy framework in place and all vehicles are still in their prototype stage. However, investment into the sector is significant. VTOL shuttles seem likely to launch, at least initially, as costly luxury services that target customers with high incomes and wealth. Though the number of vehicles themselves might increase, their adoption would be limited. VTOL adoption will remain limited for the foreseeable future.

Vertical Take-Off and Landing Machines

Forecast Community Impact

**Date of mode's market readiness is speculative. No forecast change included.*

Forecast Wild Cards

Policy frameworks and cultural responses will shape the future of VTOL. In addition, for shuttles, cost and convenience will be the ultimate determinants. In order to succeed, VTOL will need to fit seamlessly into the urban environment without causing diminishing quality of life, disturbance (from noise), or other issues.

Pressures and Trends

Demographic Impacts

While there is no data yet available, in can be reasonably expected that VTOL will be only an option for those residents willing to pay a relatively high trip cost.

Policy

There is no existing policy framework for VTOL vehicles in the City of Cambridge or the State of Massachusetts.

Market

The VTOL market is new but increasingly well-funded and competitive, with companies like Kitty Hawk, Lilium, Uber Elevate, and Volocopter working towards developing electric VTOL shuttles targeting urban consumers hoping to escape traffic congestion. Traditional aeronautics firms and agencies, like Airbus and NASA, are also experimenting with the technology.

Technology

The technology for VTOL spans industries and disciplines: aircraft, propulsion, software, engines, and simulations, among others. Development is ongoing to align these elements for prototype aircraft.

Infrastructure

Urban and inter-city VTOL shuttles will require more infrastructure development than logistics VTOL. Shuttles, especially those in highly populated environments, will require rooftop access for takeoff and landing. Logistics VTOL will also require takeoff spots, presumably in locations with significant air space distant from the urban core of the cities in which they operate, in order to handle higher load of logistics requests.

Mode Shift

VTOL development could hypothetically compete with RHVs and SOVs at a minimum, as well as public transit under the right circumstances. The companies in this space state that shuttle services will be affordable, at a rate comparable to that of an RHV. However, it seems likely that shuttles will be costly, if only because of the rooftop real estate required to make the businesses viable, making them closer in cost and purpose to the current helicopter iteration of Uber Elevate, which is a costly luxury service.

Opportunities (Reasons to Support)

VTOL shuttles, according to the companies developing the technology, could diminish pollution and congestion, freeing up street space for other uses by diminishing the number of vehicles on the road.

Challenges (Reasons to Limit)

VTOL could introduce significant aero-vehicular traffic to urban skies as a luxury only affordable for the very wealthy. Given that VTOL prototype shuttles carry no more than 4 passengers, or the equivalent of a sedan, it seems highly unlikely they'll solve urban congestion; rather, they would solve it for a fortunate few. Furthermore, VTOL shuttles are noisy, which companies have described as something that residents will become accustomed to, but could quickly become a quality of life issue, with those who can't afford trips on VTOLs largely subject to their adverse effects. It stands to be seen whether VTOLs are an opportunity just for the wealthy, or for the entire City's population.

6. Impact on Established Modes

While previous sections discussed New Mobility technologies, the following sections will review the likely impact of these new ways of travel on established modes like walking, cycling, transit, and single-occupancy driving. The methodology took the projected increases of New Mobility technologies and consider these in conjunction with the general trends discussed in Section 3. Using these comparisons, and judgement based on experience from cities in the US, a semi-qualitative prediction was made about the impact.

6.1 Walking

Forecast Summary

Walking, for all trip types, including commuting, is forecasted to increase in the short term. The gradual increase in population combined with the City's commitment to active mobility will drive this increase. Privately owned scooters or shared scooters may take away walking activity, but more data will need to be collected to understand this tradeoff.

Walking
Forecast Change
+++

Each "+" represents an approximate 10 percent increase in trip activity.

Forecast Wild Cards

It is unclear to what extent the introduction of private electric scooters, fleets, and other micromobility devices will affect the rate of walking. If scooter fleets are allowed in Cambridge, a more dramatic increase in their use could substitute for walking activity. However, it remains unclear if scooters directly replace walking trips, or partially generate their own unique demand and trip activity.

Pressures and Trends

Demographic Impacts

The number of active pedestrians is in part driven by City demographics, especially population age. The projected increase in population across younger age groups suggests a likely increase in the number of pedestrians as well.

Policy

The City recognizes the health benefits, low carbon footprint, and improved street conditions associated with increased walking and has tailored its policy to encourage more.

Relevant Policies

- Vision Zero and Vehicle Trip Reduction Ordinance
- City of Cambridge Pedestrian Plan
- City of Cambridge Complete Streets
- City of Cambridge 5-Year Sidewalk and Street Reconstruction Plan
- Access Board – Major Issues & Overview of Proposed Guidelines: Public Right of Way

Market

There is no market for walking itself, per se. However, there is a market for assisted walking devices of varying complexity, including for people with disabilities that impact navigation or recovering from injuries, and a large market for smartphone-integrated and wearable

technology that tracks user data, such as heart rate and number of steps. The market for assisted mobility is advancing, but mostly focused on recovery from injury and easing specific mobility challenges. The latter market is competitive, with numerous companies offering wearable products. Companies continue to invest large sums of money into products including smart watches and more advanced wearable technology, indicating that the market is likely to grow.

Top 5 Wearable Companies by Shipment Volume, Market Share, and Year-Over-Year Growth, 2018 (shipments in millions)

Company	2018 Shipments	2018 Market Share	2018 Shipments	2017 Market Share	Year-Over-Year Growth
1. Apple	46.2	26.8%	33.1	24.5%	39.5%
2. Xiaomi	23.3	13.5%	16.1	11.9%	44.6%
3. Fitbit	13.8	8.3%	15.4	11.4%	-10.0%
4. Huawei	11.3	6.5%	4.6	3.4%	147.3%
5. Samsung	10.7	6.2%	5.8	4.3%	85.1%
Others	66.8	38.8%	60.0	44.4%	11.2
Total	172.2	100.0%	135.0	100.0%	27.5%

Source: IDC Worldwide Quarterly Wearables Tracker, March 5, 2019

Source: https://techcrunch.com/2019/03/05/idc-apple-led-wearables-market-in-2018-with-46-2m-of-the-total-172-2m-devices-shipped/

Technology

There has been an increase in technology geared towards tracking and encouraging users to achieve walking milestones daily, leading to a variety of products related to step counting and similar smartphone-integrated wearables. Google recently purchased Fitbit, one of the leading smartwatch wearable companies, and it seems likely that technology will continue to advance in this area.

Infrastructure

For a city to be pedestrian friendly, its built environment needs to actively support walking. Walking is a direct product of population density and pedestrian comfort. Destinations need to be reasonably accessible by foot and infrastructure needs to be complete and in good repair so pedestrians can walk safely. Cambridge has a growing resident and worker population and is also investing in improving the quality of its sidewalks across the City, as detailed in its Five-Year Plan for Sidewalk and Street Reconstruction.

Priorities for Sidewalk Condition

Based on the criteria below, each block of sidewalk received a rating between 0 (excellent) and 35 (poor).

- Driveway conditions
- Trees or other obstructions
- Cross-slope
- Overall structural condition

5-Year Plan for Sidewalk Reconstruction

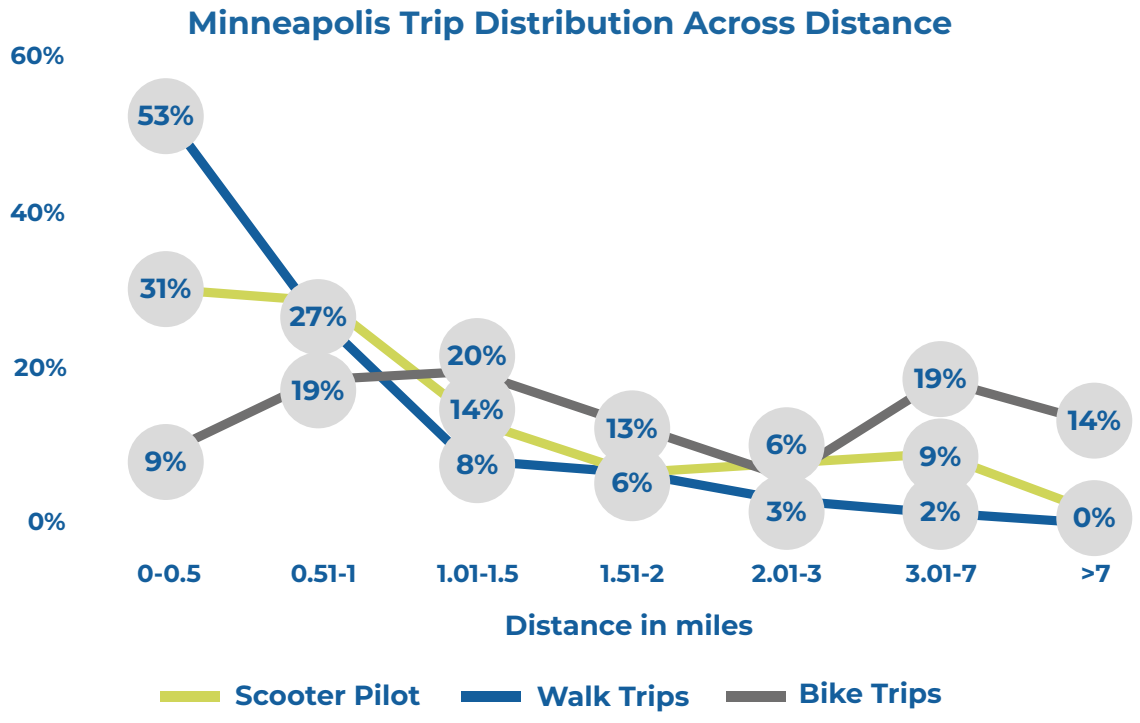
One way of estimating a City's pedestrian friendliness is through its Walk Score. Walk Score measures the walkability of a given area based on access to nearby amenities within a 5 - 30-minute walk. It also accounts for population density and road metrics such as block length and intersection density.

According to research conducted by Duncan et al entitled "Walk Score, Transportation Mode Choice, and Walking Among French Adults: A GPS, Accelerometer and Mobility Survey Study,"9 the distribution of walking trips in general will increase 17.1% from 35.8% to 52.9% if the walk score trip origin/destination is a "Walker's Paradise". A place is considered a "Walker's Paradise" if the score is between 90-100. 10

The mean overall Walk Score in the research was 87.1, which is comparable to Cambridge's current Walk Score of 87. If we assume that Cambridge's overall Walk Score will improve slightly as population density increases and more destinations are within walking distance of more residents, eventually becoming a "Walker's Paradise", we can also assume an increase in the City's walking rate. At the same time, as more residents choose to make Cambridge their home, City investments into sidewalk quality should make it easier and more comfortable to walk, increasing people's likelihood to travel by foot.

Mode Shift

Of all New Mobility modes, e-scooters have the most comparable of typical trip distance to walking. This suggests an increased likelihood of mode shift. Given that Cambridge does not currently allow scooters, data from the cities of Minneapolis and Portland, OR, where scooter companies operate, were assessed. Some walking trips between .51 and 1.5 miles, which might otherwise be pedestrian trips, could shift to electric scooters once they are permitted in Cambridge.



Average Trip Distance in Portland	
Mode	**Average Trip Distance (miles)**
Electric Scooter* **	**1.19**
Walk**	**0.58**
Bike**	**3.68**

* Scooter data from 2018 Minneapolis Motorized Foot Scooter Pilot [14]
** Walk trips and bike trips from 2017 National Household Transportation Survey Data [15]
*** Scooter data from 2018 Scooter Pilot by Portland Bureau of Transportation [16]

During a pilot conducted by the Portland, OR, Bureau of Transportation in 2018, there were 5,885 trips observed per day, with 19 percent of all trips occurring during peak hours on weekdays (1,118), possibly for commuting purposes. 37% (414) said that they would have walked had e-scooters not been available. [17]

Opportunities (Reasons to Support)

Walking supports a healthy lifestyle, encourages a more active streetscape and community interactions, and is the mode that emits the least amount of greenhouse gases, particulates, and noise when traveling through the City.

Challenges (Reasons to Limit)

There are no compelling reasons to limit walking. The City is actively encouraging more walking activity. The City should build and maintain infrastructure in a way that ensures access for individuals with mobility challenges.

14 https://lims.minneapolismn.gov/Download/RCA/8334/Scooter%20Pilot%20Summary%20&%202019%20Proposal%20Presentation.pdf
15 https://nhts.ornl.gov/
16 https://www.portlandoregon.gov/transportation/article/709719
17 https://www.portlandoregon.gov/transportation/article/709719

6.2 Cycling

Forecast Summary

Cycling is projected to increase in the short term as the City continues to roll out its bike facility policy. Also, as one of the few cities in the US approaching bicycle safety "critical mass," we expect cycling activity to consistently increase.

Cycling
Forecast Change
+++

Each "+" represents an approximate 10 percent increase in trip activity.

Forecast Wild Cards

Ultimately, the rate at which pedal cycling increases, or whether it continues to increase, is subject to any number of changes or disruptions. The rate of cycling could dramatically increase-- the extensive bike lane network could absolutely impact biking activity in Cambridge; the introduction of pedal-assist e-bikes to bike share could attract new users; additional bike parking facilities could be installed near public transit stations; or the City might choose to mandate that logistics services and deliveries, whether of food or packages, be delivered by bike. However, levels of pedal cycling might be reduced by the increasing availability and affordability of electric scooters, e-bikes, and mopeds. Or, if the Cambridge bike network expands slower than expected cycling activity also expands incrementally.

Pressures and Trends

Demographic Impacts

The number of active cyclists is in part driven by City demographics, especially population age. The projected increase in population across the younger and middle age groups suggests a likely increase in the number of bicyclists as well.

Policy

The City of Cambridge recently passed legislation called The Cycling Safety Ordinance, which requires the installation of protected bike lanes during construction on streets identified as part of the proposed Cambridge bike network in the Cambridge Bicycle Plan, as well as the five-year sidewalk and street reconstruction plan. The legislation is the first of its kind in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Cambridge passes 'first-of-its-kind' law to add protected bike lanes when reconstructing roads

By Steve Annear Globe Staff, April 9, 2019, 12:30 p.m.

The Cycling Safety Ordinance requires the city to add permanent separated bike lanes when doing reconstruction of certain roads. DAVID L. RYAN/GLOBE STAFF/FILE 2018/GLOBE STAFF

the nation and will aid the City in the expansion of its bike infrastructure. This ordinance is in addition to the already substantial bike lane network built by the City, and its efforts to create comfortable conditions for cyclists. The City also mandates bike parking for new developments, ensuring bike storage at home and at work.

Relevant Policies

- Vision Zero
- Cycling Safety Ordinance
- Vehicle Trip Reduction Ordinance
- City of Cambridge Bike Plan
- City of Cambridge Complete Streets
- Massachusetts Global Warming Solutions Act: Requirements for Transportation

Market

There has been a nationwide increase in cycling across the United States, especially in urban areas that have built bike lanes and have introduced bike sharing, such as the regional public Bluebikes system shared between Cambridge, Somerville, Boston, Brookline, and Everett. Cycling has received substantial attention over the past decade as a result of growing interest and demand for sustainable travel, and in response to the gridlock common to many American cities. There has also been an increase in bike share systems, both docked and dockless. Docked systems like Bluebikes have typically been implemented with the explicit support and collaboration of cities, while dockless systems are often privately owned, and have not always been permitted prior to increased market demand. As the dockless share market has developed, some private companies are cooperating with City governments on launching dockless bike fleets. Both docked and dockless bike share fleets have increasingly included electric or pedal-assist bikes in their fleets. Electrification seems likely to receive the bulk of future attention and investment, both for new and existing systems, as a way to attract new riders and increase the distance ridden by existing riders.

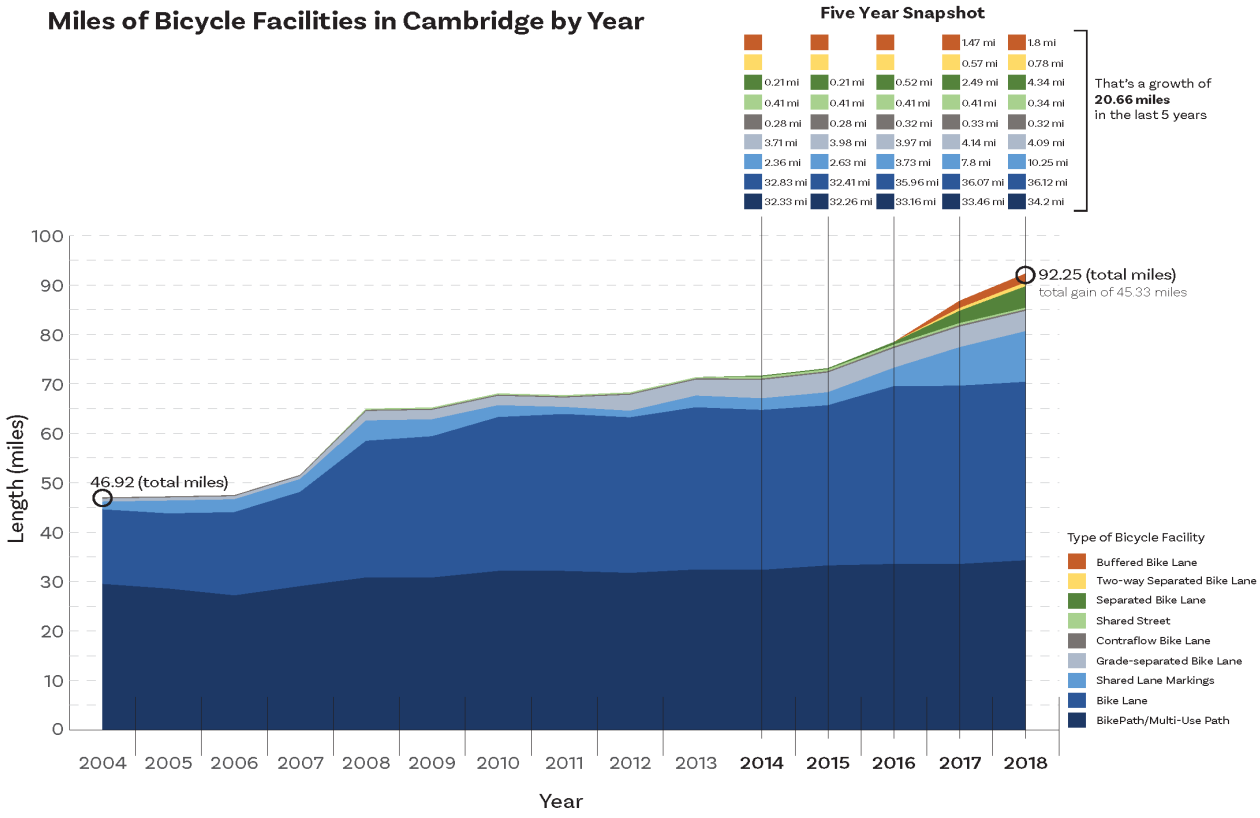
Technology

Bike share systems have been successful as a result of advances in GPS and smart phone technology that allow users to find and unlock available bikes. Dockless fleets have increasingly turned towards electric and pedal-assist bikes for their fleets, as have docked systems, though to a lesser extent. Shared electric bikes change servicing and operations requirements for bike fleets by forcing operators to ensure batteries are fully charged in addition to conducting maintenance of the bikes. Furthermore, companies are forced to ensure that brakes are better serviced, given the increased likelihood of a crash resulting from overused brakes in need of maintenance.

Infrastructure

The City of Cambridge has steadily added bike lane miles since 2004, with more than 92 miles of bike lanes installed as of 2018. Increasing bike lane miles and bike network connections will encourage new cyclists to start biking. According to research conducted by Y. Yang et al., which analyzed thirty-nine studies published in peer-reviewed journals between 2007 and 2017, there is a positive connection between the presence of bicycle

paths and facilities with both commuter cycling and general cycling. For every 1% increase in bike lane mileage, there is an associated 0.28% increase in commuter cycling, not even including non-commute cycling.



Source: http://www.cambridgema.gov/~/media/Images/CDD/Transportation/Bike/facilitiesimprovements/bicyclefacilitiesgraphdecember2018.png?la=en

Mode Shift

Pedal bikes mostly face competition from new light electric vehicle technology like e-bikes and e-scooters. Research conducted by MacArthur et al. at Portland State University shows that e-bikes are both generating new demand and substituting for trips made by pedal bikes and cars. [18]

Further research shows that e-bikes make it possible for people to ride a bicycle who might otherwise be incapable or who don't feel safe doing so. Analysis of e-bike trips indicate that e-bikes could replace various modes of transportation commonly used for errands and recreational trips, including motor vehicles, public transit, and standard bicycles.[19]

Opportunities (Reasons to Support)

The City should continue to support and encourage more pedal biking. Pedal bikes are a healthy, sustainable means of travel. They are useful for full trips, or to access transit. The

18 *https://ppms.trec.pdx.edu/media/project_files/E-bikes_in_North_America.pdf*
19 *https://bikeleague.org/sites/default/files/E_bikes_mini_report.pdf*

growing popularity of electric and pedal-assist bikes will make biking more attractive for those who aren't able to pedal a bicycle; electric bikes also increase a bike's range, which will increase the likelihood that cycling trips will substitute less sustainable modes of transit.

Challenges (Reasons to Limit)

There are no reasons to limit pedal biking. It is a sustainable and healthy mode of transportation and has strong community support. Dedicated infrastructure (such as bike lanes) ensures that crashes are rare, and the City is increasing efforts to build more protected bike lanes.

The introduction of electric or pedal-assist bikes to bike lanes, however, could cause discomfort and tension with pedal-bike users. Electric bikes move at much higher speeds than the average cyclist. The City should consider how to ensure that electric bikes could coexist with existing bike activity. Research suggests electric bikes generate new demand, making it possible for people who cannot otherwise pedal bike to travel by bike; it's critical that the city leverage the new technology to ensure new e-bike riders are able to use the new technology, but not to the detriment of current cyclists who operate at lower speed ranges.

6.3 Transit

Forecast Summary

Overall, we foresee a mixed, challenging road ahead for transit. Infrastructure improvements will likely increase ridership by improving service, but competition from new and possibly disruptive modes like ride-hail vehicles, e-scooters, and e-bikes will continue; without policy guidance, competition could increase. This is especially true of e-scooters, mopeds, and e-bikes, which are not yet prevalent in Cambridge, but are shown to be useful at distances within the City. Overall, in the near term, this competition will likely decrease transit ridership. However, the extent of ridership losses will depend on wildcard factors including the price of RHVs, traffic congestion in Cambridge, and policy guidance for e-bikes and mopeds.

Transit
Forecast Change
+++

Each "+" represents an approximate 10 percent increase in trip activity.

Forecast Wild Cards

The extent of competition with transit from new modes like e-bikes and mopeds will depend on the policy guidance ultimately put forth by the City. For example, if the City encourages synergy between electric moped, bike, and scooter trips with transit by creating mobility hubs[20], an increase in usage of those modes could also increase transit ridership. Without policy, those modes could ultimately substitute completely for transit trips. Furthermore, without policy guidance, ride-hail vehicles could continue taking ridership from public transit. However, if the cost of ride-hail trips increases, and companies like Uber and Lyft are no longer able to subsidize trip fares, then transit might become more attractive.

There are a number of other policy measures that might affect transit ridership. For example, introducing congestion pricing, increasing charges for workplace parking, or decreasing the parking supply could ultimately increase transit ridership. Dedicated bus lanes could significantly increase bus performance and increase its value relative to automobiles. Around the world, cities have experimented with decreasing transit fare prices in order to attract ridership. In Bonn and Reutlingen, Austria, an annual pass costs just 365 euro, for all public transit. In Vienna, the City introduced a cheaper annual ticket in 2012, and the number of people using public transportion doubled. Luxembourg announced that in March 2020, all of its public transit services would be free. Germany is considering making all of the country's public transit services free, as well.

20 Mobility hubs are intentional locations where 3 or more different types of transportation choices are linked. An example would be a hub, located near a transit station, that allows for walking, biking, e-biking, and carsharing.

Pressures and Trends

Demographic Impacts

As the resident and worker population of Cambridge and the region continues to increase, so will the number of people using public transit to get to and from the City. This is especially the case as the City continues to pursue transit friendly policies, in addition to parking and transportation demand management.

Policy

The City has pursued numerous transit friendly policies and continues to explore policy that discourages trips by single occupancy car in favor of using transit.

Relevant Policies

- Parking and Transportation Demand Management Ordinance, 1998
- Vehicle Trip Reduction Ordinance, 1992
- Cambridge growth policies, 1993 and 2007
- City of Cambridge Strategic Transit Plan, 2015
- Massachusetts Global Warming Solutions Act: Requirements for Transportation
- MassDOT Capital Investment Plan

Market

Transit has been competing with growing congestion on streets often amplified or created by new modes like ride-hail vehicles for passenger trips and in some respects it has been a race between the speed at which the Massachusetts Bay Transportation Authority MBTA can address the infrastructure challenges versus the establishment of new transportation choices. So far, the T has been losing this race and suffering ridership losses as a result. The MBTA is investing in capital improvements with some increases to bus and rapid transit service, which could help transit compete better with ride-hail companies. Furthermore, ride-hail giants Lyft and Uber, faced with significant pressure after having become publicly traded companies this past year, will likely phase out trip subsidies in the near future. If they do, transit may be more competitive based on value.

Technology

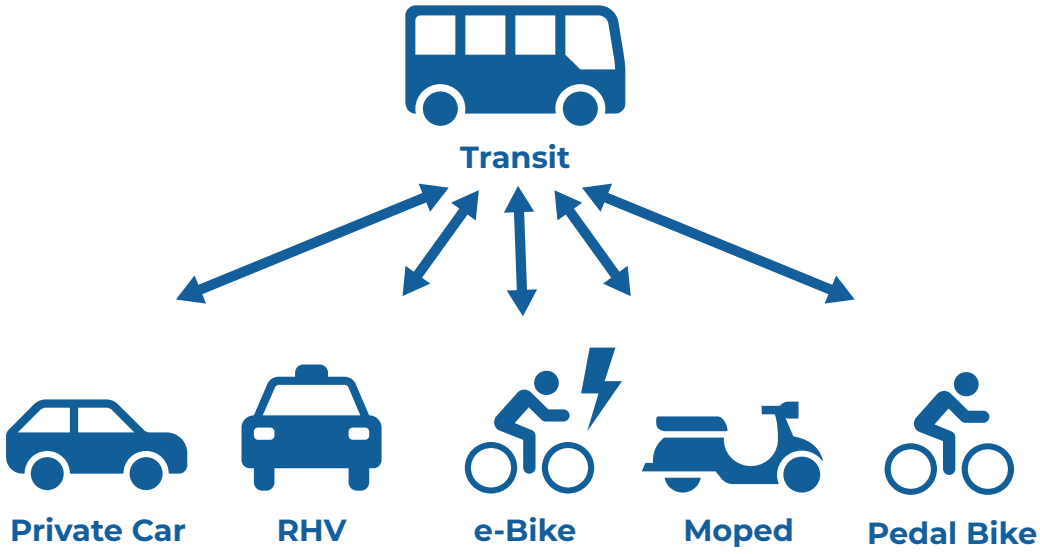
The MBTA is investing $350 million on signal systems that will allow it to increase the frequency of train service. It has endorsed a number of apps for navigating the City by transit, and is studying technologies to improve realtime bus arrival information for riders. The MBTA is also progressively electrifying commuter rail and public buses in Cambridge, as well as exploring opportunities for new modes of travel, including transportation by water.

Infrastructure

Focus40 is the long-range investment plan to position the MBTA to meet the needs of the Greater Boston region in 2040. The agency has programs including the Better Bus Project, partnerships for improved first-mile/last-mile connections, and programs for subway improvement that would hopefully encourage greater ridership.

A study by the Chicago Metropolitan Agency for Planning found that enhancing station and vehicle environments led to a small increase in ridership; effects, however, were greater for populations including older or lower income users. By contrast, vehicle improvements had a larger effect on increasing ridership among higher income travelers.

Mode Shift



Transit is in competition with RHVs and private vehicles. When a competing mode provides better value (in terms of cost or time) than transit, people consider travel by that mode instead, whether it be by car, moped, or RHV (shared or single occupancy). The general relationship with transit is complicated, however, by the increase in traffic congestion caused by new modes competing with buses for street space (especially RHVs) and the increase in transit fare prices during the same period. At the same time, the overall mean and median personal incomes have risen in Cambridge, suggesting additional expendable income for many residents that might lead to more RHV trips. Overall, research suggests that RHVs have decreased annual ridership for buses by 1.7% and for light rail (subway) by 0.4%. This has been the case since the technology's release and will likely continue to be the case.

Public transit faces challenges including the drop in the price of gasoline and the growing popularity of bike share and ride-hailing services, both of which appear to have adversely affected transit ridership. Furthermore, transit fares have risen faster than inflation, possibly deterring riders.

The Commonwealth's Future of Transportation study and MassDOT's Statewide Congestion Study also both describe challenges to transit.

Opportunities (Reasons to Support)

Transit is highly sustainable and equitable, and works very well for trips between 1 and 5 miles on the bus and rapid transit network, and greater distances on commuter rail. Especially in highly populated areas like Cambridge, and it is far and away the most efficient means of moving people without suffering pollution and gridlock. The MBTA has made significant progress towards accessibility for people with disabilities that impact navigation under the Americans' with Disabilities Act and the Massachusetts Accessible Architectural Board guidelines. Transit is the most affordable way to travel for residents across the income spectrum in Cambridge and the region.

Challenges (Reasons to Limit)

Transit can be costly to maintain and upgrade over time. There are few reasons to limit transit.

6.4 Single Occupancy Vehicles (SOV)

Forecast Summary

In general, the primary predictors of mode choice are socio-demographic and practical in nature; income, auto ownership, urban density, trip duration, and infrastructure that supports walk, bike, and transit trips, by modes all affect how people choose to get around. However, between comparable areas, the built environment is highly influential. Factors like street layout, pedestrian comfort, and sidewalk conditions, and the availability of transit and parking, directly affect whether people choose to drive. In Cambridge, the built environment plays an especially important role, where parking (especially off-street workplace and other destination parking) is likely the most significant component motivating SOV trips.

Single Occupancy Vehicles
Forecast Change
+++

Each "+" represents an approximate 10 percent increase in trip activity.

Forecast Wild Cards

The most significant unknown affecting the forecast of single occupancy vehicles is policy and regulation. There is, for example, increasing interest across the United States in congestion pricing, which makes travel by SOV significantly more expensive and would likely decrease SOV levels. Furthermore, if the City takes additional action to limit parking, either at workplaces or other destinations, it could also affect the value of travel by this mode. Globally, there are examples of regulation targeting vehicles by fuel type, like prohibitions on petrol- and diesel-fueled cars in France. There are also existing regulations for road access by both high-occupancy and single-occupancy vehicles. If either vehicle-type bans or occupancy-based requirements were enacted, it would likely impact the number of SOVs.

Pressures and Trends

Demographic Impacts

Likewise, as job opportunities continue to grow in Cambridge, so does the chance that employees who reside outside of Cambridge would choose to commute to work by single-occupancy vehicle. As resident population increases in Cambridge, so too does the potential for single-occupancy vehicle trips by residents, though residents generate far fewer SOV trips than workers. The City also experiences through-traffic from the surrounding region, at least some portion of which is single-occupancy vehicle. The City has introduced policies to limit resident and commuter demand for single-occupancy vehicle trips, but it remains to be seen how population increases affect travel patterns.

Research suggests that, in general, the quantity of SOV commuters is ultimately determined by

a combination of the factors listed in Table 1.1 Current literature does not imply that any single factor determines choice. Mode characteristics such as accessibility, cost, and convenience are commonly highlighted as important.[2]

MPOs such as the Boston Region Metropolitan Planning Organization, the New York Metropolitan Planning Council and the Southern California Association of Governments use prediction models that put[21] primary importance on individual characteristics and consider physical characteristics of secondary importance.[22]

Table 1.1: Factors Influencing Mode Share

	Variable	Parameters
1	Physical Environment	Population density, land use, topography, infrastructure;
2	Mode Characteristics	Availability, accessibility, convenience, comfort, privacy, freedom, safety, travel time, cost;
3	Individual Characteristics	Occupation, gender, age, income, car ownership, daycare responsibilities, possession of a license;
4	Trip Characteristics	Trip purpose, trip distance, trip origin and destination;
5	Attitudes	Environmental concerns, familiarity and comfort with alternative modes;
6	Policies and TDM measure	Parking costs, transit passes, emergency-ride-home programs, communications, events (Zhou 2012)

Source: "Chapter VIII. Commute Mode Choice," Office of Transportation Policy Studies, US Dept. of Transportation, Federal Highway Administration

Policy

Cambridge has a long-term city strategy to design streets and focus policies to give people choices for getting around, in order to shift people out of SOV trips and into walk, bike, transit, and high-occupancy vehicle trips. The City adopted policy to discourage automobile and SOV trips, including the Vehicle Trip Reduction and Parking and Transportation Demand Management ordinances. Planning studies also incorporate recommendations for limiting the percent of drive-alone trips, and parking ratios and TDM programs to accomplish those mode-share goals.

Relevant Policies

- Parking and Transportation Demand Management Ordinance
- City of Cambridge: Vehicle Trip Reduction Ordinance
- Complete Streets

Market

The City of Cambridge has a lower rate of trips by SOV than most of the United States. Given the car's centrality to travel in areas outside Cambridge, the City is still subject to SOV through trips from the surrounding region. However, the City's high-quality transit service, walk/bike infrastructure, and active encouragement of trips by transit, bike and walking, instead of by SOV, has limited resident SOV trips. New services including carpooling and bike share have emerged as market-based alternatives to SOV trips. RHV companies have the

21 https://www.ctps.org/data/pdf/plans/LRTP/needs/2035NA_AppA.pdf
22 "Cambridge in Transition: Regulating Parking in a Growing City," Ferrentino

ability to influence people to travel alone or by carpool, based on companies user profiling and behavioral and cost models. New tools have emerged to monetize carpooling, like Waze Carpool.

Technology

There is no technology that will specifically influence the growth of SOVs in Cambridge. However, the growing popularity of electric vehicles and availability of new charging infrastructure in and between cities might increase EV ownership and SOV rates. The automobile industry's investments into autonomous vehicle technology could also influence SOV trips once the technology is available, if personal AV ownership becomes the norm, or riders choose to travel alone by AV.

Infrastructure

According to research by Weinberger et al., private parking is ultimately the key motivator of SOV commuter trips.[23] Commuters choose the way they get to work by thinking about the advantages of each option. When parking is hard to find at either or both ends of the trip, transit starts to look more attractive than automobiles. However, when there is guaranteed off-street parking at a trip's origin, particularly if it is on site or consistently guaranteed close by, the likelihood that people will use cars even for trips that are well served by transit increases dramatically. [24] [25] The City has prioritized reconsidering the public right of way currently dedicated to car travel and parking, and has been prioritizing bike lanes, sidewalks, and dedicated bus lanes.

Mode Shift

The emergence of carpooling, e-bikes and scooters, and the improvement of public transit service all have the potential to substitute for SOV trips in Cambridge. Many SOV trips are for distances that fall within the range of emerging services. However, ride-hail vehicle trips are often taken alone, which is considered an SOV trip by the City. In between trips, drivers often continue driving while waiting for new ride requests, which worsens congestion and increases vehicle miles traveled in the City.

Opportunities (Reasons to Support)

There are few reasons for the City to support SOV trips, which cause congestion and pollution, make public transit less efficient, and increase vehicle miles traveled within the City. The City's goal is to make it convenient, comfortable, and affordable for all trips to be made by a sustainable mode. Driving is sometimes the preferred mode of choice for families who can afford to own a car, especially for non-work and school trips during times of day when there is less traffic. For residents who continue to own a car, the City is pursuing ways of encouraging EV adoption.

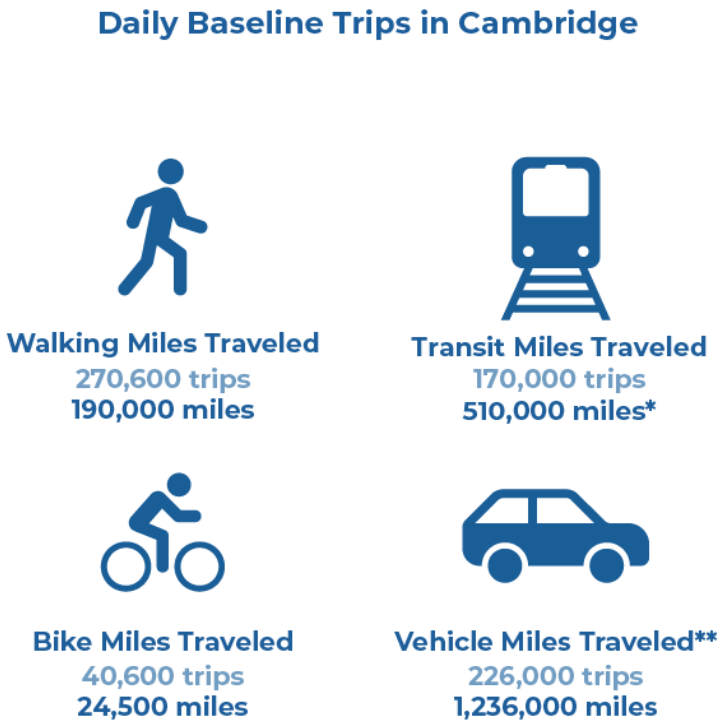
23 *"Guaranteed Parking – Guaranteed Driving: Comparing Jackson Heights, Queens and Park Slope, Brooklyn," Weinberger et al.*
24 *"Parking facilities and the built environment: Impacts on travel behaviour," P. Christiansen et al.*
25 *"The Trouble With Minimum Parking Requirements," Shoup, Donald*

Challenges (Reasons to Limit)

SOV trips are a major cause of congestion leading to gridlock and, cars with traditional internal combustion engines are a major source of greenhouse gas emissions and particulate pollution. Traffic congestion ultimately leads to even greater levels of emissions, as cars idle and pollute in place as they do so. It also makes travel by bus less efficient, which makes people less likely to travel by bus in the first place. In addition, cars pose a significant safety threat to pedestrians and other road users, especially cyclists where there is no protected bike lane. Cambridge adopted Vision Zero goals and has been strategically pursuing safer streets for pedestrians, cyclists, and other road users. In general, cars are far less space-efficient than sustainable travel options.

Appendix

Appendix



* Transit travel assumes an approximate trip distance of 3 miles per trip which is the average bus and subway trip in the MBTA area.
** Average Daily Vehicle Miles Traveled is based on estimates by the Boston Region Metropolitan Planning Organization and does not include public bus miles traveled.

Walking Miles Traveled (WMT) and Bike Miles Traveled (BMT)
Walking Miles Traveled (WMT) and Bike Miles Traveled (BMT) were calculated using a combination of bike and pedestrians count data (TIS data) and cellular data. The two were combined to estimate citywide patterns according to the following steps.

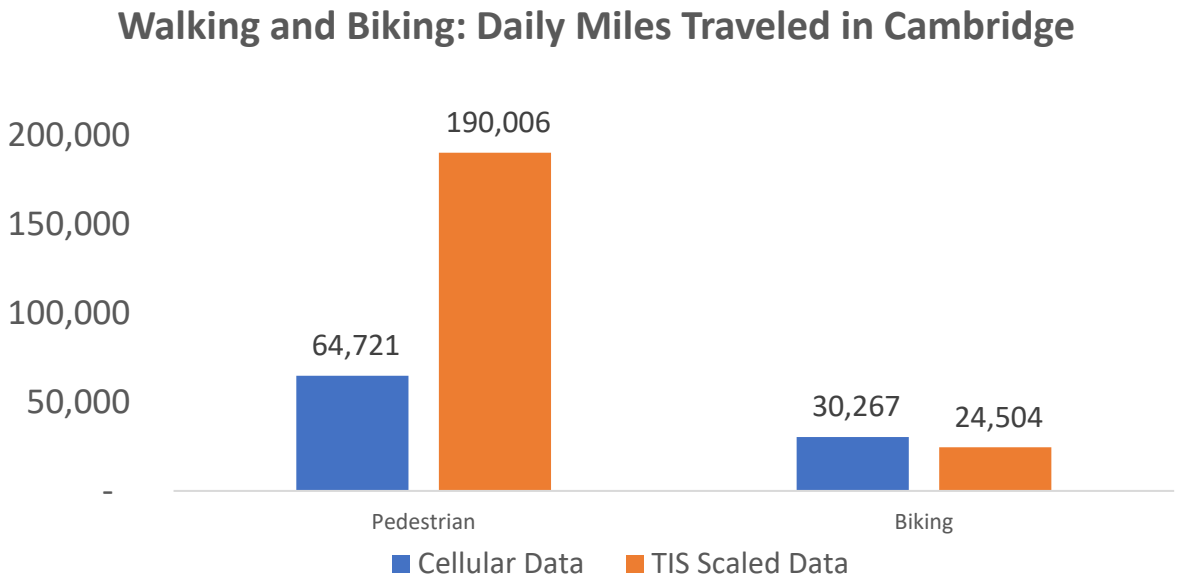
Assumptions:
GPS data captures miles traveled by biking and by walking for parts of the population. WMT and BMT were scaled proportionally using population density from GPS and TIS data with two assumptions:

- GPS data is representative of the entire population in terms of trip length
- TIS data captures the whole population at sampled locations and is representative of the entire city

Approach:

1. Data was spatially joined and reformatted into quadtree tiles.
2. Valid TIS data points were analyzed using simple linear regression and polynomial regression methods relative to cellular data in order to calculate a citywide correction factor, which was then used to scale patterns across the entire City.

3. Miles traveled was calculated for each quadtree index for cellular data and then a simple linear regression model was developed to determine the coefficient for the number of cyclists and walking miles traveled.
4. The coefficients were applied to the scaled TIS data to estimate miles traveled.
5. All miles travelled were summed for each quadtree tile.



Transit Miles Traveled (TMT)
TMT relies on data from the Massachusetts Bay Transit Authority and was calculated by multiplying route length (in miles) for public buses and subways within Cambridge by frequency on typical weekdays for Spring 2019.

Vehicle Miles Traveled (VMT)
VMT relies on the Boston Region Metropolitan Planning Organization's regional model, and its estimate for Cambridge specifically, to capture current activity within the City.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