Technische Universität Berlin
Urban Management 2017-2019

Transportation System Efficiency in High SOV, High VMT Settings: Push-Pull Policy Framework for Commuter Mobility-as-a-Service in the San Francisco Bay Area

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February 1, 2019

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Statement of Authorship

I declare that the research contained in this thesis, unless otherwise formally indicated within the text, is the original work of the author. The thesis has not been previously submitted to this or any other university for a degree and does not incorporate any material already submitted for a degree.

Signed,

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Acknowledgements

Thank you to the experts throughout California who generously donated their time and provided keen insights into transportation, as well as the hundreds of survey respondents in the San Francisco Bay Area who contributed their perspectives about transportation in the Bay Area. Your perspectives elucidated many of the findings outlined in my research.

Carrie Armel, Stanford University
Sue-Ellen Atkinson, Santa Mateo County
Marshall Ballard, Fehr and Peers
Greg Beverlin, Santa Clara County
Amber Blizinski, City of Sunnyvale
John Brazil, City of San Jose
Giovanni Circella, Institute of Transportation Studies, UC Davis
Matt Cole, Cubic
Aiko Cuenco, Santa Clara Valley Transportation Authority (VTA)
Gary Hsueh, Prospect SV
Mike Hursh, AC Transit
Mayor Sam Liccardo, City of San Jose
Doug Moody, City of San Jose
Dennis Markham, BART
Gary Miskell, Santa Clara Valley Transportation Authority (VTA)
Jarrett Mullen, City of Palo Alto
Steve Raney, City of Palo Alto Transportation Management Association
Sohail Rashid, MaaS Global
Robert Regue, Scoop Technologies
Seleta Reynolds, Los Angeles Department of Transportation
Hillary Rupert, City of Palo Alto
Brian Shaw, Stanford University
Emma Shlaes, Silicon Valley Bicycle Coalition
Nicole Soultanov, SPUR
Laura Stunchinsky, City of San Jose
Steve Swasey, Moovit
Corey Tucker, Ride Amigos
Jeanie Ward Wall, Caltrans Sustainability Office
Michael Woosley Oudahl, Google
Aaron Vogel, Santa Clara Valley Transportation Authority (VTA)
Christy Wegener, Samtrans
Jennifer Yeamans, Livermore Amadore Valley Transportation Authority (LAVTA)

Special thanks to the team at Joint Venture Silicon Valley and to Russel Hancock for your commitment to meaningful work throughout the Bay Area. To Steve Raney, you laid the foundation upon which my research builds.

Thank you to my advisor Dr. Felix Creutzig, a fearless intellect pushing the boundaries of climate change policy. Your direction and support are invaluable to me.

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ABSTRACT

In California, forty percent of greenhouse gas emissions are attributed to transportation, three quarters of which is accounted for by cars and light trucks, making the sector the largest source of total emissions in the state. California is leading in the development of comprehensive policies aiming to reduce emissions from the transportation sector, including vehicle and fuel efficiency, creating more dense, mixed use, transit-oriented development and increasing the utilization and efficiency of roadway and public transit networks. At the same time, the transportation sector must address increasing demand for highways, declining revenue streams and falling ridership of public transportation, and new models of mobility precipitated by private sector transportation network companies (TNCs).

To achieve California's climate objectives, this thesis considers how one particular model, Mobility as a Service, "MaaS", may be used as a strategy to reduce per capita vehicle miles traveled (VMT), a climate change indicator, while simultaneously preserving per capita passenger miles traveled (PMT), an indicator of mobility in low density, auto-centric contexts of the San Francisco Bay Area. The application of an interdependent "push" and "pull" policy model, land use pricing and public-private mobility integration, is evaluated as a key element of Bay Area MaaS is critical in shifting demand from single occupancy vehicle transportation to integrated, multimodal mobility that increases utilization of the region's existing transit system.

Operationalizing the multi-level perspective theory to synthesize data from stated preference commuter surveys, expert interviews and case study analyses, key drivers and barriers to MaaS for commuter transportation system efficiency are mapped at three levels: household, spatial-environmental and institutional. Results of the survey indicate that significant demand exists for alternatives to auto-mobility for commute trips, and that there is cultural acceptance of pricing policies and voluntary data donations, elements which will influence the success of MaaS in the region. Three niche MaaS innovations in the Bay Area are identified and found to address key lock-in mechanisms of commuter auto-mobility as they provide mobility in the first and last mile to access the existing transit network as well as cross jurisdictional commutes, while reducing VMT and GHG emissions. The research provides technical and institutional takeaways from these early examples and argues for the regional implementation of a 'push' and 'pull' policy mix that expands and enhances mobility and curtails vehicle miles traveled in low density, high single occupancy vehicle (SOV) settings.

Keywords: Transportation demand management (TDM), single occupancy vehicle (SOV), Mobility as a Service (MaaS), vehicle miles traveled (VMT), greenhouse gas (GHG), transportation system efficiency strategies, passenger miles traveled (PMT), transportation network companies (TNCs)

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1 INTRODUCTION

1.1 Problem Statement

In the San Francisco Bay Area, high rates of single occupancy vehicles and decreasing rates of public transit ridership are the result of the auto-centric, low density suburban cities that characterize much of California's nine metropolitan regions. Like many of its regional counterparts, development of the nine county, 101-city region has been driven by two parallel forces, car transport and single-family housing (Walker & Schafran 2015, pp 15). While the San Francisco Bay Area is considered to be the fourth largest 'urban' area in the United States, with 7.3 million people in 2010, 73 percent of total housing stock is comprised of median, single family housing (Walker 2015, pp 16). Literature indicates that suburban sprawl- comprised of four components, "residential density; neighborhood mix of homes, jobs, and services; strength of activity centers and downtowns; and accessibility of street networks" leads to significant increases in VMT per household (Ewing & Hamidi 2002, pp 1). The consequence of the built environment on travel behavior is significant as we see that, on average, suburban households driving 31 percent more than urban dwellers (Shaheen & Cohen 2018, pp 69). This is evident when comparing per capita VMT between more urban and public transit friendly landscapes such as San Francisco County, which has a per capita VMT of 11.2, and more suburban regions, such Marin and Santa Clara County, which have an average VMT per capita of 26.3 (Bay Area Census 2015, n.p.).

In the same time that per capita vehicle miles traveled has increased, use of other modes has decreased. In 2000, 13.9 percent of commute trips were made in carpools and vanpools (Brittle and Riordan 2009, pp 45) and by 2016, carpooling modes had decreased to 10.2 percent (Metropolitan Transportation Commission 2018, n.p.). Commuters driving alone to work rose to an average of 75 percent regionwide, with suburban Bay Area cities such as San Jose and Dublin averaging 83-85 percent of commute mode share (US Census 2017, n.p,). Public transport ridership declined to 3 percent of passenger miles nationwide and in the Bay Area public transit ridership decreased by 11 percent over a 30-year period, with suburban bus agencies experiencing a 33 percent drop in ridership (Metropolitan Transportation Commission 2017). BART and Caltrain, while at and over capacity during peak commute hours, report an average 4.5 percent decline of in off hour (weekend and evening) trips between 2016 and 2017 (Matier 2018, n.p.) (Caltrain 2017, pp 17).

The result of increasing single vehicle occupancy auto-mobility in the region makes a significant contribution to climate change: in 2016, transportation accounted for 33 percent of total household greenhouse gas emissions (Jones & Kammen 2015, pp 4). These factors make the expansion and identification of gaps in the region's existing transportation system critical to transitioning to the low carbon, low-VMT mobility system outlined in California's landmark climate legislation E.O. 5 and A.B. 32, which mandate 80 percent reductions in transportation-related emissions over 1990 levels by 2050. Bills such as S.B. 375 execute on these mandates by setting reduction goals for light-duty vehicle miles traveled (VMT), 7.5 percent by 2020, and 15 percent by 2035 (Institute for Local Government 2015, n.p.) while S.B. 391 stipulates that California's Department of Transportation (Caltrans) identify an "integrated, multimodal transportation system" that achieves the state's transportation climate goals every five years (Lowenthal 2009, n.p.).

This thesis considers the implication and the implementation of these policies at the local and regional level in the San Francisco Bay Area. The research identifies Mobility as a Service, "MaaS" as a strategy to increase the utilization of Bay Area's existing transit network by offering seamless, integrated mobility to suburban commuters. Implicit in suburban mode shift, however, is the need to overcome the inertia of behavior change and 'lock-in' of physical infrastructure that reinforces cultural patterns of single occupancy vehicle mobility for both commute and non-work trips. In response, the thesis explores two interdependent or "co-aligned" policies that will condition the success of a Bay Area MaaS implementation. The thesis seeks to answer important questions related to the optimization of the Bay Area's existing infrastructure, including how to balance an increase in mobility options in areas where alternatives to driving options are unavailable or inadequate, while simultaneously ensuring that these options do not increase vehicle miles traveled and GHG emissions from the transportation sector?

1.2 Research Aims

Advancing more efficient utilization of the Bay Area's transportation network supports an open research agenda that dovetails with research concepts in sustainable transportation, such as mobility-as-a-service, "MaaS", shared mobility and integrated mobility, which posit that personally owned modes of transportation will become unnecessary as seamless, efficient and multi-modal transit become more common, the result of which is higher throughput of travelers and a lower transportation carbon footprint.

Questions remain regarding the application of such concepts in suburban, low-density environments such as the Bay Area where provision of and demand for high quality public transportation is lacking or challenged for various reasons. The thesis aims to understand the specific barriers, drivers and policy framework of a multi-modal "MaaS" transit system that achieves higher utilization efficiency mobility in low density communities in the Bay Area metropolitan region. The research is guided by three questions:

- What are barriers at the household, spatial-infrastructure and institutional level that "lock-in" auto-mobility and what are the windows of opportunity that Mobility as a Service provides?
- What are the effects of local 'niche' transportation innovations on per capita vehicle miles traveled and per capita passenger miles traveled and do these innovations address the identified lock-in mechanisms of auto-mobility? What elements of MaaS do these niche innovations demonstrate, and how can they inform a regional MaaS implementation as part of making the Bay Area's transportation system more efficient?
- How can a 'push'/'pull' policy framework of public-private mobility integration and SOV pricing create demand for MaaS in order to deliver the most impact in terms of VMT reductions ad increased PMT, as well as ridership of the Bay Area's existing transit network? In the case studies analyzed, what is the role of the two policies and where is there significant room to scale the policy mix for broader impact?

Several methodologies are used to explore these questions. In the background section, a push-pull policy framework for MaaS is constructed, supplemented by secondary research. Part 1 of the research uses a stated preference commuter survey and semi-structured expert interviews to identify barriers that 'lock-in' the Bay Area's single occupancy vehicle commute patterns. In part 2, an exploratory case study analysis of three Bay Area case studies, LAVTA's 'Go Dublin' first-last mile TNC partnership, VTA's on demand, 'Flex' pilots, and Palo Alto's Transportation Management Association's partnership with Scoop Technologies, is employed to define the "[actors], resources, capabilities and networks" that compose the current mobility landscape, as well as key takeaways and performance indicators, including effects on VMT, PMT and transit system utilization efficiency, of these early examples (Smith et al. 2005, pp 1496).

The research operationalizes the theories of social technical transitions and the multi-level perspective to map the barriers and levers or "windows of opportunity" that these niche mobility pilots will face in a scalable low VMT, high PMT-MaaS implementation in the Bay Area. The thesis argues that MaaS as a system of mobility for low density commuters will only generate the desired outcomes with the adoption of a regional 'push' 'pull' policy model that internalizes the use of single occupancy vehicles through pricing and integrates data, scheduling and fares across public and private mobility providers.

MaaS will prompt redefinition and expansion of what qualifies as public transportation whereby the system may "start to take on the feel of conventional bus transport, albeit with smaller vehicles, offering improved public transport-like services that can stretch throughout suburbia or as a first and last mile connection with conventional long-haul public transport" (phone interview with Matt Cole, September 2018). Mobility is being rapidly redefined, and by supporting broader definitions of transportation through the implementation of a combined 'carrot' and 'stick' policy framework, there is significant opportunity to grow the mobility market in low density settings while advancing California's climate goals.

2 Methodology

2.1 Qualitative and Quantitative Research in Transportation Research

For this research, qualitative and quantitative methods are used to understand the micro, meso and macro barriers to mode shift in the San Francisco Bay Area and to gauge the efficacy of three current 'niche innovations' deployed at the city level. Qualitative approaches, including open ended questions and focus groups, are complemented by more quantitative elements of the survey and interviews. The objective in taking a multidisciplinary approach is to examine attitudes and perceptions of current and hypothetical transport policy in the context of real tradeoffs between the environment, institutional capacity and individual preferences in the region's transition away from SOV auto-mobility to integrated mobility as a service.

2.1.1 Stated Preference Commuter Survey

An online commuter survey was conducted with 502 commuters from across 12 cities across the Bay Area, with over half of respondents living in the South Bay, geographic sub-region of approximately 1.75 million people (World Population Review 2018, n.p.). Commuters were targeted as the primary demographic of the survey for several reasons. First, while commuting accounts for only 30 percent of total trips in the Bay Area, because driving patterns are relatively uniform across multiple days when compared to activity-based models of travel associated with non-work trips, my hypothesis was that mobility as a service interventions would more suitable and furthermore, these trips would be more likely to connect into the existing transit system (Plan Bay Area, n.y., pp 13). Secondly, congestion and elastic choice dynamics such as time and cost which are increasingly relevant to Bay Area commuters, provide additional scope for research into the viability of MaaS and mode shift, subjects which are further elaborated in length in sections below.

At the outset of my research process, I held focus groups with three individuals in San Jose and once more with three individuals in Los Gatos, both which helped me to identify important attributes and challenges associated with commuting in region. Commuter surveys are a commonly used tool employed by transportation planners to understand mode choice considerations, the influence of time-based patterns such as trip duration and distance, whether current services meet the needs of a community, societal narrative that shape behavior, as well as the potential response of commuters to proposed services (Mahmassani et al. 1993 pp 80-81). Importantly, the latter speaks to the survey's stated preference elements, an approach used to determine consumers' evaluation of hypothetical attributes, products and services (Yang et al. 2009, pp 4). This was useful as many MaaS scenarios are speculative.

Half of the online commuter survey contained questions related to commuter's perception of the region's current transportation options and top challenges faced in using these options, while the second half used a stated preference survey format, posing hypothetical choice alternatives to current options. This portion of the commuter survey sought to understand whether people show a higher intention to shift to public transport and alternative modes for work trips than for other purposes, the factors that influence these choices, support for contentious but important policies of MaaS transportation, including congestion charging and voluntary data donations, and the degree to which stated modal shift change in response to different variables, including cost, travel time, proximity to station, transfer time, and the availability of first and last mile services.

2.1.2 Semi-Structured Expert Interviews

In part two of my research, a semi-structured interview approach was used, which provided the opportunity to speak with multiple individuals and develop multiple perspectives on environmental, technical and institutional barriers to mode shift through MaaS. Generally, semi-structured interviews are comprised of standardized questions that allow researchers to delve deeply into a topic through different lenses while ensuring that questions and responses are consistently captured across different interviews (Harrell et al. 2009, pp 27). The semi-structured interviews lasted between 30 minutes to an hour, with a significant portion of time spent coding verbal data and identifying key differences and commonalities between responses. The experts identified, mentioned in the acknowledgement section, were chosen based on their roles and ability to speak to Bay Area transportation-related topics at the city, regional and state level. The approach allowed me to understand specific institutional challenges related to reducing single occupancy vehicle use and the implementation of MaaS in suburban contexts as well as gather critical information related to the implementation of early 'pilots', with a common set of questions used to define the efficacy of these programs in relation to VMT, PMT and connections to transit, and institutional best practices and challenges.

2.1.3 Exploratory Case Study Analysis

An exploratory case study analysis is intended to answer the 'how' and 'why', which helps researchers explore the "operational links and consistencies between case studies, rather than exceptions or isolated incidents" (Yin 2013, pp 8). This approach relies on direct observation via secondary research and systematic interviewing, which in this research was gathered during select semi-structured expert interviews. The objective of each case study was to illuminate "a decision, or set of decisions: why they were taken, how they were implemented and with what result" (Yin 2013, pp 12).

2.2 Theoretical Framework

2.2.1 Socio-Technical Transition Theory

The Bay Area's shift from high SOV, high GHG to low SOV, low carbon mobility, facilitated through MaaS, will be challenged by multiple lock-in mechanisms that prevent or obstruct the transition. A transition is defined as "...a gradual, continuous process of change where the structural character of a society (or a complex subsystem of society) transforms…and involve a range of possible development paths which… government policy can influence" (Rotmans 2007, pp 18). California's objective to reduce VMT by encouraging mode shift will face a host of challenges, as the existing regime, which is auto-mobility, is stabilized by sunk costs of existing car-centric infrastructure and historic land use patterns, established travel behavioral patterns and user practices, vested business and political interests, favorable subsidies and regulations. (Unruh, 2000, pp 818).

Successful regime transitions, on the other hand, can be spurred by a variety of selection pressures and "cracks in the regime" such as California's climate legislation, as well as the technology advances, and changing consumer preferences both internal and exogenous to the existing regime (Smith et al. 2005 pp 1492). The latter points to the strong input from civil society, non-governmental entities, and private interests as these actors "will be able to replace existing systems without changes in economic frame conditions, for example, taxes, subsidies, and regulatory frameworks (Geels 2011, pp 25).

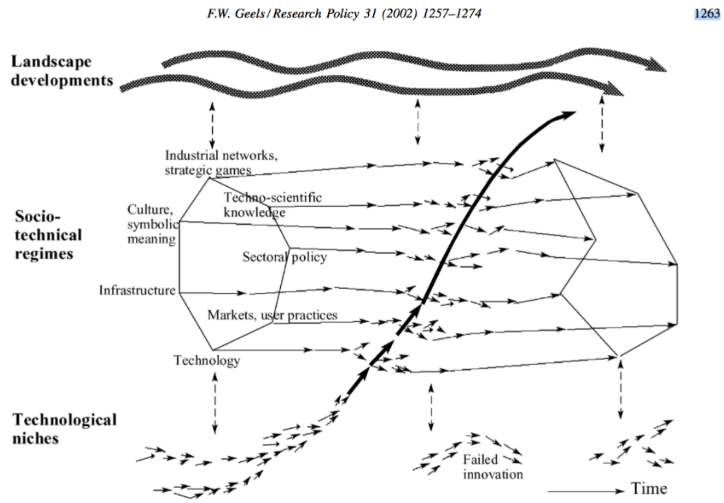


Figure 1 shows innovative niches, represented by the upward-moving arrows, as they seek to overcome various exogenous forces acting against them in the multi-level framework of socio technical transitions. Barriers reinforce the regime, while windows of opportunity accelerate transitions to new paradigms (Geels 2012)

The socio-technical approach to auto-mobility transitions highlights the multi-dimensional interactions between industry technology, markets, policy, culture and civil society groups that occur across various the various levels of government and which link horizontally (Geels Kemp 2012, pp 57).

2.2.2 The Multi-Level Perspective

The nature of the region's mobility transition can be illuminated through the multi-level perspective, a framework employed by sociotechnical transition theory, which illustrates that multiple levels embedded with regulation, infrastructure, business models and consumer practices that new technologies must negotiate. The MLP stipulates that the uptake of new regimes is the result of tensions, windows of opportunity and momentum produced at each level: niche, socio-technical regime, and landscape. Breaking through a regime is the result of social groups' activities at each level and so these transitions must involve changes in the activities, institutional arrangements and linkages in and between each level (Geels 2010, pp 506).

The basic premise of the multi-level perspective (MLP) is that transitions are "non-linear processes that result from the interplay of multiple developments at three analytical levels", including niches (the locus for radical innovations that act as a safe haven), socio-technical regimes (the locus of established practices and associated rules), and an exogenous socio-technical landscape (Geels 2002 pp 1). The MLP proposes three analytical levels: the niche, regime and landscape: Micro level safe havens can provide fledgling technologies with the opportunity to develop largely uninterrupted for a brief period of time.

The following paper applies the MLP in a slightly modified way to understand the results of early MaaS experiments and their drivers and limitations at three levels:

- Micro level: what are the perceptions of and attitudes towards costs, the value of time and reactions to public transportation configurations and hypothetical mobility scenarios?
- Meso (spatial-temporal): the physical environment (and transport infrastructures) within which these choices are made. Analysis of the built environment is an area which the MLP is not fully elaborated, requiring additional theoretical framing discussed in the next part.
- At the institutional level, service for suburban commuters/drivers is a question of institutional arrangements, practices and regulations which are deeply intertwined with physical environment and historic investments and funding sources. The scope of this level is primarily concerned with the actors and institutions responding to specfic conditions at the meso and micro levels (Nykvist Whitmarsh 2012, pp 1375)

2.2.3 Hard and Soft Infrastructures

While the multi-level perspective has strong temporal orientation (explaining processes over time), it does not elaborate on the spatial dimensions that are interwoven in travel choice decisions, despite that niche innovations are embedded hyper-locally (Lawhon Murphy 2011, pp 352). The MLP framework stops short of "conceptualizing the spatial variety and complex interdependencies that result in geographically specific forms of institutional embeddedness within regions and places" (Lawhon Murphy 2011, pp 362). While the MLP outlines the exogenous environment at the landscape level, that is "the material and spatial arrangements of cities, highways and electricity infrastructures", these environments differ depending on their geographic context, whether between cities such as New York, Singapore or San Francisco, and at an even smaller geographic scale, between urban cores such as San Francisco and the suburban, low density cities that surround it (Geels 2005, pp 451). By recognizing that the unique spatial configurations inform choice and structure activity, researchers utilizing MLP must draw from an array of theories to understand how people make choices with regard to these systems, and in turn, how these systems influence these choices in a "spatially uneven manner" (Lawhon Murphy 2011, pp 355).

Theories of the interconnections between 'hard' and 'soft' infrastructure highlight the reinforcing nature of the built environment's constituent spatial elements, such as walkable neighborhoods, public transit systems, and 'soft infrastructure', referring to the "norms, habits, and behavioral framings" that interact at different levels to reinforce and 'lock in' auto-mobility (Creutzig et al 2016, pp 176). The authors emphasize the importance of infrastructure by linking the built environment and lifestyles, arguing that the physical dimensions of cities and neighborhoods determine the "available action space" towards low or high GHG/VMT mobility (Creutzig et al 2016, pp 176). The authors assign a critical role to solutions that change the "opportunity space by offering different infrastructures", and elements which dynamically interact with the formation of endogenous preferences (Creutzig et al 2016, pp 191).

2.2.4 Co-aligned Push/Pull Policy Framework

This thesis emphasizes the role of policy in the Bay Area's transition to MaaS mobility. According to the MLP framework of socio-technical transition, policy makers can follow "two pathways if they want to influence transitions: (a) enhance the pressure on regimes through economic instruments and regulation and (b) stimulate the emergence and diffusion of niche innovations" (Geels Kemp 2012 pp 72). While these two strategies are framed as separate tracks, an interdependent 'push' and 'pull' policy mix is a framework that focuses on 'pushing' people away from single occupancy use through regulation and law and creates the policy and market environment to foster local niche innovations that 'pull' people to new mobility modes (Geels Kemp 2012 pp 72).

The co-aligned policy mix builds on previous transition study work by elucidating how two reinforcing, interdependent policy dimensions can better serve the goal, lowering SOV through an integrated MaaS network, rather than one single policy. This policy framework is known as push and pull; the former imposed on travelers in order to influence behavior through financial means, whether taxes, fees or tolls and regulatory actions that curtail car driving, such as cordons. Ultimately, push measures aim internalize the true costs of SOV journeys onto travelers by bringing attention to government subsidies currently provided to cars. The latter, pull policies, are created to discourage auto-mobility by making alternative services more competitive and attracting to SOV drivers, such as creating active transportation like pedestrian and bike infrastructure, enhancing public transportation where gaps have been identified and creating first and last mile connections (Nocera, Cavallaro 2011, pp 704-705).

Table 1: List of the most common push-measures. Source: Lautso et al., 2004, elaborated

PUSH-MEASURES		
FIELD	***MEASURE***	*DESCRIPTION, AIM*
Traffic calming	**Reduce car speed**	Reducing car speeds inside housing areas and along the most critical sectors of extra urban roads. Improvement of safety and minimization of environmental impacts
	Speed regulation programme	Changing vertical horizontal alignments, or narrowing the roadway. Reduction of speeds for environmental reasons
	Zero tolerance; speed limit enforcement	Enforcing speed limits using video analysis and recognition techniques or speed sensors on vehicles. Enhancement of the effect of traffic calming measures and improvement of safety, especially for pedestrians and cyclists
Overall system management	**Commuter plans**	Forcing employers to introduce commuter plans. Increase in the use of soft modes and Public Transport (PT)
Parking pricing policy	**Parking costs**	Growth of parking cost prices. This induces a discouragement in the use of the car
General car pricing	**Progressive fuel tax**	Reduction of vehicle kilometrage and of fuel usage
General car pricing (continuing)	**Car costs**	Growth in car costs. Discouragement in the use of the car
	Distance based charging	Introduction of the distance based charging with the help of advanced technologies. Effective potential in reducing total trips and travel times
Congestion pricing	**Congestion pricing**	Road Pricing with fixed toll. Increase in both user and social welfare
	Progressive toll	Road Pricing with peak-hour toll. Congestion pricing with continuous distributed values of time.Increase in both user and social welfare
Road investment	**Capacity reductions**	Reducing capacity of the main roads leads to a reduction of traffic

Table 2: List of the most common pull-measures. Source: Lautso et al., 2004, elaborated

PULL-MEASURES		
FIELD	***MEASURE***	*DESCRIPTION, AIM*
Rail and Public Transport(PT) investment	**Rail investment program**	Introduction of new infrastructures for rail and services. Increase of mobility and reduction of car dependency
	PT speeds	Fostering to the shift from personal cars to public transport
Intermodalism	**Transfers**	Improving transfers between rail and public transport modes as well as transfers between PT and soft modes. Promotion of less polluting and alternative systems
	Park & Ride	Implementation of parking facilities for park & ride on the borders of urban agglomeration and on the intermodal centres. Reduction of urban congestion
	Smart card	Introduction of a single smart card for payments in all modes of PT. Increase in the ease-of-use of PT, providing also valuable data for PT planners and authorities
	Mobility centre	Setting up a mobility centre which provides information and reservations on PT, taxis, shared rides. Improvement of the image of PT
	Intermodal centre	Infrastructural development of intermodal centres may help to provide aconsistent alternative to road transport
	Management efficiency	Enhancement of management efficiency increases attractiveness of freight villages by reducing time waste and hence costs
Overall system management	**Telematics**	Traffic management: optimising traffic signals, implementing congestion and incident detection systems, providing PT information both pre-trip and in-trip and deploying route guidance services. Remarkable reduction of congestion
	Mobility credits	Introducing tradable mobility credits. Encouragement of modal shift to PT
	Liberalisation of market	Liberalization of good and passenger market. Reduction of prices for users
PT pricing	**PT pricing**	Reduction of public transport pricing. More attractiveness of PT

Figure 2 illustrates push and pull policies that may be deployed to reduce GHG emissions from the transportation sector on their own, or as the authors and this paper suggest, together as 'policy mixes' (Nocera, Cavallaro 2011).

Studies have shown that push measures result in modal split, with up to 10 percent shifting to less polluting modes, while pull measures alone result in 1 percent in mode shift (Nocera, Cavallaro 2011, pp 22). Research has demonstrated that the concurrent adoption of push- and pull-measures achieves the overall lowest CO2 emissions as ridership of rail traffic increases and traffic congestion is decreased (Nocera, Cavallaro 2011, pp 710).

In the EU context, this combining of policy packages is projected to reduce GHG emissions by 75 percent per capita from 2010 to 2040 (Creutzig 2012, n.p.). This is because co-alignment of these policies through the implementation of multiple pricing instruments, including fuel tax and parking management strategies, combined with "complementary actions on infrastructures" for inter-city public transport and feeders into the system, is most effective at incentivizing modal shift (Creutzig 2012, n.p.).

Integrated policy approaches deployed under the California framework S.B. 375, encompassing pricing, transit investment and land use tools, is shown to achieve the greatest results in terms of reductions in VMT, reaching a reduction of 30 percent over a ten-year period, versus 20 percent for pricing alone, and 5 percent for transit investments and land use tools (Bedsworth et al 2011, pp 5). The research shows that coalignment of 'push' with 'pull' policies is an important strategy in reducing GHG emissions from transportation, further motivating research into a push-pull policy for MaaS in the Bay Area.

2.3 Limitations

2.3.1 Respondent recruitment

During the research process, significant challenges arise in relation to respondent selection. Primarily, there is respondent self selection bias as those who have time to come to meetings or respond to surveys online are not often representative of the entire population (Grosvenor 1998, pp 10). One way to overcome this limitation is by employing more random and spontaneous methods of surveying, however, as time was limited to four months of research, there was not enough time to conduct in person, intercept style surveys. As a result, the methodology was limited in its representation of complete views, preferences and experiences of the Bay Area population.

2.3.2 Lack of Access to the Private Sector

During the research process, access to private sector representatives of riding hailing services and first-last mile active transportation solutions proved challenging. Operational performance and primary qualitative data gleaned through semi-structured expert interviews with additional private sector actors would be valuable in future research efforts.

2.3.3 Time Considerations

Many of the case studies analyzed are in their first or second years of development, therefore, performance data is limited. While the case study analyses used does reveal important takeaways, there will additional learning to be gained from the continued iteration of the identified pilots.

2.3.4 Expressed Preference Versus Actual Behavior

Concerns and preferences expressed in the commuter suvey do not necessarily correspond to the actual actions taken by the respondents. In the stated preference survey approach, there is often a discrepancy between a respondent's expressed preference under the hypothetical scenario and actual behavior observed, for example, intent to use public transportation versus the behavior exhibited, such as driving a car alone (Yang et al. 2009, pp 4).

3 BACKGROUND

By 1930, 1 in 5 Californians owned a car, a trend leading to the rise of California as a suburban state, comprised of greenfield sprawl and metropolises with multiple centers (Walker 2015, pp 10). Auto-centric development and increasing rates of car ownership would increase into the next decade, leading to environmental issues including severe air pollution and increasing per capita greenhouse gas emissions and vehicle miles traveled. Established in response to the smog caused by car tailpipe emissions in the 1960s, California's EPA led the way in combatting air pollution through a series of landmark environmental policies, with the state building on these precedents in the early 2000s to reign in the transportation sector. In 2005, then-governor Schwarzenegger set in motion an executive order requiring the reduction of GHG emissions to 80 percent below 1990 levels by 2050, with the Global Warming Solution Act (AB 32) in the following year requiring the California Air Resources Board to develop market signals and regulations that would reduce GHG emissions to 1990 levels by 2020. In the years following, California set in motion key policies, including new legislation on low carbon fuel standards and zero emission vehicles (ZEVs), sustainable community strategies supporting transit oriented development and active transportation modes including walking and cycling, as well as the California Department of Transportation's role in reaching 80 percent reductions in transportation sector related emissions by 2050, without stifling growth of the economy, mobility or quality of life (Caltrans 2016, pp 23)

Further decentralization of the San Francisco Bay Area has been prompted by the region's economy, which has made the Bay Area "the only US metropolis with three central cities: San Francisco, Oakland, and San Jose" (Walker 2015, pp 11). Over the last one hundred years, Oakland, Silicon Valley, Fremont and the North Bay have become home to commercial centers, and with them, commuters (Walker 2015, pp 13). After the recession, the economy has significant outpaced the construction of new housing: since 2011, 531,400 new jobs have been created, while only 123,801 new housing units were permitted (Vorderbrueggen 2017, n.p.). The housing deficit is widespread in the region and is manifested in the region's jobs to housing imbalance, a metric indicating the distribution of employment in relation to the employees' residential distribution. A well-balanced community is one where residential accommodation is equal to the number of available jobs. By 2011, there were 4.3 jobs per housing unit, exceeding the recommended balance of 1.5 jobs per housing unit (Vorderbrueggen 2017, n.p.). This development has become a focus of transportation planning, as a significant imbalance means that workers must drive more, leading to increased commute times, vehicle miles traveled and peak hour congestion (Guiliano 1991, pp. 306)

Historically, federal funding for roads and highways has outcompeted funding allocations for public transportation, with any funding reserves at state and local governments used for automobile infrastructure expansion and improvements. Local funds comprise half of all public funds spent on transportation, derived mostly from local sales tax ballot measures, with the remaining balance cobbled together through local general funds, transit fares and local measures (Whitaker 2011, n.p.). Over the last ten years, there has been significant debate between state and local entities surrounding the use of these funds, as demand for transportation infrastructure has outpaced available funds. Ongoing state fiscal problems continue to give rise to inconsistent funding for public transportation projects on an annual basis. Furthermore, state costs to operate and maintain, allocated via the Public Transportation Account, have doubled from $55 million to almost $100 million annually (Caltrans 2016, pp 2). Deficient funding has meant that over time transportation has had less money to maintain, let alone enhance and expand infrastructure, with the passage of the 2006 senate bill 1B providing some reprieve to public transit agencies.

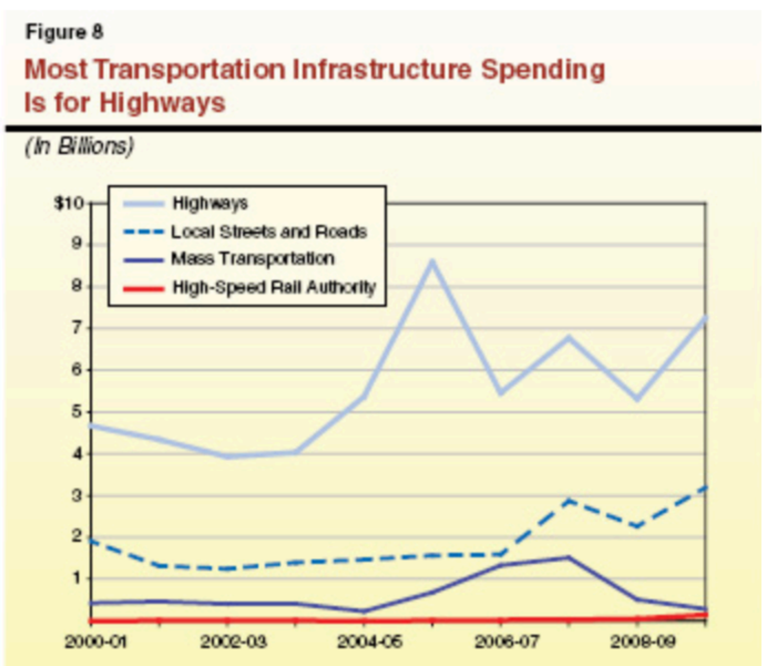


Figure 3 shows highway spending versus spending on public transportation (Whitaker 2011)

Despite historic investments in highway and road infrastructure, demand for highway travel has eclipsed the number of people living in the state, with highway congestion increasing 80 percent since 2010 (Metropolitan Transportation Commission 2018, n.p.). Compared to drivers in other states, California commuters now spend more than the national average of 35 hours a year stuck in peak-hour traffic congestion (Fields and Feigenbaum 2018, n.p.).

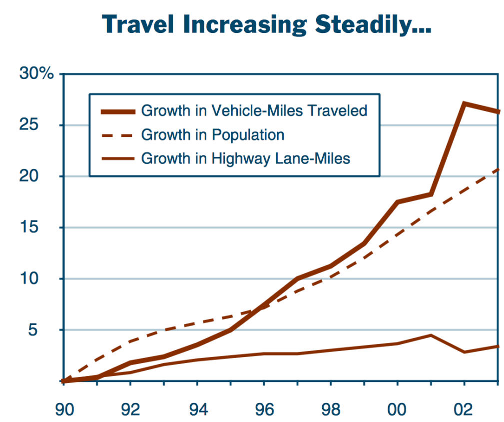


Figure 4 shows the increasing trend of vehicle miles traveled over time (Whitaker 2011), which increased by 26 percent from 1990 to 2003, outpacing population growth in the state. VMT has remained relatively stable since 2003, 22.9 miles per capita. (Metropolitan Transportation Commission 2017, n.p.)

Auto-centric mobility finds further reinforcement through invisible subsidies for parking, which makes driving seamless and inexpensive when compared to other options. At the national level, SOV subsidies amount to $7.3 billion in potential tax revenue each year and introduce an additional 820,000 cars during peak commute hours that would otherwise find other ways of getting to and from work (Frontier Group 2014, n.p.). Such subsidies have been found to increase single occupancy vehicle driving by 60 percent (Lovaas 2014, n.p.). While California mandates that employers with 50 or more workers provide an optional cash out program to trade in the value of their parking space for transit subsidies, the law applied to only 3 percent of the 11 million free workplace parking spaces in 2015 (Weikel 2015, n.p.).

Reversing subsidies could have a profound effect on these trends: a study by the California Air Resources Board found that implementing a $3-per-day minimum price for employee parking in the Bay Area would reduce regional vehicle-miles traveled by 2.3 percent and number of hours spent in traffic delays by 7 percent (Deakin Harvey 1996, pp 3-6). The strategy extent of the policy is vast: while certain cities and commercial districts in the region have instituted parking maximum requirements for new development, even the region's most urban areas like San Francisco charge for 10 percent of parking (Shoup 2018, n.p.).

Parallel to the proliferation of Bay Area suburban cities has been the multiplication of suburban transit agencies, which now number 26 across 101 cities throughout the Bay Area (Metropolitan Transportation Commission 2019, n.p.). Despite this, suburban bus operators, including the Santa Clara Valley Transportation Authority, SamTrans along the peninsula and AC Transit, experienced ridership declines of 30 percent to 40 percent between 1990 and 2016 (Metropolitan Transportation Commission 2017, n.p.). In contrast, long-haul commuter rail like Bay Area Rapid Transit reported an increase of 76 percent since 1991 and Caltrain, which runs along the length of the Bay Area peninsula, reported growth of 200 percent in the same period (Metropolitan Transportation Commission 2017, n.p.). These suburban transit agencies report farebox recovery ratios, or the cost to operate versus the portion of the trip paid for by passengers, of 2-3 percent, while the Bay Area Metropolitan Transportation commission mandates minimum quotas of 20 percent ((STANCOG 2018, pp 54). Because funding is tied to performance for California transit agencies, the situation leads to a cyclical erosion of transit services as these agencies face ridership and fare declines, service elimination, and funding gaps (STANCOG 2018, pp 54).

Overall, auto-mobility in the Bay Area benefits from economies of scale as "transport infrastructure…becomes more efficient and gains momentum when more users are plugged into the system... [locking] the system into a chosen direction" (Klitkoa et al 2015, pp 3). Prior transportation investments and land-use decisions in the San Francisco Bay Area for the last half century have led to a path dependency that lock in auto mobility and challenge attempts to transition to a new mobility regime.

And yet, there are cracks beginning to form that effectuate the displacement of auto-mobility in favor of a more diverse, balanced and efficient transportation system, including state climate legislation, the proliferation of new technologies and new transportation models, including integrated, multi-modal Mobility-as-a Service (Geels 2012, pp 479).

3.1 Pressures on Auto Mobility: California Climate Legislation

California's Transportation Plan 2040 is the response to state climate legislation and outlines the potential actions available to the each of California's nine regions in order to reduce emissions from the transportation sector. The three scenarios listed in the plan, fuel and vehicle efficiency, transportation system efficiency and future land use are based on climate models projecting the reductions associated with the adoption of each scenario. Together, the three policy approaches compound to meet the 80 percent reduction target by 2050; separately vehicle and fuel efficiencies “scenario 3” achieves the most at 60 percent, followed by transportation system efficiency strategies “scenario 2”, which adds an additional 15 reduction and Future Land Use “scenario 1”, associated with a 5 percent reduction potential (Caltrans, pp 82).

3.1.1 Future Land Use

The state’s senate bill 375 stipulates that each of California’s metropolitan region set per capita reductions of passenger vehicle miles traveled (VMT), an indicator influenced by travel mode, number of trips and distance traveled which acts as a proxy of per capita greenhouse gas emissions (Sperling et al. 2014, pp. 92). The San Francisco Bay Area’s VMT goal is 7 percent by 2020 and 15 percent by 2035 (Bedsworth et al. 2011, pp 4). There are many potential challenges to reducing VMT, not least is of which are historic trends towards sprawling employment and residential density, declining transit ridership despite increasing transportation investments per capita and widespread hostility towards pricing policies (Sperling et al. 2014, pp 92). Furthermore, in the absence of a robust enforcement mechanism, some have referred to the 375’s SCS approach as a toothless instrument that relies on voluntary policy making and incentives rather than enforcement and compliance between the state and local governments and cities (Mawhorter 2018, pp 22). However, the passage of SB 743 does provide a degree of enforcement by removing long-standing level of service (“LOS”), a measurement of vehicle delay for a specific time and location and replacing it vehicle miles traveled for new development projects of a certain size (Governor’s Office of Planning and Research 2019, n.p.). In recognizing VMT as “the most appropriate metric of a project's potential transportation impacts”, the bill signifies a shift for land use and transportation planning fields by creating a mechanism by which cities must benchmark prior and projected VMT and make plans to mitigate excessive VMT, thereby incentivizing denser, better connected and more active infrastructure (Lee Handy 2018, pp 2).

3.1.2 Fuel and Vehicles Efficiency

Scenario 3, advances in fuel and vehicle technologies, accounts for a 60 percent reduction in transportation-related GHG emissions, for a total of 80 percent when coupled with savings from Scenarios 1 and 2. The approach outlines the expansion of cleaner vehicle and fuel markets through the incorporation of alternative fuel technology, including bio-methane and renewable diesel, hydrogen, butanol, and algae-based fuels and zero emission vehicles supported by state policies (Caltrans 2016, pp

62). Because of the state's reliance on petroleum for vehicle use, comprising 40 percent of all energy consumption statewide, Scenario 3 assumes that current fleets will evolve concurrently with renewable energy sources.

3.1.3 Transportation System Efficiency Strategies

Scenario 2, "transportation efficiency strategies" defined as "having a choice of easily accessible travel modes, lowering the need for SOV travel, and increasing opportunities for para-transit, transit, and non-motorized travel" achieves a 20 percent reduction in GHG emissions by 2050 (Caltrans 2016, pp 68), (Vernez-Moudon et al. 2003, pp 1). The scenario, while open ended, encompasses strategies to optimize the entire system of transportation infrastructure by increasing utilization of network by investing in digital capabilities, high occupancy vehicle lanes, bus rapid transit, intelligent transportation systems and ride sharing services and instituting regional transit incentives, car sharing measures, parking policies, and public awareness campaigns (Caltrans 2016, pp 103). The pathway highlights California's high-speed railway, seeing it as the "backbone of an integrated transit system with one stop ticketing and coordinated transfers" as well as further investment in the connectivity and coverage of intercity commuter rail (Caltrans 2016, pp 107). The ultimate goal of this approach is preservation of mobility currently afforded by single occupancy vehicle driving while reducing vehicle miles traveled, by balancing demand between California's public transit infrastructure and highways.

3.1.3.1 Translating Transportation System Efficiency Strategies at the Local Level

This research expands on scenario two to understand the challenges and opportunities to promoting balance and optimization of the transportation network in contexts where single occupancy vehicle driving is the dominant mode of mobility. The research evaluates MaaS for commuters as one potential strategy to fill empty seats in the existing network, including highway and public transportation system (Sperling 2018, pp 189).

While densification and vehicle and fuel efficiency are equally important challenges in reducing transportation sector GHG emissions, optimizing transportation system efficiency is critical in several respects. For example, we have seen that while Sweden's government subsidies have resulted in the most sales of "clean" cars per capita, the country has simultaneously experienced emissions from the country's transportation sector, as a result of EV's plugged into a grid still reliant on fossil fuels (Speck 2012, pp 54). Through legislation including SB 100, California is making strides towards a 100 percent renewable grid by 2040, which will play a strategic role in GHG reductions from the transportation sector

(California Senate 2018). However, these gains overlook the detritus of single occupancy vehicle automobile patterns, whether electric, autonomous or not: the real problem with cars is not that they don't get enough miles per gallon, it's that the embodied infrastructure needed to support them produces an addition 50 percent more pollution beyond the actual vehicle emissions (Speck 2012, pp 54). Furthermore, one key area of concern is whether these technology substitutions continue to erode ridership on existing transit network and alleviate congestion plaguing Bay Area roadways. These concerns make future land use decisions central to reversing the provenance of single use auto-mobility. However, the applicability of future land use, besides the development of future employment hubs, is a central topic in question, as it will likely not dramatically influence the auto-centric development patterns of the Bay Area's established suburban cities housing three quarters of the region's population. Bearing these considerations in mind, the following research evaluates the technological and institutions levers that exist to shift mode choice in established SOV-centric suburban contexts to improve the efficiency of existing public infrastructure, including roads, highways and public transit.

3.2 Pressures on Auto-Mobility: New Models of Mobility

Additional cracks in the dominant auto-mobility regime are represented by new models of mobility enabled by technology, such as ride-hailing and other forms of on demand mobility. Indeed, "the need to reduce greenhouse gases…means that new directions must be found, including new technologies for transport… demand management…and innovative public-private partnerships for commuting and beyond, the use of pricing for parking and road use and improved transit coordination and services" (Deakin and Cervero 2008, pp 17). Whether perceived as a boon or bane, complimentary or competitive, technology has inevitably resulted in the diversification of the transportation market including service oriented, pay-as-you-go models and enhancing capabilities in transportation optimization including dynamic road pricing, intelligent corridor management and improved information for travelers.

Ultimately, the applications and consequences of technology-enabled transportation are important considerations in advancing California's climate change goals. For example, a 2018 study found that ride hailing apps, while highly successful in increasing urban mobility, also led to a 47 percent increase in VMT from 2010 to 2016 (San Francisco County Transportation Authority 2018, pp 4). As the study shows, increased mobility without the use of a car may be lost as benefits if new mobility services increase congestion, VMT and GHG emissions. A UC Davis study found that on-demand mobility led to a 22 percent increase in car-based trips that would have otherwise not been taken without such a service (Clewlow & Shankar, 2017, pp 26).

The thesis considers the policies able to create a balance between runaway VMT increasingly associated with on demand, 'as a service' mobility and the need to improve mobility for low density commuters enough to attract utilization of these options. One viable way is to utilize ride hailing and on demand mobility as services to the existing public transportation network, as it is able to remove the most people from the road in the smallest footprint, an indicator known as utilization efficiency (Forscher & Shaheen 2018, pp 2). For example, pooled services such as Uber Pool and Lyft Line, and carpools move up to 8,000 people per hour in both directions, light rail at 22,000 people per hour, and double lane bus rapid transit BRT at 45,000 people per hour (Forscher & Shaheen 2018, pp 2).

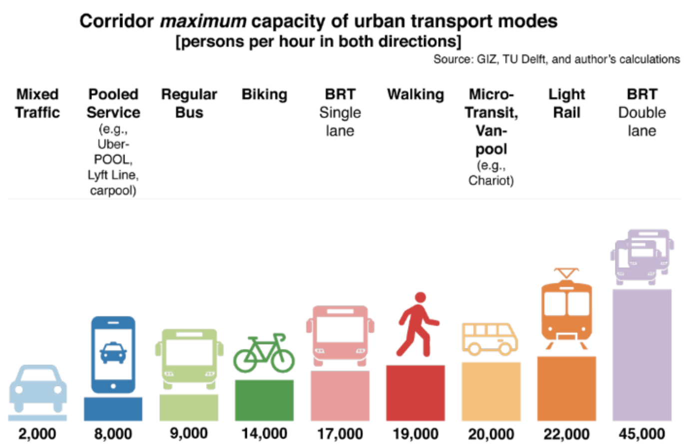


Figure 5 shows that pooling results in the following two things: significantly reduces VMT & GHG emissions and the congestion during peak hours. So how can technology enabled TDM, ultimately that is brought onto a platform, promote carpooling as a viable option (Shaheen 2018).

As the private sector continues to advance it is clear that "there is a great need for institutional flexibility in managing and coordinating all users of transportation infrastructure" (Forscher Shaheen 2018, pp 2). The state has committed to facilitating the transition in pursuit of its climate obectives, both by deploying intelligent transportation systems and by generating knowledge and capacities to use new technologies to increase ridership on public transportation systems (Barkalow et al. 2007 pp 47). The transition will prompt significant integration across all actors, necessitating a shift from isolated agency-by-agency transportation provision to a shared mobility marketplace in which public and public and private and public transport providers are not pitted against one another. For private companies such integration makes good business sense, as multi-modality between and to and from high density transit nodes will "[shift] the focus to multiple riders and away from single passenger taxi like services" (Sperling 2018, pp 190).

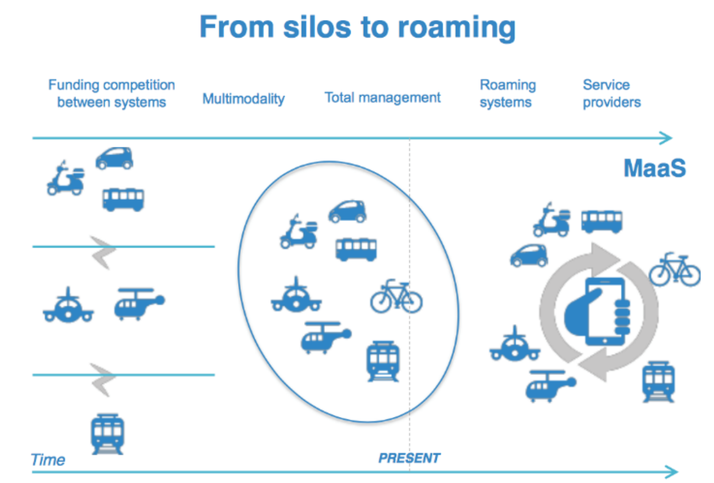


Figure 6 shows the Bay Area's current transportation model (siloed and competitive) versus complimentary, integrated mobility, both private-to-public and public-to-public which puts the traveler at the center (Heitanen 2016). In a MaaS scenario, everyone becomes a mobility provider in order to exploit underutilized capacity in the system (SOV to HOV, for example)

3.2.1 Retooling Transportation Demand Management for the Future

At the local level, one possible way that technology may be utilized to achieve climate goals is through transportation demand management, a planning tool aiming to decrease the number of single-occupant vehicle (SOV) trips during peak commuting periods. Dating back to the 1970s, TDM historically focused on expanding roadway capacity and parking infrastructure, while more recent efforts have focused pricing measures such as parking and congestion management, employee commuter benefits and providing commuters with better information about alternative mobility, including public transit, biking and carpool options (Rye 2008, pp 31). With the rise of TNCs, new service-based models of mobility and ICT, TDM is evolving to reflect integrated mobility considerations. As traditional TDM tools are updated with new technological capabilities, an entirely new set of demand management tools are available to planners and policy makers. In this way, transportation planning, with its historical emphasis on capital intensive 'concrete and steel' infrastructure including roadway expansions and high occupancy vehicles lanes, will over time shift more towards investment in digital infrastructure that exploits excess capacity in the network and dynamically prices infrastructure and identifies riders in order reduce congestion and other environmental externalities (Sperling 2018, pp 73).

The evolution of transportation demand management at local and regional levels is at the center of the political assignment of aligning the state's ambitious climate change goals with new technology capabilities and existing infrastructure. In creating policies and programs that advance state goals, it is important to note the 'social efficiency' of TDM policy, which is defined as the difference between the social benefits and costs to end users (Rotaris and Danielis 2015, pp 159). In this respect, social efficiency consideration must be weighed alongside projected policy outcomes in order to successfully scale MaaS within wider institutional, political and cultural networks that might otherwise resist such a transition.

3.2.2 Shared and Integrated Mobility

If the question is how to ameliorate congestion and reduce climate change, then filling empty seats in the existing transportation network must be "the principal focus of our thinking and actions related to transportation" (Sperling 2018, pp 189). An increasingly eminent model in achieving such goals, shared mobility is defined as the convergence of carsharing, bike- sharing, ridesharing (carpooling/vanpooling), public transit services, on-demand ride services, scooter sharing, and mobility submarket services including shuttles and micro-transit (Cohen Shaheen 2018, pp 12). By some estimates, shared mobility could result both in significant declines in vehicle ownership and bring about a massive reduction in energy use, estimated at a 50 per cent reduction over, automation plus electrification technology substitution scenarios by 2050 (Oxford Institute for Energy Studies 2018, pp 15). In terms more traditional sharing of single occupancy vehicles, studies show that 33 million gallons of gasoline could be saved daily if each average commuting vehicle carried one additional passenger (Cohen Shaheen 2018, pp 25). Other ancillary benefits of sharing include sold vehicles or delayed or foregone vehicle purchases, increased use of some alternative modes of transportation, and reduced vehicle miles/kilometers traveled (VMT/VKT) and other embodied emissions associated with auto infrastructure (Cohen Shaheen 2018, pp 26).

Indeed, "offering integrated mobility services with public transport as a backbone and complemented by other modes such as car-sharing, bike-sharing, taxis, cycling and on-demand services is the only mobility solution able to compete with the private car in terms of flexibility, convenience and cost-structure," (Cerfontaine 2016, n.p.). Modeling conducted by the International Transport Forum found that in Lisbon, Portugal, an integrated system of ride hailing taxis integrated with the city's existing rail network could decrease vehicle kilometers during peak commute hours by 44 percent for a 53 percent reduction in transportation sector related CO_2 emissions (International Transport Forum 2017, pp 7).

3.2.3 Mobility-as-a-Service

Mobility-as-a Service brings these concepts together, offering a vision for mobility that is multi-modal, integrated, and seamless for travelers (Dotter 2016, pp 9). While MaaS faces a considerable degree of ambiguity based on early definitions related to pay as you go pricing, at its core it assumes the cooperation and interconnectedness of the public and private sectors in providing mobility services to effectively meet traveler's needs (Hietanen 2016 pp 44). This Public-private cooperation is facilitated by data sharing arrangements, with information communication technology platforms that collect, transmit, process, and present information playing a central in MaaS development (Peraphan et al. 2016 pp 2). A second, and still underdeveloped point in the literature is the way in which mobility as a service "opens the door to connecting the use of roads and transportation more broadly and incentivizes change" by enabling users to participate by "exploiting excess capacity in transport" in real time in a cost efficient manner (Dotter 2016, pp 11) (Holmberg et al. 2016, pp 13). Whereas autonomous and electric vehicles substitute or supplement technology to increase vehicle efficiency, Mobility as a Service is an information service platform that physically transports people, instead of a specific transport technology on its own.

The two fundamentals of mobility as a service, public-private partnerships predicated on information sharing and connecting mobility to land use through pricing are closely aligned with the policy framework outlined by the state in scenario 2 "transportation efficiency strategies" and can provide a pathway for TDM's evolution that both increases mobility choice and decreases single occupancy vehicles and associated environmental impacts.

3.3 'Push' Policy: Integrating Public and Private Mobility Providers

Formal coordination between public and private actors via integration of information and fare structure are necessary conditions of emerging mobility and important challenges, as private and public stakeholders regard the lack of existing coordination between for example public and private service providers as a prime barrier to the development of MaaS (Karlsson et al 2017, pp 5).

3.3.1 Fare Integration

A critical element of transportation integration is seamless mobility across the network by aligning disparate systems of payment and fare structures. Mobility as a Service posits that an ICT platform is the adhesive through regulation and technical support and facilitate the integration of fares. However, fare integration also requires significant cooperation, alliance and mutual benefit to "govern common fares, common conditions of carriage, and distribution of revenues generated by common fares (Berlepsch et al. 2018, pp 15). Bringing together multiple providers each with their own business models and fare structures is complicated as each mode and its associated provider, “must be appropriately compensated for its portion of the trip” (Lund et al. 2017, pp 18). Without the right compensation model or market incentive, the private sector will not be compelled to participate in MaaS.

One significant advantage for a Bay Area MaaS implementation is that the Clipper Card has brought together the region’s public transit providers onto one common payment system, despite challenges of “[apportioning] fares between the operators in the backend system on a daily basis based on an agreed formula” (Kamargianni et al. 2016, pp 3296). Subsequent efforts, as envisioned by a MaaS scheme, would bring the region’s private TNCs, shared mobility providers and other high occupancy fleets together with the public sector onto one common platform.

3.3.2 Information Integration

Open APIs and standardization of data between the public and private sector, will become the differentiating tools of reformed mobility environment (Sperling 2018, pp 129). Within new mobility partnerships, the “integration of information is of vital importance and a pillar in MaaS: it is what the end user receives and upon which the whole supply network builds upon” (Jittrapirom et al. 2017, pp 21). Increasingly, traveler information and transportation data will only become more sophisticated and readily available, playing a larger role greater in determining how people and goods travel, and how system operators manage the system. This will require formal information sharing arrangements across integrated mobility providers as well as the technical capacity and investment to “support data collection, model development, documentation, and data visualization activities to support policy-making activities” (Caltrans 2016, pp 114).

This development is especially relevant to public sector actors, as private transportation network companies (TNCs) are accumulating crucial travel datasets and will have vested interests and claim to the markets and end consumers, the results of which may undermine the environmental and equity-related goals of the public sector. Already, it is apparent in travel demand models and the state climate models that infrequent household travel surveys are not sufficient in meeting the more dynamic needs of modern travelers.

Reversing the data asymmetry that exists between public and private providers will help inform future transportation investments, verify utilization and dynamically price infrastructure and will prove perhaps to the most challenging "precondition in the development of integrated mobility services" (Lund et al. 2017, pp 12). Integration will encounter significant challenges in regard to establishing the necessary trust between data providers, as individual service providers have demonstrated resistance to sharing any kind of data for fear of cannibalism, brand dilution, loss of competitive advantage created by proprietary technology, and loss of ridership, despite the potential gains of accessing bigger market share (Karlsson et al 2017, pp 8).

3.3.3 MaaS Pull Policy: Pricing

One of the most significant opportunities of Mobility as a Service is the ability to regulate network efficiency by incorporating road pricing as an input into the price of mobility. MaaS, in unifying all modes of travel, offers the digital platform which can dynamically price road infrastructure according to the time of day, location, type of infrastructure utilized, and mode utilized (Wong et al 2018, pp 8). This kind of real time verification of spatial and temporal modes can dynamically generate subsidies in order to account for the externalities associated with less spatially efficient modes, prompting users to shift to higher density modes. In this context, MaaS can support dynamic strategies that match mobility supply with mobility demand. Through such pricing mechanisms that induce "peak shaving", MaaS can provide a pathway to optimizing transportation network efficiency (Alazzawi et al. 2018, pp 101).

Several scholars have argued for the integration of transport policy and infrastructure pricing. When drawing out a view of a 'sustainable mobility paradigm', Banister argues that it is important to "strengthen the links between land use and transport" (2008, pp 73). Research suggests that California's TOD approach should go one step further by integrating local land and economic policy including congestion and cordon charging, with public transport subsidies, and designated high occupancy lanes as part of the transition (Geels 2012, pp 475). In doing so, policies that restrain cars are needed to complement investment in intermodal interchanges (Geels 2012, pp 475). Pricing can act as a follow-on lever in a series of incremental and complimentary policy packages beginning with advancements in fuel efficiency, followed by 'pull' policies making alternatives modes like biking and public transit more attractive and 'push' pricing policies that make SOV less attractive to drivers (Creutzig et al. 2012, n.p.).

This need for 'push measures' or "sticks" calls attention to the underlying political and cultural tensions that will continue to exist in the future in the transition away from dominant auto-mobility. Ultimately, fuel and vehicle efficiency do not fully address the central issue, which is achieving more balance in the transportation system and more choice of public transport and active mobility options (Nikitas 2017, pp 17). The EPA has concluded that continued advancements in technology to reduce emissions will come at a large cost and do not address the problem: increasing numbers of vehicles on the road and vehicles miles traveled (Winters 2000, pp 3).

Economists argue that road pricing should be the first tool utilized in transportation policy, as it is effective during peak commute hours, which would be the very roads requiring roadway expansion. Moreover, unlike the capital intensity required of this kind of infrastructure, "road pricing achieves significant benefits without using public financial resources" (Winston & Langer 2004, pp 24). As noted previously, there is growing recognition amongst stakeholders that highway expansion and new parking garages do not alleviate the problem, in fact, they induce demand. Research has shown that the congestion cost savings from "one dollar of highway spending in a given year would amount to a modest twenty-five cents in that year, indicating that such spending is simply not a cost-effective way to reduce congestion" (Winston & Langer 2004, pp 2**).** This is because improvements will necessarily increase capacity and attract additional users during peak periods who would otherwise utilize "transit, alternate routes, off-peak travel times, and so on who tend to fill the available capacity during peak travel periods (Winston & Langer 2004, pp 3)

Pricing to drive utilization efficiency play a significant role in climate model assumptions outlined in Caltrans' scoping plan, with carpool lane occupancy increasing from 2+ persons to 3+ persons in seven counties including the Bay Area in order to yield reductions of VMT. In California, pricing achieves a broad strategy extent quickly, meaning that it impacts driver's VMT more than other policy or planning tools and reaches the most drivers (Boarnet Handy 2017, pp 4). These effects are multiplied in that pricing strategies expand alternative options to single occupancy driving by creating new revenue streams, critical in addressing transportation funding's 55 percent deficit through 2020 (Caltrans 2016, pp 2).

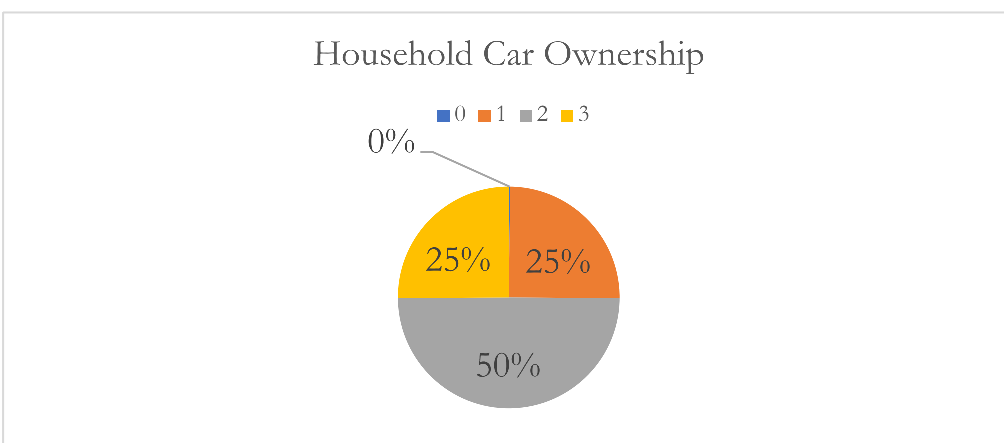
Furthermore, MaaS pricing will become increasingly urgent as congestion is "likely to become less random and somewhat more predictable, but it is unlikely to disappear" (Henscher 2017, pp 2). In the future, congestion is expected to increase as the region's population increases by 2.1 million people by 2040 and the economy adds 700,000 new jobs (Metropolitan Transportation Commission n.y., pp 32).

4 COMMUTER SURVEY RESULTS

A total 502 residents were surveyed across 12 different cities in the South Bay, a sub region of the Bay Area. The approach aimed to understand micro-barriers, or perceived or experienced barriers for households and individuals in utilizing public transportation for their daily commute, as well as the elasticity of comparative advantages such as time and cost under hypothetical scenarios. The object of such analysis is to understand the relationship between micro-level barriers and their relationship to specific built environment configurations, or "hard infrastructures" of public transportation.

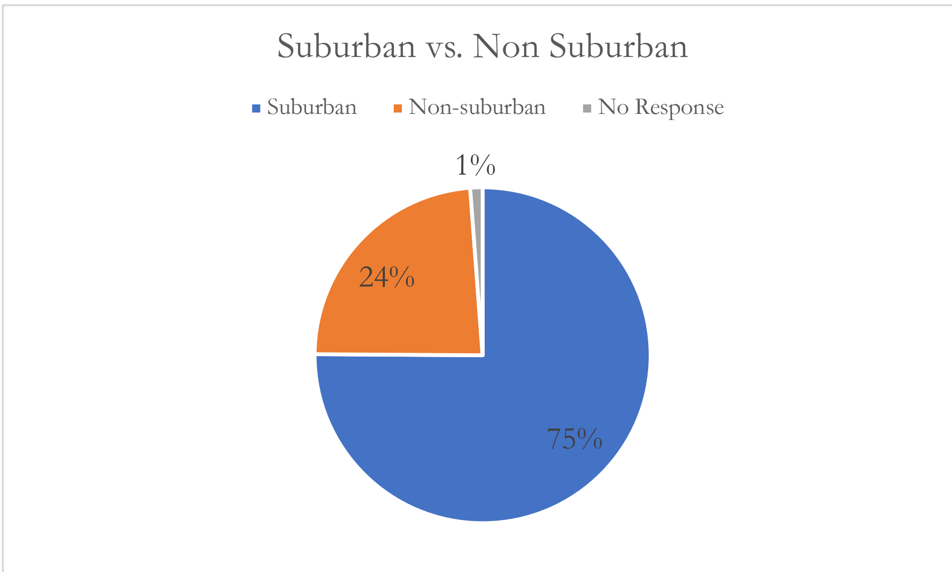
Results of the commuter survey and semi-structured expert interviews show that dominant auto-mobility SOV regimes are the result of low-density transport-land use systems that are "deeply intertwined with complex individual and social action and beliefs" (Mercator Research Institite on Global Commons and Climate Change 2018, n.p.). The commuter survey revealed that 90 percent of respondents drive alone to work, 8 percent walked or bike. The following section highlights that while there seems to be a genuine willingness to move out of the car for the journey to work, commuters generally perceive this 'hard infrastructure' as an impediment to mode shift making alternatives unviable. Additionally, while distance to public transportation is one obstacle to overcome, with 49 percent of respondents listing it as a top concern, the second most important consideration in travel choice is time, with 48 percent of respondents listing this as a top consideration in mode shift. In this respect, historic low density development patterns "preshape" or precondition the chance for end users to utilize higher density and therefore lower greenhouse gas modes (Creutzig et al 2016, pp 176).

I. Car ownership per household



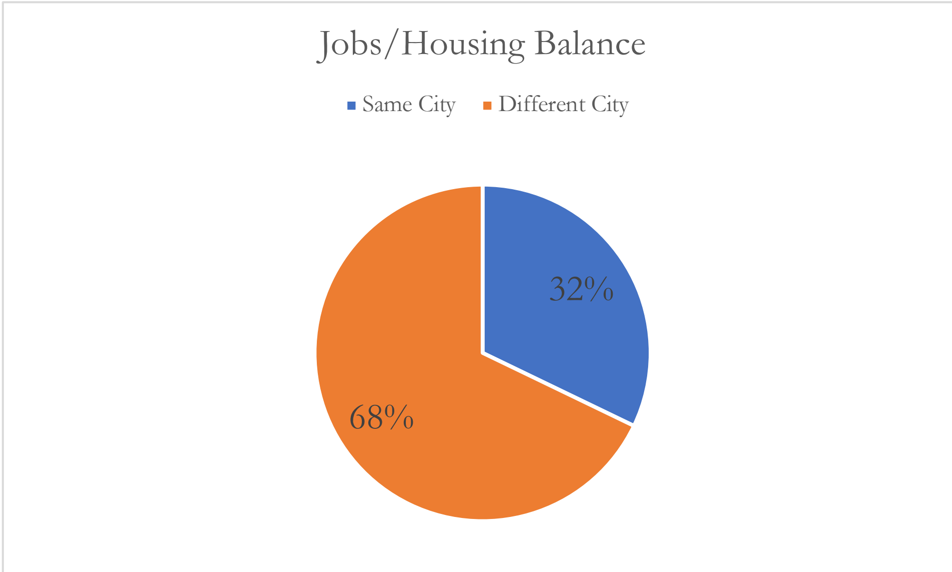
There are societal trends which help to stabilize cars, this includes a preference "for private property rather than collective ownership and use", this preference is illustrated by the vast majority of survey respondents who own at least 1 or more cars per household. A majority of households own 2 or more cars (74 percent).

II. Suburban versus urban drivers



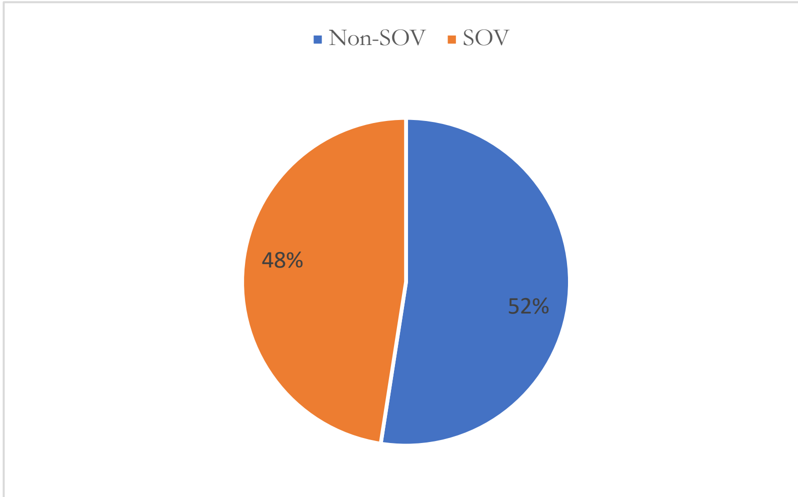
Seventy-five percent of respondents consider their neighborhood to be "suburban". This is important as longer distances between origin and destination, typically characterizing suburban communities make modes of transport such as walking and other forms of nonmotorized transport less viable. Importantly, public transportation must meet certain minimum density (either in residential or commercial/employment areas) to be viable.

III. Jobs to housing balance



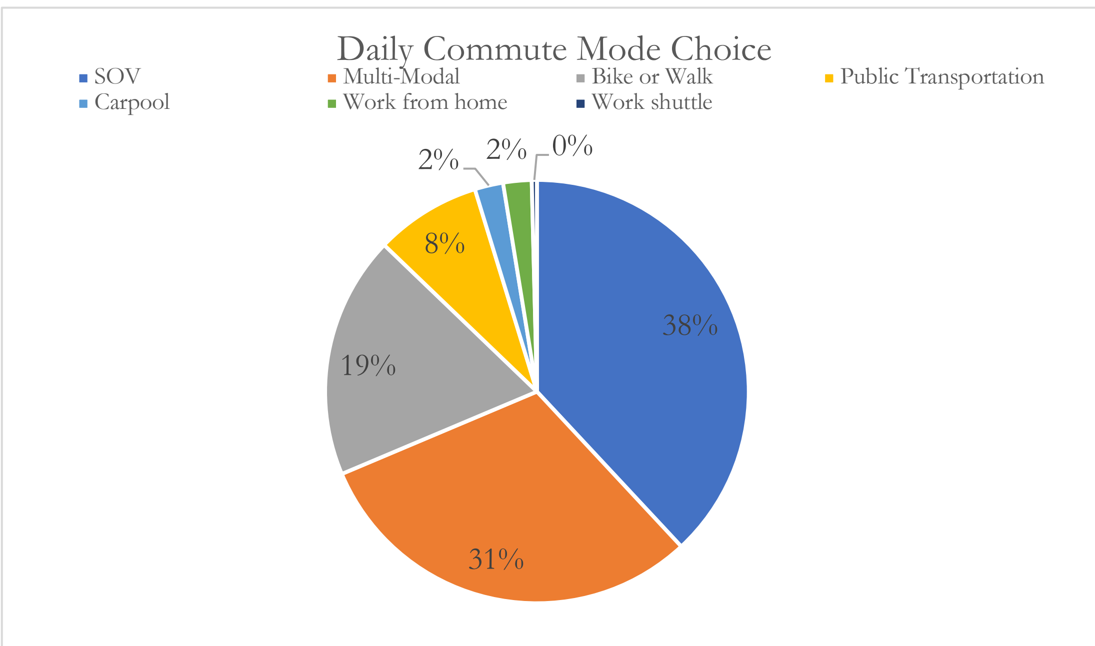
Jobs-to-housing ratio is a measure of even/mixed use of employment and residential distribution across a city. The survey illustrates that for respondents indeed the physical landscape (urban structures with a separation of work and home, roads) has been shaped around the car and stabilizes it. 67 percent of respondents live in a different city than they work. Literature shows that is the density of employment centers, residential density and chosen transport mode, with lower population density (i.e. "suburban" neighborhoods reinforcing the use of single occupancy vehicle use (Creutzig et al 2016, pp 185). 33 percent of survey respondents live and work in the same city. 41 percent of individuals living and working in the same city utilize active transportation (bike or walk) or take public transportation for their commute trip.

IV. Jobs to housing balance commute patterns



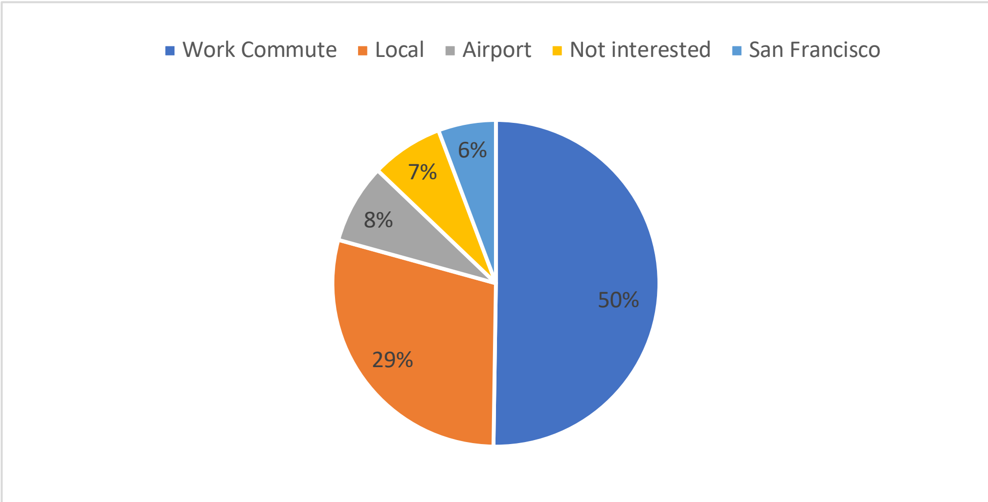
For individuals living in the same city as they are employed, it is more likely that they take an alternative to driving alone, including bike or walk, multi-modality options, including bike or walk to public transportation, solely public transportation, or carpooling.

V. Mode for current commute trips



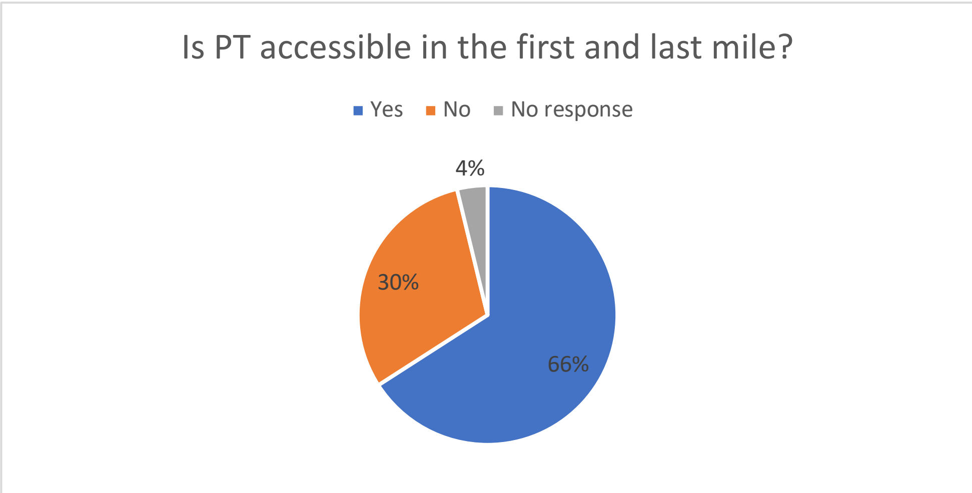
While a majority of commuters use their own cars for commute trips, almost an equivalent number of respondents use a diversity of modes throughout the week, including carpooling, biking, ride-hailing and public transit. This indicates that not only are people interested in using alternatives to their own cars, but also that they actively use SOV-alternatives for commute trips. A significant number of respondents, 19 percent, indicate that they bike or walk for daily commute trips. For people owning 2 or more cars, 48 percent drive alone to work.

VI. For what trip are you most likely to use an alternative to your car?



In the San Francisco Bay Area, 30 percent of trips are made for work, with an average distance of 13 miles one way, 14 percent for college or school, and 14 percent for shopping (Plan Bay Area Draft, n.y. pp 13). Mode switching/shifting refers to transport behavior change involving a shift from car use to lower CO_2 modes of travel such as walking, cycling, bus, or train. The majority of respondents stated that they would use an alternative mode during commute trips (56 percent) while almost a third of respondents stated they would consider an alternative mode for local non-work trips (28 percent).

VII. Perception of public transportation (focus on spatial consideration)

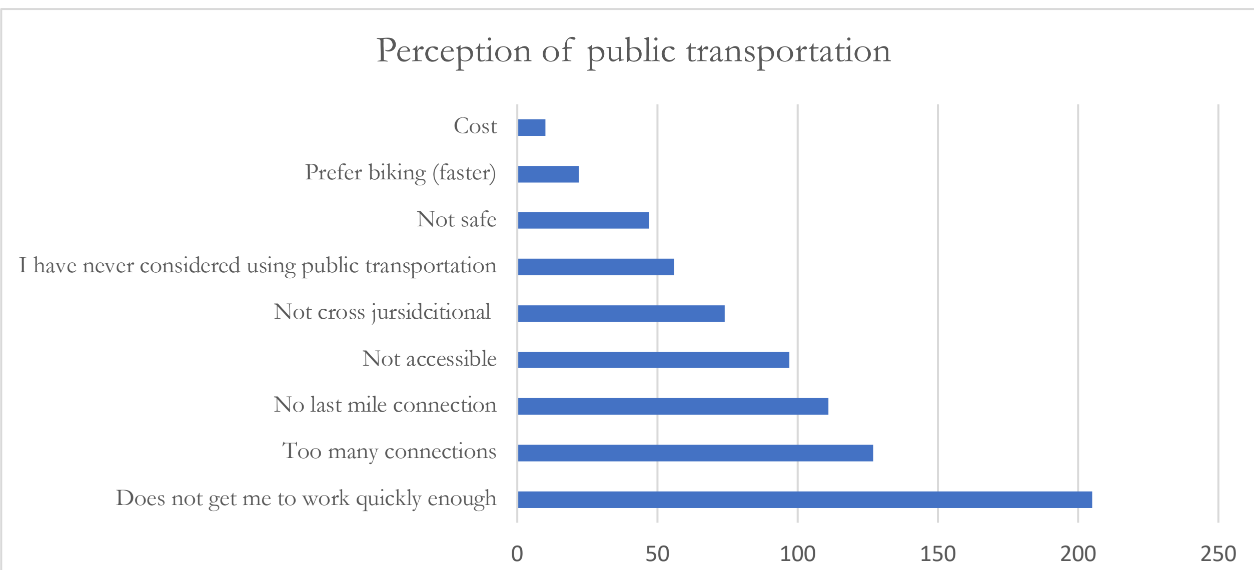


Many noted that while public transit is accessible, either by walking or biking, it is not a sufficient means of commuting as it not get them to where they need to go, requires too much travel time, is crowded or unsafe, or is hard to get to, for example:

Yes, however:
- I can walk safely from Caltrain to work; I cannot safely or easily bike or walk from my home to the Caltrain station. - It's walking/biking distance, but the infrequent timing, and needing to connect to a shuttle to get to a remote workplace, make it very time consuming. - It is accessible, but Public transit would add hours to my commute and is not a viable option - it is in biking distance but cannot find bike parking - Bus is walkable, but my route is faster via BART, but to get there partions of the bike route are high car traffic without good bike lane

These attitudes are discussed in depth in the following section.

VIII. Perception of Public Transportation (focus on temporal, spatial, other considerations of travel choice)



Perception and experience using public transportation is of critical importance and critical to address in promoting mode shift. Identifying these perceived or actual barriers is of critical important and "if there are one or two micro barriers that are salient that you don't address, the [mode shift] program won't be successful" (phone interview with Carrie Armel, September 2018). Therefore, this question looks closely at characteristics that increase ridership, with questions addressing past research on elasticity of rider choice to service frequency, direct/express routes, cost, total travel time and safety.

Responses reveal that for commuters, time has the highest elasticity in using public transportation for work trips. The second response, minimizing connections, also speaks to time as a factor, in both headways and that there is clear preference for direct routes to work. Research has found that most important service characteristics for non-users of transit are increased frequency and direct routes from home to work (Mierzejewski 1990), with service frequency twice as important as fare cost (Perone 2002 pp 13). The elasticity of transit use based on increases of service frequency (called a headway elasticity) is 0.5, meaning that with every 10 percent increase in frequency accounting for an increase in ridership by 5 percent (Litman 2018, pp 12). Additional transit routes, especially those that are direct, are a powerful attractant to new riders, albeit only within a quarter mile radius of walking (Johnson 2003, pp 126).

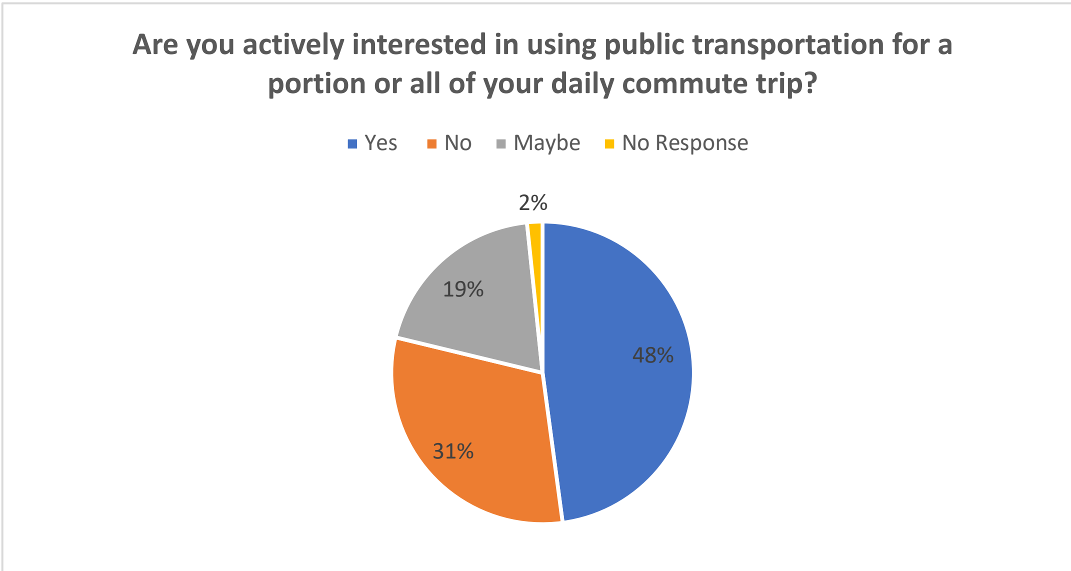
The third and fourth top concerns raised are related to connections in the first and last mile. Although public transportation achieves high density throughput, with the "connecting ends of the FLM to be the weakest link of transit systems" (Smith 2016, pp 2-3). Without proper accommodation made at either end of the transit system, first and last mile connectivity plays a significant role in influencing "an individual's choice of choice to use transit given the lengthy travel time and travel discomfort often associated with FLM" (Smith 2016, pp 2-3). These insights reveal that balancing a multi-modal system that prioritizes direct routes and that integrates schedules between connecting modes with accessibility is a key determinant in mode shift potential.

The second and fifth factors, too many connections and no cross jurisdictional options, are related to one another, as direct routes are preferred over multi-connection commutes. Within these concerns are institutional challenges, such as the proliferation of transit agencies that work within their own city's boundaries, but not across, as would be aligned with 68 percent of commutes in point III.

Interestingly, cost is of little importance, which points to several factors. Time is more elastic than fare cost, however, it should be noted that the sample population is small and therefore not truly representative of the elasticity of comparative advantages of the entire Bay Area. However, it does tie into the phenomenon which is that as households become wealthier, one indicator of which is number of cars per household (50 percent of respondents have 2 cars per household), car driving is the preferred option as it is the time effective, and therefore convenient, when compared to public transportation.

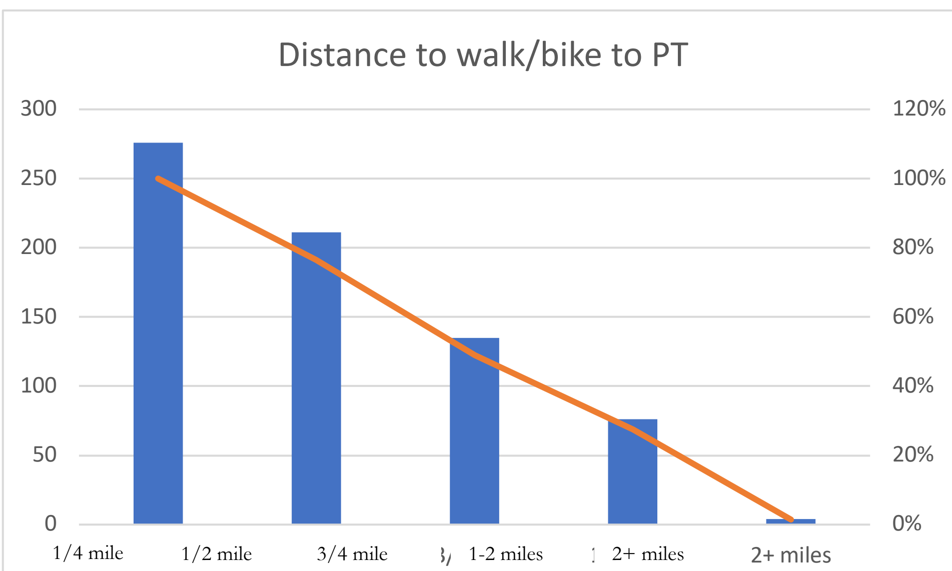
Opposingly, pricing, or internalizing the true cost for cars is shown to be an elastic determinant of mode shift in California (Bournet Handy 2017, pp 7).

I. Mode shift away from Non-SOV option



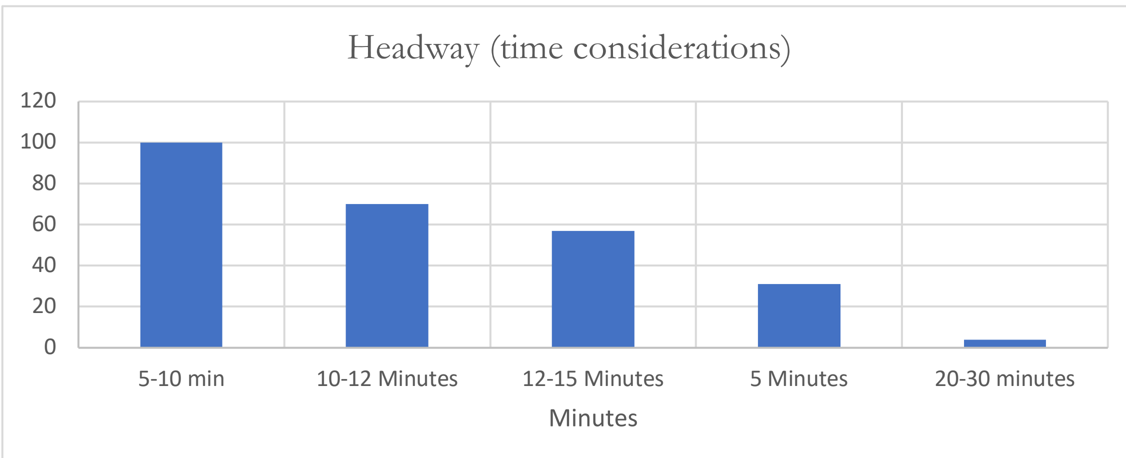
Sixty-one percent of respondents are actively interested in utilizing active transportation provide additional encourage for considering introduction of new public transit-TNC alliance so as to offer an alternative to SOV for suburban commuters.

II. Distance Decay



Proximity to public transportation is one consideration in travel choice dynamics. Distance decay studies show there is an association between residents who live closer to transportation are more likely to use these services versus those who live further away. While 28 percent of respondents are willing to walk between ¼ and ½ mile to access public transportation, subsequent choice considerations, including frequency and coverage, play a more important role and challenge the provision of public transport in low density settings.

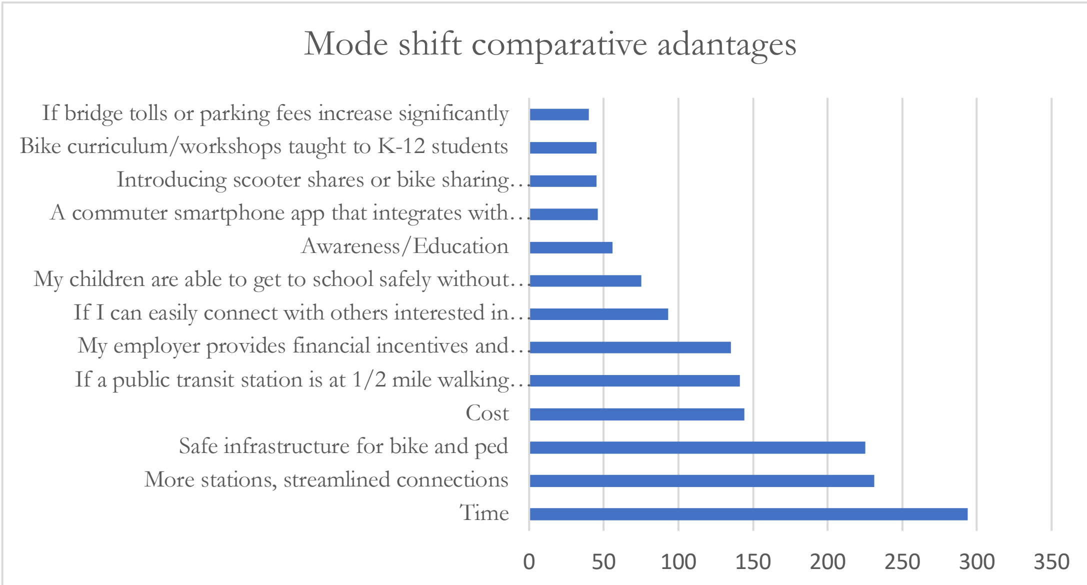
III. Passenger Wait Time Perceptions



A majority of respondents indicate that they would be willing to wait for a maximum time of 10 minutes. Understanding the value of time is relevant because wait savings/ travel time are of top concerns for travelers and can be used to justify more frequent and higher speed transportation.

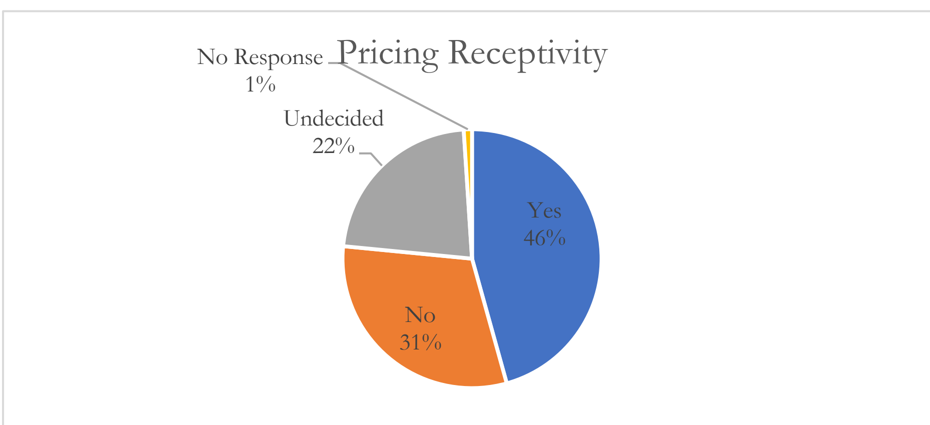
Of particular concern is the value that that travelers attribute to time spent waiting for a transit vehicle as literature shows that travelers view waiting as more negative than equivalent time spent in travel (Hess et al. 2004, pp 68) This waiting period is known as a function of service headway, which is the elapsed time between a bus or train. Studies show that reliable transit features waiting time that is half of the actual headway, whereas when transit service is poor when average wait times are longer than half of headway. In response, passengers facing long headways will rely on alternative, often single occupancy vehicle modes (Hess et al. 2004, pp 69)

IV. Considerations impacting travel choice



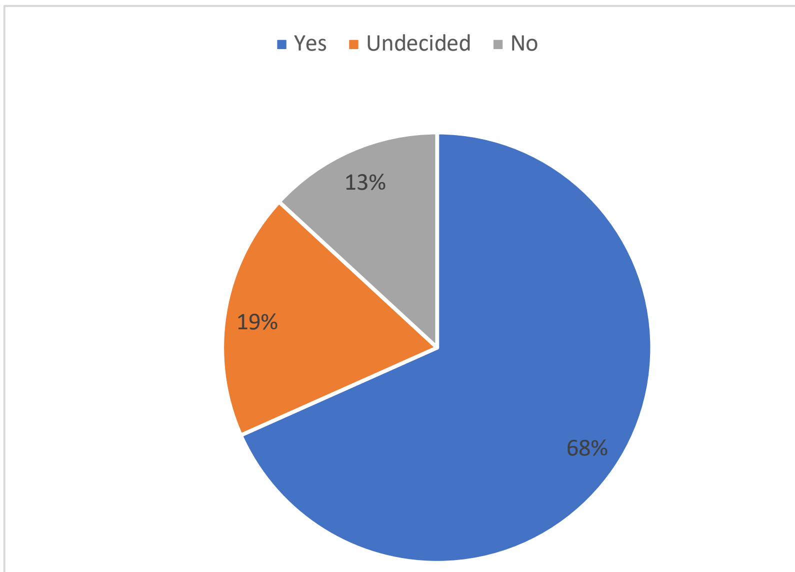
Two-hundred-and-ninety-two people out of 502 list time as the most important consideration in choosing an alternative mode for commuting. 47 percent of respondents list wider coverage, including more stations, routes and connections as the second most important incentive to using an alternative to their personal car. 44 percent of respondents list safer bike and pedestrian connections as a third most important consideration, followed by cost, with 28 percent of respondents listing this as their fourth consideration.

V. Openness to Pricing Strategies to Improve Public Transportation



Congestion pricing is one of the 'pull policies' of the mobility as a service policy framework that is the subject of this research. The survey indicates that 47 percent of survey respondents say that they would support congestion pricing, defined as variable priced depending on the level of demand with specific pricing strategies including variably priced lanes (HOV versus SOV lanes), variable tolls on roadways, cordon charges imposed within or into congested areas and area wide charges on all roads depending on peak commute traffic. Thirty percent of respondents say they would not support such a measure, with 22 percent undecided. The question does not mention explicit cost related to such a measure. In the Bay Area, Measure 3, which increases bridge tolls by $1 dollar passed in June 2018 with an approval rating of 54 percent, 70 percent of which will be allocated to public transportation across the Bay Area's nine counties.

VI. Openness to Voluntary Data Donation collected by Public Sector Entity



Sixty-nine percent of respondents say they are willing to donate their data to a public entity charged with improving public transportation, 13 percent are unwilling to donate their data, and 16 percent are undecided about whether they would want to donate their travel data. This was posed as a question as a key challenge of mobility as a service is data ownership, namely, what entity owns the data (public versus private versus third party) and are travelers willing to make their data available to such an entity?

In the development of MaaS, one potential lever is private citizens' role in providing "voluntary data donations", similar in concept to opting in to data-sharing agreements with services such as Waze or Google Maps (In-person meeting with Dr. Creutzig Mercator Institute, June 2018). This is key as data asymmetry has fueled competition, rather than collaboration, between the public and private sectors. Transportation network companies, having direct lines to end user origin and destination "O and D" data through smartphone apps, have outstripped the data collection and analysis capabilities of the public sector that relies largely on census data or increasingly, Inrix's Streetlight 'big data' for its own transportation demand models (phone interview with Marshall Ballard, November 2018). Having direct inroads to traveler data through voluntary data donations, therefore, is advantageous to a public sector-driven MaaS scheme.

Discussion

This research approach used a stated preference commuter survey to understand commuters' perception of public transportation, whether they are open to shifting to non-SOV modes, and the elasticity of riders to certain dynamic factors, including service pricing (fare cost), time, including wait time and travel time. The commuter survey revealed that the most important consideration is time. Respondents frequently mentioned that while they are interested in taking public transportation, it is not a viable option from the standpoint that it takes double or triple the time it takes them in their own car. Time can be divided into two categories: headway time, or time spent waiting for a public transit option, which is the second most important consideration after travel time. From the latter consideration we can infer several factors: commuters passing through one or more jurisdictions do not find it easy to connect between fragmented public transportation options or in some cases, these services do not get them close enough to work. We can assume with a mobility as a service or integrated/shared mobility for low density commuters that reducing travel time through the creation of direct routes and increasing frequency of these services that alternative transit options can be competitive with single occupancy vehicles in terms of convenience.

First and last mile access is a key concern of commuters after travel time. The survey reveals that, assuming increased frequency and direct routes to increase time savings, public transportation within 1/2 mile is a viable option for commuters taking active transportation modes, including both walking and biking. Regarding perceptions of public transportation in its current form, respondents cited both lack of access in the first and last portions of their trips, citing safe pedestrian and bicycle infrastructure in these segments and more direct connectivity to work as ways as incentives to use these services.

Analysis revealed that respondents are open to donating their travel data and in having congestion charges levied in the improvement of public transportation in the Bay Area. These points are encouraging as these open up avenues to integrated mobility by opening up revenue streams for transportation subsidies and improvements and speak broadly to traveler's openness to data sharing in pursuit of faster and more convenient mobility options.

As the survey data suggests, despite that a majority of commuters are interested in using alternatives to SOV, spatial barriers and institutional barriers interlink to reinforce auto-mobility. For example, the region's unequal jobs/housing ratio (meaning disparate, low density origin (home) and destination (work) journeys) for 67 percent of commuters combined with low fare box recovery along these low density journeys results in infrequent and low quality public transportation services for these commuters, reinforcing the necessity of single occupancy vehicle use. This finding broadens the multi-level perspective's strong for temporal considerations to spatial 'infrastructure' considerations that lock in dominant auto mobility.

5 SEMI-STRUCTURED INTERVIEW RESULTS

Part two of this research employed semi structured interviews to highlight the multi-dimensional interactions between hard and soft infrastructures, or the built environment and commuters' norms and habits resulting from particular topographical configurations, with industry and institutional practices and rules locking in auto-centric mobility development patterns and established travel behavior.

This section was aimed at understanding specific constraints identified by commuter survey respondents related to the built environment (meso level) and how these topographical configurations relate to specific challenges identified by expert interviewees at the institutional level. Semi-structured interviews were conducted with 30 experts from local municipalities, regional government, non-profits, for-profit companies, state government as well as private sector transportation providers around the Bay Area. Specific questions related to current cost constraints and fare box ratios, the proliferation of transportation agencies and the limitations surround regional, rather than local service aligned with cross jurisdictional commute sheds, and the opportunities and challenges relating to multi-modal integration, including whether integrated models are viable in the Bay Area and what challenges have or may emerge in their development. The aim was to identify what factors limit the provision of public transportation in low density suburban cities in the Bay Area and therefore 'lock-in' established single occupancy vehicle commuting patterns. The 'lock in' mechanisms identified are mapped in addition to the barriers identified at the micro (household) level from the previous commuter survey to form a comprehensive diagram of the Bay Area's transition to an efficient, low VMT transportation system that preserves rather than erodes at the mobility of commuters.

'Institutional' Barriers to Transportation system Efficiency and Preservation of Mobility (3 Categories)	Responses
Status of Regional Transportation Strategy	- **57** percent view the top barrier to multi-modal integration as: Lack of strong regional governance and policy that fosters cooperation between cities, transit agencies, and the private sector - Interviews cited that often times Bay Area transportation representatives look to represent solely their own stakeholders and have largely failed to adopt a 'transit first' mentality that could make bold moves to support public transit as the dominant form of mobility in the region.
Private-Public Integration: Fare & Data Cooperation	- **93** percent of interviewees believe that the public and private sectors must collaborate together in order to offer integrated mobility services that are competitive to the private automobile. - **Integrated Fare Policy: 42 percent** say the third priority of the public sector should be unlocking the potential for subsidies as part of a concerted effort to sign up TNCs to integrated mobility platform: Many interviewees mentioned a lack of state mandated "seamless fare" integration and institutional barriers for public transportation barriers in the form of federal regulations and union challenges that reduce innovation potentials. - **Data Standards: 42 percent** see lack of data standards: practices of data sharing/open APIs between the private and

	public sectors (signifying a need for a third party data warehousing intermediary (42 percent of interviewees believe that a third-party foundation is the entity best suited to managing real time commuter data as part of integrated public-private mobility platform; **35** percent believe the private sector, with the fewest number of respondents believe that the public sector should take on this role) - **71** percent say that the second most important role for public sector is to create policy environment to support partnerships between public and private mobility providers.
Pricing	• **50** percent view third barrier as lack of widespread pricing policies that could fund public transit and induce demand for pooling • **71** percent say the first role of government is to create a regional to local pricing strategy for use of public infrastructure (congestion pricing, parking management, curbside management, cordon charges
Non-Highway Transportation Funding	• 90 percent of interviewees mention lack of funding for public transportation as a significant challenge. Limited funding has resulted in inter-agency competition and inter-sector (public vs. private) competition that undermines mobility in and of itself

Through the semi-structured expert interview approach, it is clear that the primary obstacle to transportation system efficiency and the preservation of mobility is the disperse spatial environments in which public transportation operates. All 31 respondents agree that it is the Bay Area's disperse suburban form, in which commuters must travel between disparate origin and destinations that has outpaced the ability for local transportation agencies to provide high quality, high frequency, high-density alternatives. The resulting institutional challenges can be grouped into four categories: regionalism, integration between the private and public transportation sectors, pricing policy, and available transportation funding.

Regionalism

Fifty-seven percent of those interviewed view the single greatest challenge to preserving mobility and reducing VMT as a lack of regional oversight that funds and steers policy on a cross jurisdictional rather than city by city basis. Interviewees divulged that local control undermines the coordination needed to provide mobility to inter-city and inter-county commuters. Local control is the description for the myopic views of transit agencies, private companies, and cities that address the mobility within their direct purview, despite that a significant portion of work-related trips happen at the regional level.

Closer Ties Between the Public and Private Sectors

A majority of respondents see public-private partnerships as a crucial factor in increasing mobility options for suburban commuters, especially in cases where high farebox recovery ratios will strip public transportation of its capacity to maintain service in the long run. Of particular interest to respondents is the use of smaller, more flexible vehicles, such as micro-transit ad subsidized TNCs and carpools that can operate more efficiently at these scales. Half of the respondents view a lack of data sharing and open APIs between public and private sector transportation players as a barrier to cross sector collaboration, with many respondents calling for the creation of market signals that align the goals of the private sector with more equity- and environmentally-minded public sector actors.

Respondents view one of the first steps in leveling the playing field in order to provide mobility to suburban commuters as making it easier for public sector entities to innovate and build partnerships with non-unionized and non-Title VI private mobility companies and for federal transit national transit data (NTD) requirements to loosen regulations tied to the distribution of funds in light of these partnerships.

Data ownership remains a central issue of integrated mobility with a lack of consensus on what entity- whether public, private or third party (foundation or university)- is best suited to managing commuter data. Access to traveler information underpins successful MaaS as aligning data such as origin and destination with current system configurations to perform gap analyses that can inform new mobility interventions, justify expansions in the existing system facilitate the formation of partnerships. Frequently mentioned is that while the public sector desires access to real time traveler information, there is recognition that the public sector faces "technical debt", or the inability or lack of resources to utilize this data effectively. Beyond data's role in system gap filling, respondents also see view real time traveler information as a critical component to verifying the use of public subsidies for public infrastructure like parking, HOV lanes or subsidies provided to TNCs. If a traveler offboards from a trunk line service such as BART and boards a last mile TNC service to get to work, there needs to be commitment by both parties to validate that trip in order to pay out the subsidy to both providers. Notably, the stated preference commuter survey revealed that a majority of commuters are willing to share their commute data with a public sector entity in order to improve transportation options to and from work.

Several respondents did not see any integration between private and public transportation providers as necessary, believing that public agencies would be able to successfully replace current cost inefficient fleets with flexible TNC services provided a loosening of federal regulations tied to funding.

Pricing

Fifty percent of respondents view a lack of regional and local pricing policies as a major challenge to implementing more integrated, multi modal efficient mobility. Public sector and private respondents agree that dynamic pricing levied on single occupancy vehicles is key to both improving service delivery and reducing congestion by intervening at the behavioral level to highlight the long-standing subsidies provided to single occupancy vehicle cars. One interviewee mentioned, "there is a huge opportunity for dynamic pricing on our curbsides and in our express lanes, which will free up resources to better deliver [public transportation] services." However, many pointed out that pricing mechanisms must be deployed after or during the creation of competitive alternative mobility. An interviewee framed the latter point by expressing, "you can't lead with pricing, but if it is thoughtfully and dynamically implemented along with providing better alternatives, we can amplify the behavior change we are targeting" (phone interview with Seleta Reynolds, September 2018).

Funding

Respondents viewed the fourth threat to integrated, multi-modal public transit as the lack of public funding and public confidence in transportation as a public good. One interviewee articulated the tension of declining ridership, limited funding streams, and the pressure to innovate new business models for public transportation: "we can't measure ourselves this way [based on ridership] in the long run as our funding will be tied to success metrics that are not viable (phone interview with Christy Wegener, September 2018)." Another respondent noted, "The taxing mechanism that once was enough to pay for improved public transportation infrastructure has been allowed to dry up," (phone interview with Gary Miskell, August 2018).

6. CASE STUDY ANALYSES

Three Bay Area niche MaaS innovations, LAVTA's 'Go Dublin' first-last mile TNC partnership, Santa Clara Valley Transportation Authority's on demand, 'Flex' Service pilots 1 and 2, and Palo Alto's Transportation Management Association's partnership with Scoop Technologies, are studied to understand how each addresses the identified micro, meso and macro level 'lock-in' barriers, and the effects of each on the commute choice of travelers, with particular attention paid to VMT and GHG reductions achieved over the course of their life cycle. Other key indicators reviewed are origin and destination of riders, especially in relation to whether it provides first and last mile services, in order to increase utilization of the existing network, or creation of direct routes to work for commuters, qualification of location-specific variations, including urban density, and public transit service and availability, and operational and capital costs. The analysis evaluates whether such early MaaS innovations increase mobility, while decreasing vehicle miles traveled and greenhouse gas emissions, and in what ways systemwide integration is achieved to more meet the mobility needs of commuters.

6.1. Go Dublin: First-Last Mile Public-Private Partnership

Dublin is an inland city located in Alameda County with a population of 70,000 residents. 77 percent of commuters in Dublin drive alone getting to and from work, with the average commuter spending 39.0 minutes (one way) and driving 30+ miles for these trips (San Francisco Planning Commission 2017, pp 6). By comparison vehicle miles traveled per capita in a more 'urban' such as San Francisco is 5-10. (U.S. Census Bureau 2017, n.p.). Dublin's jobs/housing balance is f 1.33, meaning that the city employs more people than it houses (Association of Bay Area Governments 2014, pp 1). The population density of the city is 4,345 people per square mile over a total of 15 mi^2, with a majority of housing being single-family detached homes. By comparison, San Francisco's population density is 18,679 (Open Data Network 2017). Public transit ridership constituted 12.1 percent of total mode share in 2016, increasing from 9.2 percent of total mode share in 2013 (Data USA, n.y., n.p.).

Dublin is served by the Livermore Transit Authority (LAVTA), which operates 5 routes within and in between Dublin and the city's two neighboring cities, Pleasanton and Livermore, including three local and two express routes with connections to the BART (Bay Area Rapid Transit) station in the city. Each year, LAVTA serves nearly 2 million passengers between the three cities between its paratransit services and Wheelbus, a multi-year program created to improve efficiency and ridership between the three cities (LAVTA 2016, n.p.) Between 2010 and 2014, several of LAVTA's routes in Dublin experienced significant declines in ridership, an average drop of 5 percent in ridership each year and an increase in service operating cost increase of 29 percent (Yeamans 2018, pp. 3). During peak commute hours, two of the inter-city bus routes carried an average of 5 passengers, whereas systemwide service standards are 15, equating to a subsidy of $15/passenger trip.

Origins of Go Dublin Pilot

The Go Dublin pilot was launched in 2016, as LAVTA recognized that its traditional "big bus" service was not achieving the farebox recovery ratio and ridership rates to continue these services on an ongoing basis (Wheelsbus 2016 pp 5-16). As a result, LAVTA's unproductive intracity bus routes were eliminated and replaced with a first-last mile ride hailing service provided by Uber, Lyft and DeSoto Cabs, which offers users up to a $5 subsidy to use within a geofenced boundary (Dublin city limits). The aim of the partnership is to test whether subsidizing first-and last-mile travel through 'ride-hailing' TNC vehicles preserves mobility and LAVTA ridership in a more cost-effective way than prior fixed route transit using full-size buses.

The stated goals of Go Dublin are to improve connections for BART riders, with the Go Dublin service acting as a 'feeder' model to the broader public transportation network and therefore alleviate demand for parking at the BART parking station, which faces a deficit of 6,000 parking spaces in total, induce ride-sharing, and to improve farebox recovery ratios in low-density areas where more frequent bus services, which might otherwise attract ridership, are constrained from an op-ex standpoint.

For Go Dublin trips, LAVTA pays up to 50 percent or up to $5 through the ride-hailing app itself- either Uber, Lyft, and DeSoto Cabs using a specific code to identify these trips. At the outset of the pilot, the intent was that Go Dublin trips would use UberPOOL, Lyft Line or DeSoto Share options in order to offset an increase in VMT associated with single-use fetches through ride-hailing services (Clewlow and Mishra 2017, pp 26; SFMTA 2018, pp 4).

Total Potential Riders (number of seats multiplied by size of fleet)	**Origin and destination "O & D" Data**	**Daily ridership/ Annual ridership**	**Cost**	**Average trip mileage**	**VMT Reduction**	**GHG reduction** Emissions savings: Lbs GHG: 0.906 VMT * 0.906	**Utilization efficiency of entire PT network**
N/A Alternative: 6000 (based on parking space deficit at BART station)	Majority of rides are between low-density residential to BART. Most trips are made during midday and peak hours.	Daily average: 34 Total/year: 1,800	$2.35 per trip (versus fixed-route subsidy around $15.00 per ride)	5 miles (1-2 miles per pickup; 2-3 miles per fare)	1800 total trips x 3 (average distance) x 2 (number of occupants besides driver) **10,800 miles not driven**	10,800 x .906 9,784.8 lbs GHG **Approximately 1 car off the road for an entire year, however significant connections made into BART, where most savings in terms of GHG occur**	Increase ridership for BART by increasing access; for first-last mile trips themselves it is unclear what the utilization efficiency in regard to whether these are pooled or not [lack of data transparency]

Analysis

In the two years that Go Dublin has been in operation, has the private-public partnership "[generated] a win-win for communities", defined as "[increasing] mobility — that is, passenger miles traveled — while reducing vehicle miles traveled?" (Sperling et al. 2018). By providing a first and last mile option, Go Dublin has effectively resolved the issue of access and time for potential BART users, especially as these users might otherwise be deterred otherwise as a result of BART's severe parking deficit. In terms of time, headway was decreased from 30 minutes to 7-8 minutes and travel time to BART was reduced from 30 minutes through previous bus services to 8-9 minutes. By addressing these micro-level barriers, 34 riders per day are now accounted for in LAVTA's network and the broader public transportation network, without the use of SOV trips.

From a vehicle miles traveled perspective, it is unclear whether ride-sharing has been effectively induced, as a fully operational data sharing agreement has been challenged between LAVTA and its private sector partners Uber, Lyft and DeSoto Cabs. This is problematic in two ways. First, there is not sufficient data transparency between private TNCs and LAVTA to know the average occupancy of these trips, whether 2 or 3 (driver and occupant, or driver and two occupants) despite that only multi-passenger rides were intended to be subsidized. Reducing solo travel in such fleets will occur only if the public sector can verify occupancy of such trips, and only then if an agreement is reached around terms of data sharing. Secondly, the lack of data sharing poses a threat to federal funding as TNCs are unwilling to provide critical operational data, without which agencies such as LAVTA cannot comply with National transit data (NTD) requirements set by the Federal Transit Agency (phone interview with Christy Wegener, September 2018)

The average cost of a trip is $2.35, an 84 percent cost decrease versus LAVTA's prior operation of big bus, fixed-route services. Understanding the true cost of these trips from the viewpoint of TNCs themselves, however, will ultimately determine the long-term viability of such partnerships. For example, the primary operating cost for big bus services is not the fleet itself, rather the cost of labor (phone interview with Mike Hursh, October 2018). In terms of fare, the burden of variable cost, anything above a $5 trip, for this service offering, is the responsibility of the end user. From an equity standpoint, this pricing approach is problematic from the standpoint that it may price out potential low-income users from taking advantage of the service. Ultimately, depending on the elasticity of price as a travel choice consideration, end users may revert to using their car depending on relative price and time points of either option.

MaaS also prompts the need for tying transit and climate outcomes with land use decisions, making BART's 6,000 parking space deficit especially interesting. The consequence of an increasing Bay Area population and economic opportunity will increasingly strain roadways, making high capacity mobility through BART an imperative. Understanding such bottlenecks and providing critical last mile TDM not only is more cost effective but also achieves mode shift, while supplying additional parking does not.

The question remains whether these interested riders find alternative ways to connect to BART, via Go Dublin, biking or walking, or alternative services like Scoop Technologies or traditional carpooling, or if they opt to drive instead. By framing the system as a whole, through which an entire commute, from origin and destination, is matched with a suitable mode of mobility, Mobility as a Service also takes into consideration possible levers of mode shift in the last mile. For example, commuters constrained by lack of BART parking in the origin of their trip may opt for SOV. However, if parking is constrained or unavailable in the last mile, the necessity of mode shift heightens. Ultimately data that can help to produce feedback between shared mobility adoption and incentive/disincentive strategies (that is, increasing choice vis a vis Go Dublin and constraining parking availability in the first and last mile) could be key to unlocking higher vehicle occupancy first-last mile feeder routes to public transit trunk lines.

The partnership demonstrates the potential of a suburban transit agency in providing first and last mile connections in low-density settings, whether rides can be matched, and the effects on VMT and passenger miles traveled. A primary consideration of the pilot is to understand what options commuters would utilize were it not for Go Dublin, including their own cars, which is especially important if potential riders are not able to use the existing intercity rail system because of parking limitations. Therefore, systemwide planning, pricing policies and incentives between TNC first and last connections led by LAVTA and BART are all important challenges in scaling reductions in VMT and preserving mobility, as demonstrated in the first two years if the Go Dublin pilot.

6.2. Palo Alto Downtown Transportation Management Association- Scoop Technologies Partnership

In 2017, Palo Alto had a population of 67,178 residents (City Data 2019, n.p.). The city's jobs to employed residents ratio is 3.02, indicating that more Palo Alto workers live outside Palo Alto than within the city, and thus must commute into the city, leading to peak hour congestion (Better Cupertino 2018, n.p.). The population density of the city is 2,497.5 people per square mile over a total of 25.77 mi2, with the housing stock comprised mostly of single-family detached. The average travel time to work in Palo Alto is 21.8 minutes and a VMT per capita of 53, the latter responsible for 80 percent of total VMT, as a result of the 'daytime' population that comes into the city for work each day (Palo alto comprehensive plan update 2014, pp 12-35). Over a ten-year period, single occupancy vehicle mode share has decreased from 74.5 percent in 2000 to 67.3 percent from the American Commute Survey 2006-2010 (US Census Quickfacts 2018, n.p.). Over the same ten-year period, public transit ridership grew from 3.4 percent to 4.6 percent and cycling grew from 5.6 percent to 6.8 percent (Bay Area Census, n.y., n.p.) The city is served by Caltrain, with two stations, the Stanford Marguerite shuttle, operated by Stanford University, a fare free shuttle, AC Transit, VTA and Samtrans.

Origins of Palo Alto Transportation Management Association-Scoop Technologies Partnership

Primarily as a result of its jobs to housing imbalance, Palo Alto receives over 87,000 commuters between coming into the city to get to work each day (Palo alto comprehensive plan update 2014, pp 12-35). The situation has led to significant efforts led by the primary employers in the area, including Stanford University, Lucile Packard Hospital and Stanford Research Park to expand their transportation demand management programs. A fourth entity, Palo Alto's downtown Transportation Management Association (PATMA), launched in 2015 to address downtown traffic congestion. The city's downtown area is composed of 300 small-to-medium sized businesses located between El Camino Real to the east and Webster street to its west. In 2015, more than half (55 percent) of the trips taken into downtown are single-occupant-vehicle trips and 19 percent arriving by public transit (Patras et al 2015, pp 7).

As a response to increasing congestion, the Palo Alto Transportation Management Association was formed in 2016 to deploy a targeted transportation demand management program for the downtown area. At the time, the city had established a goal of reducing SOV commutes to and from downtown by 30 percent over 2015 baseline levels of 70 percent SOV (Sheyner 2017, n.p.) The city had initially prospected an additional parking structure to accommodate car traffic to the downtown area, equivalent to a subsidy for SOV of $3,408 per capita per year or $60,000 over 30 years (Raney 2018, pp 17). Rather than pursue the construction of the parking lot, Palo Alto's TMA was created to remove the need for overflow parking altogether by increasing the traction of non-SOV commuting options, including subsidized public transit passes, digitally-enabled carpooling and Lyft for short trips (Palo Alto TMA 2019, n.p.)

A TMA is a membership-based coalition of businesses, institutions and municipalities that are joined together on a contractual basis, bound together to provide and promote mobility options to employees, especially in the first and last mile to reduce traffic congestion and emissions related to SOV. In this respect, TMA's are hybrid public-private coalition extending beyond city or employer-led transportation demand management efforts. The stated goal of Palo Alto's TMA is to "[reduce] Single Occupancy Vehicle (SOV) trips, traffic congestion and demand for parking by delivering targeted transportation solutions to the Downtown area's diverse range of employers, employees, visitors and residents" (Palo Alto TMA 2019, n.p.). PATMA's initial focus was to target the downtown area's roughly 2,000 service workers, as an initial study of employers in the area found that large tech employers such as Palantir, A9, and Houzz already had a 35 percent SOV mode share while the service worker mode share was approximately 70 percent (PATMA 2019, pp 33). In response to the demographic pattern, Palo Alto's TMA adopted a social equity focus as it primarily targets service workers coming into the downtown area

(PATMA 2019, pp 11). An intercept commuter survey was conducted at the outset of PATMA to gauge attitudes towards SOV alternatives, which indicated that 67 percent of respondents preferred to drive to work on their own, while 35 percent showed interest in taking carpool or vanpool. Responses suggest that 50 percent have a general interest in taking an alternative to their own car, with the primary barrier being that there are not viable options available to them, as depicted in Figure 7.

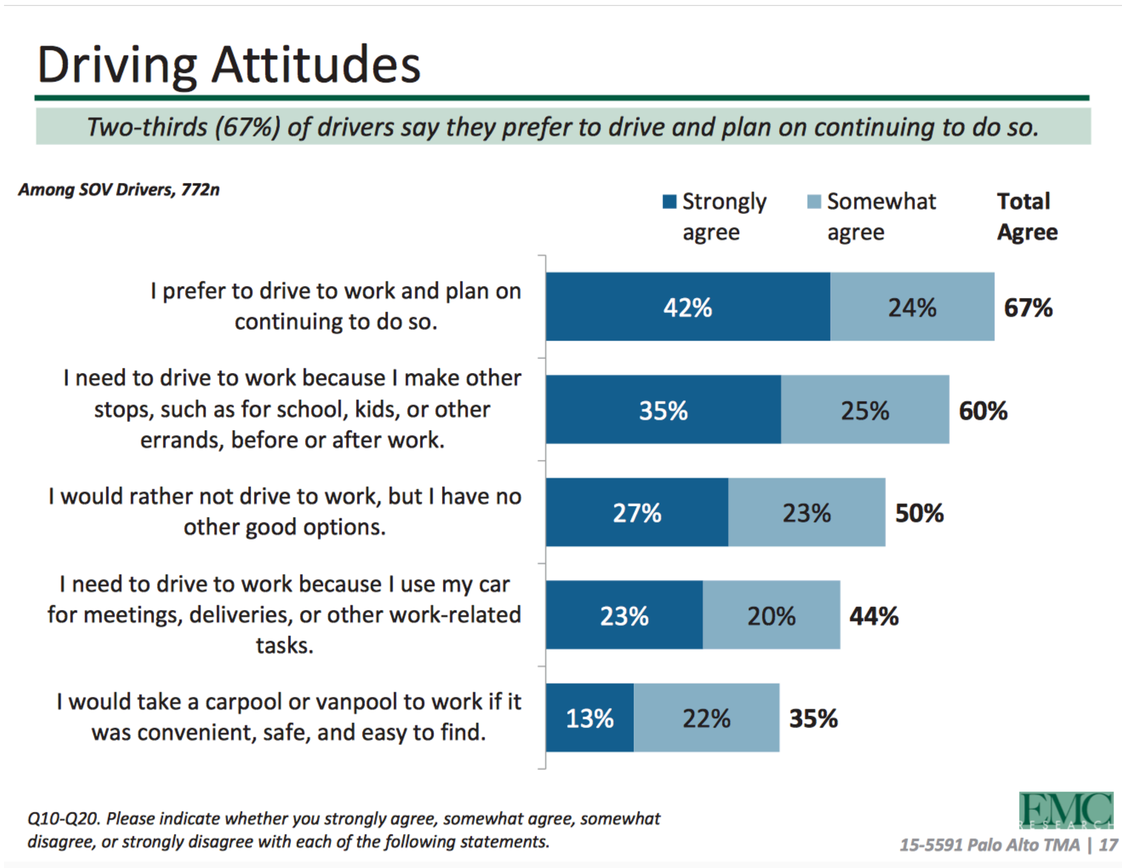


Figure 7 Travel choice attitudes of downtown Palo Alto employees (PATMA 2015)

The case study focuses on one PATMA's offering in particular: a partnership with Scoop Technologies, a MaaS carpool software company connecting employees based on common destinations. To date, despite California's considerable investments in high occupancy vehicle lanes, carpooling to a large extent has been a failure within the state. However, in the past several years, Scoop Technologies has quickly accelerated the viability of carpooling, utilizing several key advances in technology including flexible driver and pickup designations, enterprise level partnerships with cities and other public entities to create single and/or concentrated destinations, the combined effect being the successful matching of commuters in low-density suburbs. This approach has enabled Scoop to match more drivers in the San

Francisco Bay Area than all previous carpooling companies combined, including Avego, Goose Networks, Carticipate, Piggyback, and NuRide (PATMA 2019, pp 13).

In January of 2016, PATMA partnered with Scoop Technologies at an annual cost of $2,678 annually per capita to subsidize trips, roughly equivalent to a $4.25 subsidy per day for Scoop users. The source of the subsidy is from the University Avenue Parking fund, with $480,000 in revenue generated from the city's downtown parking meters in 2018, with another $280,000 secured by the TMA from other sources (PATMA 2019, pp 3)

Results

Total Potential Riders (number of seats multiplied by size of fleet)	**Origin and destination "O & D" Data**	**Daily ridership/ Annual ridership**	**Cost**	**Average trip mileage**	**VMT reduction**	**GHG reduction** Emissions savings: Lbs GHG: 0.906 VMT x 0.906	**Utilization efficiency of entire PT network**
1,853 total registered users within PATMA as of Dec' 18	Employee residential neighborhoods to downtown Palo Alto (19 unique destinations- 4 of them large companies in downtown, remaining are small downtown businesses, the Caltrain stop, and co-working spaces.)	2018 average = 187 active users. 130 total trips completed (monthly average) Total annual trips made: 8,275 (1 way- 2-person trips)	$2,678 annually per capita to subsidize trips, equivalent to a $4.25	15.5	8,275 total trips x 15.5 (average distance per trip) x 1 individual **128,262.5 miles not driven**	128,262.5 x .906= 116,205.825 **11 cars off the road per year**	Higher utilization of previously SOV trips. Higher utilization of transportation system (roads, highways, especially HOV infrastructure)

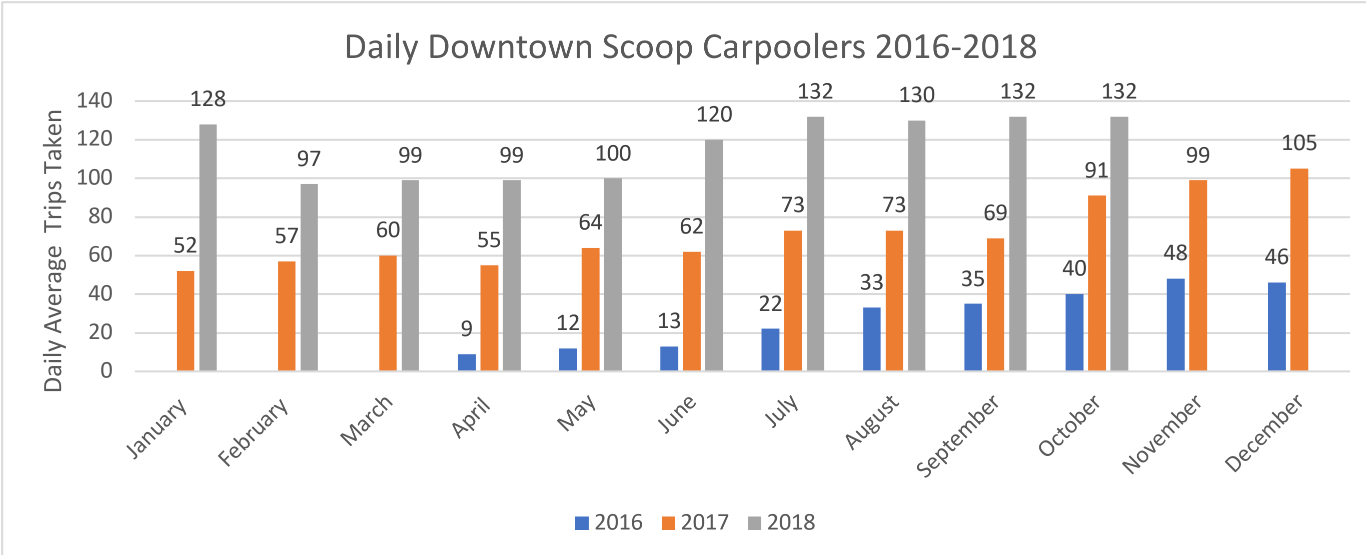


Figure 8 Increases in Scoop Ridership 2016-2018 (Raney 2019, pp 24)

Analysis

Palo Alto's TMA's partnership with Scoop technologies successfully preserved mobility for 187 users in 2018 while reducing VMT per capita, an average savings of 128,262.5 miles not driven and approximately 11 cars taken off the road in terms of annual GHG emissions. The partnership overcomes two primary barriers to mode shift identified in the previous section: time, as HOV highway infrastructure provides priority to Scoop users, no stops are necessary along the way to the final destination, and headways are significantly reduced or altogether eliminated as users can define a time to meet according to their schedules. Cost savings is another benefit as trips are subsidized up to $4.25, meaning that drivers who would otherwise cover the cost to own and operate the car cut the cost in half for commute trips and are paid an additional $4.25 towards the trip cost. Over time, it is assumed that reliance on carpooling as a regular commute mode will normalize, a 'graduation' effect which is very valuable to maintaining SOV reductions ((PATMA 2019, pp 23).

Similar to the arrangement between LAVTA and TNCs, commuters utilize the Scoop app through PATMA's subsidy, but no information is shared except the number of trips taken daily, the number of employees registered for Scoop through PATMA's program, and downtown destinations of users. Origin, average trip time, driver-passenger matches, and attrition are not shared with PATMA. In the long run, if carpooling services are to scale to become an integral part of the Bay Area's transportation network, this kind of data would need to be made available, especially in integrating fares. This is relevant to Scoop Technologies as, without the ability to flexibly vary incentives to fit supply and demand, there is an imbalance that undermines the company's long-term business model. Integrating fare in acknowledgement of these imbalances necessitates the need for information sharing in the long run. The partnership illustrates that digitally-enabled carpooling can transform many single occupancy vehicle commuters into transportation providers subsidized in the same way that rail or bus lines are subsidized, making real time data related to the availability and operation of these 'HOV fleets' integral to any fare strategy.

In connecting land use to transit outcomes, Scoop's "cars out of the parking lot" metric illustrates the number of cars that would otherwise require parking. For 2018, the number of parking spaces freed was 50 spaces, equating to an annual savings of $2,379 annual cost per space freed. Pricing is another key aspect of Palo Alto TMA's efficacy, as downtown parking revenues have both created funding sources for its own TDM efforts while also reducing demand for parking altogether through the implementation of TDM programs. Rather than build new parking structures as was initially envisioned, PATMA's partnership with Scoop, as well as its other programs demonstrate that bringing the private sector on board can result in the creation of more efficient, inexpensive commute options while fulfilling state climate objectives and local SOV reduction objectives. What's more, incorporating land pricing, whether congestion or parking management schemes, into the operation of these efforts creates a durable funding source. This is especially critical as the Bay Area's economy and population continues to grow, while available space for parking continues to shrink. As one TDM expert in the South Bay revealed, "we are hiring at a rate of 100 new employees per month and we are already running out of parking spaces, we are proving that TDM is effective at reducing SOV at the fraction of the cost of a new parking structure (phone interview with Greg Beverlin, October 2018). Furthermore, with the introduction of pricing beyond downtown parking meters, but also widespread pricing of highways and other auto-centric infrastructure, "it may be that with the future introduction of behavior-changing congestion pricing, an unsubsidized Scoop may thrive" (Raney 2018, pp 13).

6.3. VTA's Flex 1 & 2 Pilots

San Jose is a city in the South Bay of the Bay Area with a population of 1 million people (Data USA 2016). The city has a single occupancy vehicle 'drive alone' commute rate of 75.9 percent and a mean travel time to work of 29.4 minutes (Data USA 2016). In 2016, 11.6 percent of commuters carpooled and 4.68 percent of people took public transportation (Data USA 2016). San Jose's jobs to employee-resident ratio is .89, meaning that it houses more people than it employs, and its population distribution is 5,718 residents per square mile over 180.5 mi^2 (Open Data Network 2016).

San Jose is served by Santa Clara Valley Transportation (VTA) light rail and bus services and intercity rail service Caltrain to the city's downtown Diridon station. The city will also welcome Bay Area Rapid Transit within one of its neighborhoods, Berryessa, approximately five miles away from the downtown area. From 2012 to 2018, operating expenses grew twice as fast as revenues, while ridership on buses and light-rail trains dropped 23 percent from 2001 to 2016 (Richards 2018, n.p.). As a result of heightened financial pressures, VTA launched an agency wide effort called the 'Transit Ridership Improvement Program', which entails the redesign of several underutilized bus routes, known as the 'Next Network' project, creation of efficient linkages between existing VTA routes and imminently ready Milpitas and Berryessa BART stations, the improvement of VTA's farebox recovery rate and improvement of its core services.

Origins of Flex 1

In 2016, VTA launched 'Flex' in San Jose to test the viability of an on-demand transit service that used a dispatching algorithm to automatically assign four, 26 seat buses based on real-time customer trip requests within a 3.25 mi^2 area of San Jose. The Flex pilot ran for a six-month period on weekdays to provide direct pick-ups based on prescheduled or subscribed requests within the geofenced area and aimed to address inadequate first and last-mile mobility options between trunk line transit including Diridon station and VTA light rail stations, as well as additional gaps in the network within several of San Jose's commercial and employment districts. The project represented VTA's first attempt to implement real-time ride matching and dynamic routing and to evolve service models in low-density areas. In the last three months of the six months of Flex, the Metropolitan Transportation Commission (MTC)- funded pilot expanded its catchment area to a 5.5 mi^2 in an effort to increase the number of riders.

Total Potential Riders Calculated as number of seats multiplied by size of fleet	**Origin and destination "O & D" Data**	**Daily ridership/ Annual ridership**	**Cost**	**Average trip mileage**	**VMT reduction**	**GHG reduction** Emissions savings: Lbs GHG: VMT * 0.906	**Utilization efficiency of entire PT network**

4 x 26-seat shuttles= 104 seats x number of trips= 282,256 Total registered accounts: 2,677	35% of FLEX trips were to/from other VTA bus/rail service nodes 1. Rivermark Village 2. Seely at River Oaks **3.** 1st at River Oaks **LRT station** 4. Renaissance at Enclave Apt 5. Tasman at Champion **LRT station**	313 riders over six month period: 16 per day in first three months, to 33 in last three months (due to expansion of service route area and promotional rides)	Operating cost averaged $200 per passenger over the course of the 6-month pilot. With ridership at 0.4 boardings per revenue hour, the pilot had low farebox recovery at 1% Flat fare for end user: $2 midday, $3 peak hours Total operating cost: $905,280	2,714 total trips x 8.5 minutes (1.99 miles= average distance assuming bus is traveling 14.1 mph)	2,714 trips x 1.99 miles= **5,400 miles not traveled**	5,400 x .906 = 4,892 lbs GHG **½ car per year not driven**	35 % of trips taken are to a light rail station: acts as a feeder into intra-city public transit system 25% rode transit more 48% have their own cars= "choice riders"

Origins of Flex 2

Flex 2 will be launched in 2018-2019 and is the next iteration of demand responsive services offered by VTA after its initial Flex 1 pilot in 2016. In line with VTA's ongoing effort to test dynamic and flexible transit services, VTA is partnering with the City of Sunnyvale and private developers to implement "Peery Park Rides," a Metropolitan transportation commission-grant funded pilot offering flexible last mile shuttle services in Sunnyvale's Peery Park from 2019-2021. Peery Park, a 446-net acre development project, is located in an older industrial area of Sunnyvale approximately .5 to 1.5 miles away at either end from the Caltrain intercity rail system. To date, the two Caltrain stations—Sunnyvale and Lawrence—that are within five miles of the Peery Park development generate a significant number of last-mile trips during commuting hours.

In line with the state's VMT policy mechanism SB 739, the partnership comes in response to the Peery Parks development trip cap mandate, requiring the reduction of single occupancy vehicles by 30 percent to the business park. Across the entire campus, Peery Parks must comply with minimum and maximum parking requirements set by the City of Sunnyvale enforceable under its traffic impact analysis, CEQA process and transportation demand management requirements.

The partnership aims to test supply and demand side strategies, including parking reductions and the simultaneous deployment of the VTA last mile shuttle in order to provide commuters with viable commute options outside of their cars and to prove a model of mobility for large employment centers located in low-density, suburban areas. Generally, job sites of 48 or more people per acre support high frequency transit services with job sites averaging 96 jobs per acre creating enough density for transit headways of 2-5 minutes during peak commute periods (Nelson/Nygaard 2015, pp 3-3). Under this qualification, Peery Parks, estimated to support 1,200-1,800 new jobs, does not qualify for high frequency transit. It remains to be seen whether enough commuters will find Caltrain's 4 per hour peak commute train service and integrated last mile Peery Park Rides shuttle enough an incentive to shift away from SOV modes. Bearing in mind that 34 percent of commute trips into Santa Clara County, where Sunnyvale is located, are cross jurisdictional- originating in San Francisco, the Peninsula, the East Bay, and the Tri-Valley area- services such as the Peery Park Rides last mile shuttle may not be sufficient in addressing the disperse origins in order to achieve long term VMT/SOV reduction goals (Nelson/Nygaard 2015, pp 3-9).

Total Potential Riders Calculated as number of seats multiplied by size of fleet	**Origin and destination "O & D" Data**	**Daily ridership/ Annual ridership**	**Average Cost**	**Average trip mileage**	**VMT reduction**	**GHG reduction** Emissions savings: Lbs GHG: VMT * 0.906	**Utilization efficiency of the entire network**
Shuttle operating during peak commute hours with 6-10 seats 30,000 = potential employees plus residents in the surrounding neighborhood	Between Caltrain station and Peery Parks commercial center; bus route runs along El Camino, through downtown Sunnyvale and around the perimeter of the Peery Park development	Projected: 1,296 last mile trips per day	Cost is fare free to end user; Half of net cost ($1.98m for two years of operation) is funded by MTC grant, the City of Sunnyvale, VTA, and the private developer share the	.5-1.5 miles between Caltrain and Peery Park development	428 auto trips reduced per day 3,220,388 vehicle miles traveled over lifetime of project Equal to 239 cars off the	889.18 metric tons of CO_2 over the life of the project Equal to 193 cars in terms of GHG emissions	Connects commuters with Caltrain (solving last mile problem); increases mobility of residents and Peery Park employees to travel into downtown without the use of a car

			remaining costs.		road (over lifetime of project)		

Analysis

For Flex 1, mobility stayed the same or increased for end users, with Flex 1 pilot users reporting that they rode transit 25 percent more, while 56 percent reported no change in their transit use, indicating that many riders were already users of public (Santa Clara Transportation Authority 2017, pp 12). The pilot overcame issues surrounding first and last mile access to public transit options, as Flex ensured that riders were picked up where they were, with 35 percent of the trips connecting users into VTA light rail stations, thereby increasing ridership and utilization efficiency, across VTA's entire network (Santa Clara Transportation Authority 2017, pp 12). Headway wait times was significantly decreased, overcoming time barriers associated with public transit, with riders waiting an average of 7.5 minutes (Santa Clara Transportation Authority 2017, pp 9).

Flex 2 differs from Flex 1 in that it will operate a fixed route last-mile shuttle between the Caltrain station and Peery Park business campus. Besides speed/time, the commuter survey revealed that last mile options are the second most important consideration in using public transit. As the Flex 2 table shows, mobility will increase and VMT significantly decreases as a result of systemwide VMT reductions supported by Caltrain and VTA in unison. The Peery Park Rides proposal notes that the shuttle will operate outside of peak commute hours in order to accommodate commuters wanting to go out for lunch. Many commuters do not take public transportation to get to work as the cite the desire to have their cars for midday trips (phone interview with Aiko Cuenco, December 2018). In providing an off-hour mobility option, the intent is to address such commuter micro-barriers. Cost, albeit a relatively smaller concern within the commuter survey, is an additional barrier overcome as the Peery Park rides is fare free to employees of the business park and to the surrounding community. Over the course of the pilot, price elasticity will be analyzed as an incentive or disincentive.

Flex 1 demonstrates that new on-demand, flexible transportation models can help to address key first and last mile access, time, cost and be highly rated by its end users, but may not be sustainable from a long-term operational standpoint of the provider. In an evaluation of the Flex 1 pilot, sustainability from a cost perspective is a key issue and the application of technology does not necessarily make transportation services in low-density areas less expensive: "technology doesn't make it cheaper, in fact, on demand flexible service models are more expensive" (phone interview with Aiko Cuenco, December 2018).

Flex 2 may prove a more durable mobility model for several reasons. First, the cost to operate the shuttle may go significantly down as autonomous driving technologies may replace high cost labor. Second, the Peery Park development will be required to generate demand for alternative commuter mobility in order to comply with trip cap requirements mandated by the city of Sunnyvale. In this respect, it is in the best interest of both public and private stakeholders to invest in transportation demand management and the provision of mobility. It is intended that the partnership will result in steep SOV, VMT and GHG reductions as the last mile mobility option will create systemwide demand for public transportation by addressing the second key concern raised by 'choice' commuters in the survey, as well as free land otherwise committed to parking for hundreds of SOV commuters each day. Fare free last mile mobility, a key element of the arrangement, will inform the elasticity of cost as well as convenience of seamless transfers, for choice commuters using these services rather than their own cars.

The carrot and stick policy arrangement suggested as a key part of fostering MaaS is highlighted in the Peery Parks example, as the 'push' is investment as a fare free, last mile mobility service while the 'pull' is the trip cap mandate, which while the onus of the developer, is ultimately transferred to the individual as a constraint of parking and truncating the supply of parking typically offered by employers in the Bay Area. In executing such an arrangement, the Peery Park Flex 2 pilot represents a viable way to decrease SOV by increasing seamless mobility within the framework of trip caps required of new developments by state-level policy SB 743.

7. Discussion

The stated preference commuter survey reveals high demand for alternatives to single occupancy vehicles for commute trips. For these trips, speed and first and last mile connections are the most elastic factors in terms of commuter mode choice, with many respondents noting that available public transportation options do not cross city lines and/or require too many connections. Importantly, the stated preference survey reveals acceptance of pricing as a strategy to improve the transit system and willingness to voluntarily donate data to the public sector, which is a key leverage point in a Bay Area MaaS implementation.

From a built environment perspective, a majority of respondents live in different cities than they work. Sprawl is counter to the density required for cost efficient and frequent public transportation services, so innovative gap filling is needed for commuters in the first and last mile as is an expansion of the 'backbone' of inter-city rail available to suburban commuters.

The case study analysis demonstrates how the push/pull policy mix is adopted within niche MaaS innovations, the combined effect of which represents the viability of MaaS for low-density areas in several key permutations:

- First mile mobility as a service 'feeder' option: LAVTA's public-private partnership connects riders to BART and other commercial areas in Dublin without the use of their car.
- HOV mobility as a service: In lieu of public transportation to create direct routes to work PATMA's enterprise partnership with Scoop Technologies coordinates riders and drivers through shared destinations, increasing utilization of would-be SOV trips
- Last mile mobility as a service option: VTA's Peery Park Flex 2 pilot will provide fare free option to commuters utilizing Caltrain

The mobility options were found to address key barriers outlined in the stated preference commuter survey, in particular, 1) speed 2) first and last mile access, 3) door to door travel/convenience 4) cost.

Flex 1-2 and LAVTA first-last mile pilots did reduce SOV, VMT and GHG to an extent, however, the true impact of each is in creating connections into the existing network, where the most savings in terms of these climate indicators occur. From this standpoint, both Flex and Go Dublin deliver systemwide value, in that they may not take off a significant quantity of cars off the roads for the trips that they are directly responsible for. Rather, they both enable the sizable GHG and VMT savings achieved through the high-density intercity rail network. Scoop Technologies increases the utilization of highways and roads, by increasing the occupancy of what would otherwise be SOV trips. Notably, Scoop's other partnerships, including one with BART, provides high occupancy first and last mile connections to the existing intercity rail network.

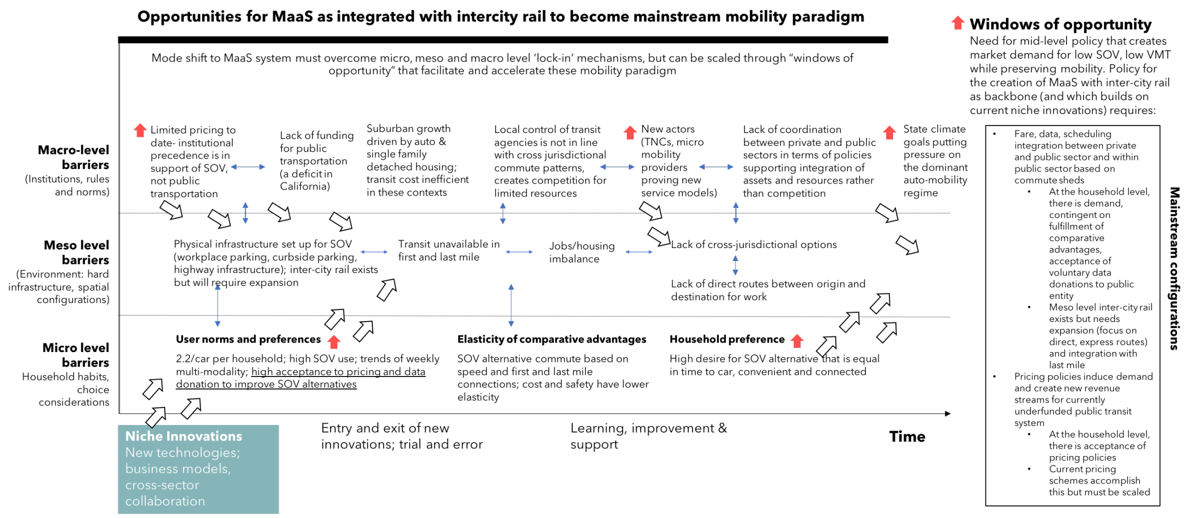


Figure 9 The socio technical transition multi-level perspective framework is used as a template to map the various lock-in mechanisms and windows of opportunity that will challenge and facilitate mode shift through MaaS (own work 2018)

The three niche MaaS innovations show promise towards simultaneously mobility and reducing VMT by enabling a diversification of the mobility market beyond the public sector to include private company TNCs, end users themselves as HOV carpools.

Further investigation is needed into the ideal fare structure for these fleets, as well as the implications of TNCs in terms of vehicle miles traveled if higher utilization pooling is not achieved. From a policy perspective, promoting integration, both in information sharing, fare structure and scheduling from an interagency and private to public sector perspective is of critical importance. Research should focus on common goals to advance integration, as a traditionally profitable service may not be profitable for the private sector under conditions in which service and fare structures are imposed. In addition, impact of new innovation is curtailed by a lack of mid-level policy that makes long term funding available to scale these mobility services and their outcomes over time.

Policy implications

In terms of achieving transportation system efficiency strategies as a climate pathway, MaaS is a viable option. In low-density contexts where ridership is low, applying a push and pull or "carrot or stick" combined policy mix will be a key determinant of mode shift through 'as a service' options. Advancing policies related to the development of MaaS intended to increase utilization of the network, both public transportation and highways, is a critical to advancing the sustainability and efficiency of Bay Area mobility:

- The case studies show that integration of scheduling is critical to ensuring seamless transfers. For last and first mile TNCs, integrated scheduling may be nothing more than an app that provides necessary information related to headway waits. Integration of fare is critical because it ensures ease of use for end users and creates subsidies for the private sector, including TNCs *and* HOVs. Integration of data is critical to ensuring the longevity and sustainability of the mobility system by making new metrics of success, such as utilization efficiency and transfers across the network available. Furthermore, data is key to elucidating origins and destinations in order to exploit excess capacity across the system and identify where flexible services or significant infrastructure expansion is needed.
- The case studies show the efficacy of pricing in terms of creating demand and funding the supply of new mobility. Regional pricing is a critical next step in inducing demand from origin to destination. This is especially important as cross jurisdictional commute sheds are often subject to different pricing policies that dilute the broad strategy extent associated with such pricing policies in the first place. As PATMA and TDM efforts of Flex 2 demonstrate, pricing can be a direct revenue stream for MaaS implementation.
- As Flex 2 pilot indicates, autonomous vehicles, while marketed largely to the consumer market, will have far reaching implications for the mobility sector. Cost savings afforded by the advance in technology will significantly impact the durability of sustainable first and last mile transportation services. Ensuring that innovation is applied to increase ridership across the existing network, rather than proliferating single occupancy autonomous vehicles is an important challenge.
- Marketing and education of MaaS is a key component of meeting state climate objectives. Normalizing non-auto centric commuting through marketing campaigns, employer commute programs, and by making visible the invisible subsidies that cars currently benefit from, is the final leg of a MaaS push/pull policy ecosystem. The ‘graduation’ effect of Scoop Technology users is a primary example of this: as carpooling behavior is normalized over time, the more SOV trips will naturally evolve into HOVs.

8. Conclusion

It is clear that many of California's long-standing policies, historic investments, cultural norms and institutional practices are determinants in how much California's residents and employees utilize single occupancy vehicle driving now and in the future. Multi-decadal highway and roadway expansion and declines in inflation-adjusted state gas tax, coupled with institutional challenges to expanding public transit and dense transit-oriented development will all contribute to increasing VMT per capita and challenge California's climate targets

In reversing this trend, the thesis proposes Mobility as a Service as a key strategy to address mobility challenges in low density, high SOV contexts to achieve the California's ambitious climate objectives. The research uses the multi-level perspective theory as a theoretical lens to evaluate the barriers and windows of opportunity to scaling Mobility as a Service through a coordinated push/pull policy framework, as well identifies key technical and institutional learnings from three early MaaS innovations in the Bay Area.

The conclusion builds on a growing set of literature offering new models of mobility that support higher utilization efficiency of the transit network through integration, sharing, and 'as-a-service'-based transportation models. Sperling (2018), Speck (2012), and Handy and Boarnet (2017) recognize that filling seats in existing fleets are critical to reaching the state's climate targets, with all three researchers calling for improved and expanded mobility options by building closer ties and transparency between the public sector and private sector and by legislating regional pricing policies, including dynamic pricing. Shaheen (2018) argues that significant public sector investment in digital infrastructure, public-private coordination, and standardization of transportation data, including the use of open APIs, are vital steps in improving overall transportation system efficiency. This research expands on the literature by connecting MaaS to a push-pull policy framework, proving the success of such an arrangement in the analysis of three Bay Area case studies.

As the analysis shows, commuters express high demand and willingness to transition away from SOV mobility for work trips, supporting investment into public transit through regional pricing and volunteering of personal travel data. Data revealed that the primary obstacles to this transition occur at the spatial level as a result of the Bay Area's significant jobs/housing imbalance and a lack of transit availability and adequacy along their work routes, undermining highly elastic commute choice factors including time and first and last mile considerations, as door to door service (convenience), cost and safety.

Elements of MaaS manifest in the early niche innovations identified, including partnerships that integrate TNCs and public transit in the first mile, subsidize direct-to-work trips through digitally enabled carpooling, and last mile fare-free, seamless connections to and from intercity rail. This is accomplished by extending public subsidies and determining mutually beneficial fare structures for public and private providers, by taking advantage of the strengths of each actor, with the private sector offering more flexible, on-demand services and the public sector offering subsidies and connections into intercity rail including BART and Caltrain and light rail. The pilots also demonstrate sharing of data between these actors, although additional data transparency is needed to sustain these partnerships long term. Such configurations also incorporate pricing policies, as LAVTA finds demand through BART's parking deficit, which creates demand for first mile trips that could otherwise be made by SOV, while the Palo Alto Transportation Management Association's TDM efforts utilize revenue streams generated as a result of Palo Alto's downtown parking management strategy. Flex 2's Peery Park Rides last-mile shuttle also finds support through the City of Sunnyvale's trip cap mandate which will constrain parking at the outset, with money reallocated to creating alternatives for would-be SOV commuters. The combined push and pull effect of the three pilots are significant- each day, approximately 450 cars are projected to be taken off the road during peak commute hours.

Implementing a regional pricing policy will further induce demand for these services and continue to increase non SOV commute trips. Notably, the focus on commute trips raises interesting questions in a large-scale implementation of MaaS in the Bay Area. The survey reveals that drivers are more likely to shift their behavior for work trips, and these trips are those which low-density commuters are when most likely to take intercity, dense and efficient public transportation, revealed by declines in off-hour public transit ridership. Would MaaS for non-work trips simultaneously increase passenger miles traveled while reducing VMT in the same way as the three MaaS "feeder" innovations demonstrate, or would VMT increase as a result of the savings not incurred through high density, trunk lines?

Ultimately, multi-level perspective analysis reveals that while demand and innovation exist at the micro level, projected outcomes will not possible without the implementation of regional pricing policies as well as legislation bridging private and public, and public and public mobility providers, to increase the performance and efficiency of the entire transit system.

References

Alazzawi, Sabina, Hummel, Mattias, Kordt, Pascal, Sickenberger, Thorsten, Wieseotte, Christian Wohak, Oliver (2018): Simulating the Impact of Shared, Autonomous Vehicles on Urban Mobility - A Case Study of Milan, EPiC Engineering (2). file:///Users/bresem/Downloads/Simulating_the_Impact_of_Shared-_Autonomous_Vehicles_on_Urban_Mobility_a_Case_Study_of_Milan.pdf accessed 22.11.18, pp. 101

Association of Bay Area Governments (2014): Jobs/Housing Balance. https://abag.ca.gov/planning/housingneeds/notes/10-19-06_Agenda_Item_2_-_Jobs-Housing_Balance.pdf, accessed 11.10.2018, n.p.

Bannister, David (2008): The Sustainable Mobility Paradigm. Transport policy (15). https://www.sciencedirect.com/science/article/abs/pii/S0967070X07000820?via%3Dihub accessed 13.12.18, pp. 73

Barkalow, Gina, Bemis, Gerry, McKeever, Nancy, Ohinney, Suzanne, Vinton, Joanne (2007): The role of land use in meeting California's Energy and Climate Change Goals, California Energy Commission. https://www.energy.ca.gov/2007publications/CEC-600-2007-008/CEC-600-2007-008-SD.PDF, accessed 24.10.18, pp. 47

Bay Area Census (n.y.): City of Palo Alto- County of Santa Clara. http://www.bayareacensus.ca.gov/cities/PaloAlto.htm, accessed 29.11.18, n.p.

Bay Area Census (2015): Per Capita Vehicle Miles Traveled Bay Area. http://www.bayareacensus.ca.gov/transportation/VitalSigns/Per-capita_vehicle_miles_traveled_2015.xlsx, accessed 1.1.19, n.p.

Bedsworth, Louise, Hanak, Ellen, Kolko, Jed (2011): Driving Change: Reducing Vehicle Miles Traveled in California, Public Policy Institute of California. https://www.ppic.org/content/av/EventBriefing_DrivingChange_02_11.pdf, accessed 09.10.2018, pp. 4-5

Berlepsch, Hans-Jörg, Böttger, Christian, et al (2018): Public Transport Integration and Transit Alliances, GIZ-SUTP. https://www.sutp.org/files/contents/documents/News/2018_March/3f_Transit_Alliances_SUTP_TUMI_GIZ_final.pdf, accessed 12.12.18, pp. 15

Better Cupertino (2018): Job-Housing Balance in Cupertino is Better Than Santa Clara County Average and Most Surrounding Cities. http://bettercupertino.blogspot.com/2018/02/job-housing-balance-in-cupertino-is.html, accessed 19.10.18, n.p.

Boarnet, Marlon Handy, Susan (2017): A Framework for Projecting the Potential Statewide Vehicle Miles Traveled (VMT) Reduction from State-Level Strategies in California, National Center for Sustainable Transportation. https://ncst.ucdavis.edu/wp-content/uploads/2017/03/State-Level-VMT-Strategies-White-Paper_FINAL-03.2017.pdf, accessed 09.10.2018, pp. 4

Brittle, Chris and Riordan, Bruce (2009): Transportation, Land Use and Greenhouse Gases- A Bay Area Resource Guide, Metropolitan Transportation Commission. https://www.reimaginerpe.org/files/Resource_Guide_9-30-09_0.pdf, accessed 13.10.18, pp. 45

California State Senate (2018): Californians Want A Clean Energy Future. https://focus.senate.ca.gov/sb100, accessed 09.10.2018, n.p.

Caltrain (2017): Annual Passenger Count Key Findings. http://www.caltrain.com/Assets/_Marketing/caltrain/pdf/2016/2017+Annual+Count+Key+Findings+Report.pdf, accessed 29.11.18, pp. 17

Caltrans (2016): California Transportation Plan 2040- Appendix 6 Revenues and Expenditures. http://www.dot.ca.gov/hq/tpp/californiatransportationplan2040/final-draft-ctp2040/docs/ctp2040-final-draft-appendix-6-022616.pdf, accessed 09.23.18, pp. 2

Caltrans (2016): California Transportation Plan 2040. http://www.dot.ca.gov/hq/tpp/californiatransportationplan2040/Final%20CTP/FINALCTP2040-Report-PRINT-NoBleed_secured.pdf, accessed 09.24.18, pp. 18, 32, 62, 68, 103

Cerfontaine, Caroline (2016): Mobility As A Service: An Alternative To Owning A Car, UITP- Advancing Public Transport. https://www.uitp.org/news/maas-finland, accessed 12.09.18, n.p.

City Data (2019): Palo Alto http://www.city-data.com/city/Palo-Alto-California.html Accessed 13.11.19, n.p.

City of Palo Alto (2014): Palo Alto Comprehensive Plan Update Draft Existing Conditions Report. http://www.paloaltocompplan.org/wp-content/uploads/2014/09/12_Transportation.pdf, accessed 26.12.18, pp. 12-33,35

Clewlow, Regina, Mishra, Gouri (2017): Disruptive Transportation- The Adoption, Utilization, and Impacts of Ride-Hailing in the United States. https://steps.ucdavis.edu/new-research-ride-hailing-impacts-travel-behavior/, accessed 14.11.2018, pp. 26

Cohen, Adam, Shaheen, Susan (2018): Is It Time for A Public Transit Renaissance- Navigating Travel Behavior, Technology, and Business Model Shifts in a Brave New World, Journal of Public Transportation (21) https://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=1820&context=jpt, accessed 14.10.2018, pp. 69, 72

Cohen, Adam, Shaheen, Susan (2018): Planning for Shared Mobility, American Planning Association PAS Report (583) https://cloudfront.escholarship.org/dist/prd/content/qt0dk3h89p/qt0dk3h89p.pdf?t=p67zt1 Accessed 27.10.2018, pp. 12, 25

Cox, Wendell (2017): America's Most suburbanized cities, New Geography. http://www.newgeography.com/content/005640-us-metropolitan-areas-from-polycentricity-dispersed, accessed 07.12.2018, n.p.

Creutzig, Felix, Fernandez, Blanca, Hamberl, Helmut, Khosla, Radhika, Mulugetta, Yacob, and Seto, Karen (2016): Beyond Technology: Demand-Side Solutions for Climate Change Mitigation, Annual Review of Environment and Resources (41). https://www.annualreviews.org/doi/pdf/10.1146/annurev-environ-110615-085428, accessed 01.12.2018, pp. 176, 185, 191

Creutzig, Felix, McGlynn, Emily, Minx, Jan, Edenhofer, Ottomar (2011): Climate Policies For Road Transport Revisited (I): Evaluation of the current framework, Energy Policy (39). https://www.pik-potsdam.de/members/edenh/publications-1/CPFRTRI.pdf, accessed 22.01.18, n.p.

Creutzig, Felix, Mühlhoff, Rainer, Römer, Julia (2012): Decarbonizing urban transport in European cities: four cases show possibly high co-benefits. Environmental Research Letters (7). http://iopscience.iop.org/article/10.1088/1748-9326/7/4/044042, accessed 22.01.18, n.p.

Data USA (n.y.): Dublin, California. https://datausa.io/profile/geo/dublin-ca/#mode_transport
Accessed 13.10.18, n.p.

Data USA (n.y.): San Jose, California https://datausa.io/profile/geo/san-jose-ca/#housing
Accessed 13.10.18, n.p.

Deakin, Elizabeth, Harvey, Greig (1996): Transportation Pricing Strategies for California: An Assessment of Congestion, Emissions, Energy and Equity Impacts, California Air Resources Board. https://cloudfront.escholarship.org/dist/prd/content/qt723002kt/qt723002kt.pdf, accessed 11.09. 2018, pp. 3-6

Deakin, Elizabeth, Cervero, Robert (2008): The
Challenge of Urban Transportation in California. Access Magazine (32). https://www.accessmagazine.org/wp-content/uploads/sites/7/2016/04/Access-32-03-Challenge-of-Urban-Transportation.pdf, accessed 22.11.2018, pp. 13, 17

Dotter, Fred (2016): Civitas Insight-Mobility-as-a-Service: A new transport model. Civitas Initiative (European Union). https://civitas.eu/sites/default/files/civitas_insight_18_mobility-as-a-service_a_new_transport_model.pdf, accessed 13.10.18, pp. 9, 11

Elkin, Ethan (2011): All Aboard- How California Can Increase Investments in Public Transit. UC Berkeley Law. https://www.law.berkeley.edu/wp-content/uploads/2015/07/All-Aboard-July-2011.pdf
Accessed 04.11.2018, pp 1

Federal-Aid Highway Association (2015) Lane – Length Miles by System. https://www.fhwa.dot.gov/policyinformation/statistics/2015/pdf/hm48.pdf, accessed 18.10.18, pp. 1

Fields, Gregory, Feigenbaum, Baruch, Purnell, Spence (2018): Ranking the Best, Worst, Safest, and Most Expensive State Highway Systems — The 23rd Annual Highway Report, Reason Foundation. https://reason.org/policy-study/23rd-annual-highway-report/, accessed 08.10.18, n.p.

Finger, Matthias, Bert, Nadia, Kupfer, David (2015): Mobility-as-a-Service: from the Helsinki experiment to a European model? FSR Transport (1). http://fsr.eui.eu/Documents/WorkshopPaper/Transport/2015/150309MaaSObserver.pdf, accessed 13.11.18

Forscher, Teddy and Shaheen, Susan (2018): Pooling Passengers and Services. ITS Berkeley Policy Briefs (07) https://cloudfront.escholarship.org/dist/prd/content/qt9985x1rx/qt9985x1rx.pdf?t=p45otq, accessed 23.11.18, pp. 2

Frontier Group (2014): The Multibillion-Dollar Tax Subsidy That's Making Your Commute Worse. https://frontiergroup.org/reports/fg/subsidizing-congestion, accessed 24.08. 2018, n.p.

Geels, Frank (2002): Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Research Policy (31). http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.153.5270&rep=rep1&type=pdf, accessed 14.10.2018, pp. 1

Geels, Frank (2005): The Dynamics of Transitions in Socio-technical Systems: A Multi-level Analysis of the Transition Pathway from Horse-drawn Carriages to Automobiles (1860 – 1930), Technology Analysis & Strategic Management (17).

https://www.sams.kth.se/polopoly_fs/1.713979!/SAMS%20workshop%20fördjupningsmaterial.pdf, accessed 13.10.2018, pp. 451

Geels, Frank (2010): Ontologies, Socio-Technical Transitions (To Sustainability) And The Multi-Level Perspective, Research Policy (39). http://www.transitionsnetwork.org/files/Geels,%202010,%20RP,%20ontologies.pdf accessed 29.10.2018, pp. 506

Geels, Frank (2011): The Multi-Level Perspective On Sustainability Transitions: Responses To Seven Criticisms. Environmental Innovation and Societal Transitions (1). https://www.sciencedirect.com/science/article/pii/S2210422411000050, pp. 25

Geels, Frank, Kemp, Rene (2012): The Multi-Level Perspective as A New Perspective for Studying Socio-Technical Transitions. Automobility In Transition? A Socio-Technical Analysis of Sustainable Transport, Research Gate. Pp. 57, 72, 73

Giuliano, Genevieve (1991): Is Jobs-Housing Balance a Transportation Issue? Transportation Research Record (1305). http://onlinepubs.trb.org/Onlinepubs/trr/1991/1305/1305-037.pdf, pp. 306

Governor's Office of Planning and Research (2019): Transportation Impacts (743). http://opr.ca.gov/ceqa/updates/sb-743/, accessed 11.10.18, n.p.

Graham-Rowe, Ella, Skippon, Stephen, Gardner, Benjamin, Abraham, Charles (2011): Can we reduce car use and, if so, how? A review of available evidence, Transportation Research (45). https://www.sciencedirect.com/science/article/pii/S0965856411000309

Grosvenor, Tim (1998): Qualitative research in the transport sector, Transportation Research Circular. https://pdfs.semanticscholar.org/8b9b/107cf9209ea631d811455f9331cf14ea7cff.pdf, accessed 28.11.18, n.p.

Harrell, Margaret, Bradley, Melissa (2009): Data Collection Methods- Semi-Structured Interviews and Focus Groups, Rand Corporation https://apps.dtic.mil/dtic/tr/fulltext/u2/a512853.pdf, accessed 08.10.18, pp. 27

Henscher, David (2017): Tackling road congestion – what might it look like in the future? Institute of Transport and Logistics Studies (ITLS). http://www.brt.cl/wp-content/uploads/2017/12/2017-Hensher-Tackling-Congestion.pdf, accessed 11.11.18, pp. 2

Hess, Daniel, Brown, Jeffrey, Shoup, Donald (2004). Waiting for the Bus. Journal of Public Transportation (4). https://www.nctr.usf.edu/jpt/pdf/JPT%207-4%20Hess.pdf, accessed 25.11.2018, pp. 68

Hietanen, Sampo (2016): Mobility as a service: Can it be even better than owning a car? Forum Vilium Helnsinki. https://www.itscanada.ca/files/MaaS%20Canada%20by%20Sampo%20Hietanen%20and%20Sami%20Sahala.pdf, accessed 15.10.18, pp. 44

Hodson (2010): Can cities shape socio-technical transitions and how would we know if they were? Research Policy (39). https://www.geos.ed.ac.uk/~sallen/dave/Hodson%20and%20Marvin%20(2010).%20Can%20cities%20shape%20socio-technical%20transitions%20and%20how%20would%20we%20know%20if%20they%20were.pdf, accessed 17.10.2018, pp. 497, 482

Holmberg, Erik, Collado, Magda,Sarasini, Steven, Williander, Mats (2016): Mobility As A Service- Describing The Framework. Victoria Swedish ICT.

https://www.viktoria.se/sites/default/files/pub/www.viktoria.se/upload/publications/final_report_maas_framework_v_1_0.pdf, accessed 23.10.2018, pp. 13

Institute for Local Government (2015): The Basics of SB 375. https://www.ca-ilg.org/post/basics-sb-375, accessed 08.10.18, n.p.

International Transport Forum (2017): Transition to Shared Mobility- How large Cities Can Deliver Inclusive Transport Services. https://www.itf-oecd.org/sites/default/files/docs/transition-shared-mobility.pdf accessed 29.10.18, pp. 7

Jittrapirom, Peraphan, Marchau, Vincent A.W.J., Meurs, Henk (2017): Dynamic Adaptive Policymaking For Implementing Mobility As A Service (Maas), European Transport Conference 2017. https://pdfs.semanticscholar.org/6f37/1aef0219c59b85356cf031b5591c45ba220e.pdf?_ga=2.87937368.1994716682.1546283653-269772444.1546283653, accessed 15.10.18, pp. 2, 21

Jittrapirom, Peraphan, Caiati, Valeria, Feneri, Anna-Maria, Ebrahimigharehbaghi, Shima, Alonso- González, Maria, Narayan, Jishnu (2017): Mobility As A Service: A Critical Review Of Definitions, Assessments Of Schemes, And Key Challenges. https://www.cogitatiopress.com/urbanplanning/article/view/931/931, accessed 03.11.18, pp. 21

Johnson, Andy (2003): Bus Rapid Transit and Land Use Bus Transit and Land Use: Illuminating the Interaction. Journal of Public Transportation (3). Accessed 10.10.18, pp. 126

Jones, Christopher, Kammen, Daniel (2015): A Consumption-Based Greenhouse Gas Inventory of San Francisco Bay Area Neighborhoods, Cities and Counties: Prioritizing Climate Action for Different Locations. https://escholarship.org/uc/item/2sn7m83z, accessed 11.10.2018, pp. 4

Kamargianni, Maria, Li, Weibo, Matyas, Melinda, Schäfer, Andreas (2016): A Critical Review Of New Mobility Services For Urban Transport, Transportation Research Procedia (14). http://discovery.ucl.ac.uk/1502113/1/1-s2.0-S2352146516302836-main.pdf accessed 13.11.18, pp. 3296

Karlsson, Marianne & Koglin, Till & Kronsell, Annica & Mukhtar-Landgren, Dalia & Lund, Emma & Sarasini, Steven & Smith, Göran & Sochor, Jana. (2017). Mobility-as-a-Service: A Tentative Framework for Analyzing Institutional Conditions. https://www.researchgate.net/publication/322570758_Mobility-as-a-Service_A_Tentative_Framework_for_Analysing_Institutional_Conditions accessed 02.11.18, pp. 5, 8

Klitkoa, Antie, Bolwig, Simon, Hansen, Teis, Wessberg, Nina (2015): The Role Of Lock-In Mechanisms In Transition Processes: The Case Of Energy For Road Transport. Environmental Innovation and Societal Transitions (16) https://www.researchgate.net/profile/Antje_Klitkou/publication/280698246_The_role_of_lock-in_mechanisms_in_transition_processes_The_case_of_energy_for_road_transport/links/55c8834508aeca747d66c782/The-role-of-lock-in-mechanisms-in-transition-processes-The-case-of-energy-for-road-transport.pdf accessed 04.11.2018, pp. 3

König, David, Eckhardt, Jenni, Aapaoja, Aki, Sochor, Jana Karlsson, Marianne (2016): Business and operator models for MaaS, Mobility as a Service for Linking Europe MAASiFiE. https://www.vtt.fi/sites/maasifie/PublishingImages/results/cedr_mobility_MAASiFiE_deliverable_3_revised_final.pdf accessed 09.11.18

Lawhon, Mary, Murphy, James (2011): Socio-technical regimes and sustainability transitions: Insights from political ecology, Progress in Human Geography (36) http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.827.9352&rep=rep1&type=pdf accessed 6.11.2018, pp. 355, 362, 364

Lee, Amy, Handy, Susan (2018): Leaving level-of-service behind: The implications of a shift to VMT impact metrics, Research in Transportation Business and Management. (http://www.fehrandpeers.com/wp-content/uploads/2018/03/Lee-Handy-2018-Leaving-LOS-Behind.pdf, accessed 19.10.2018, pp. 2

Lindquist, Kathy, Wendt, Michael, Holbrooks, James (2009): Transit Farebox Recovery and US and International Transit Subsidization: Synthesis. http://www.wsdot.wa.gov/NR/rdonlyres/55CF12C9-9D4E-4762-A27A-407A44546BE2/0/TrasitFareboxRecoveryandSubsidiesSynthesisKTaylorFINAL2.pdf, accessed 12.11.2018, pp. 2

Litman, Todd (2018): Transit Price Elasticities and Cross-Elasticities, Victoria Transport Policy Institute. https://www.vtpi.org/tranelas.pdf, accessed 13.11.18, pp. 12

Livermore Amador Valley Transportation Authority (LAVTA) (2016): History of the Livermore Amador Valley Transit Authority. https://www.wheelsbus.com/about/history-of-the-livermore-amador-valley-transit-authority/, accessed 28.10.2018, n.p.

Lovaas, Deron (2014): Rethinking "Free" Parking Policies.https://www.nrdc.org/experts/deron-lovaas/rethinking-free-parking-policies, accessed 24.08. 2018, n.p.

Lowenthal, Alan (2009): California Transportation Plan Senate Bill 391 http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200920100SB391 accessed 22.08.2018, n.p.

Lund, Emma, Kerttu, Johan, Koglin, Till (2017): Drivers and Barriers for Integrated Mobility Services. K2 Working Papers (3).
http://www.k2centrum.se/sites/default/files/drivers_and_barriers_for_integrated_mobility_services_k2_working_paper_2017_3.pdf accessed 01.12.18, pp. 12, 18

Mahmassani, Hani S., Joseph, Thomas, Rong-Chang, Jou (1993): Innovations in Transportation Survey Methods, Transportation Research Record.
http://onlinepubs.trb.org/Onlinepubs/trr/1993/1412/1412.pdf#page=86 accessed 28.11.18, pp. 80-81

Marana, Patricia, Labaka, Leire, Sarreigi, Jose (2018): A framework for public-private-people partnerships in the city resilience-building process, Safety Science (110).
https://www.sciencedirect.com/science/article/pii/S0925753517303016, accessed 30.10.18, n.p.

Matier, Phil (2018): Bart Ridership Declines on Nights, Weekends, San Francisco Chronicle.
https://www.sfchronicle.com/bayarea/matier-ross/article/BART-ridership-drops-on-nights-weekends-13166386.php, accessed 15.1.18, n.p.

Matyas, Melinda, Kamargianni, Maria (2018): The Potential Of Mobility As A Service Bundles As A Mobility Management Tool https://link.springer.com/article/10.1007/s11116-018-9913-4, accessed 01.11.2018, n.p.

Mawhorter, Sarah, Martin, Amy, Galante, Carol (2018): California's SB 375 and the Pursuit of Sustainable and Affordable Development, Terner Center. http://ternercenter.berkeley.edu/uploads/SB375_Final.pdf accessed 01.11.2018, pp. 22

McCoy, Kevin; Andrew, James; Glynn, Russell; Lyons, William (2018): Integrating Shared Mobility into Multimodal Transportation Planning: Improving Regional Performance to Meet Public Goals, Federal

Highway Administration Office of Planning.
https://www.planning.dot.gov/documents/SharedMobility_Whitepaper_02-2018.pdf

Mercator Research Institute on Global Commons and Climate Change (2018): Systematizing and Upscaling Urban Solutions for Climate Change Mitigation. https://www.mcc-berlin.net/en/events/recent/suuccm/about-suuccm.html accessed 17.12.2018, n.p.

Metropolitan Transportation Commission (n.y.): The Bay Area in 2040.
https://mtc.ca.gov/sites/default/files/2-The_Bay_Area_In_2040.pdf, accessed 25.09, pp. 32

Metropolitan Transportation Commission (2018): Commute Mode Choice. Metropolitan Transportation Commission. http://www.vitalsigns.mtc.ca.gov/commute-mode-choice, accessed 18.10.18

Metropolitan Transportation Commission (2017): Daily Miles Traveled.
http://www.vitalsigns.mtc.ca.gov/daily-miles-traveled, accessed 11.12.10, n.p.

Metropolitan Transportation Commission (2019): Transit Operators. https://mtc.ca.gov/about-mtc/what-mtc/partner-agencies/transit-operators, accessed 29.12.18, n.p.

Metropolitan Transportation Commission (2017): Transit Ridership.
http://www.vitalsigns.mtc.ca.gov/transit-ridership#chart-1, accessed 1.09. 18, n.p

Meyer, Berndt (No date): Case studies. Researching Translation and Interpreting (14).
https://www.taylorfrancis.com/books/e/9781317479390/chapters/10.4324/9781315707280-27

Mulley, Corrine (2017) Mobility as a Services (MaaS) – Does It Have Critical Mass? Transport Reviews. (37). 10.1080/01441647.2017.1280932, accessed 13.12.18, pp. 247-251

Nelson/Nygaard Consulting Associates (2015): Core Connectivity Study- Final Toolkit, Local Context, and Market Analysis and Final Implementation Plans for Pilots 1 and 2, accessed 28.11.18, pp. 3-3

Nikitas, Alexandros, Kougias, loannis, Alvavina, Elena, Tchouamou Eric (2017): How Can Autonomous and Connected Vehicles, Electromobility, BRT, Hyperloop, Shared Use Mobility and Mobility-As-A-Service Shape Transport Futures for the Context of Smart Cities? Urban Science (1) https://www.mdpi.com/2413-8851/1/4/36, accessed 17.11.18, pp. 17

Nocera, Silvio, Cavallaro, Federico (2011): Policy Effectiveness for containing CO2 Emissions in Transportation, Social and Behavioral Sciences. https://core.ac.uk/download/pdf/82132293.pdf, accessed 13.11.2018, pp. 704-705, 710

Nykvist, Born, Whitmarsh, Lorraine (2012): A multi-level analysis of sustainable mobility transitions: Niche development in the UK and Sweden, Technological Forecasting & Social Change (75).
http://psychdemo.cf.ac.uk/home2/whitmarsh/Nykvist_TFSC%202008.pdf accessed 05.11.2018, pp. 1375

Open Data Network (2017): Geographic Population Density San Francisco. Socrata
https://www.opendatanetwork.com/entity/1600000US0667000/San_Francisco_CA/geographic.population.density?year=2017, accessed 13.10.2018, n.p.

Open Data Network (2016): Geographic Population Density San Jose. Socrata
https://www.opendatanetwork.com/entity/1600000US0668000/San_Jose_CA/geographic.population.density?year=2016, accessed 13.10.2018, n.p.

The Oxford Institute for Energy Studies (2018): Disruptive Change in the Transport Sector: Eight Key Takeaways. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2018/01/Disruptive-Change-in-the-Transport-Sector-8-Takeaways.pdf, accessed 14.09.2019, pp. 15

Palo Alto Transportation Management Association (2019): homepage. http://www.paloaltotma.org, accessed 13.11.18, n.p.

Palo Alto Transportation Management Association (2019): City Council Staff Report https://www.cityofpaloalto.org/civicax/filebank/documents/68450 accessed 15.11.18, pp. 11, 33

Parkhurst, G., Kemp, R., Dijk, M., & Sherwin, H. (2012). Intermodal personal mobility: a niche caught between two regimes. In F. W. Geels, R. Kemp, G. Dudley, & G. Lyons (Eds.), Automobility in Transition?: A Socio-Technical Analysis of Sustainable Transport London, U. K.: Routledge.

Patras, Tom, LaBatt, Sara, MacDowell, Doug (2015): Downtown Palo Alto Mode Split Survey, EMC Research. https://paloaltomatters.org/wp-content/uploads/2017/07/Mode-split-survey-2015.pdf, accessed 01.12.18, pp. 7

Perone, Jennifer (2002): Advantages and Disadvantages of Fare-Free Transit Policy. National Center for Transportation Research. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.504.198&rep=rep1&type=pdf, accessed 12.10.18, pp. 13

Plan Bay Area 2040 (n.y.): Public Review Draft Environmental Impact Report: Part Two: Settings, Impacts, and Mitigation Measures. https://www.planbayarea.org/sites/default/files/pdf/Draft_EIR_Chapters/2.1_Transportation.pdf, accessed 18.10.18, pp. 13

Plan Bay Area (n.y.): 2040 Final Plan- Forecasting the Future. http://2040.planbayarea.org/forecasting-the-future, accessed 21.10.18, n.p.

Raney, Steve (2018): City of Palo Alto- Palo Alto Transportation Management Association (TMA) Annual Report. https://www.cityofpaloalto.org/civicax/filebank/documents/68450, accessed 22.11.18, pp. 13, 17, 24

Richards, Gary (2018): VTA's $25 million deficit could lead to service cuts, buyouts and higher fares. The Mercury News. https://www.mercurynews.com/2018/12/07/vtas-25-million-deficit-could-lead-to-service-cuts-buyouts-and-higher-fares/, accessed 29.11.18, n.p.

Ring, Edward (2018): California's Transportation Future, Part Four – The Common Road, California Policy Center. https://californiapolicycenter.org/californias-transportation-future-part-four-the-common-road/

Rodier, Caroline, Farzad, Alemi, Smith, Dylan (2015): Synergistic Integration of Transportation Demand Management Strategies (Land Use, Transit, and Auto Pricing) with New Technologies and Services (Battery Electric Vehicles and Dynamic Ridesharing) to Enhance Reductions in VMT and GHG. Mineta Transportation Institute. http://transweb.sjsu.edu/research/synergistic-integration-transportation-demand-management-strategies-land-use-transit-and, accessed 07.10.2018, n.p.

Rotaris, Lucia, Danielis, Romeo (2015): Commuting to college: The effectiveness and social efficiency of transportation demand management policies. Transport Policy (44) https://pdfs.semanticscholar.org/3053/413fb0eb0cc195157cff0400efeef1e3b0c9.pdf, accessed 13.12.18, pp. 159

Rotmans (2007): Transition Management- New mode of governance for sustainable development. IPG Books. pp. 18)
Rye, T., Ison, S. (Ed.). (2008). The Implementation and Effectiveness of Transport Demand Management Measures. London: Routledge, pp. 31

San Francisco Planning Commission (2017): Jobs-Housing Capacity & Growth Overview of Data and Policy Considerations.
http://commissions.sfplanning.org/cpcpackets/Jobs%20Housing%20Capacity%20Informational%205Oct2017_FINAL.pdf, accessed 17.10.2018, pp. 6

San Francisco County Transportation Authority (2018): TNCs and Congestion.
https://www.sfcta.org/sites/default/files/content/Planning/TNCs/TNCs_Congestion_Report_181015_Final.pdf accessed 14.12.2018, pp. 4

Vogel, Aaron (2017): Flex- CalACT Conference. Santa Clara Valley Transportation Authority, accessed 14.12.18, pp. 9-12

Shaheen, Susan (2017): Impact of Shared Mobility and Technology on Public Transportation. UC Berkeley Transportation Sustainability Research Center. http://onlinepubs.trb.org/onlinepubs/excomm/18-01-Shaheen.pdf, accessed 13.11.2018, pp. 16

Sheller, M., 2012. The emergence of new cultures of mobility: stability, openings and prospects. In: Geels, F.W., Kemp, R., Dudley, G., Lyons, G. (Eds.), Automobility in Transition? A Socio-Technical Analysis of Sustainable Transport. Routledge, New York, pp. 182

Sheyner, Gennedy (2017): Palo Alto Commits Funds to Fight Solo Driving
https://www.paloaltoonline.com/news/2017/09/20/palo-alto-commits-funds-to-fight-solo-driving
Accessed 14.12.18, n.p.

Shoup, Donald (2018): How to improve San Francisco, one parking space at a time.
https://www.sfchronicle.com/opinion/openforum/article/How-to-improve-San-Francisco-one-parking-space-13149747.php, accessed 24.08.18, n.p.

Smith, Jarrell (2016): First/Last Mile Challenge Perspectives of Millennials. https://planning-org-uploaded-media.s3.amazonaws.com/document/First-Last-Mile-Challenge-Perspecties-of-Millennials.pdf, accessed 01.12.18, pp. 2-3

Smith, Adrian, Stirling, Andy, Berkhout, Frans (2005): The governance of sustainable socio-technical transitions. Research Policy (34),
https://www.researchgate.net/profile/Andy_Stirling/publication/222413375_The_Governance_Of_Sustainable_Socio-Technical_Transitions/links/5a391b8b0f7e9b25638b2da5/The-Governance-Of-Sustainable-Socio-Technical-Transitions.pdf, accessed 16.10.18, pp. 1492, 1496, 1501

Speck, Jeff (2012): Walkable City: How Downtown Can Save America, One Step at a Time. D&M Publishers, accessed 26.12.18, pp. 54

Sperling, Daniel. Three Revolutions: Steering Automated, Shared, and Electric Vehicles to a Better Future. Island Press. pp. 73, 129, 189-190

Sperling, Daniel, Brown, Austin, D'Agostino, Molly (2018): Could Ride-Hailing Improve Public Transportation Instead of Undercutting It? Policy Institute for Energy, Environment, and the Economy. https://policyinstitute.ucdavis.edu/could-ride-hailing-improve-public-transportation-instead-of-undercutting-it/, accessed 14.10.18, n.p.

Sperling, Daniel, Eggart, Anthony (2014): California's Climate and Energy Policy for Transportation, Energy Strategy Reviews (5). https://cloudfront.escholarship.org/dist/prd/content/qt5r75m45b/qt5r75m45b.pdf, pp. 92

Sriraj, P.S.,Metaxatos, Paul, Reuter, Jake, Barnum, Adam, Bernal, Margarita (2017): Integration of Transport for Improved Mobility, Urban Transportation Center University of Illinois at Chicago. https://utc.uic.edu/wp-content/uploads/Integration-of-Modes-Report-Final-July-2017.pdf, accessed 25.11.18, pp. 15

Stancog (2018): Draft Regional Transportation Plan/Sustainable Communities Strategy: System Preservation. http://www.stancog.org/pdf/rtp2018/ch6-system-preservation.pdf, accessed 29.08. 2018, pp. 54

Whitaker, Mark (2011): A Ten-Year Perspective: California Infrastructure Spending, Legislative Analyst's Office. https://lao.ca.gov/reports/2011/stadm/infrastructure/infrastructure_082511.aspx, accessed 09.21.2018, n.p.

Ulli-Beer, Sylvia., 2013. Conceptual Grounds of Socio-Technical Transitions and Governance. Springer Link. Dyamic Governance of Energy Technology Change. https://link.springer.com/chapter/10.1007/978-3-642-39753-0_3, accessed 8.12.18, n.p.

Unruh, Gregory (2000): Understanding Carbon Lock In, Energy Policy (28) https://www.sciencedirect.com/science/article/pii/S0301421500000707, pp. 818

US Census Quickfacts (2017): Palo Alto city, California; Dublin city, California; San Jose city, California; U.S. https://www.census.gov/quickfacts/fact/table/paloaltocitycalifornia,dublincitycalifornia,sanjosecitycalifornia,US/PST045217, accessed 20.10.2018, n.p.

Victoria Transport Policy Institute (2016): Transportation Management Programs-An Institutional Framework for Implementing TDM. https://www.vtpi.org/tdm/tdm42.htm, accessed 14.09.18, n.p.

Vorderbrueggen, Lisa (2017): San Francisco Bay Area Jobs-Housing Imbalance Grows. https://www.biabayarea.org/san-francisco-bay-area-jobs-housing-imbalance, accessed 22.10.2018, n.p.

Vernez-Moudon, Anne, Cail, Pergakes, Matthew, Forsyth, Colin, Lillard, Lora (2003): Strategies And Tools To Implement Transportation-Efficient Development: A Reference Manual. https://depts.washington.edu/trac/bulkdisk/pdf/574.1.pdf accessed 04.11.18, pp. 1

Walker, Richard, Schafran, Alex (2015): The Strange Case of the Bay Area. Environment and Planning (47). https://geography.berkeley.edu/sites/default/files/walker_107.pdf, accessed 18.10.2018, pp. 11, 13, 16

Weikel, Dan (2015): Effectiveness of State's 'Parking Cash-Out' Program Is Unclear, Los Angeles Times. https://www.latimes.com/local/california/la-me-california-commute-20150113-story.html accessed 30.10.18, n.p.

Winston, Clifford and Langer, Ashley (2004): The Effect of Government Highway Spending on Road Users' Congestion Costs, Journal of Urban Economics. https://www.fhwa.dot.gov/policy/otps/060320c/060320c.pdf, accessed 10.11.18, pp. 2-3, 24

Wong, Yale, Hensher, David, Mulley, Corrine (2018): Emerging transport technologies and the modal efficiency framework: A case for mobility as a service (MaaS), Institute of Transport and Logistics Studies (ITLS), The University of Sydney Business School. https://ses.library.usyd.edu.au/bitstream/2123/17503/1/Thredbo_15_Thredbo_15_Paper_44.pdf, accessed 14.12.18, pp. 8

Winters, Philip (2000): Transportation Demand Management-Transportation in the New Millennium. http://onlinepubs.trb.org/onlinepubs/millennium/00123.pdf, accessed 19.11.18, pp. 3

Wiser, Ryan, Olson, Scott Bird, Lori et al. (2004): Utility green pricing programs: A statistical analysis of program effectiveness, Lawrence Berkeley National Laboratory. https://cloudfront.escholarship.org/dist/prd/content/qt1dg6t02z/qt1dg6t02z.pdf

World Population Review 2018: San Jose http://worldpopulationreview.com/us-cities/san-jose-population/, accessed 28.11.18, n.p

Yang, Lang, Choudhary, Charisma, Ben-Akiva, Moshe (2009): Stated Preference Survey for New Smart Transport Modes and Services: Design, Pilot Study and New Revision. ITS-SCUSSE https://its.mit.edu/sites/default/files/documents/wp_trsys_2009_mar_lyang_et_al%282%29.pdf accessed 24.10.2018, pp. 4

Yeamans, Jennifer (2018): LAVTA's TNC Partnership: The Story So Far. Livermore Amadore Valley Transit Authority. https://caltransit.org/cta/assets/File/2018%20Fall%20Conference/Concurrent%20Sessions/FPP-Livin%20in%20the%20Future-Yeamans.pdf, accessed 23.10.2018, pp. 3

Yin, Robert (2013): Case study research- design and methods, Applied Social Research Methods Series (5). http://www.madeira-edu.pt/LinkClick.aspx?fileticket=Fgm4GJWVTRs%3D&tabid=3004, accessed 25.08.2018, pp. 8, 12