Best Practices for Improving User Experience in AV Shuttles

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Chapter 1: Introduction

What is an AV Shuttle?

What is an AV Shuttle? They're a new vehicle technology also sometimes called Autonomous Vehicle Shuttle Buses, Driverless Buses, Autonomous Minibuses, Shared Autonomous Vehicles (SAVs) or in less professional settings, "toasters on wheels." For the most part, they're about the same size as a conventional shuttle bus or van with seats for 4-10 people plus room for a few more standing. Most have an emergency steering wheel for a human steward to take over when need be. Others can be driven remotely by an emergency operator. They are outfitted with numerous sensors and cameras feeding information to on-board computers that drive the vehicle.

As a subset of the larger suite of autonomous vehicles being developed, they exemplify what Daniel Sperling, professor at UC Davis calls the three revolutions: automation, electrification, and sharing rides.[1] Automation promises to dramatically increase safety on the roads while relieving us error-prone humans from the task of driving. Electrification promises to make the vehicles considerably simpler, cheaper, and able to travel many more miles over their lifetime than a combustion engine. Electrification also promises to reduce pollution and make streets quieter and more livable. Sharing rides promises to reduce the need for private car ownership, reducing the cost and expanding equitable access to transportation.

AV shuttles have some additional advantages and promises. Because they operate on a fixed, relatively short route with minimal machine learning they have already been operating in over 60 cities around the world. This has given them a significant headstart over the launch of private AVs able to drive anywhere. Will they be able to establish shared mobility as the dominant mode before private AVs hit the market? The answer to this question may depend on whether they live up to their promise of increased frequency. That promise is based on the fact that 50-85% of the operating costs of a standard bus goes to the driver. Under that system it makes sense to have the driver operate the biggest bus possible hitting their stops once an hour. Without a driver, an AV shuttle system might be able to invest instead in six small shuttles that can now frequent their stops every ten minutes. If costs and speeds work out, that's a gamechanger for transit.

These promises have excited over 60 communities worldwide to run AV shuttle pilot projects over the last three years. New projects are being announced every few weeks. We've tried to keep track of their characteristics in a database included in the Appendix to this manual. The pilots have helped to advance the technology and operations. But none are yet reaching the promised speeds or lower costs that will facilitate mass adoption. The hurdles to implementation include technical concerns, job loss concerns, and regulatory requirements for on-board stewards wiping out the labor cost advantage while low production rates for now also mean high capital costs.

Another obstacle for AV shuttles is growing competition from a host of new personal mobility devices – especially rental electric scooters. They also tend to be used for 1-3 mile distances – but are both faster and more flexible. They're dangerous, don't work well in bad weather, and clearly aren't for everyone – but they're extremely popular, a lot of fun, and connect with users, always asking them to rate their ride. By comparison AV shuttles are safe, boring, slow, and treat users more or less the same as cargo.

The Purpose of this Manual

Are there lessons that AV shuttles can learn from scooters and from attention to user experience in general that could help build ridership? The purpose of this manual is to improve the user experience of getting to, waiting for, and riding on AV shuttles so they can better live up to their promises. It is intended to help guide communities that are interested in AV shuttles in how to leverage them beyond mobility to achieve broader economic, environmental and equity goals.

This manual focuses on ways smaller towns and suburbs can both prepare and design for a future with autonomous vehicles. In many ways, suburbs have both the most to gain and the most to lose from autonomy. Lacking ample transit and already being highly car-dependent, they are likely to see high adoption rates of private autonomous cars. However, studies predict that such behavior could easily lead to a doubling of congestion as zero-passenger trips and current non-driver trips increase.[2] Instead of creating more traffic, high-frequency, user-friendly AV shuttles in suburbia have the potential to reduce traffic, noise, and air pollution while increasing walkability, bikability and overall health.

The key to such a future is getting people to choose to share rides. That's why this manual focuses on user experience. It is important to create buy in and overcome the perception that public and shared transit are a mode of last resort. This manual focuses on four main themes that cover planning and vision, getting to, waiting for, riding on and the use of the data created by these vehicles. We pay special attention to shared mobility as a better use of urban space and the most likely near-term implementation of autonomous vehicles.

This manual is meant to build on the Principles of Shared Mobility and on the NACTO *Blueprint for Autonomous Urbanism*. While that document focuses on larger cities, we focus on smaller communities and how users can become central to the act of designing for an autonomous transit future. The manual does not provide procedural information on setting up a regional consortium, financing or selecting a vehicle provider, delivery vehicles, or finding new jobs for newly unemployed drivers.[3] It is focused on users and the integration of mobility with urbanism. What is autonomy if not the expansion of individual agency?

The manual is intended to help community leaders and the larger public leverage AV shuttles to achieve larger community goals from equitable transit access to building a culture of trust and sharing. In the best cases, it will help communities start conversations about what kind of place they aspire to become and how new forms of mobility, urban design, and autonomy can shape that future.

Not changing is not an option. In the coming years the mobility revolution will continue to change how we move people and goods about our cities. This will necessarily alter the ways in which we consider how our cities are put together. Today, cities within the United States have become both materially and socially defined by the current dominant means of transportation, the individually owned car. However, new technologies are already enabling new transportation decision, especially amongst younger cohorts. We can expect further advances in the technologies of automation and data to further increase the options available.

Cultural opinions about the personal car are already shifting with marked declines in car ownership among younger Millennials and Gen-Z. One can debate the reasons, but the facts are that those coming into adulthood now are less likely to own cars than those that came before them. They show marked

preferences for more urban lifestyles – even in the suburbs. They are more and more often opting for experience over possessions[4], preferring access over ownership[5]. More and more they are becoming a relevant economic force that will radically alter the demands placed on communities small and large.

Forbes Magazine in 2019 points to the growth of an experience economy dominated primarily by Millennials. This economy charges for being part of and engaging with. It is not an economy necessarily of the accumulation of material goods, but rather of affects. According to the Pew Research Center 46% of Americans in 2017 felt freedom, connection and self-actualization come from smartphones, through digital experiences, media and the capacity of social media to connect people together.[6] For transportation decision making it means that there now needs to be more focus on options, comfort and considering the experience of the user every step of the way. It is not enough any more to look at utility as the sole metric of design, but to begin to incorporate the human experience of the rider's journey.

Using the Manual

Is it presumptuous to recommend best practices for a technology still largely in the pilot phase? Chapter 2 discusses this in relation to the broader context of autonomy.

Is it even more presumptuous to focus on user experience when there haven't been all that many users and the pilots have focused on testing safety and operations? Aside from a few surveys assessing riders' degree of trust of the technology, there is essentially no data on user's perceptions of what they did or did not like about their overall Autonomous Vehicle, (AV) shuttle trip. Yet, AV shuttles are simply one piece of a much larger "mobility revolution." As the number of multi-modal choices continue to expand, the success of AV shuttles will depend as much on exceeding users' expectations for comfort and convenience as it will on providing safe, predictable rides. Precisely because the rate of adoption of AV shuttles is rapidly increasing, this manual argues that those in charge of designing and implementing them need to consider user experience, local context, and broader community goals from the start. Chapter 3 kicks off with Best Practices for community-scale planning for change.

Luckily, the vast majority of best practices that apply to improving the experience of walking, biking, and taking conventional transit also apply to improving the desirability of getting to, waiting for, and riding on AV shuttles. Transit agencies have not historically paid much attention to these factors. However, that's been changing with customer-focused apps, better-designed bus stop amenities and mixed-use transit stations, (in addition to more general investments in pedestrian- and bike-friendly urban design.) Whether driven by renewed market interest in urban lifestyles – even in the suburbs; by concerns to mitigate climate change through shifting trips from cars to transit; or by increasing equitable access to transit, the efforts to increase access to and ridership on conventional transit provide the basis for many of the best practices in this manual. These are presented in Chapters 4, 5, and 6.

At the same time, the combination of AV sensor technology, smart city communications and the ubiquity of smart phones invite communities to innovate new ways to customize and improve the local experience and manage data. They also present new challenges including hacking, privacy and ethical concerns. These aspects of AV shuttles are new to transit agencies and the best practices presented here on these topics are both more speculative and cautionary. These are discussed in Chapter 7.

Acknowledgements

This manual was produced at the Georgia Institute of Technology with a Georgia Smart Communities Grant in partnership with the city of Chamblee, Georgia. Chamblee is a small town 15 miles north of Atlanta that began asking in 2001 how it could grow into a better version of itself that was more in keeping with changing demographics and technology. The most recent in a series of physical changes the town has committed to is the introduction of an AV shuttle - not as a pilot for testing the vehicle, but as an integrated mobility asset for residents. Chapter 3 describes the planning and preparation Chamblee undertook to position itself as a good candidate for an AV shuttle. It is intended to assist other communities in making such a leap.

The principal authors are Zach Lancaster, a Ph.D student in the Digital Building Lab of the School of Architecture and Ellen Dunham-Jones, professor and director of the Master of Science in Urban Design in the School of Architecture. We wish to offer sincere thanks to all of our collaborators: Neerja Dave, an MSUD student was principal author of the AV Shuttle Database; Rey Angeles, an ISYE student authored the Data Management Plan. At Chamblee, Mayor Eric Clarkson supported the project and Rebecca Keefer was the planner in charge of the AV shuttle; Craig Lewis, Michelle Orfield, and Joel Mann of Stantec wrote the Feasibility Study and Operations Plan for the Shuttle. And we are very grateful for the peer reviews of the early draft of the manual by Jeff Tumlin of Nelson Nygaard, Harriet Tregoning of NUMO, and Dan Sturges. Finally, none of it would have happened without the superb guidance of the Georgia Tech Smart Communities team of Debra Lam and Greg McCormick. We thank all of these individuals and hold none of them to blame for the contents.

Chapter 2: The Current State of Autonomy and AV Shuttles

The transportation of the 20th century in the United States came to be dominated by the automobile. It has shaped modern society in profound ways. Much of modern life, such as grocery stores, could not exist without the logistical flexibility of automobile transportation. But there have been unintended downsides to the proliferation of the car. Aside from the environmental impacts, the car spawned leap frog development patterns that segregated communities. There was no longer any direct correlation between the place of work and the location of home. This diffusion across the landscape slowly but surely steadily decreased the utility of cable cars, street cars, local bus service, trains and other means of communal transit until most eventually went out of existence.

This loss of shared mobility as an option has been noted in both popular and academic media. Groups such as the hundred thousand strong Facebook community “New Urbanist Memes for Transit Oriented Teens” are but one example of groups now pining for this older way of experiencing the city to be restored. This sentiment views the user experience of the city as one experienced at a human scale and through human interactions. Tension between the current state of transportation and this new desire has been leading more and more towards innovation in the transportation space. Shared bikes, scooters and the rise of companies like Uber and Lyft have caused many people to consider whether the single occupancy car is even a necessity of 21st century transportation.

There is a great deal of enthusiasm around what autonomous vehicles might be able to provide. But, it’s important to remember that the future is not here. Members of Nelson Nygaard in conversation for this

project have been quick to point out there are many large hurdles that we will need to overcome before we are able to realize these potentials. There is skepticism about the capacity of autonomous vehicles, of any configuration, to safely navigate complex urban environments. There are also enormous infrastructural hurdles that must be addressed for many of the mobility-as-a-service visions of companies such as Kia or Ford to be achieved and replace private car ownership. Which vision will win out? No one knows. But all of them involve revisiting the ways roads are partitioned and arranged, how curbs are managed, how traffic is arranged and how we manage the networks of data and sensors that support the vehicles and other connected systems traffic management systems.

The physical and technical interventions are only some of the major hurdles that must be overcome for broader patterns of autonomy to take off. In many ways these interventions exist at a level above suburban communities and will take years to manifest. Currently 100% of shuttles in operational pilots have operated at or below 15 mph[14]. This problem is as much a technical one as it is a policy issue. While many states have general policies or guidelines on how AVs may operate there are a great number of open policy questions[15]. Policy will guide a lot of the ways that autonomous vehicles, especially those operating in a shared capacity, end up behaving and how they will be used. Policy will shape who operates the vehicles and the services they provide and how those services serve their communities. There is as much need for design and innovation around this as there is around street sections and technologies.

While there is a great deal of enthusiasm about the possibilities of autonomous vehicles and the possibilities of a driverless future. This future is not here yet. There are many technical hurdles that will need to be overcome in order to realize true autonomy. What we hope can be taken away from this manual is not that the best practices are required for autonomy itself, but rather that making many of these changes will create a better place, regardless of if autonomous transportation arrives at all.

Chapter 3: Planning and Vision

Introduction

Why should a small town, suburban community, or large property owner consider implementing an AV shuttle? As discussed in Chapter 1 there are a host of benefits to offering shared mobility as an alternative to trips by private car. Not surprisingly, we see many AV shuttles starting out in low-density office parks, retirement communities, medical and university campuses – areas that are reliant on private cars but may have a high-proportion of non-drivers.[16] We also see several communities planning to use the AV shuttles to expand the reach of existing transit, often referred to as “first/last mile service”. There are also quite a few tourist destinations using the shuttles to navigate narrow historic streets, waterfronts, and entertainment districts.[17] In these cases, in addition to taking over the driving if necessary, the on-board stewards serve as tour guides.

However, at present AV shuttles remain expensive to operate, move at less than half their maximum speed, and few of the pilot programs are being continued past their initial run. Before buying into a technology that is continuing to evolve and a project that is at risk of being a one-off, communities would be wise to explore ways that their investments will have enduring value. Instead of looking at AV shuttles simply as a new vehicle fleet, we recommend that communities ask themselves: how can we leverage AV shuttles to achieve our broader transformational goals?

A well-designed AV shuttle system will have impacts at the scale of the route, the bus stops, and the streets and paths connecting to those stops. If a community's top goal is equitable mobility – improvements to area sidewalks, bike/multi-modal lanes, and a dedicated lane for the shuttle are likely to do the job whether or not the bus is autonomous. Similarly, if the goal is to increase transit ridership and reduce the environmental impact and traffic congestion from private cars, improving the user experience of shuttle and multi-modal trips will help regardless of the specific technology. A critical component for most users in either case is improving walkability.

The City of Chamblee, Georgia provides an excellent model in how to first envision and plan for positive change and then integrate an AV shuttle into achieving those goals. A series of plans, rezonings, and improvements to pedestrian infrastructure over 18 years have succeeded in kickstarting the revitalization, reconnection, and repositioning of their historic small downtown. In 2018 Stantec produced a Feasibilty Study for the AV shuttle to explicitly test how different routes might meet the community's economic, mobility, and environmental goals and contribute to the vision for downtown and the identity of Chamblee as a center for innovation and forward thinking. While identifying regional connections for future expansion, the initial 1.5 mile route received more detailed plans for each stop in Stantec's 2019 Operations Plan. It includes Phase 2's 1-mile extension to the newly operating AV shuttle at Assembly Yards, a mixed-use Transit-Oriented Development that is under construction on the site of a former General Motors manufacturing plant in the adjacent city of Doraville.

A railroad town fourteen miles northwest of Atlanta, by the 1990s Chamblee's downtown was pretty sleepy. It had a cluster of antique shops, several auto-repair and other small businesses, a few underused warehouses, and several vacant sites and parking lots. But it also had two significant assets: a relatively compact, walkable street grid, and a MARTA rail transit station with direct access to many of metro Atlanta's major job centers.

Starting in the early 2000's Chamblee re-wrote its ordinances, invested in a new City Hall and took steps to further increase Downtown's walkability and support the redevelopment of its parking lots into urban housing. By embracing many traditionally good urban practices Chamblee has managed to recover a great deal of "leftover" space, connect neighborhoods, and focus on where and how people are able to move around the city. A Whole Foods market has moved in and several of the former small businesses and garages have been renovated into restaurants, many of them reflecting the city's diverse ethnicities. New senior housing and a new medical clinic serving the homeless and un- and underinsured further help meet city residents' diverse needs. Expanded trails and plans for a new downtown park and civic buildings are in the works but the city has already significantly succeeded in transforming its downtown into an attractive location for the growing market of young professionals and retirees interested in more urban lifestyles with transit access, (and at a cheaper price point than in the heart of Atlanta.) With this new population in place and growing, it makes great sense to further expand access and connectivity to the MARTA station. Unlike AV shuttle pilot projects that are primarily testing vehicle operations and building consumer trust, Chamblee is committed to growing its downtown by using the AV shuttle to expand first-last mile mobility.

Best Practice: Build on the parking lots

Discussion

Where a community's vision calls for a shift away from urban form that might be characterized as "drivable suburbia" towards "walkable urbanism," building up on the parking lots is the low-hanging fruit.[18] In the Atlanta region, walkability adds on average a 112% premium to real estate value.[19] This is true regardless of access to transit. However, in areas proposing AV shuttles a further reason to build on the parking lots is to improve walkability and the user experience as a way to build ridership. Large, unimproved, open spaces, be they parking lots or empty lots, deprive pedestrians of the pleasures of walking past building frontages that are designed to address them – whether with shopfronts, front yards, or other treatments that dignify the act of walking and reward the pedestrian eye. Instead, many people feel uncomfortable and unsafe walking past large, open lots void of activity and eyes on the street. Those who can will choose to drive rather than take transit if they find their walk to it stressful.

Chamblee's solution is twofold. The city incentivized building on top of existing parking and required buildings to front directly onto the street. Changes in the zoning code have enabled new developments, specifically around the area of the MARTA station. These new developments have also been required to hide parking from the view of the street, either mid-block or behind the building. Not only has this resulted in more transit riders next to MARTA and the proposed AV shuttle, it creates a more "human focused" rather than car-focused experience of getting to the transit.

Design Tips and Resources

- Reduce parking requirements, especially near transit. Early in the process consider which lots are most valuable as catalyst or demonstration projects and create partners early.
- Create zoning policy and incentivizes for higher density around transit areas.
- Allow parking to be unbundled from housing and available at a separate cost.
- Enable shared parking.
- Encourage new buildings to coordinate lobby locations to overlook bus stops or designated car-hailing pick-up/drop-off locations.
- Encourage new buildings to integrate bike storage and bike parking.
- Encourage new parking garages to be designed to be retrofittable in the future with flat decks, more steel, higher floor-to-floors, and removable ramps.
- Where surface parking lots are still needed, encourage the construction of small liner buildings that screen the cars from view and enhance walkability. These have been used very successfully as local retail incubators at Mashpee Commons in Mashpee, Massachusetts.[20]
- Where new parking lots are needed, require them to be designed as future building sites with utilities in drive lanes intended to become future streets.
- Resource: Donald Shoup, *The High Cost of Free Parking*
- Resource: Todd Littman, *Parking Management Best Practices*

Best Practice: Create Active and Engaged Street Frontages

Discussion

A great many commercial streets in suburbia lack a sense of place and discourage pedestrian or bike activity. Long expanses of parking lots, strip malls, industrial buildings, and office buildings behind bermed landscapes communicate through signage designed to be read at 45 miles per hour. Large setbacks and numerous curb cuts create contentious zones where cars and pedestrians are forced to interact – and complicate the installation of a dedicated shuttle lane at the curb. If the roads are high-speed, the sidewalks immediately bordering them feel unsafe. Blank walls and minimal landscaping further discourage walking and contribute little to the identity of the community.

Research by Jan Gehl and others has demonstrated that pedestrians prefer streetscapes that provide visual stimulation, comfort, and enough of a sense of enclosure from building fronts that the street feels like an outdoor room. Traditional tree-lined Main Streets where diverse shopfronts of 25-30' display their wares and occasional benches and cafés invite lingering perform these functions admirably and create a strong sense of place. Even the non-retail buildings on such a street engage passers-by with distinguished front entries, textured and crafted details, and attractive windows rather than blank walls. A consequence of having such pedestrian-friendly fronts is the need for equally coordinated backs for trash and loading docks. Alleys perform this function well as does a pattern of "A and B" streets where the B streets provide the service functions. Residential streets can still follow these design principles with street trees, planters, and requirements for buildings to face and engage the street.

Chamblee adopted a Form-Based Code that designates different street types, including "storefront streets." The different street types correspond to different set-backs and building characters that go from highly urban conditions with taller buildings immediately at the sidewalk edge closest to the MARTA station, to larger setbacks and lower-rise buildings in the more purely residential areas. Chamblee's Village Commercial and TOD zoning codes have succeeded in revitalizing several blocks north of the MARTA station with a lively mix of renovated buildings with new uses and attractive new buildings.

Design Tips and Resources

- Consider use of Form-Based Codes to structure pedestrian-friendly street frontages – but do not require retail at all ground floors. Retail will not succeed everywhere. Provide building owners with flexibility as to how to provide visual stimulation to pedestrians at their ground floors.
- Decrease minimum setbacks to create more street level engagement with new buildings or activate vacant space by creating seating and furniture zones within large setbacks that create more room for people to make use of the space.
- Require greenery within all existing and new setbacks
- Adjust zoning to support both mixed use and smaller minimum square footages for commercial retail spaces. This decreases bay size, increases shop diversity, and creates more interest along the street.
- Access to parking should be moved away from streets with high pedestrian flow to avoid confusing and ambiguous traffic conditions. Consider creating a "B-street" behind commercial strip retail to provide continuous access to services and parking.

- RESOURCE: Jan Gehl et al, *Life Between Buildings* (2011)*; Cities for People* (2010)
- RESOURCE: Daniel Parolek et al, *Form-Based Codes*
- RESOURCE: David Baker and Amanda Loper "Focus on the First 20 Feet", *Spur*, (2014), https://www.spur.org/publications/urbanist-article/2014-06-10/focus-first-20-feet

Best Practice: Leverage Transit for Growth and Placemaking for All

Discussion

Public-sector investments in fixed-route transit provide opportunities to plan for significant private-sector investments in transit-oriented development (TOD). The Washington DC Metro system has converted many of its older park-n-ride stations as well as new suburban stations into TODS. Its good planning and follow-through on the Rosslyn-Ballston corridor has reduced highway congestion as more residents and employees now choose to ride transit. Through streets designed as outdoor rooms, buildings that serve as terminal vistas, active street frontages, designed densification - and reduced parking availability – Clarendon is a particularly good example of how transit and placemaking combine to stimulate growth. However, in a pattern being repeated in many parts of Metro Atlanta, especially the Old Fourth Ward along the Beltline, those same investments also often trigger gentrification and displacement of long-time, lower-income residents. New investments in transit should always be accompanied by policies to preserve and expand affordable housing and small businesses so that growth benefits all.

It remains to be seen whether fixed-route AV shuttles and other forms of Bus Rapid Transit will have the same impact on private development as heavy and light rail have had. The common wisdom is that the more permanent the investment the public sector makes in the bus stops, the more it eases developers' concerns that the bus /shuttle might be re-routed in the future and they'll lose their access. We recommend that communities integrate new AV shuttle stops into larger neighborhood or community hubs (parks, retail centers, gathering spaces in office districts, etc.) This both makes getting to and waiting for the shuttle more pleasant, activates the hub's uses, and demonstrates the permanence that developers are looking for.

Chamblee began the century with 9,500 residents and swelled to more than 28,000 by 2016. This growth has created a net positive financial impact for the city, enabling more investments in pedestrian infrastructure, more apartment buildings, more restaurants and shops that enhance the experience of living and moving around within Chamblee. It has helped the city create a more distinguished physical setting and sense of place. To date, the growth has occurred through annexation at the city's edges and by incremental development on vacant/underused lots in the downtown. There has been an increase in the number of small businesses and little evidence of displacement from gentrification in the downtown– yet. However, such pressures are growing in other parts of the city and protections will likely be needed in order for Chamblee to insure that all benefit from growth and a diverse culture.[21]

Design Tips and Resources

- Connect AV shuttle routes and stops to available community assets.

- Create alliances with neighboring and new communities to discuss growth of the transit network and greater connectivity
- Incentivize density around existing assets and plan for how to deploy density to new assets as you create them
- Identify the populations most vulnerable to displacement from gentrification and establish policies to mitigate such displacement prior to commencement of the new transit service.
- RESOURCE: Wendie N. Choudary, Kinder Institute Research, "Mitigating Gentrification: How Several Sun Belt Cities are Responding" (Kinder Institute Research), https://kinder.rice.edu/2018/12/12/mitigating-gentrification-how-several-sun-belt-cities-are-responding
- RESOURCE: Analysis of economic value and social equity benefits provided by walkability see Tracy Hadden Log, Christopher Leinberger, and Jordan Chafetz, *Foot Traffic Ahead* (Smart Growth America, 2019)
- RESOURCE: Shared Mobility Principles for Livable Cities, www.sharedmobilityprinciples.org

Best Practice: Integrate AV Shuttles into Larger Transit and Pedestrian Networks

Discussion:

Designing an AV shuttle system is far more than just the selection of a vehicle, it is figuring out how it integrates into a larger network of both existing and planned mobility solutions. Designing the shuttle as a part of this system is vital to its success in reducing VMT and becoming a viable mobility solution for the community as a whole.

Transit systems have long sought means to expand first-last mile connectivity and access to their services. AV shuttle systems seem perfectly suited to the task. But many questions remain. With an average wait time today of 15-minutes and speeds of less than 12 miles per hour, are AV shuttles more suited for everyday commuting, for connecting with intercity transit, or for internal trips between terminals at large stations? How might AV shuttles be differentiated for these different kinds of routes? AV shuttles have already been operating at a few airports and train stations – but so far their routes have been too limited to adequately answer these questions and the promise of higher speeds, frequencies and lower costs remains a consideration. Chamblee's AV system will be a test case.

Communities without good existing public transit stand to benefit most from investments in AV shuttles and increasing walkability/bikability. Both can build advantageous networks incrementally and support each other. The success of the Atlanta Beltline has inspired an explosion of off-street trail and greenway networks in the surrounding communities – including Chamblee. These often start with short connecting easements between culs-de-sac or through areas otherwise not conducive to roadbuilding. They continue along railways or riverbeds where topography again frustrates construction of a street network. They often provide pedestrians and cyclists with more direct routes and safer networks than those provided to automobiles, making them particularly useful systems to connect to AV shuttles.

Communities might also consider how AV shuttles could expand school bus and other specialized transit networks. Babcock Ranch in Florida is a masterplanned community designed for AV shuttle integration. It operated an AV shuttle school bus until state authorities deemed it inadequately tested. AV shuttles could also enhance para transit and non-emergency medical transportation with ride-hailing like

services for the elderly and disabled, another growing market both in urbanizing and rural small towns. Nishikata, Japan, a rural town where one third of the population is over 65, began a trial of 6mph Robot Shuttles in 2017 aimed at helping the older population get around. In all cases, AV shuttles should serve a broader network that supports a community as a whole.

Design Tips and Resources

- Make the process of transfer from the AV to another system seamless and easy with integrated single-payment systems through apps or revenue sharing agreements.
- Co-locate stops with other modes and consider how they can be used to support those modes. For example, AV shuttle stops could also be designated pick-up and drop-off points for ride-hailing car services.
- Look for high value places and ways to improve walkability with particular attention to those places that will improve connectivity to the sidewalk system within the "10 minute" walkshed (0.5 miles for most able-bodied people) from every existing and planned bus stop.
    - Anticipate the challenges and additional infrastructure needed. Will you need to change traffic patterns? Will you need additional cross-walks? Will timings need to be changed?
    - Consider not just the cost of installation, but also the costs of lighting, seating and street trees.
    - Once the ½ mile walkability network is in place start to look at the 2-3 mile bike shed (also a 10-minute ride for most cyclists and e-scooters). Look for other nodes within that distance to prioritize connecting to.
- Look for evidence of "desire trails", such as worn down grass or other evidence of "cut through" behaviors," both now and as the system starts to become operational. Consider how these can be formalized, from just trimming and packing dirt paths to full paving.
- RESOURCE: Jeff Speck *Walkable City Rules* (Island Press, 2018)
- RESOURCE: Jeffrey Tumlin, *Sustainable Transportation Planning: Tools for Creating Vibrant, Healthy, and Resilient Communities* (Wiley, 2011)

Chapter 4: Getting To

Introduction

While the previous chapter focused on larger-scale connectivity and planning for transformational change, this chapter zooms in to that component of a trip that involves getting to the transit stop. It's been relatively ignored by traditional transit agencies. They tend to think of a trip in terms of stop-to-stop. However, from a user perspective, the trip is from door-to-door. The quality of the experience they have getting to and from these stops will color their opinion of the system before they even step foot on a shuttle. Best practices for autonomous shuttles begin with getting to the bus stop.

But why have bus stops? Can't autonomy deliver door-to-door service providing the same appeal as privately-owned automobiles, taxis, and car-hailing? Yes and no. By far most AV shuttles are operating on dedicated routes with limited stops. Through machine learning they continue to gain knowledge of what to expect along that route. Several systems can respond to on-demand requests to pick up passengers at designated stops but they cannot leave their route. Meanwhile, AV taxis are being tested today but only in very limited markets and within limited boundaries, (most extensively by Waymo in a

100-square mile area of suburban Phoenix.) Most experts assume such services will not be widely available for many years and may never be able to go everywhere. And, as referenced in Chapter 1, the convenience of private door-to-door travel comes with the risk of worsening traffic congestion, a problem that is best mitigated by shared mobility in dedicated lanes.

There are exceptions. In 2019, vehicle manufacturer Sensible 4 began pilot operations of its Gacha shuttle in the town of Espoo and on Nokia's corporate campus in Kera, Finland. Designed for all-weather operation on both city streets and small, unmarked suburban roads, the shuttle follows pre-planned routes without a steward on board. However, a user living half a mile from the route can use an app to request the bus to optimize its route to pick them up. The bus sends an alert so the passenger can be outside just in time. It also connects them with existing transportation services and optimizes ease of transfer. [22] No data has been released yet on the performance of the vehicle or the on-demand routing.

Are shared mobility users best served by door-to-door service (even if the timing becomes somewhat unpredictable similar to use of Uber and Lyft's carpooling services,) or by predictable timing at designated stops? There's no single answer. However, communities may well be best served by AV shuttles that serve a fixed number of well-known places. There are operational benefits, but also opportunities to create places for socializing, (re)building communities within disconnected neighborhoods, and attracting new transit-oriented development along the routes to the stops.

Unfortunately, because so much of the built environment is designed assuming all trips are made by car, the experience of getting from one's door to a shuttle stop by foot, by bike, skate board or other human-scaled mode, is often not a pleasant one. The lack of safety and enjoyment in the experience of getting to and from may discourage many riders. Studies have shown that transit travelers view time spent outside vehicles as roughly three times more onerous as that of time riding on.[23] This perception can be correlated to a lower likelihood of engagement, or put another way, a higher likelihood of choosing to drive instead. While these studies tend to focus on the experience of waiting, rather than that of getting to a station or stop they are illustrative of how relative levels of comfort impact decision-making in a utilitarian model.

The attraction of riders, specifically new riders, to a new mode such as an AV shuttle needs to begin with a focus on improving the experience of getting to and from the stop. This requires a consideration of how and why people make choices, how they wish to get to their destination and making comfort a key metric for the entire trip.

Best Practice: Plan the Pedestrian Experience for Transit

Discussion

Since most AV shuttles operate on fixed routes to designated stops, it is important that communities examine the routes that pedestrians are most likely to take to reach those stops. Are there opportunities to expand pedestrian access? Improve safety? Enhance the experience?

In the case of Chamblee we see a community engaged in reshaping its streets to support more than just cars. Already there are plans in place to re-allocate space in the public right-of-way for the AV shuttle, re-align the roads around the town center and break up large blocks with an extended rail trail. Smaller blocks generally increase pedestrian activity by making routes more direct.

Secondly, but just as important, Chamblee's current master plan calls for the reshaping and restructuring of a great number of intersections within its town center and adjacent areas. The narrowing and reshaping of these areas prioritizes the safety and experiential needs of pedestrians. Drivers will still be able to maneuver through them just fine, but will notice the more visible pedestrian infrastructure.

Design Tips and Resources

- Invite community members to participate in "walkshops," along the shuttle route gathering input on useful connections, problematic intersections, sidewalk conditions, etc.
- Perform a similar inventory of all pedestrian routes within a ½ mile ped shed of each stop and prioritize improvements.
- Decrease the width of intersections, or when that is not possible provide protected pedestrian islands.
- Increase crossing times at larger intersections
- Look for opportunities to convert pavement-to-plazas, especially, but not excusively at bus stops. Often simply a matter of repainting excess asphalt and setting out some planters and seating, this "tactical urbanism" strategy tames traffic, sends a signal of valuing pedestrians, and encourages walking.
- Reconsider transit priorities in favor of pedestrians as a guiding principle.
- Keep pedestrians, cyclists and other vulnerable modes of transit away from high speed traffic using trails and segregated lanes where possible.
- Document baseline data on accessibility and trip modal split BEFORE the AV shuttle to allow for monitoring of impacts afterwards
- RESOURCE: Series of books and guides on Tactical Urbanism by Mike Lydon and Anthony Garcia at tacticalurbanismguide.com.

Best Practice: Expand Multi-Modal and Last-Mile Access To and From Shuttle Stops

Discussion

While communities are planning for the pedestrian experience of getting to bus stops, they should also plan for multi-modal access: bikes, electric scooters, electric skateboards, and whatever new small personal vehicle the mobility revolution produces in the future. The two do not neatly converge. Bikes, scooters, etc. should never be encouraged to use sidewalks and they have a considerably larger range, an approximately 2-3 mile bike shed. However low-speed, low-travel streets that create a pleasant sidewalk environment for pedestrians often also work well for multi-modal use of car travel lanes. However, many would-be cyclists are afraid to ride with traffic and prefer the safety of bike lanes or off-street multi-use paths. To significantly expand last-mile access to AV shuttle systems in their built-out state, communities should start the process of providing bike/scooter lanes and paths.

All transit systems wrestle with the last-mile problem. It describes the challenge of moving people from the end point of a transit trip to their final destination. In commercial logistics this "last mile" has always been the least efficient leg, comprising 28% of total cost.[24] Like AV shuttles themselves, bikes and the many new forms of electric personal mobility are already providing last-mile service to many existing

transit systems. In fact, their faster speed and ease of use makes them highly competitive with AV shuttles that are only 1-2 miles in length. And despite the contentious battles they have instigated in nearly all areas in which they've been deployed,[25] communities would do well to consider how to integrate bikes/scooters into the "getting to" plans for AV shuttles. The next challenge for communities who want to support them is providing them with safe and adequate infrastructure.

This generally requires re-allocating the right-of-way in local streets either by narrowing lanes or reducing lanes with what is called a "road diet". As streets are re-striped to provide a dedicated lane for an AV shuttle, consideration should also be given to restriping the connecting streets to accommodate bike lanes or multi-modal lanes. Gabe Klein calls them "slow lanes."[26] Dan Sturges, in his upcoming book *Bounce* refers to them as "local lanes".[27] This new form of infrastructure carves out space from excess road capacity. They vary in size but in some future scenarios allow mobility devices operating at different speeds and different levels of autonomy to co-exist together safely and out of the way of both pedestrians and motor vehicles. These become more valuable as mode shares shift and as VMT decreases.

Dan Sturges, building on his 30 years of experience producing neighborhood electric vehicles, points out that an increasing percentage of local trips should not require a car. Data from the 2017 Household Travel Survey finds that 21% of trips are under 1 mile. This places 1 in 5 trips inside of a 20-minute walk or a 5-minute bike ride. While another 35% are under 2 miles (10 minutes by bike or e-scooter) and 46% are within 3 miles, which is bikeable in under 15 minutes for the average person. These are errands or local appointments that many users might choose to make using a healthier, cleaner and more affordable mode if the trip felt safer and less stressful. Local merchants benefit too. This can all be achieved by reclaiming space on streets that is already present but is in need of re-allocation.

Design Tips and Resources

- Multi-modal access can be a powerful driver for increasing ridership to AV shuttles. More than one quarter of Lime Scooter riders reported using them to connect to public transit in the 2018 *Lime One Year Report.*[28]
- Look for excess capacity in existing roads and streets. For preliminary design purposes, assume that a travel lane can accommodate 10,000 cars/day, compare that to the average daily traffic count, and determine if any lanes can be eliminated, allowing space for slow/local lanes.
- Look for further excess capacity in travel lane widths – reducing them to 10' wide - while taming vehicle traffic speeds and improving walkability and bikability.
    - While slow/local/bike lanes can be indicated just through restriping the existing asphalt this solution does not provide security. Look at ways to create protection, such as planters, raised curbs or eventually converting extra lane space to off street paths.
    - Allow for flexibility in the design of slow/local/bike lanes so as to accommodate as yet unknown vehicles
- Create investment schedules early in the process so that funds can be set aside at predictable intervals to move gutters, repave and upgrade this infrastructure as necessary.
- Give careful design consideration to the interaction of bike lanes and shuttle bus lanes. As of 2017, Sandt and Owens report that AV detection rates for pedestrians and cyclists were much lower than for other vehicles.

- Consider paving slow/local/bike lanes with permeable paving and deploying rain gardens to control run off and protect the AV shuttle lane from ponding.
- RESOURCE: Gabe Klein, "How Slow Lanes Can Speed Up New Mobility (And Save Lives)," *Forbes,* 4 December 2018, https://www.forbes.com/sites/gabeklein/2018/12/04/how-slow-lanes-can-speed-up-new-mobility-and-save-lives/#615854c2dc5f
- RESOURCE: Dan Sturges, *Bounce* (forthcoming 2020)
- RESOURCE: L. Sandt, J.M. Owens, "Discussion Guide for Automated and Connected Vehicles, Pedestrians, and Bicyclists," www.trid,trb.org, https://trid.trb.org/view/1483163
- RESOURCE: *NACTO Urban Bikeway Design Guide* and *NACTO Urban Street Design Guide*
- RESOURCE: "Road Diets' Economic Impacts," Federal Highway Administration, US Department of Transportation, https://safety.fhwa.dot.gov/road_diets/resources/pdf/fhwasa17019.pdf
- RESOURCE: The Vision Zero Network, resources for communities to keep people safe on streets, sidewalks and bikeways by reducing traffic fatalities and severe injuries to zero: https://visionzeronetwork.org/about/vision-zero-network/

Best Practice: Increase Safety and Trust with More "Eyes on the Street" Near Shuttle Stops

Discussion

Perceptions of safety in the public realm vary considerably. Many people perceive bus stops as dangerous places and feel safer cocooned in a car. Cultural narratives of "Stranger Danger" have inculcated suspicion towards the kind of simple, civil interactions that older generations remember as commonplace and a way of building trust. Can AV shuttles establish new protocols that re-build trust amongst riders and increase perceptions of safety?

In her most well-known work, *The Death and Life of Great American Cities,* Jane Jacobs identifies the sociological problem of security and misperceptions. What Jacobs observed in both places like downtown office blocks and the stairwells of large apartment towers was that the places that people identified as dangerous were places that lacked what she called "eyes on the street". What she observed was that as the number of people on the street decreased, a consensus of the place as unsafe developed. Put more positively Jacobs stated that "Life attracts life", that as activity increases and more people are present even more people will join in. This required providing different uses with different reasons to be in a place at different times. This is why mixed-use buildings with day and night-time activities provide so many benefits. They are able to help populate the street regardless of the time of day. They do not hollow out completely while people are away at work, or after the working day is done. In fact, they can remain active well into the evening due to restaurants and entertainment venues, helping improve safety for the transit rider's last mile. The same can go for bus stops (discussed in more detail in Chapter 5.)

This social perception of a place as dangerous can be reinforced by a failure of the material conditions. If a place is dimly lit, has poor sight lines, is overgrown or looks uncared for people will make assumptions about its ability to attract people and their ability to see threats. It is important that the shuttle stops not fall into decay or disrepair and that they appear at a glance to be well maintained. Each stop must

be a place in itself, and be a place that people can imagine themselves going. As people adopt this idea, it follows that more people will join in and push back against a view of the public realm as unsafe.

Design Tips and Resources:

- Assess night lighting along routes to stops. Is it adequate to serve pedestrians?
- Provide monitoring equipment, such as police call boxes and safe spaces that people can retreat to in the event of an emergency along major routes getting to major stops. For an example of how this kind of design can work to restore a sense of safety see the work of Violence Prevention Through Urban Upgrading and their Active Boxes project[29].
- Build a culture of active social participation around the AV shuttle system by encouraging users to greet each other.
    - Create communal seating and waiting areas – or locate near a café or pub that appreciates sharing its seating (and its wares) with AV riders
    - Food and service carts so that there is a person that acts as both a person who creates conversation, but also creates safety.
- Use zoning and other incentives to create active and diverse uses around the stops to ensure that they are used outside of traditional commuting times.
- Locate stops in areas with good sight lines from multiple buildings from multiple angles. Do not hide or "tuck" structures behind or next to larger structures unless nesting them within the structure itself.
- RESOURCE: CPTED - Crime Prevention Through Environmental Design. Inspired by the writings of Jane Jacobs in the 1960s and advanced by criminologists, CPTED strategies have evolved and been proven to be highly successful. There are several associations and websites with more information.
- RESOURCE: Perceptions about security and how re-allocating resources helps (https://www.journals.uchicago.edu/doi/abs/10.1086/652200?journalCode=cj)

Chapter 5: Waiting For

Introduction

People don't like to wait. Surveys of transit users consistently reveal frustration with wait times, unreliability and long headways. They tend to perceive time spent waiting as anywhere from 1.2 to 4.4 times longer than it actually is, although the presence of amenities at the bus stop bring that time closer to actuality.[37] Research suggests that a wait of 5 to 10 minutes is tolerable to most people – yet 15 minutes (which is considered high frequency in most of the US) is considered by most a nuisance.[38] While waiting many transit riders also indicate safety and comfort (or the perceived lack thereof) as pain points. Although this research related primarily to conventional bus and rail, these concerns have to be addressed by AV shuttles and other emerging forms of transportation.

But what if AV shuttle bus stops did more than provide minimal safety and comfort? What if it was possible for shuttles to make time spent waiting more productive, playful and community oriented? What if bus stops became community and multi-modal transportation hubs?

Eventually, the AV shuttles' promise of lower operating costs should enable communities to invest in enough shuttles to reduce waiting times and perhaps eliminate the need for elaborate shelters and bus stops. But for the foreseeable future AV shuttle systems would do well to court riders with the best bus stop experience they've ever had. The core principles to keep in mind are improving the environment, providing options, mitigating a sense of wasted time, seeking feedback, and meeting user expectations.

Best Practice: Exceed user's expectations on providing them with safety, comfort, & respect

Discussion

Because so many bus stops in the US are little more than a stick in the ground with a single-word sign, many riders feel disrespected. In turn, bus ridership has been stigmatized despite improvements in service in many places. Raising the quality of bus stops raises the perception and the experience of the quality of the entire service.

Design Tips and Resources

- At a minimum, provide shelter from sun and rain, seating that is comfortably set-back from the street, and ensure full handicapped and stroller access. Note that the combination of providing shelter, seating, and real-time information is most likely to reduce the perceived length of the wait time.
- Consider how much lighting at the stop is too little and too much. It should enable the occupant to see their surroundings without feeling that they are in a spotlight.
- Where possible, restore the practice of providing water fountains as civic infrastructure and make it part of the bus stop.
- When possible integrate stops into buildings even small public out buildings.
    - Address issues around insurance, liability and maintenance of a stop
- Budget for high-levels of maintenance and cleaning of shelters, emptying of trash, etc.
- Consider installing cameras at bus stops

Best Practice: Provide Real-Time Information on the Status of the System

Discussion

When people cite unreliability as a source of frustration it is less about the actual variance from their expectation, it is the lack of knowing that the variance exists that induces stress and thusly negatively impacts the experience of waiting. [39] It is not necessarily the act of waiting that is so problematic, but rather the inability to create meaningful expectations about how long the wait may be.

Reducing wait times is obviously helpful, but equally important is providing the user with real-time information so that the user can modulate expectations for themselves and others. Status updates in dynamic messaging signs or apps go a long way in managing user expectations.

It is also possible for connected autonomous vehicles to make sub-optimal decisions that result in larger expectation-matching behaviors. This is more than on-time behavior, but rather about creating a predictable and regular distribution of arrivals and departures. Across time these don't need to be

uniform, but should follow easily understandable patterns that facilitate user decision-making, especially for frequent riders.

Design Tips and Resources

- See Visionect for inspiration on design of real-time information displays (https://www.visionect.com/technology-and-research/digital-bus-stops/)
- Build and maintain a single mobile application that manages trips and disseminates real-time arrival information. See OneBusAway for an easy open-source solution software stack that has been deployed by major transit agencies such as Atlanta's MARTA in its ItsMARTA app.
    - Open Mobility Foundation policy guidance for API development
    - Enable open source third party application development for scheduling and payment
- User Interfaces on apps and signage are integral parts of the user experience (UI/UX)
    - Signage should be clear and easy to locate
    - There should be UI/UX support for those with visual impairments
    - Signage and indication should be more than just screens, consider environmental methods such as sculpture, light and other queues
- Create a reliable pattern of arrivals and departures. Allowing buses to be separated by 5 minutes would avoid instances of "bus stacking" in which multiple vehicles on the same route arrive at the same time.
    - Enable connected traffic systems

Best Practice: Design AV Shuttle Stops to Celebrate the Identity of Both the AV Shuttle System and Each Stop's Local Neighborhood

Discussion

As opposed to the general lack of identity in most US bus stops, AV shuttles have the opportunity to both call attention to the identity of the new system in place, as well as to the local identity of individual stops. From a user perspective, this helps make the stops both easily recognizable within a larger urban context and be distinguishable from each other.

Transit infrastructure should be comprised of enough unitized components to be easily recognizable as part of the larger system. But it is helpful to users if the designs are also distinct from each other so that individual stops are easily recognizable. In Eastern Europe bus stops have been used as community identifiers since the middle part of the 20th century. These have been constructed with an eye towards creating a unique identifier for each community. While the structures are materially uniform, made from precast and poured concrete, they are each uniquely designed and immediately recognizable as a sign one has arrived in a specific community.

Another example of this kind of community identifier can be found in the Tokyo subway system where each stop is announced by a short 7 second jingle. These unique musical pieces identify each of the stations providing riders a sense of where they are without need for a map. Many people in Tokyo can identify their station both by name, but also by the small musical number (which anecdotally local riders will consider to be their favorite of the set of more than 200 jingles).

These approaches seek to use transit to help create or reinforce a localized identity, to pull the stop or station out of the image of pure utilitarianism by linking to human memory. In both cases limited palettes of materials construct consistent experiences, but ones that are immediately recognizable and distinguishable.

Design Tips and Resources:

- Develop both visual and auditory means of providing a distinct media experience related to each stop
    - Example: Changing light patterns inside of the vehicle
    - Example: Short videos played on the screens
    - Example: Short graphics and animations that play throughout the bus
- Develop media that announce the arrival and departure of a bus that is pleasant and possibly customized. For example more playful jingles might be used for routes focused on children.
- Work with neighborhoods to gather ideas about what facets of local identity they would like celebrated. Are there historical events, noteworthy people ore specific local destinations that can be featured or integrated into the design of the bus stop?
- For examples of the Tokyo Subway jingles see *Music in Japanese Train Stations* from Experience Japan, 2016 (https://www.japan-experience.com/to-know/understanding-japan/music-in-japanese-stations), retrieved 18 July 2019
- For more information on Eastern European bus stops see Christopher Herwig *Soviet Bus Stops*, 2015
- Examples of great bus stops:
    - Santa Monica Big Blue Bus Stops
    - Portland Bus Stops
    - Detroit Q Line
    - Ottawa and Montreal

Best Practice: Make Waiting Active Time

Discussion:

Waiting is too frequently seen as time that could be better spent doing something else. But waiting doesn't need to be time wasted, but can rather be time to socialize or be productive. What is important to the user experience is taking attention away from the act of waiting itself. By providing an environment where people are able to engage in other activities the horizon where people are willing to wait gradually extends.

Open Internet Access

Providing public internet access, especially in places people are expected to be waiting, gives users the ability to access other activities, such as work or entertainment, on a device of their choosing. This connectivity also becomes a way to gauge presence and activity while people are waiting.

Activities For Everyone

Place things in and around a waiting area that people are able to interact with. From small shops in more dense areas, to gardening or games in places further out from the town center. Placing activities

that people can take part in (with or without others) gives both a motivation to return, but also something to keep the mind and body engaged.

Design Tips and Research:

- Make wait time more productive for users.
    - Provide Wifi (possibly solar powered)
    - Provide opportunities to learn more about the neighborhood
    - If a community garden is adjacent, users might be provided re-usable gardening gloves and invited to help with weeding in exchange for taking some veggies with them
- Make wait time more useful for users.
    - Provide re-charging stations for mobile devices (possibly solar powered)
    - Provide additional furnishings that are more conducive than benches to do work at, (possibly picnic tables or ledges at different standing heights.)
- Make wait time more playful for users.
    - Consider locating bus stops at active parks. If riders don't actually participate in sports and games, at least they can watch the play. Bus and light rail passengers line up on the edges of Pioneer Courthouse Square in Portland, Oregon as part of the busy scene. A more suburban example is the bus stop that lines Belmar Square Park in Lakewood, Colorado.
    - Consider integrating forms of both individual and interactive play – from wall-size scrabble or ping pong to musical swings like the Montreal Balançoires: http://awards.ixda.org/entry/2013/21-balancoires/
    - Atlanta's "Soccer at the Station" program integrates astroturf soccer fields into rail stations. Teams from around the city sign up to play while transit passengers enjoy watching the games.
    - For more on kids playspaces at transit facilities see Kaboom's Transit Playbook, https://kaboom.org/playbook/design_guides/transit

Best Practice: Support Pop-Ups and Small Businesses Catering to Bus Stops

Discussion

Transit infrastructure attracts users and supporting businesses eager to serve them in dense urban areas. But many bus stops are isolated from shops and services that could make riding transit more convenient to users. However, with retail formats shrinking there may be opportunities for AV shuttles to attract mobile food trucks, temporary (even possibly autonomous) vendors, and other pop-up carts and small businesses. There are interesting examples of secondary uses that can fill in around bus stops. Take for example the transit allees in Berlin and the BRT infrastructure found in Medellin, Columbia.

The Berlin transit allees show the benefit of creating a responsive local condition made up of flexible store types that have come about from a historical lack of regulatory authority over the space. Shops within these allees can be very specific to a given community and its tastes. On the other side of the world the areas around the Medellin BRT stations takes this idea of locality even further, adapting not just to place but also to time. The areas around the stations bustle with ephemeral activity with whole markets coming and going. Here activity follows the ebbs and flows of transit patterns with differing uses appearing as stalls and carts arrange their activities (and goods) to follow the patterns of the day.

For another example a recent installation by artist George Barratt-Jones took over a bus stop transforming it into a coffee shop that, for one day at least, surprised and delighted riders.[40] These are example of how allowing for transformation of the area in and around the bus stop can have positive impacts on the experience of waiting.

Design Tips and Resources:

- Define a small zone around a stop that can serve as a zone of low regulation that can support the presence of small and pop-up services that serve local needs and desires
- These businesses are good from a cost benefit standpoint. Consider subsidies to help provide security.
- Consider designing bus stops as multi-use arcades that can incorporate various vendors informally on designated "market-days". Or – provide space to accommodate mobile food stands (similar to food trucks)
    - Atlanta, GA's MARTA rail system offers the Fresh MARTA Market stand once a week with locally grown produce at 5 stations with limited food options
- Create support and incentive structures for non-traditional business owners to experiment with new ideas in these areas.
- Assess interest in more permanent micro-retail. Shoppes on Fatherland and The Idea Hatchery are examples of 400-800 square foot shops and business incubators. These spawned nearby redevelopment in the East Nashville neighborhood of Nashville, TN.
    - For more information see The Shoppes on Fatherland (http://fatherlanddistrict.com/shoppes-on-fatherland/)
    - The Idea Hatchery (http://theideahatchery.net/)
- For more examples of how entrepreneurial individuals use flexible and leftover space for retail transactions see Margaret Crawford et al, *Everyday Urbanism*

Best Practice: Integrate Activities and Information into the Bus Stop to Make it a Community Hub

Discussion

Why does waiting have to be a frustrating experience? Why can't bus stops be places that people come together to meet and get to know those in their community? If AV shuttles are to begin to make a real impact in how people move around, even if just for errands and local trips to restaurants and other local appointments, there is an opportunity to make the act of waiting one that builds community. Time spent waiting can become time spent getting to know others in the community, and learning about local events happening nearby.

Community building happens within a place. It is possible to build a community of transit riders that will come to know each other and become in a small way accountable. There are many versions of anecdotal stories of "the old woman" that rides the bus every day, and after missing it for a day or two is found by a well-meaning rider either sick or otherwise in distress. It is this kind of external community and accountability that expanded ridership has the ability to turn from urban legend into urban reality.

There are many examples of places that have attempted to take transit and turn it into a time and place that people can interact with one another around common interests. For example, the Books on the Bus

initiative on the Seattle bus system. This project sought to create social interaction by prompting people to read a specific book and then encouraged riders to take their book with them, display it and use that display as an invitation to discuss it with other riders during a trip[41]. This sought to create pro-social behavior on the bus, turning waiting and riding into a time to build new social connections with people you may not have otherwise met. While there are few metrics concerning the success of this program it is clear that the intention was to connect people and integrate social activities into the act of riding.

The United Kingdom started "Chatty Bus Day" in 2019 specifically to combat the loneliness epidemic. The BBC provided publicity to encourage transit riders to sign up as Chatty Bus Champions and volunteer to talk to strangers on the bus. Deemed a success, it was soon followed by Chatty Bus Week and now several transit agencies are introducing chatty buses into their regular service, providing various games and ice-breakers – and even a few "piano buses" as well as putting up posters on the buses with suggested conversation starters.

Another tactic may be to turn bus stops into something that people can engage with and care for collectively. Gilchrist, London, a low-income counsel block, had its bus stop transformed from a place people considered dangerous to one that people cared for and tended to on a daily basis through the installation of a public garden. This type of installation is simple, low cost and gives people an activity they can rally around, and also reap benefits from. Much like the book club it gives people a common activity and interest that can break down barriers[42]. This project has been seen as a success and as reclaiming the space for those that live there by meeting multiple community goals, not simply transportation.

Design Tips and Resources:

- Design the shelter to accommodate diverse community gatherings while it serves as a bus stop. This may be as simple as adding a picnic table (or two) under an extended canopy.
- Install community billboards that can play host to local flyers.
- Provide parking for bikes and scooters and insure that there is car parking near by
    - Provide the ability to recharge e-bikes and scooters at the stop
- Meet with neighborhood groups to see if there is any interest in a specific group adopting a bus stop and providing maintenance and programming on activities such as the installation of a community garden, little libraries or rotating art installations.
- Create a hashtag and Instagram account for each bus stop/community hub where community groups can post info about activities, shuttle users can post comments, and transit operators can both provide alerts and monitor user engagements and satisfaction levels.
- Consider having the bus stop also serve as a car-hailing pick-up/drop off location. This both further activates the space, provides another option for last-mile connectivity, and helps the city better manage curb space.
- For ideas and precedents for mobility hubs see the Shared Use Mobility Center (https://sharedusemobilitycenter.org)
- For ideas for simple and effective temporary interventions to improve existing bus stops (or create new ones) see Mike Lydon *Tactical Urbanism: Short-term Action for Long-term Change*, 2015 and San Francisco Planning *Public Space Stewardship Guide*, 2016

Chapter 6: Riding On

Introduction

The act of riding on a shuttle, bus, or other mode of transit can come to define the whole experience. If you have a bad experience it can quickly color how you think about it the next day and how motivated one is to become a repeat user. For AV shuttles to compete with cars they must provide an alternative that offers all of the physical comfort and security of a car and then more. The experience of riding should be one that is mentally relaxing and socially engaging, there is no reason it cannot be a time where it is possible to meet others from around your community, engage with them and build new relationships. AVs are also poised to flip the economics of transportation on their head. Aaron Bastani has pointed out that if AVs follow other recent trends of technology falling costs of production and operation for autonomous vehicles will make it possible for AV shuttles to provide a high-quality luxury experience at an eve- falling price point. This falling price has the potential to allow cities and operators to extend access in equitable ways that begins to relieve the burden of transportation costs for all[49].

The experience of riding on however is not comprised just of physical factors. There is a social component to riding public transit. This topic has been brought up in previous chapters because it is not just an important factor, but also one of the great potentials of autonomous transit. The shuttle becomes a new venue for social interaction. But this new space for socializing has to meet the desires of differing groups of people. Complaints about people having loud conversations on the bus can be met with just as many people who find themselves in a small compartment in uncomfortable silence. There are real questions about the size of the number of riders and the social protocols expected.

Shared autonomous vehicles have the capacity to offer an experience that rivals if not exceeds those of any personal vehicles for many if not all trips. But it is important to remember that experience is highly individualized. Within the User Interface/User Experience (UI/UX) sphere there is a recognition that usage changes significantly based on the individual. This requires a deep data driven understanding of your population and their patterns of movement. This allows the creation of personae that are useful for speculative design and planning in the future.

AV shuttles, and eventually larger systems should be new social spaces people are invited into, but in no way obligated to be a part of. This social space is something no car can ever provide and can serve as a way to help address, for example, increasing problems of social isolation and loneliness.

Best Practice: Define the Role of Riders and Stewards

Discussion

Jeff Tumlin of Nelson Nygaard, in an interview for this manual noted that there is little practical difference between a ride-hailing service and an AV shuttle services[50]. These services operate using algorithms to determine pick up and drop off and simply replace a computer with a human to do the mechanical act of driving. This driver plays another role in these rides though, that of social referee and facilitator. While there is a great deal of excitement around the promise of autonomy, there is also already indication that the lack of a driver creates a bland, boring and monotonous experience.[51]. While companies like Kia are promising luxury and the ability to video conference while riding there are limits

to these kinds of digitally mediated experiences, one being that they really only work in "single player" environments. What is clear is that autonomy does not actually remove the role of driver, it just changes it.

Drivers become freed from the increasingly tedious task of driving, the driver can shift to another task acting as a steward, or even a concierge, to the vehicle and its occupants. This vehicle steward serves to inculcate behavioral norms and mediate disputes therein. This person is not a guard, but is much more like a guide to help riders navigate the social setting of the AV system. We can see an early version of this in the early days of Lyft's driver training where the company attempted to create a specific atmosphere, a role that fell to the drivers themselves while still operating all the machinery of the car and the app[52]. While this may seem an inversion of the value proposition that these vehicles become valuable due to the lack of need to pay a driver, in many cases, the value of people and their ability to influence and interact with others may be well worth the investment. A boring, sterile environment will not win out over the privacy and security of a private car. Several AV shuttles have already relied on stewards as tour guides along the Strip of Las Vegas, as well as various riverfronts and historic hilltowns. Numerous Uber-like companies have risen up with vetted drivers specifically for sparing parents the responsibility of driving their children between after-school activities. Some advertise that all of their drivers are Moms, others hire off-duty or retired policemen.[53] Would certain AV shuttle routes at certain times of day benefit from a Shuttle Mom? These stewards can quickly become stable anchors giving the system a specific identity and unique social milieu that may attract certain riders.

Design Tips and Resources

- Create a role for a vehicle steward, especially during early piloting phases. But recognize that this is a role may need to, or be desirable to exist in perpetuity
- The Steward is as much a part of the experience as the vehicle materials
- Select the right stewards for the right tasks, for example recruit care takers to attend to the shuttles with children.
- Recognize the value of people and social interactions. The ability to socialize and interact can become a major amenity that cannot be provided by other modes
- Create interiors that consider more than the utilitarian function of the shuttle but create specific social environments.
    - Example: Seating in the round for highly social small groups
    - Example: Row seating for higher capacity "quiet" shuttles
    - Example: Facing row seating for more intimate social settings
- Define a basic definition of the role of the steward, but leave final interpretation up to an individual. This will create unique social environments that even further allow people to customize their experience

Best Practice: Do Not Imagine The System as Fixed, Use The Flexibility of Autonomy to Your Advantage

- Remember that unlike traditional systems routes and vehicles are not necessarily fixed. A single vehicle can dynamically assemble a path

- Allow people to express a preference based on social experience desired. This does not need to necessarily be per trip, but allow for expression when necessary.
- The flexibility of vehicles to reroute and reoptimize by time of day, demand and even predictable patterns (i.e. the end of school) means that both physical and social capital can be deployed in efficient ways

Best Practice: Create Seamless Payment Systems

- Integrate payment systems for multiple systems together
- Create payment apps that can interact with the system directly without need for constant swiping or tapping
- Create reward and benefit systems that operate through the payment system.
    - Example: Work with local business to provide incentives for frequent or recurring ridership
- Integrate payment systems with both stops and shuttles. Think of ways to experiment with incentivizing pro social behavior

Best Practice: Charge for Convenience and Customization Rather Than Access

- Consider making rides free, consider revenue generation from other sources.
- Consider how to monetize convenience and customization
- Identify elements of the system that can be customized or that people identify with and would be willing to pay more fore
- Consider the economic benefits of removing the burden of transportation. Especially from low income households
- Design for a minimum and maximum standard of convenience
- Look for partnerships with local retailers or other groups to help create revenue streams not from riders but from other secondary opportunities

Best Practice: Create Systems That Respect the Value Of Time

There is a perception that the value of time of a CEO is somehow greater than that of a nanny or housekeeper. As it turns out, this is quite the opposite. If the CEO is late there is little to no consequence, but for a person working an hourly job the impacts of not valuing their time can be disastrous. While we propose allowing people to pay for convenience, to essentially "jump the line" it is important to remember that value of time is inversely proportional to total income. This means that there must be a minimum value of time, or put another a maximum trip length.

Chapter 7: Detecting User Experience and the Challenges of Data

The Machine Gaze

"The operating system, the right of way and the curb, is publicly owned" – Harriet Tregoning, NUMO

Growth in the capacities of data platforms and sensor technologies has created a wealth of new opportunities. IOT, wearable technologies and advances in data science and automation have simply made access to data and the ability to understand it easier. There is so much potential within this new

wealth of devices, even within the realm of autonomous shuttles. The ability to pay remotely or engage with the system in a more human way. While these technologies open a lot of possible doors, such as mobile payment and scheduling, it presents a great number of potential hazards to both shuttle projects and to the public at large. These hazards must be at least understood such that actions taken in the pursuit of a better future do not expose or exclude communities from the benefits, specifically those most vulnerable. This chapter will do its best to keep the conversation focused around the topic of shuttles and related technologies. This is hampered however by the fact that there is very little in the way of deployed solutions. This means that quite frequently we will be drawing from the state of technology from elsewhere to analogously trace possible futures concerning shuttles and their adjacent technologies. To keep this whole conversation about speculative technologies in check we wish to discuss in particular two specific topics. The first is the growth of smart and wearable sensors and how these can and possibly will change how we think of collecting data. And second we wish to discuss privacy and how data comes to live and die in a system.

Before we discuss the possible futures of technology it is important to address a current reality with data. Data are often treated as objective fact when in reality data are always in parallax; a view of a moving landscape. This position, as discussed by Christina Borgman, is always constructed from a context, a technical armature and some reasons (political or not) for collection[59]. Data are therefore already political and already non-neutral. It is important to keep this in mind when dealing with data that comes from any source, even yourself. Biases and the limitations of the armature will always be baked into the data at the moment of inception and can never be fully disentangled and renders data only "supposed evidence" of any material action. This isn't to say there is not a place for data, or for its use in decision making or for optimization. This is just a warning against placing too much trust in the neutrality and authority of data as our discussion continues.

Apple's 2019 operating system update for their flagship iPhone product represents a vanguard moment concerning the sensing of people. This version of the operating system rolled out a series of high-fidelity health records. Apple Health had been evolving as a platform over a few years, but this update brought deeper data level integration into the platform.[60] What this shows is not only the willingness to collect but the willingness to have collected intensely personal data about a person's physical condition. There is a great deal more that can be sensed about a person than just heart rate and these data points can mean a great deal when placed in the right context, or when the right questions are asked.

Brian Massumi has discussed the importance of the affective qualities of the world and how these impact people and the ways they interact with the world. The affective according to Massumi is both physical and pre-subjective.[61] It is the response of the body to outside stimuli in the environment and is an action taken by the body prior to an emotional reaction. While we cannot sense affects directly, a sensor enabled world can pick up the traces of affects on the body of the individual. Using the example of work by German researcher Hertha Sturm, Massumi notes that there is evidence that galvanic skin response, heart rate and other physical responses are able to be used to detect these affective qualities.[62] This study of course has its limits but points to the possibilities of looking at our world with an eye towards sensing experience as pre-subjective.

Bringing these two ideas together the question becomes not what can we, but what do we want to sense and why. We have reached a point where we are able to look at a much wider range of signals in the physical world than we've had in the past. For example, in 2019 a Chinese firm launched a product

designed to be able to detect a single face in a crowd of thousands[63]. This camera sported an impressive 500-megapixel resolution and basically enabled a technology of vision capable of monitoring masses in real time. What are the potentials of this type of device? What could we see and ask of this new technology of vision?[64] What limitations might we be able to overcome? Would it be possible to use this new mechanical eye to pick up the traces of affect on bodies and understand at a new level how people are encountering and experiencing our urban environment? What happens when we mesh this together with other data streams?

When we talk about how we measure experience especially in terms of space, we run into a real problem, that of scale. When we bring together these technologies of data collection (i.e. Apple Health) and advances in machine vision (i.e. mega scale cameras) we are able to overcome this problem of scale.[65] Already the technology of the mega scale camera is able to pick up subtle physical details beyond facial features with the capacity to detect and identify based on gait. We can easily sketch out the form of a system that uses both of these to report back to an operator dense data along multiple axes. For example, it would be possible to easily monitor more than just position, but also posture, gaze, and other factors that can be used to describe someone's experience.

The ability to look at a gaze, where a person is fixing their vision, or posture, are they in a braced or unbraced position, begins to tell us about them. This requires repeated observation across time for individuals and requires new and different ways of analyzing these data but could yield positive results that move the conversation around the success of transit from purely utilitarian to a conversation. Biometrics from wearables and health tracking apps when paired with this kind of image data about experience opens a much wider avenue of understanding. This pairing gives designers and operators access to both internal (biometric) and external (physiometric) expressions of bodily responses. This is a new view of the world, one taken through the massively parallel subjective view of a machine rather than through the singular position of a person.

This kind of "seeing" allows for the asking of new questions and gives new ways of generating knowledge. Where the inclusion of the human element as a matter of utility was difficult due to the problem of scale the massively parallel nature of the machine allows questions to be asked of much larger patterns. Kenneth Train in his core text on discrete choice modeling, a method for predicting consumer behavior, indicates the importance of these non-material factors on decision making utility[66]. By including this new eye conversations of operational utility can be tempered with conversations around the successes or failures of experience design and how these interventions do or do not increase utility.

We can then imagine a system comprised of cameras on shuttles and in stops that using WiFi, bluetooth and other existing technologies tie images to individuals. This new vantage point begins to tie together data about breathing and heart rate, what the individual is looking at and engaging with. This is grouped and clustered with like individuals and data is returned. Combined then with external data, such as weather, a more complete story can be woven together. A smiling face on a rainy day might indicate relief and joy at seeing the approaching shuttle as a means of escaping the rain. A relaxed posture and lowered heart rate demonstrates comfort and ease. A sudden spike in galvanic skin response an extreme emotional response. These are new metrics not as easily put into numbers, but are nonetheless valuable. This data rich view, what we might call "the machine gaze", begins to tell us new things about

bodies in space and how that space is affecting them. If we can start to see this way as well, what are the avenues of design now open to us?

Open Data, Closed Data: Data Privacy and Policy in a world of Perpetual Surveillance

Despite our increasing technological capacities we cannot forget how data impacts people. Our issue when confronting this is that our historical constructions of privacy are now inconsistent with our current technologies.[67] This is a larger problem, but one that anyone dealing with massive data collected on or about the public at large should consider.[68] Failure to recognize that there is a need for privacy, even if that meaning has changed, can lead to the erosion of trust and the ultimate breakdown of the data hungry algorithms that enable many of the machines that will come to operate an autonomous transportation system. To combat this image that data is being collected and misused we propose the concepts of open data, data security and a data life cycle.

The idea of open data is not new. As an idea it was first proposed in 1942 by Robert Merton. As a more formal term it arose in the 1990's to describe that which could "...promote a complete and open exchange of scientific information between different countries, a prerequisite for the analysis and understanding of these global phenomena."[69] Much like the climate and geophysical data being proposed for distribution above, data about a community or transit system is data of interest to audiences much wider than just the operator or the city. The reason that there is such a push for open data in many fields is that ultimately this creates a way of viewing data from many angles and the construction of new lenses through which to view those data. As these data come into contact with other data, other ways of seeing, data gains new meaning in context, what Yanni Loukissas describes as a data setting.[70].These interpretations exist in parallax, with each subjective position providing a new view on the overall data set, and each honest view providing some new information for the original steward.

While many cities have created open data portals with New York and Los Angeles perhaps being the most notable, these tend to be warehouses but not exchanges. This is a positive step, it provides access to data itself. This level of access allows publics to see what has been done with data that has been collected, how has the material they have been provided been transformed into a product. Open data needs to do more than this. While access to data needs to be provided, so does access to the metadata layer. Specifically access to data about how those data have been accessed and used and for what purposes. This creates transparency as data is used to create a better system. Tools are also required as many of the tools for analysis are expensive and highly technical (though that is changing). Providing the tools for analysis creates the opportunity for what Helen Hester described as a radical amateurism, where non-professionals make use of the tools in perhaps unexpected ways to generate new understanding.[71] Lastly there is a requirement that this become a two-way street. Data is not a tool of imperial authority, it is subjective and open to interpretation. These one-directional warehouses need to transform into two-way repositories where new data settings are absorbed into a larger data corpus.

This idea of a radical openness though presents a problem. How do we protect those observed from abuse and harm? Personally identifiable information (PII) will still be a factor and must be considered in protecting publics from harm. There is still a need to secure this data as the potentials for abuse are so great with these kinds of data. To begin with identifying what is PII and what is not becomes critical. This is of course problematized as we link data together into increasingly complex data settings as the

relational links can be followed to any other point in the graph. Identification becomes a good first step as it is then possible to limit those links. The second easily accessed means is anonymization, the process of removing the formally identifiable information. This only goes so far. Locational data creates a distinct fingerprint especially when put into context with other data streams.

There needs to be a better approach. A way that openness can be maintained while still protecting people from the abuses of data. There is a great deal of power that can be gained through abstraction. What would happen if instead of asking an individual you asked all individuals somewhat like them simultaneously? Then repeated this process a million times. Mathematically we'd expect convergence. Protecting PII while remaining open becomes about more than just keeping certain data invisible from analysis, but instead becomes a question of how it is packaged. If instead of providing raw data sets more and more open data portals where it is possible provided instead the statistical metadata necessary for simulation then the risk of PII is minimized, for in the simulation all people become no specific individual. This is of course not always possible, for example with cadastral data, but in most cases where there is numeric or image data it is possible to create simply new versions out of historical data sets. For an extreme example take the project *This Person Does Not Exist* a catalog of algorithmically generated images of people. This is done not by magic, but rather by a deep machine understanding of the relationships between pixels and the distributions of each possible values for each pixel. Similar methods could be developed to create synthetic people, Lancaster et al. propose such a system in their 2018 paper.

An unnamed hacker once declared that PII had become "The toxic waste of the 21st century" and security expert Bruce Schneier in 2016 has called data a "toxic asset". These statements in a quick way encapsulate the problem. PII is everywhere and everything it touches becomes infinitely more difficult to deal with from many practical stand points, and the more of it that is there, the more resources it takes to maintain. There is an idea within a great deal of data warehousing and "big data" operations that data is perpetual. This needs to be opposed. Data loses relevance over time, data from a date far enough in the past has only minimal relevance in the current model. The data lifecycle describes the ways in which data is created, managed, analyzed, stored and should eventually describe how it comes to die at the end of its relevance.

The current conceptualization of the data lifecycle typically ends with archiving or reusing data, and does not normally recognize deletion as its final step. This is largely a data governance problem, policies must be put in place that insure that data is kept only so long as it is necessary. This ability to 'forget' a record is a step forward again in creating trust between those being observed. This ability to remove data becomes an ability to be forgotten, and become invisible to the system. The lifecycle ensures that not only will data go away at some point in the future, but should a person have a reason to, they can compel those mechanisms. Once again, this builds trust that the system operates on behalf of those being observed, and not arbitrarily at the behest of those doing the observing.

The growing number of devices and possibility, from wireless payment to on demand services to the ability to detect the traces of emotional experience, we need an ecosystem in which data becomes a civic asset. For that to be the case there must be mechanisms of trust between the observed and observing. We need to begin to move towards understanding data and its uses as a tool for describing the world and our interactions within it. This same move needs to bring access to that data to everyone while still protecting them. We should be seeking to enable everything we can, but not doing so in a

haphazard way. Change will be incremental, but by setting goals for openness and how you will protect and engage people there is a better chance that a larger project will emerge.

Chapter 8: Conclusions

Fully autonomous vehicles will come in time. AV shuttles represent a first step that communities can take to not only embrace this new technology, but begin to change the ways people make decisions about transportation. While this manual has attempted to show how design decisions can improve the user experience of transportation, we hope that the final message is that experience plays a role in the transportation decisions of all individuals. If you can create a positive experience, even in small ways, these pay off in dividends. For these shuttle projects to ultimately be successful, outside of their initial pilot phases, they need to be integrated components of a larger mobility network, accentuating existing transit if it exists and expanding equitable access to affordable mobility. They need to reduce overall vehicle miles traveled and promote a new vision of transportation where shared rides and experiences are valued and dependence on the car for mobility is not a default assumption.

To affect this change requires not just the deployment of a shuttle or even shuttles. Success will be built as much on good design as it will be on good vision. As is made clear by the work Chamblee has done to improve itself, it is in a better position to take advantage of autonomy as it emerges. But more importantly, it is in a better position period – even if autonomy stalls.

Noted planners, Jeff Tumlin and Harriet Tregoning reinforced this point in a recent podcast that investments now in public transit, bike lanes, and sidewalks will only serve to improve the operation of AV's in the future.[72] As the system matures, paths and sidewalks become whole systems that overlay existing networks allowing multiple networks of mobility to reinforce one another. When these networks are appealing experiences people are able to make meaningful decisions about how they go about getting from A to B instead of defaulting to hopping in the car. This opens up the ability for shuttles and other new modes of autonomous transit to become a successful option for suburban communities. The core of the changes that can be done today embrace and accentuate transit opportunities that are already available, reinforce those opportunities with new ones that do not favor cars, and pay attention to the way people perceive the value of their time.

As important to the success of shuttles will be how they pay attention to the way people perceive the value of their time. Is waiting perceived as time wasted or time gained? The private AV concept cars are already marketing the idea of being driven as a Chauffeur-like luxury experience of stylish lounging, napping, or working in the back seat. As suggested in Chapter 6, in order to compete, AV bus stops will need to be much more than simply a place to wait.

In the final analysis the success of AV shuttles will be judged in their ability to reduce vehicle miles traveled, expand affordable mobility options, and build community in the process. This will have the most impact on low-income households and reinforces the imperative for equitable accessibility.

There is a great deal of potential in autonomous vehicles. There is also a great deal of room to begin now to experiment, test and gauge what works and what doesn't in low risk pilot projects that bring

people together in conversation around new visions for how people will move around small and medium sized suburban communities, and the technologies that will enable that. These futures though will not make themselves. For all of the promises of people like Elon Musk there is no market that will magically create a desire for shared transit. It is incumbent upon communities to decide for themselves how this will work, to what extent they want it, and then ultimately what the best ways of enabling that change is. But what is clear is that not only is the technology coming, but there is a desire for a future in shared autonomous transit.

Appendix I: AV Shuttle Database

Appendix II: Chamblee Data Management Goals and Priorities for Autonomous Vehicle Operation

[1] Daniel Sperling, *Three Revolutions: Steering Automated, Shared, and Electric Vehicles to a Better Future,* (Island Press, 2018)
[2] See Michele D. Simoni, Kara M. Kockelman, Krishna M. Gurumurthy, Joschka Bishoff, "Congestion Pricing in a World of Self-Driving Vehicles: An Analysis of Different Strategies in Alternative Future Scenarios", *Transportation Research part C: Emerging Technologies,* November 2018. See also Peter Calthorpe and Jerry Walters, "Autonomous Vehicles: Hype and Potential," *Urban Land Magazine,* March 1, 2017
[3] Some of these topics are covered in *Autonomous Vehicles: A Policy Preparation Guide*, by the National League of Cities, 2017.
[4] Blake Morgan, *Nownership, No Problem: An Updated Look At Why Millennials Value Experiences Over Owning Things*, Forbes, 2 January 2019, retrieved 19 July 2019
[5] Zipcar Inc., *2011 Key Findings In Millennials & Driving: A Survey Commissioned by Zipcar*, 2011 (https://www.slideshare.net/Zipcar_Inc/millennial-slide-share-final/2011_Key_Findings_In_2011), retrieved 19 July 2019
[6] Andrew Perrin, *10 facts about smartphones as the iPhone turns 10*, Pew Research Center, 28 June 2017 (https://www.pewresearch.org/fact-tank/2017/06/28/10-facts-about-smartphones/), retrieved 19 July 2019
[14] In a review of more than 60 shuttle projects it was found that 100% operated below "maximum operating speed". With almost all operating below 15 miles per hour, the speed a dedicated cycle commuter can average on a day to day basis. A matrix of these results can be found in the appendix of this document.
[15] A guide to currently enacted policies within the US may be found NCSL website at http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx
[16] For example, see the AV shuttles in Bishop, Ranch in San Ramon, CA; Coffs Harbor in Adelaide, Australia; Charité Hospital in Berlin-Mitte, Germany; and the Kent Ridge National University of Singapore campus.
[17] See for example Sion, Switzerland; Darwin, Australia; Columbus, Ohio and Las Vegas, Nevada.
[18] See Christopher Leinberger, *The Option of Urbanism* (Washington DC: Island Press, 2007)
[19] Christopher Leinberger, *The Walk UP Wake-Up Call: Atlanta* (George Washington University, Smart Growth America, 2013.
[20] See case study on Mashpee Commons in Dunham-Jones E., and Williamson J., *Retrofitting Suburbia; Urban Design Solutions for Redesigning Suburbs* (Wiley, 2008).
[21] Fears of gentrification along Buford Highway in Chamblee have prompted the formation of a non-profit, We Love BuHi to try to raise the clout of the immigrant communities that live and work along it.
[22] Jesus Diaz, "Muji's Adorable Autonomous Bus Hits the Road in Finland," *Fast Company,* 03.15.19, https://www.fastcompany.com/90320687/mujis-adorable-autonomous-bus-hits-the-road-in-finland
[23] Hiroyuki Iseki and Brian D. Taylor, "Style versus Service? An Analysis of User Perceptions of Transit Stops and Stations," *Journal of Public Transportation,* vol 13, no. 3, 2010.
[24] Luigi Ranieri, Salvatore Digiesi, Bartolomeo Silvestri, and Michele Roccotelli, "A Review of Last Mile Logistics Innovations in an Externalities Cost Reduction Vision," *Sustainability*, 10, 782, 12 March 2018
[25] Take for example Atlanta Magazine's article "Bird Invasion" published August 2018 (https://www.atlantamagazine.com/news-culture-articles/bird-invasion-atlantas-electric-scooters-are-fun-dangerous-exciting-annoying-and-unstoppable/)
[26] Klein, G., "How Slow Lanes Can Speed Up New Mobility (And Save Lives)," *Forbes*, 4 December 2018.
[27] Sturges, D., *Bounce*, (forthcoming 2020) and in telephone interview of Dan Sturges by Zachary Lancaster, 15 January 2019.
[28] Lime Scooters *Lime One Year Report (*https://www.limebike.com/hubfs/Lime_Official_One_Year_Report.pdf), 1 July 2018, Retrieved July 2019.
[29] Violence Prevention Through Urban Upgrading (VPUU) *Active Boxes* (http://vpuu.org.za/safe-node-area/active-boxes/)
[37] In fact, transit users tend to perceive wait times as significantly longer than they actually are, prompting researchers to create the "wait time multiplier." However, if a shelter, bench, and real-time information are provided, users produce much more accurate perceptions of the wait time. See Fan, Y., Guthrie, A., and Levinson,

D., "Waiting time perceptions at transit stops and stations: Effects of basic amenities, gender, and security," *Transportation Research Part A: Policy and Practice,* vol 88, June, 2016.

[38] The NACTO report added the caveat that this was highly subjective and depended greatly on context, environment and access to information. See *Perception of Waiting Time at Transit Stops and Stations* 2015 (https://nacto.org/wp-content/uploads/2016/02/1_Fan-et-al-Perception-of-Waiting-Time-at-Transit-Stops-and-Stations_2015.pdf) Retrieved 18 July 2019

[39] Yinglin Fan *Perception of Waiting Time at Transit Stops and Stations* 2015

[40] George Barratt-Jones *First Class Bus Stop by George Barratt-Jones*, 2019 (https://vimeo.com/345066412), retrieved 18 July 2019

[41] Laura Dannen, *Book Club for Bus Riders*, Seattle Met 2012, (https://www.seattlemet.com/articles/2012/6/26/book-club-for-bus-riders-june-2012), retrieved 19 July 2019

[42] For more information on the Gilchrist "Edible Bus Stop" see *The Incredible Edible Bus Stop*, Modern Farmer, 2013 (https://modernfarmer.com/2013/08/the-edible-bus-stop/) and *The Edible Bus Stop: transforming urban space one stop at a time*, The Guardian, 26 July 2012 (https://www.theguardian.com/lifeandstyle/gardening-blog/2012/jul/26/edible-bus-stop), retrieved 19 July 2019

[49] Aaron Bastani *Fully Automated Luxury Communism*, 2019 Verso Books

[50] Lyft shuttle and it's Uber equivalent Uber Express are experimental services that uses fixed stops that are regenerated on a regular basis but ultimately behaves in a fashion similar to a bus. For more information see Uber's materials on Express Pool (https://www.uber.com/ride/express-pool/).

[51] Journalists covering the launch and rollout of autonomous vehicles are already noting that the experience, while safe, is boring. For example journalist Carly Page writing for The Inquirer covering the 2019 Consumer Electronics Show write the that she found the ride to be "delightfully boring". In a more polemic piece journalist Alanis King of Jolopnik stated, in 2017, that "as novel and new as the whole "self-driving cars" thing is, it's already melding into a big puddle of blah" in his article *Autonomous Cars Aren't Even Here Yet And I'm Already Bored With Them*.

Carly Page, *We took a trip in a self-driving car and it was delightfully boring*, The Inquirer, 7 January 2019 (https://www.theinquirer.net/inquirer/feature/3068839/we-took-a-trip-in-a-self-driving-car-and-it-was-delightfully-boring), retrieved 19 July 2019

Alanis King, *Autonomous Cars Aren't Even Here Yet and I'm Already Bored With Them*, Jalopnik, 11 September 2017 (https://jalopnik.com/autonomous-cars-arent-even-here-yet-and-im-already-bore-1803756153), retrieved 19 July 2019

[52] If passengers wanted to talk they would sit up front, insuring conversations were kept to a minimum volume. Greetings were handled through a wordless fist bump. Passengers in the back seat could expect a quiet ride. While much of this has passed into the past as Lyft has matured it shows the role that drivers could play in cultivating a specific social setting.

[53] Joe Pinsker, "What is the Future of Getting Kids to Soccer Practice?" *The Atlantic*, 19 October 2018.

[59] Christina Borgman, *Big Data, Little Data, No Data* 2017

[60] "Health" apple.com Apple Inc. 2019

[61] Massumi, B., *Parables of the Virtual* (Duke University Press, 2002)

[62] __, ___, ___ pp. 23-25

[63] Freddie Hayward, "China unveils 500 megapixel camera that can identify a face in a crowd of tens of thousands." *The Telegraph*. 26 September 2019. https://www.telegraph.co.uk/news/2019/09/26/china-unveils-500-megapixel-camera-can-identify-every-face-crowd/

[64] It is clear that the purpose of this device is mass surveillance. But we contend that its potentials are far greater than societal control, even though the potential for abuse is equally as great.

[65] Donna Haraway, "Situated Knowledges: The science questions and the privilege of partial perspectives." *Feminist Studies*. Vol. 14, Issue 3 (Autumn 1988) pp. 575 - 599.

[66] Kenneth Train, *Discrete Choice Methods with Simulation Second Edition*, Cambridge University Press. 2009

[67] Our current views on privacy are constructed primarily in the wake of the United States war for Independence and the French Revolution. Both establishing liberal orders that rejected the concept of a monarch's right to enter, survey or surveil private property.

[68] The issue of privacy at this scale is a much larger topic and we encourage anyone interested in this topic to research it themselves. Books such as *The Local Code*, *Digital Ground*, and *All Data Are Local* can serve as good starting points.

[69] Simon Chignard, "A brief History of Open Data", *Paris Innovation Review*, 29 Mach 2013. http://parisinnovationreview.com/articles-en/a-brief-history-of-open-data

[70] Yanni Loukissas, *All Data Are Local*, MIT Press, 2019, pp. 165-166.

[71] Helen Hester, *Xenofeminism*, John Wiley & Sons, 2018

[72] Episode 1, "Redesigning Cities with Autonomous Vehicles," REDESIGNING CITIES: The Speedwell Foundation Talks at Georgia Tech, 4 December, 2018; https://arch.gatech.edu/redesigning-cities-speedwell-foundation-talks-georgia-tech-0

No.	Country	Location	Shuttle	On Demand	In Service	Context	Operation Range	Lane Type	Shuttle Size	Service Area (miles)	Frequency	Operational Speed (mph)	Speed Range	Cost (USD)	Provider	Operator	Partners
1	**Australia**	Adelaide,SA	Yes	No	Yes - Aug 19	Urban	October 2018 to June 2019	On Street-pub	S	-	30 minutes	-	-	-	EasyMile10	-	Sage Automation
2	**Australia**	Coffs Harbour,NSW	Yes	To Designated Stop	yes	Suburban Retirement Village	December 2018 - December 2019	On Street	M	-	10 minutes	15	Fast	-	EasyMile	-	-
3	**Australia**	Adelaide,SA	Yes	No	Yes	Urban	-	On Street	M	0.75	10am - 2pm	20	Fast	5,401,000	NAVYA	Flinders University	Future Mobility Lab, City of Adelaide, Royal Automobile Association
4	**Australia**	Adelaide,	Yes	In Future	Yes	Campus	June 2019 -	-	-	60	24 hours	15	Fast	1,800,000	RDM Group		-
5	**Australia**	Darwin,NT	Yes	No	No	Water-front	February 2017 - September 2017	On Street	M	1.2	-	20	Fast	150,000	EasyMile	Northern Territory Government	-
6	**Australia**	South Perth,WT	yes	no	Yes	Bay-front + Historic precinct	August 2016 -	On Street-pub	M	2.1	-	15	Fast	250,000	NAVYA	-	RAC
7	**Australia**	Sydney,NW	yes	no	?	New Masterplanned Comm'y	September 2018 - September 2019	On Street	M	-	-	-	-	-	-	-	HMI Technologies,Telstra, NRMA, IAG and Sydney Olympic Park Authority (SOPA)
8	**Canada**	Calgary,Alberta	Yes	No	No	Last Mile - Urban	October, 2018	-	M	0.37	-	7.4	Slow	50,000	Pacific Western Transportation, Telus, Atco	-	University of Alberta
9	**Canada**	Candiac,CA	Yes	No	Yes	-	October, 2018 - Present	On Street		1.7	-	18	Fast	600,000	NAVYA	-	-
10	**Canada**	Edmonton,CA	Yes	No	No	-	Fall, 2018	On Path	M	3 routes	-	-	-	-	ELA (product of EasyMile)	Pacific Western Transport Group	U of Alberta
11	**China**	Shenzen,Guangdong	Large Bus		-	Suburban FTZ	April, 2017	On street-pub	L	4 routes - 0.8	-	-	-	76,000	Shenzhen Haylion Technologies		-
12	**Denmark**	Aalborg,Nordjylland	Yes	No	-	Suburban	March, 2016	Path	M	0.8	-	27	Fast	-	NAVYA	Autonomous Mobility	ARMA
13	**Denmark**	Copenhagen / Nordhaven,Oresund	Yes	No	No	Urban nhd	-	On Street-pub	-	0.8	10am - 5pm	-	-	54,600,000	LINC	Autonomous Mobility	16 partners - EU, LOOP City, Gate 21 &others
14	**Denmark**	Lyngby,Oresund	Yes	No	No	Campus	May, 2017 -	On Street - priv	S	-	-	9.3	Slow	?	EasyMile	LINC	DTU
15	**Denmark**	Koge, Slagelse ,Zealand	Yes	No	3 phases	Hospital to Train Station	May, 2018 - August, 2018	1.lobby, 2. path, 3 street	-	-	-	-	-	?	-	Autonomous Mobility	Movia, Region Sjælland, Region Hovedstaden and Metroselskabet
16	**Finland**	Helsinki,	Yes	No	Yes	Downtown	March, 2019 -	On Street-pub	M	Different Route	15 minutes	15	Fast	?	Gacha	Metropolia U of Applied Sciences	City, EU
17	**Finland**	Espoo,	Yes	No	Yes	Suburban Office Park	April, 2019 -	On Street	M	1.2	-	25	Fast	?	Gacha	Sensible 4; Muji.	Aalto U
18	**France**	Lyon,Auvergne-Rhône-Alpes	Yes	No	?	Urban	April, 2016 - April, 2017	On Street	M	0.8	-	12	Slow	?	NAVYA	-	-
19	**France**	Paris,Ille-de-France	Yes	No	Yes	Airport	April, 2018 -	On Path	-	-	-	-	-	?	NAVYA	-	-
20	**France**	Rouen,Normandy	Yes	To Designated Stop	Yes	Mostly Suburban	October, 2018 -	On Street-Pub	-	6	-	-	-	?	-	TransDev	-
21	**Germany**	Berlin, Berlin-Mitte,Brandenburg	Yes	No	yes	Insitutional	August, 2019 - December, 2019	Hospital Grounds	S	2.1	-	7.44	Slow	4,520,000	EasyMile + Navya	Berlin Transport Dept	Charite Univ Hospital, State of Berin
22	**Germany**	Berlin, Pforsheim,Brandenburg	Yes	Yes	Yes	Urban	July, 2019 -	-	-		-	-	-	?	Ioki (Deutsche Bahn)	Sudwestbus	Berlin Transport Dept
23	**Germany**	Bad Birnbach,Bavaria	Yes	No	-	Suburban Office Park	October, 2017 -	On Street	-	0.43	-	9.3	Slow	?	EasyMile	-	-
24	**Germany**	Hamburg,Hamburg	Yes	No	-	-	Future	-	S		-	-	-	-	-	-	-
25	**Germany**	Berlin,Brandenburg	Yes	No	Yes - Aug 19	-	-	On Street-pub	S	0.75	-	-	-	?	EasyMile10	BVG	-
26	**Greece**	Trikala,Thessaly	Yes	No	yes (after pilot)	Urban	March 2014 - March 2016	On Street-pub	-	1.5	-	-	-	?	-	-	-
27	**Korea**	Seoul,Gyeonggi	Large Bus			Downtown	September, 2018 -	On street-pub	L	3.5	-	25	Fast	?	-	-	-
28	**Netherlands**	Amsterdam	Yes	No	Yes	Urban	January, 2016 -	Highway	S	0.12	-	5	Slow	112,000	-	-	-
29	**Netherlands**	Haarlem-Amsterdam	Yes	No	Yes	-	July, 2016	On Street	-	12.5	-	43.5	Fast	225,000,000	Multiple	-	Heavy Vehicle Manufactures, Province of Noord-Holland
30	**Netherlands**	Rotterdam	Yes	No	Yes	Suburban Office Park	July, 2016	On street-pub	-	-	-	-	-	?	-	-	-
31	**Norway**	Akershusstranda	Yes	No	Yes	-	July, 2016	On Street	-	0.8	-	-	-	?	-	Autonomous Mobility	-

32	**Norway**	Stavangar	Yes	No	Yes	Suburban Office Park	January, 2017 - 2019	On Street-pub	-	2.5	-	-	-	?	EasyMile	-	-
33	**Singapore**	Singapore City	Multi-Modes	No	No	-	Soon	-	L	3.5	-	-	-	?	-	-	SMRT, ABB
34	**Singapore**	Singapore City	Yes	-	Yes	Tourist Island	August, 19 - November 2019	On street-pub	L	3.5	10am to 12pm - 2pm to 4pm	-	-	?	-	-	Nanyang Technological University and Volvo Buses
35	**Singapore**	Kent Ridge	Yes	No	Yes	Insitutional	July, 2019 -	University Campus	M	0.9	20 minutes	-	-	?	EasyMile10	-	Inchcape Singapore
36	**Sweden**	Stockholm,Uppland	Yes	No	No	Suburban Office Park	January, 2018 -	On Street	M	-	-	-	-	?	EasyMile	Ericsson	-
37	**Sweden**	Gothenburg	Yes	No	Yes	-	May, 2018 - June, 2018	Path	M	-	-	20	Fast	?	NAVAYA	TU Chalmers	-
38	**Switzerland**	Cossonay,Vaud	Yes	No	No	Small Town	December, 2017		M	1	-	20	Fast	?	NAVAYA	BestMile	-
39	**Switzerland**	Fribourg,CH	Yes	No	Yes	Suburban	August, 2017 - present	On Street	-	0.8	7 minutes	15	Fast	704,040	NAVYA	Fribourg Public Transport	-
40	**Switzerland**	Sion,Valais	Yes	No	?	Historic Downtown	Summer, 2016 - 2018	On Street-pub	M	1.5, but extended	-	-	-	?	NAVYA	PostBus	-
41	**Switzerland**	Schaffhausen,Schaffhausen	No	-	No	Small Tourist Town	March, 2018	On street	-	0.3	-	-	-	?	-	-	-
42	**Taiwan**	Taipei	Yes	No	Yes	Downtown	July, 2017	On street-pub	M	0.62	-	-	-	?	EasyMile	7Starlake	-
43	**UK**	Cambridge,Cambridgeshire	Yes	No	No	-	October, 2017	Path	M	2.7	-	15	Fast	66,66,000	RDM Group	-	SME
44	**USA**	Arlington,TX	Yes	No	Yes	Stadium - Events loop	August, 2017 - August, 2018	Path	M	0.75	30 minutes	15	Fast	272,000	EasyMile	City of Arlington	SME
45	**USA**	Ann Arbor,MI	Yes	No	No	Institutional	June, 2018	On Street	M	1	10 minutes	18	Fast	?	NAVYA	University of Michigan	MCity
46	**USA**	Austin,TX	Yes	No	No	-	July, 2018 - July, 2019	Private street	M	-	-	-	-	?	EasyMile	City of Austin, CAP Metro	-
47	**USA**	Austin,TX	Yes	No	Yes	Airport	August, 2019	on Street -airport	S	0.75	8 hrs / day	12	Slow	?	EasyMile10	Austin-Bergstrom Int'l Airport	-
48	**USA**	Austin,TX	Maybe	No	No	Downtown	2020	various	L	city-wide	5 - 7 minutes	-	-	?		CAP Metro - Project Connect	-
49	**USA**	Babcock Ranch,FL	Yes	No	No	Town internal	November, 2017 - October, 2018	On Street - priv	M	-	-	8	Slow	?	EasyMile	TransDev	-
50	**USA**	Bryan,TX	Yes	No	2018	Small Town Downtown	August, 2017	On Street-pub	S	0.8	5 minutes	10	Slow	?	-	-	City of Bryan, Texas A&M
51	**USA**	Columbus,OH	Yes	No	No	-	2020	On Streeet - priv	M	1.5	20	-	-	?	-	-	
52	**USA**	Columbus (Grove City),OH	Yes	To Designated Stop	Yes	Different parts of Suburb	December, 2018 - 2019	On Street-pub	M	1.5	6am - 10pm	-	-	?	Via	Columbus Transpo Authority	Smart Columbus
53	**USA**	Columbus,OH	Yes	No	Yes	Downtown Tourist Loop	December, 2018 - 2019	On Street-pub	S	1.4	6am - 10pm	12	Slow	4,000,000	-	May Mobility	Smart Columbus, Drive Ohio, OSU
54	**USA**	Denver,CO	Yes	No	No	Suburban	January, 2019	On Street-pub		-	-	-	-	?	EasyMile	TransDev	-
55	**USA**	Detroit,MI	Yes	No	Yes	Downtown	June, 2018 -	On Street-pub	S	1	5 - 7 minutes	11	Slow	?	May Mobility	May Mobility	-
56	**USA**	Doraville,GA	Yes	No	No	Suburban	March, 2019	On Street - priv	-	-	15 minutes	-	-	?	NAVYA	-	Assembly
57	**USA**	Farmington / Salt Lake / Park City,UT	Yes	No	Yes	Different cities in Utah & Uni of Utah	June, 2019 - Early 2020	On Street-pub	M	4 stops	-	-	-	?	-	-	-
58	**USA**	Frisco,TX	Yes	To Designated	No	Business Park	July, 2018 - December, 2018	On Street-pub	-	-	-	-	-	?	Nissan NV200	Drive.ai	-
59	**USA**	Gainesville,FL	Yes	No	Yes	Downtown	April. 2018 - present	On Street	M	1.2	15 minutes	11 to 25	Slow / Fast	2,700,000	EasyMile	TransDev	FDOT, University of Florida
60	**USA**	Greenville,SC	No	No	No		Summer, 2017	On Street	-	-	-	-	-	?	-		Clemson, State of SC
61	**USA**	Houston,TX	Yes	No	Yes	Suburban Campus	June, 2019 -	Path	S	1	-	12	Slow	?	-	Metropolitan Transit Authority	Texas Southern U
62	**USA**	Jacksonville,FL	Yes	-	-	Downtown	Future	Skyway AV Route	M	2.5	30hrs/week		-	?	-	-	JTC
63	**USA**	Knoxville,TN	Yes	No	No	Downtown	2017 - 2019	-	M	-	-	25	Fast	?	Local Motors 'Olli'	-	-
64	**USA**	Las Vegas,NV	Yes	No	Yes	Downtown	November, 2017 - 2018	On Street	M	0.6	-	15	Fast	150,000	NAVAYA	Keolis	City of Las Vegas, RTC
65	**USA**	Minneapolis / St. Paul,MN	Yes	-	No	Midtown	2018	On Mix Path- Bike + AV shuttle	M	2.5	10am - 4pm	25	Fast	50,000	-	-	-
66	**USA**	Rancho Cordova,CA	Yes	-	No	Business Park	August, 2019	On Campus	M	518,156	-	25	Fast	-	Local Motors	-	-

67	**USA**	San Ramon,CA	Yes	No	yes	Suburban Office Park - some pub rd	April, 2017 -	On street	M	-	15 minutes	-	-	-	EasyMile	FirstTransit	City, CA DMV, Contra Costa Transpo Authority, GoMentum Station
68	**USA**	Tampa,FL	Yes	No	yes	Campus + Downtown	January, 2018 -	On street	-	1	8-10 minute	25	Fast	500,000	-	-	-

Note : For 'Shuttle Size' category, **S**-Small (6 or less people) ,**M** - Medium(6 - 15 people) **L** -Large (More than 15 people)

Data Management
Best Practices & Plan for
Shared Autonomous Vehicle User Experience

Rey Angeles
City of Chamblee
Georgia Institute of Technology
July 2019

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1 Introduction

- About the Research Intern
- Motivation/ Objective
- Shared Autonomous Vehicles Project Overview
- City of Chamblee Overview

2 Data Governance Framework

- Data Governance Overview
- Data Governance Organization
- Data Governance Principles
- Data Policies
- Data Standards
- Data Procedures
- Data Ethics/ Privacy

3 Data Lifecycle Management

- Data Creation and Collection
- Data Analysis
- Data Archiving

4 User Experience (UX) Metrics

- User Experience Defined
- Getting to
- Waiting For
- Riding On

5 Conclusion

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ABOUT THE RESEARCH INTERN

REY ANGELES

GA Smart Community Corps Intern

Candidate, MS Supply Chain Engineering (Fall 2019)

Fulbright Scholar

Hometown: Quezon City, Philippines

Immediate Supervisors:
Rebecca Keefer (City of Chamblee),
Fariba Hollister (GA Tech),
Dr. Ellen Dunham-Jones (GA Tech)

MOTIVATION

Public transportation has primarily been focused on operations and safety. It is usually not focused on customer service or the user experience which is an integral aspect.

OBJECTIVE

The objective of this study is to prepare the data management strategy for Chamblee's SAV project that could be used as benchmark for other US communities:

- What data could and should be collected, and how to collect the data
- Which data are feasible
- How to store and analyze data
- Ensure that the trust of people and city will not be compromised

Shared Autonomous Vehicle Project Overview

GOALS

Establish the first/ last mile connection from the Chamblee MARTA train station.

- **Mobility**: Strong multi-modal connections
- **Economic**: Minimized traffic congestion
- **Environmental**: Reduced environmental pollutants

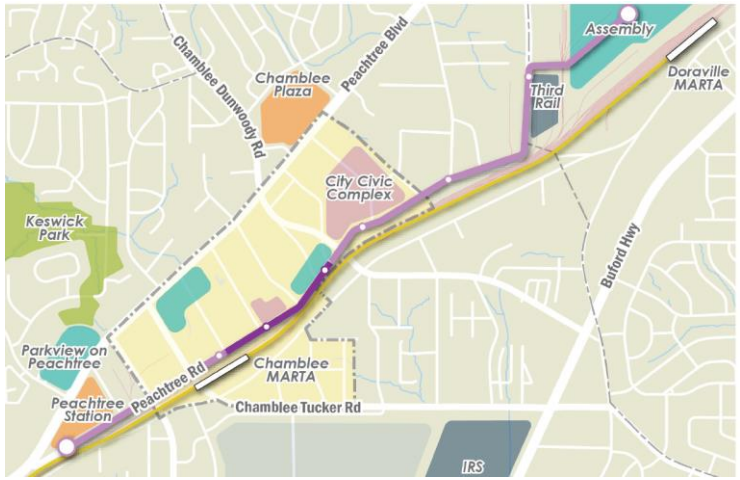
KEY FEATURES

A combination of redundant sensor systems is used to ensure precise location of vehicle and accurately identify surrounding objects.

- Driverless
- Top Speed: 25mph
- Capacity: 8-16 people
- Operates in both directions
- Redundant Braking Mechanism
- Wheelchair-accessible
- Direct telecom and emergency stop button
- Single Battery Charge: 3-10 hours

TARGET ROUTES

- City Civic Complex
- PDK Airport
- Peachtree Station
- Chamblee Plaza
- Keswick Park
- Third Rail/ Assembly
- CDC/ IRS



PROJECT PHASES

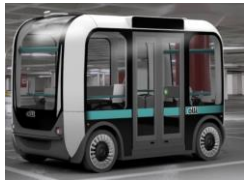
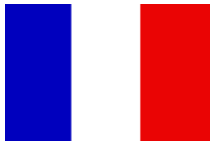
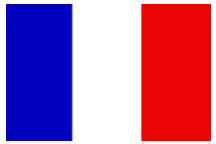
- ✓Feasibility & Concept Plan
- ○ Preliminary Planning
- ○ Construction, Pre-Implementation, & Testing
- ○ Opening Day
- ○ Ongoing Operations & Performance Monitoring

FURTHER DETAILS

Visit https://www.chambleega.com

Shared Autonomous Vehicle Project Overview

PROSPECTIVE VENDORS

	EasyMile (EZ10)	Navya (Autonom Shuttle)	Local Motors (Olli)
			
Headquarters			
US Office	Denver, Colorado	Michigan	Maryland
First Launched	April 2015	Sept 2015	2016
Vehicle Dimensions	4,050 x 1,892 x 2,871 mm	4,750 x 2,110 x 2,650 mm	3,920 x 2,050 x 2,500 mm
Deployments	200	115	
Remarks	Partner for US DOT grant		• Host for Atlanta Fleet Challenge • Shuttles are manufactured via 3D printer

2019-06-14: Local Motors Factory Tour in Knoxville

City of Chamblee Overview

29,428

Chamblee Population (2017)

49% of population is **single, 39%** are married, **22%** with kids < 18

45% of population are **Spanish-speaking Hispanics**

Average income is **USD 74,960**

23% of population are **millennials/ young adults** (25-34), **17%** are aged 35-44

Reference: Demographics: Chamblee, GA - Official Website.

2

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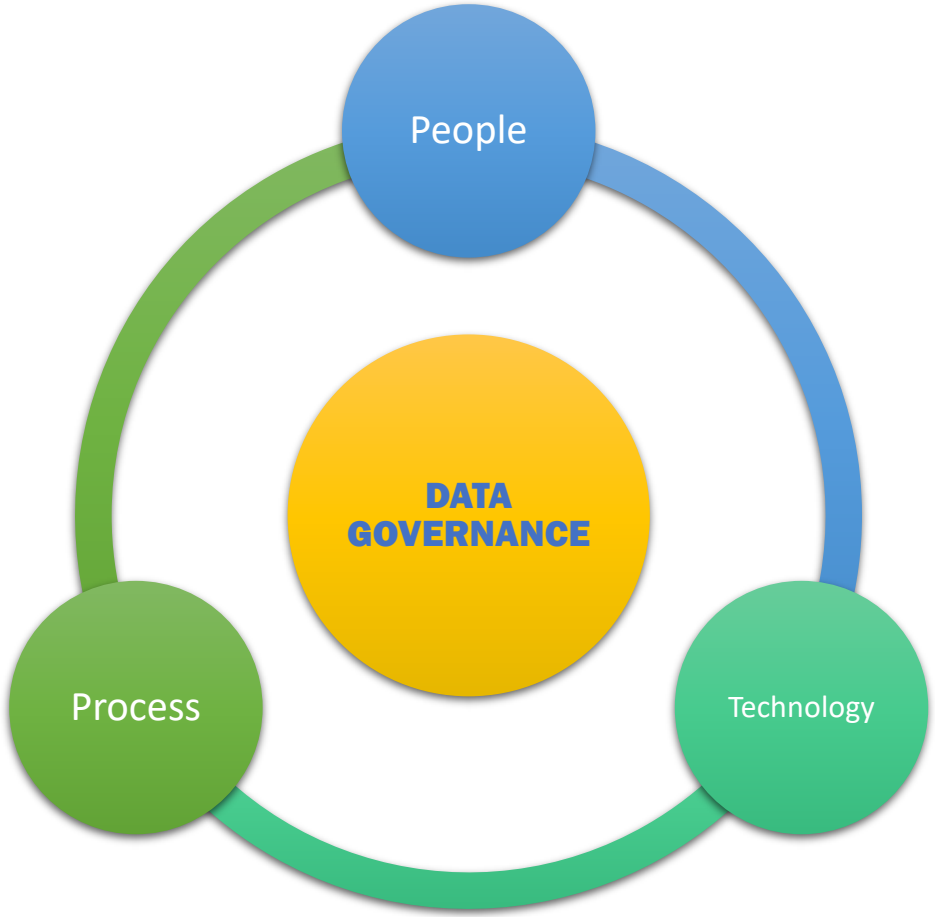
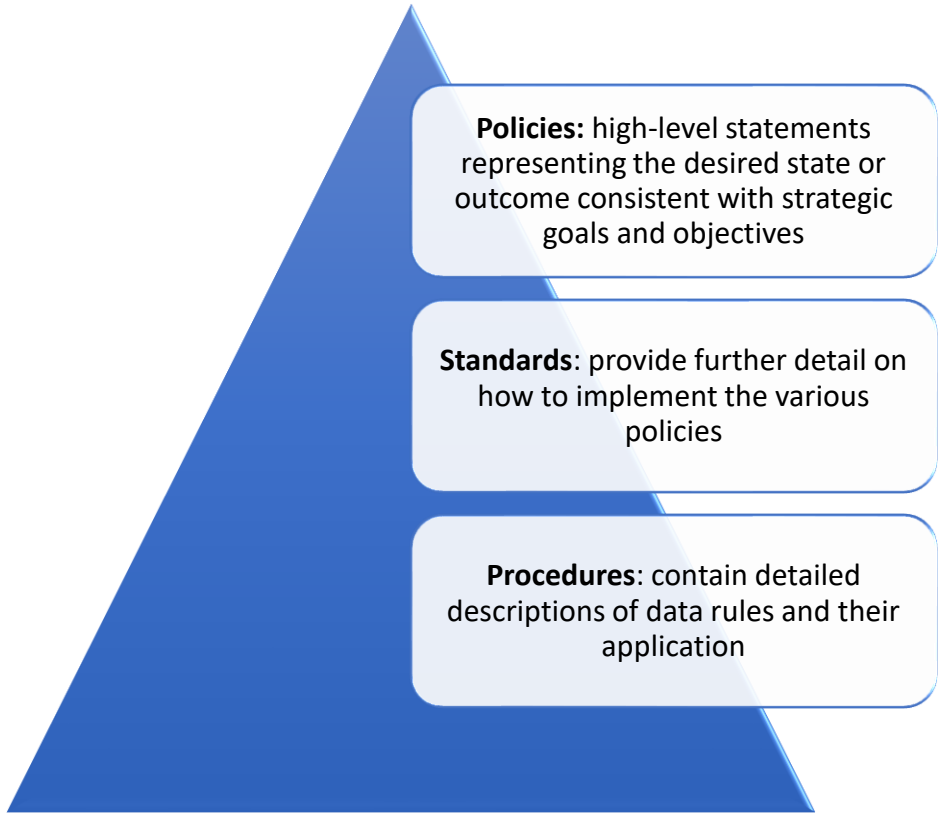
Data Governance Overview



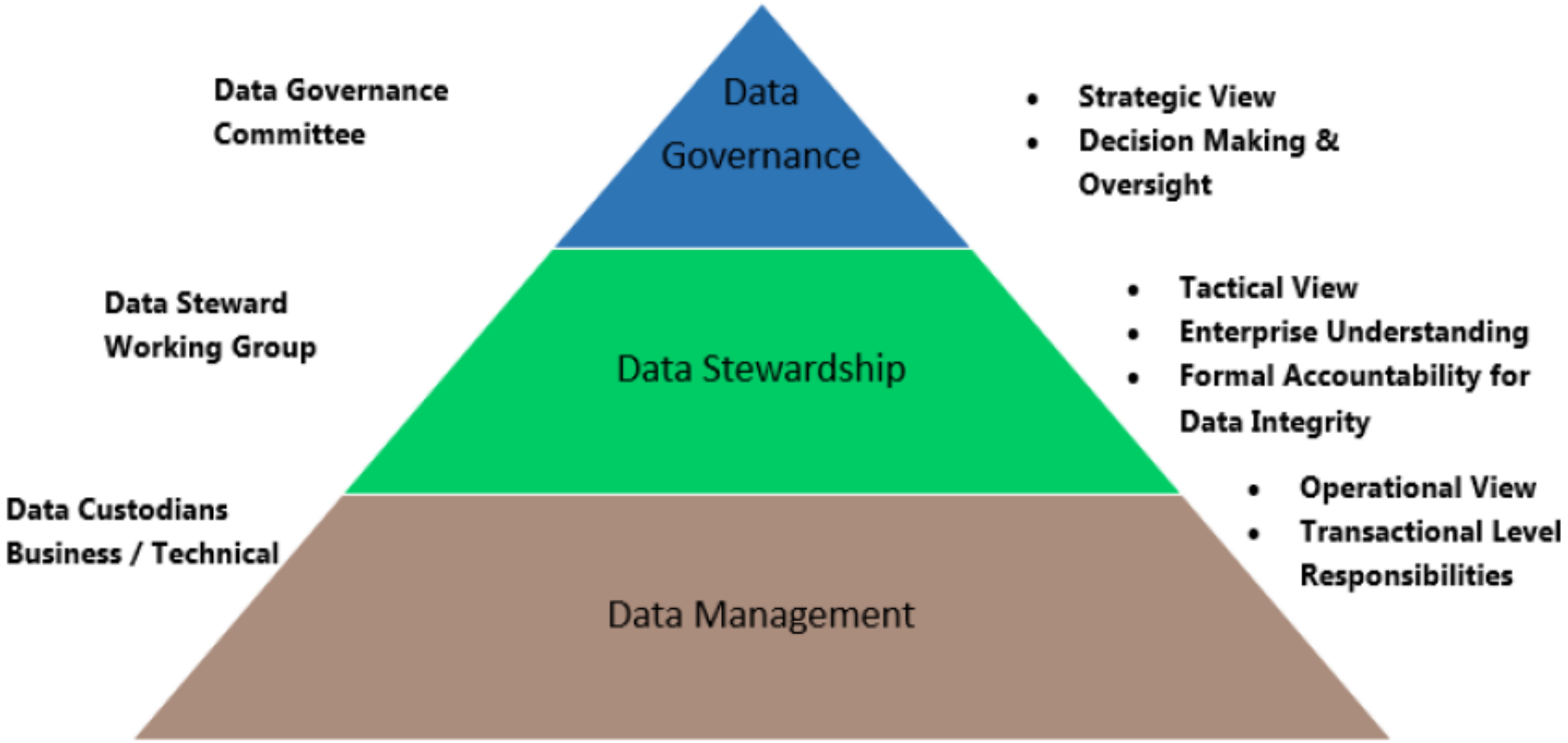
Data Governance Framework Hierarchy



Data Governance Definition (MDM Institute):
"the formal orchestration of people, processes, and technology to enable an organization to leverage data as an enterprise asset"

Reference: Data Governance Best Practices and Recommendations Report (Rep.). (2019).

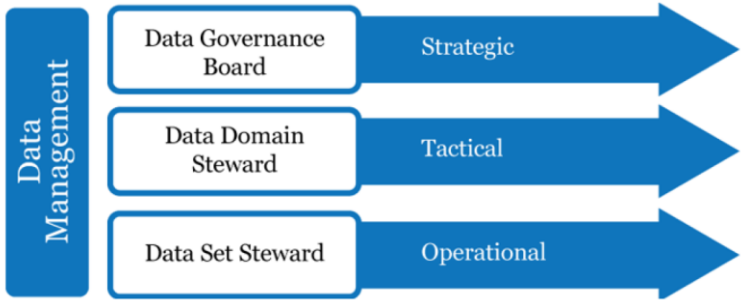
Data Governance Organization



The Florida DOT presents this simplified relationship among the aspects of the framework – the left side shows the people (roles) while the right side lists high-level responsibilities and processes.

Reference: Data Governance Best Practices and Recommendations Report (Rep.). (2019).

Data Governance Organization



Data Governance Board

- Executive team consists of data governance stakeholders
- Responsible for establishing data governance policies and championing data accessibility and quality improvements.

Enterprise Data Steward

- Functional "enterprise" business experts
- Responsible for leading assigned functional data working groups comprised of Data Stewards and Data Custodians from each organization
- Reporting to the Data Governance Board
- Advocating for data quality, prioritization and data system usage (not control)

Business Data Steward

- Functional data expert from each organization
- Responsible for overseeing capture, maintenance, and dissemination, as well as validating quality, and participating in data working groups
- Advocating for local users
- Developing Data Steward Data Plans

Data Custodian

- Operational management of data from each organization
- Responsible for data capture, maintenance, and disseminateion and following data governance policies/ procedures and participating in data working groups

Reference: Data Governance Best Practices and Recommendations Report (Rep.). (2019).

Data Governance Organization

Sample Goals and Objectives

No.	Goal Title	Goal Description	Objectives
1	Leadership	Champion data solutions to ensure accountability and increase the value of data assets.	• Promote data governance within FHWA. • Communicate data-related changes to all interested parties. • Monitor progress and ensure accountability of data governance tasks and projects.
2	Quality	Oversee efforts to provide acceptable quality data that is accurate.	• Establish a Data Quality Assurance Program. • Increase the accuracy and clarity of data. • Improve accessibility of data.
3	Prioritization	Prioritize efforts to address data gaps and needs.	• Establish clear priorities to address data gaps and needs. • Communicate priorities to FHWA business units.
4	Cooperation	Facilitate cross-organizational collaboration, data sharing, and integration.	• Increase opportunities for data sharing. • Eliminate data silos and other barriers. • Ensure business units know the identity of Data Stewards. • Ensure Data Stewards know the identity of Data Users.
5	Flexibility	Encourage creative and innovative solutions to data needs.	• Identify innovative data solutions throughout FHWA. • Communicate innovative solutions to Data Stewards and Data Users.
6	Utilization	Improve data utilization and ease of access.	• Promote appropriate data usage throughout FHWA. • Provide staff the means to determine the extent and availability of FHWA data.

Reference: Data Governance Best Practices and Recommendations Report (Rep.). (2019).

Sample Performance Measures

No.	Objective	Performance Measure
1	Data meet established need-driven standards for accuracy.	% of data that meet standards.
2	Meaning of data is readily understood.	% of data elements for which clear definitions have been established.
3	Communicate data-related changes to all Data Users.	Affected users are aware of data-related changes at least 30 days before changes are implemented.

Data Governance Principles

Principle statements are values used to guide organizations with their priorities. They could either be **Business-Oriented** or **Data-Centric**. The examples provided are the principles set by the Colorado Data Organization (CDO) and Minnesota DOT (MnDOT).

Business-Oriented Principles

The CDO is a multidiscipline function to further an end state through strategies, policies, governance, architecture, and collaboration that:

- Advances data awareness, discoverability, accessibility, and utilization
- Fosters opportunities to integrate existing data sources with new data sources, and third-party data
- Facilitates re-usable, consistent, and repeatable exchange of data between systems via a data integrate layer and web services
- Advances interoperability and data sharing, breaks down silos
- Inspires innovation and create and cooperative problem solving; maximizes business insight through optimizing utilization of data
- Creates a dynamic, curious, data-driven environment inclusive of big data, artificial intelligence, predictive modeling, deep learning and more

Data-Centric Principles

MnDOT has adopted the following principles to better govern data. All decisions related to data should align with the principles.

- Data shall be managed as a state asset
- Data quality fits its purpose
- Data is accessible and shared as permitted
- Data includes standard metadata
- Data definitions are consistently used
- Data management is everyone's responsibility
- Data shall not be duplicated

Reference: Data Governance Best Practices and Recommendations Report (Rep.). (2019).

Data Governance Principles

- These are the four principles set by NACTO for managing mobility data:

Public Good	Protected	Purposeful	Portable
• Require access to data from mobility services operating in the public realm • Use their authority to issue and enforce contractual agreements to guide private sector actions and protect the public interest • Expand their capacity to analyze the data • Develop or update strategic plans for managing mobility in a digital age • Coordinate to create or adopt standardized, open data formats	• Treat geospatial mobility data as • Ensure that their data policies and practices are routinely updated • Update data privacy and insurance policies to limit city liability • Require mobility companies and vendors to prove that they are in compliance with contractual requirements, industry standards, and laws regarding data privacy and consumer data protection • Coordinate with other cities	• Be clear about what questions they are trying to answer • Develop internal capacity to audit the data • Ensure that their regulatory scheme and analysis tools allow them to retroactively request data • Encourage and negotiate with mobility companies to update user agreements and request and receive consent for collecting and using personal information from their customers.	• Use open standards whenever possible. • Update procurement policies to prioritize open standards and standard formats. • Review privacy policies and data management practices of platforms and vendors. • Limit

Reference: Managing Mobility Data (Rep.). (2019, April).

Data Policies

Data policies are intended to guide how data will be treated and managed. They cover data creation, acquisition, storage, quality, integrity, interoperability, security, and privacy. The following policies are based on the existing policies of the Federal Highway Association (FHWA):

No.	Policy Name	Policy Description
1	FHWA data are an enterprise asset	Data, structured and unstructured, and the corresponding meta-data, are business and technical resources owned in whole or in part by FHWA. FHWA data include shared data about managed entities, interests, finances, employees, resources, customers, providers, business affiliates, best practices, operating procedures, experimental results, etc. All employees must recognize that the proper management of strategic enterprise data is critical to the success of the organization.
2	FHWA data programs and activities must undergo IT investment process	FHWA data programs or data related activities within IT projects require Investment Review Board (IRB) approval prior to and during an ongoing effort. This process is typically initiated, liaised, communicated to IT project managers, or executed by the Data Stewards. They are ultimately responsible for following the FHWA Information Technology Investment Process in order to gain IRB approval prior to and during all planned/ongoing data activities.
3	FHWA data must be consistent	All strategic FHWA data shall be modeled, named, and defined consistently, according to standards, across the organization. Efforts must be made by management to share data and not maintain redundant data without justification. Originating business stewards of data must recognize the informational needs of downstream processes and business units that may require FHWA data.
4	FHWA data must be of acceptable quality	Quality data are critical to ensuring FHWA mission success. Data Stewards are responsible for ensuring that FHWA data are accurate and correct for the intended purpose and use, and that data providers follow all reporting requirements regarding the collection, processing, and reporting of FHWA data, and meet all requirements of the Data Quality Act. Data quality standards shall be managed and applied actively to the approved reliability levels of FHWA data as defined by the business owners.
5	FHWA data must be interoperable with dependent systems	All enterprise data (structured and unstructured) must conform to a common set of standards and schemas across all data sharing parties. Data sharing must also be accounted for and facilitated through a designated authority.
6	FHWA data must be maintained at the source	All FHWA data must be maintained as close to the source as feasible, to reduce the collection and storage of redundant data.
7	Enterprise data must be safe and secured	FHWA data, in all electronic formats, shall be safeguarded and secured based on recorded and approved requirements and compliance guidelines. These requirements are to be determined by the OITS. Appropriate backups and disaster recovery measures shall be administered and deployed for all FHWA data. The enterprise data must adhere to the privacy rules and requests made by each respective business steward both internal and external to FHWA.
8	FHWA data must be accessible	FHWA data, information, and meta-data shall be readily accessible to all, except where determined to be restricted. When restrictions are made, business stewards of the data are accountable for defining specific individuals and levels of access privileges that are to be enabled. The OITS will be responsible for the implementation of proper security controls.
9	Meta-data will be recorded and utilized	All FHWA information system development and integration projects will utilize the defined meta-data program for data naming, data modeling, and logical and physical database design purposes. The DGAC is responsible for developing plans to capture and record specific data administration-focused meta-data consistent with the defined meta-data program.
10	Data stewards will be accountable by job description	Individuals designated as stewards will have specific enterprise data accountabilities incorporated into their job descriptions.
11	Timeliness of data	Data must be obtained, processed and be made available in a timeframe consistent with its intended use.

Reference: Data Governance Best Practices and Recommendations Report (Rep.). (2019).

Data Standards

Data Standards will be initiated when one of the following trigger events occurs:

- A data program undergoes a regular or periodic reassessment that examine data utility and viability.
- New data fields are added to an existing data system.
- A data redundancy, quality, or consistency issue is identified that has led to one or more of the following:
    - Increased data collection and/ or reporting burden
    - Increased data storage and/ or analysis burden
    - Inability to perform quality data analysis or convert data into meaningful information

NIEM Standards & Compliance

National Information Exchange Model (NIEM) is a community-driven, government-wide, standards-based approach to exchanging information. FHWA highly recommends its adoption for developing data modeling schemes and interoperability.

NIEM compliance can be applied to the ff. scenarios in exchanging data:

- Data that exist in multiple systems, platforms, or storage locations (i.e. redundant data) must follow the established consistency and reliability standards.
- Data that exist within only one system, or are in use by a close family of systems residing in an isolated platform, must be consistent with naming conventions.
- Variances in schemas and formats corresponding to external data may exist in any form specific to the external systems' business needs. However, the datasets must conform to data rules.

Metadata

Metadata is defined by the National Information Standards Organization (NISO) as "structured information that describes, explains, locates, or otherwise makes it easier to retrieve, use, or manage an information resource."

- **Descriptive metadata**: describes resource for data purposes such as discovery and identification
- **Structural metadata**: indicates the composition of object data
- **Administrative metadata**: statistical information about managing the data resource(s)

Metadata must be created by each system owner and stored in a central location for easy reference by both internal and external data users.

Reference: Data Governance Best Practices and Recommendations Report (Rep.). (2019).

Data Standards

Data Integrity

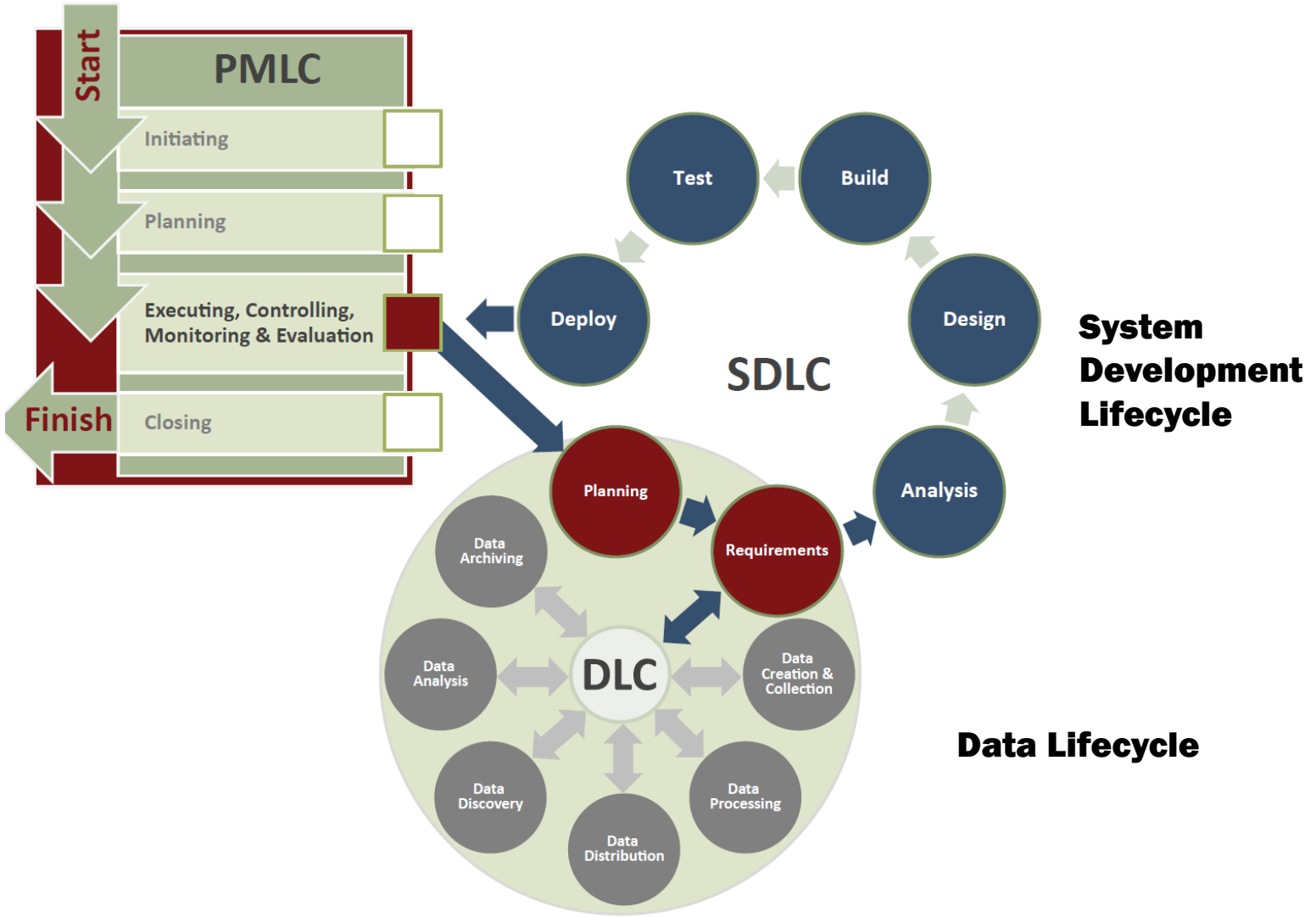
- Data must be consistent across all domains and locations.
- To ensure data integrity, copies of data, static or dynamic (i.e., working data) must be uniformly stored and accessible across all platforms, systems, or locations.
- Data should only be collected if there is a clear, unique business requirement. drifting from this governing policy could lead to unnecessary data collection resulting in unforeseen consequences such as definition conflict or unnecessary management overhead.
- Any changes must be made to the data or schema must be performed in a methodical fashion. Only authorized users or systems may conduct adjustments or edits to data, after being granted proper adjudication, and by following a previously approved modification plan.
- All data exchanges shall ensure, from a high level, the following data characteristics remain consistent and unchanged.

No.	Information Characteristic	Characteristic Description
1	Names and Attributes	The variable names and associated attributes must be unique across all systems. The names may be static, or determined during system execution run-time.
2	Container Format	The FHWA content data must be accurately documented to reflect the expected character types, formats, field min/max lengths and all other format specific characteristics.
3	Content Length	All uniquely defined variables must specify reasonable data length. All mapping variables should in turn conform to the specified content length.
4	Data Definition Conformity	Data definitions must be established and specified between mapping entities and variables.
5	Schema Uniformity	All XML/Database schemas developed as the result of a cross-boundary information exchange must be uniform and conform to the developed Information Exchange Packages (IEPs).
6	Central Metadata Repository	All metadata associated with the information exchange must be stored in an agreed upon central location and accessible to all parties having a business need for access to the data.

Reference: Data Governance Best Practices and Recommendations Report (Rep.). (2019).

Data Procedures

Information Architecture Life Cycle



Project Management Lifecycle

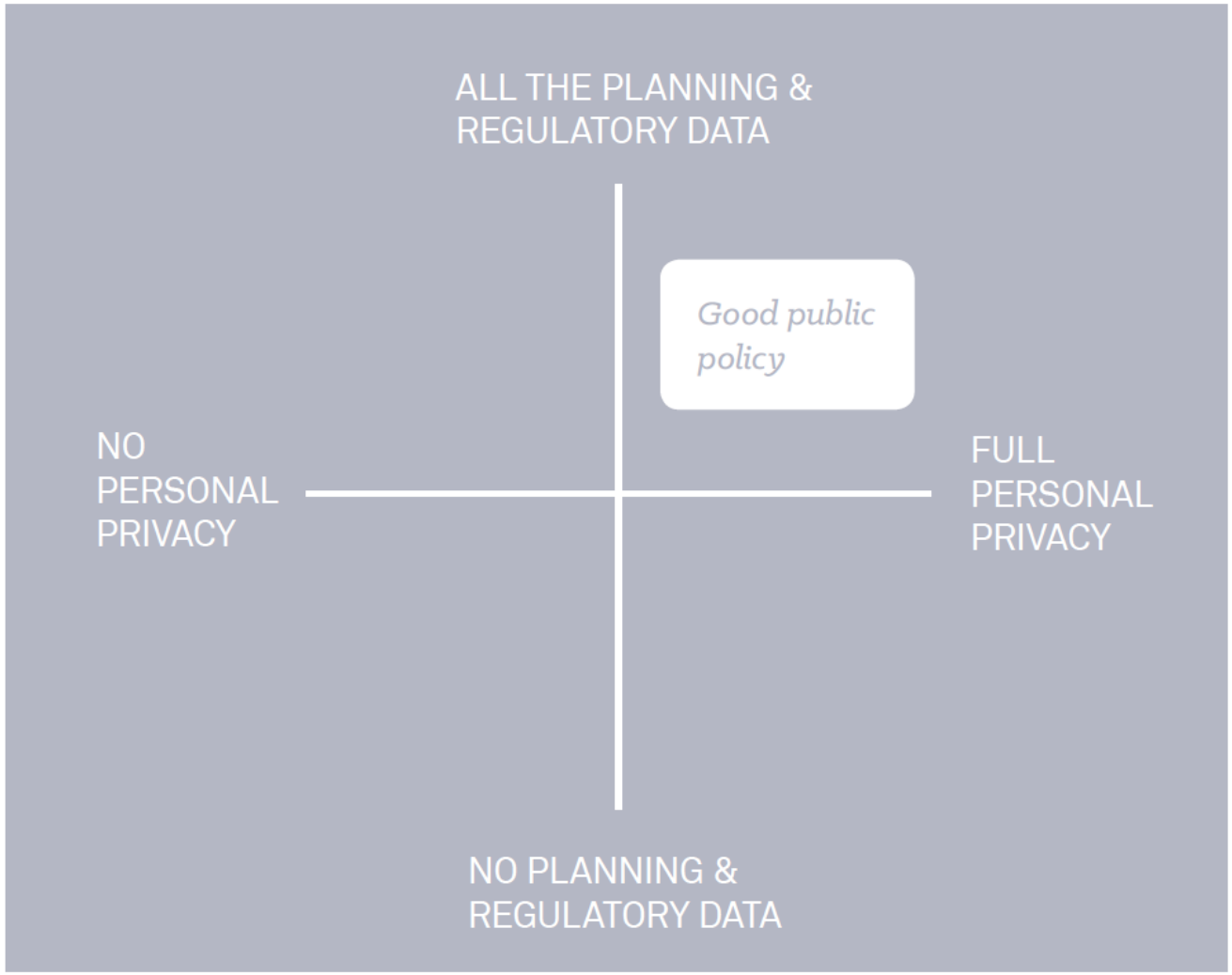
System Development Lifecycle

Data Lifecycle

Reference: Data Governance Best Practices and Recommendations Report (Rep.). (2019).

Data Ethics/ Privacy

- The challenge in managing mobility data is to reconcile the two objectives of protecting the privacy of the individual and gaining information to help city administration to implement plans and policies that would support positive outcomes for the community.
- “A positive outcome uses thoughtful tools and principles to ensure cities have more data from which to make decisions and policies, and individuals retain more privacy. Bad outcomes occur either when personal privacy is diminished whether or not governments have access to essential information, or when privacy is fully protected but governments have no access to the data needed to make informed decisions and policies.”



Reference: Managing Mobility Data (Rep.). (2019, April).

Data Ethics/ Privacy

Platforms at Risk

- Cloud data
- Online portals for citizens
- Application patching

Compromised Security

- Hacks
- Leaks
- Exceptions to privacy
- Not all data is meant to be private

Data Ethics

- Privacy
  - Confidentiality
  - Unauthorized
  - Sources not designated for sharing
- Anonymity
  - HIPAA regulations
  - Proprietary data
- Copyright
  - Data on webpages, PDFs, images, etc.
  - Use may violate copyright
- Other considerations: Potential Bias, Overconfidence

Reference: Poulson, B. (2016, July 27)

3

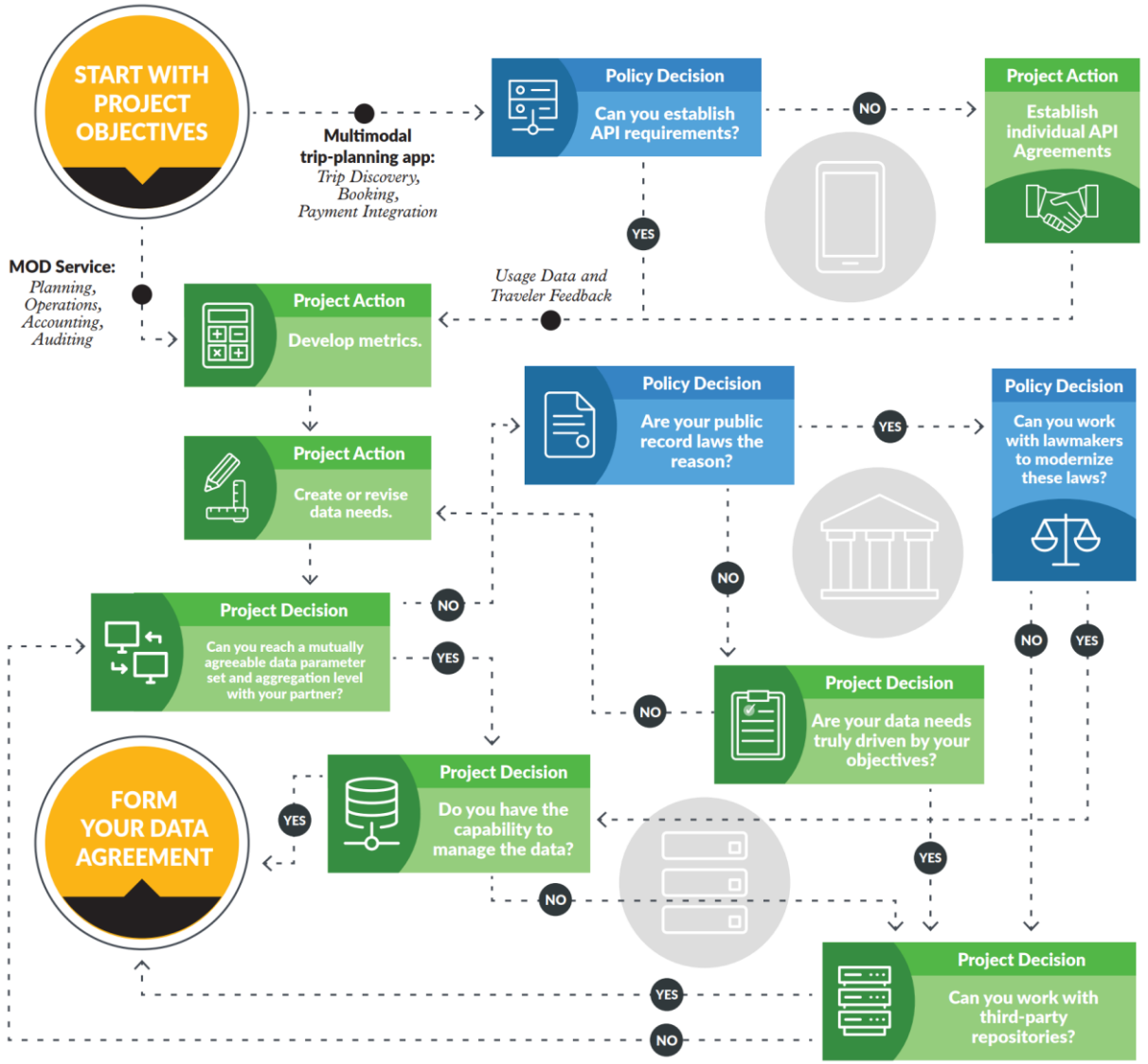
Data Lifecycle Management

Data Creation & Collection
Data Analysis
Data Archiving

Data Creation & Collection

Approach

The decision tree is created by the Shared-Use Mobility Center to guide agencies in deciding from various pathways to form the structure and details of their data agreement. This may be applied as well to forming partnerships with agencies for data sources for SAVs.



Reference: Objective-Driven Data Sharing for Transit Agencies in Mobility Partnerships (Rep.). (2019).

Data Creation & Collection

Decision	Advantages	Disadvantages
Mutually agreeable parameter set and aggregation level	• Direct negotiation with provider to address concerns and data delivery format • Addresses specific needs for project and methods for data ownership and handling	• Data resolution may be too coarse • Lack of standard requires one-off agreements for every project, including extensions • Differences may not be reconcilable in the end
Modernize public records laws	• Clarity on what data are protected • Establishes bounds for future projects/ agreements	• May be a longer-term solution • Requires time and resources for legislative outreach and cross-departmental coordination
Manage data in-house	• Data ownership sits with agency; can query as needed • Additional benefits for agency; can use for planning • Possible monetization in the future	• Data handling expertise required • IT infrastructure may be needed • More burdensome as services grow beyond pilot stage
Use third-party repositories	• Possible protection for personally identifiable information from public disclosure • Warehousing, management, and/ or analysis of raw data, as needed	• Data resolution may be too coarse • Requires additional work to check against public records laws • Data ownership sits outside agency • Legal and governance framework still not mature

Reference: Objective-Driven Data Sharing for Transit Agencies in Mobility Partnerships (Rep.). (2019).

Data Creation & Collection

Decision	Advantages	Disadvantages
Establish API requirements for mobility service providers	• All providers will be seen by travelers • Avoids separate or differing agreements for individual providers	• Lack of standards for most trip discovery and payment APIs • Requires legislative or regulatory action
Individual API agreements	• Work with providers who are ready to integrate • Avoids legislative process	• Lack of uniform standard for API connections • Might not include providers with large market share

Reference: Objective-Driven Data Sharing for Transit Agencies in Mobility Partnerships (Rep.). (2019).

Data Creation & Collection

Challenges

These are the data sharing challenges identified to receiving quality data and information for MOD (Mobility on Demand) services. These could also be extended to SAVs.

Concerns/ Challenges	
Traveler Privacy (Concerns with Location Data)	Paired origin-destination data, even if anonymized, is at significant risk of identifying individuals when combined with publicly available data sets
Competitiveness	Data generated from partnerships may also contain proprietary information of the private mobility service provider (algorithms, predictive features, data analytics methods)
Public Records Laws and Related Regulations	Public records (Freedom of Information) laws do not explicitly address the technological advancements that have allowed for gathering and storing large amounts of granular data (with personally identifiable information). Non-disclosure agreements or contract provisions might not supersede laws regarding disclosure
Data Security	Data handling and security protocols must be discussed thoroughly before forming partnerships and clearly defined in agreements, while adhering to regulations regarding data and privacy at the local, state, and federal levels
Data Aggregation	Resulting resolution of aggregation may be too course to be useful for the agency to monitor the service's performance relative to its metrics and objectives
National Transit Database (NTD) and Performance-Based Funding	NTD performance data are used to apportion FTA funds to transit agencies in urbanized areas
Capability Limitations	Transit agencies may not have the technical expertise or infrastructure to handle, store, and analyze large amounts of data

Reference: Objective-Driven Data Sharing for Transit Agencies in Mobility Partnerships (Rep.). (2019)

Data Creation & Collection

Transportation Data Types

Data Type	Components
Transportation Trends – Archived, Post-Processed Data	Travel patterns Pick-up/ drop-off locations
Service Planning – Archives, Post-Processed Data	Response time Service area (geographic area, times of operation, population served)

Service Delivery, Effectiveness, Accountability – Trip Data	• Operations Data: service performance/ user behavior
	  • Origin-destination (O/D) pairs
	  • Pickup and drop-off times
	  • Wait times
	  • Travel times
	  • Vehicle occupancy
	• Accounting Data: actual cost vs. budget
	  • Trip-level data: traveler fares, total cost
	  • Program-level aggregated data: surge pricing trends, average fares, pooled vs. non-pooled rides
	• Auditing Data: accounting data + compliance data
	  • Fulfilment of wheelchair requests

Integrated Trip-Planning and Payment – Real-Time Data	• APIs for integrated multimodal trip-planning
	  • Trip availability
	  • Vehicle location
	  • Cost
	• Transit: General Transit Feed Specification (GTFS)
	• Bikeshare: General Bikeshare Feed Specification (GBFS)

Reference: Objective-Driven Data Sharing for Transit Agencies in Mobility Partnerships (Rep.). (2019)

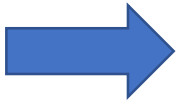
Data Creation & Collection

Creating Data

- **Intervention**
  - **Observational**
    - Interviews
    - Surveys: watch for wording/ sampling bias
  - **Experimental**
    - Experiments: best method for cause-and-effect data
- **Data Type**
  - Quantitative
  - Qualitative
- **Location**
  - Online
  - In person

Collecting Data

- **Existing Data**
  - In-house data
  - Open data
  - Third party data (Data-as-a-Service)
- **APIs (Application Programming Interface)**
  - REST API
  - Language-agnostic
  - JSON format



Shuttle Sensors

- **Scraping Data – when APIs don't exist**
  - HTML Text/ Tables
  - PDFs
  - Media

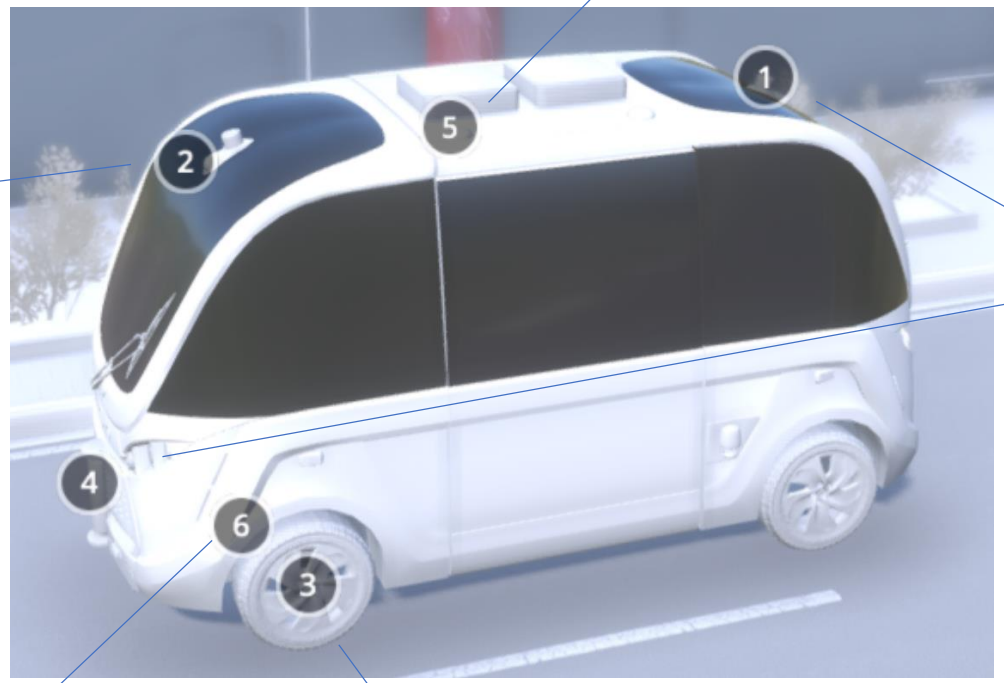
References:
Poulson, B. (2018, April 02). Predictive modeling of public opinion.
Poulson, B. (2016, July 27). Existing data.

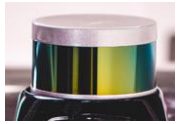
Data Creation & Collection

Shuttle Sensors/ Hardware

Cameras: analyze vehicle's surroundings (road signs, traffic lights) and contribute to obstacle detection and identification

GNSS Antenna: global positioning system that communicates between the GPS sensor and a base station (GNSS RTK system) that provides precise positioning, accurate to the nearest centimeter





LIDARs (Laser Detection and Ranging) Sensors:
Ensure detection of obstacles and calculate the vehicle's precise positioning via 3D-mapping

IMU: measures vehicle accelerations and rotations, allowing vehicles to confirm positioning information and improve precision

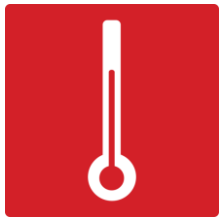
Odometry sensor: estimates and confirms the vehicle's location and speed while moving

Data Creation & Collection

Mileage

Speed

Status (Auto/ Manual)

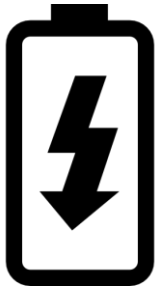


Internal/ External Temperature

Ramp State

Door State

E-Stop Status



Payload of Vehicle

Battery

Hit Ratio

Number of Passengers

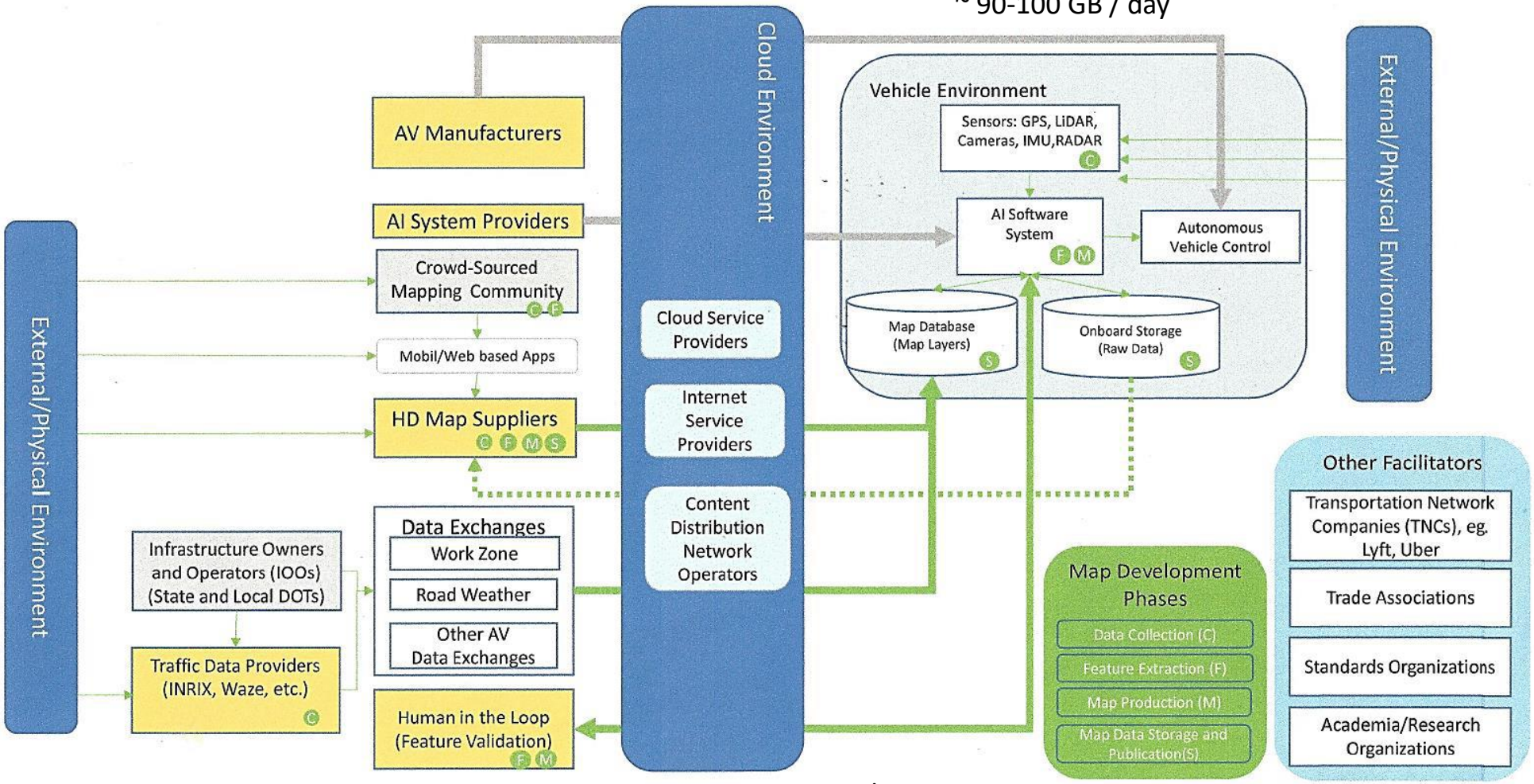
Fleet Positioning

Energy Use

Data Creation & Collection

AV Data Flow (US DOT)

~ 90-100 GB / day



NAVYA: Amazon Web Services

Data is encrypted and sent to secure cloud server via VPN

Reference: Data Governance Best Practices and Recommendations Report (Rep.). (2019).

Data Creation & Collection

Survey Creation

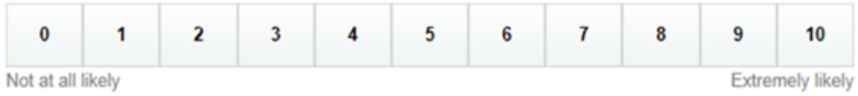
The following are the recommended questions/ customer experience metrics and format by which they should be asked.

1. Overall Experience

- Overall Experience question: How would you rate your overall experience today? – provides the ideal dependent variable for multiple regression analysis to determine the impact of different items on a visitor's overall satisfaction
- The offset labels reduce text and numeric bias, while the extreme positive point (labeled 'Outstanding') is set apart to reduce the positive skew associated with scales that use 9 or more points

2. Net Promoter Score

- How likely is it that you would recommend [brand] to a friend or colleague?



- To calculate NPS, respondents are grouped into the ff. categories:
  - Promoters (score 9-10): Loyal enthusiasts who will keep buying and refer others, fueling growth
  - Passives (score 7-8): Satisfied but unenthusiastic customers who are vulnerable to competitive offerings
  - Detractors (score 0-6): Unhappy customers who can damage the brand and impede growth through negative word-of-mouth
- Subtract % of Detractors from % of Promoters to arrive at Net Promoter Score, which can range from a low of -100 (every respondent is a detractor) to a high of 100 (every respondent is a Promoter)

Reference: Anderson, D. (n.d.). The 4 Most Important Customer Experience Metrics.

Data Creation & Collection

3. Visitor Intent

- Provides a clearer view of visitor (user) needs and expectations, moving away from periodic and expert analysis of satisfaction studies and towards the ongoing data-driver world of digital analytics.
- “Which of the following best describes the primary purpose of your visit (use) today?”
- A ‘single-select’ format is preferred for the response; ‘multi-select’ options defeat clear segmentation and complicates analysis with no real benefit

4. Task Completion

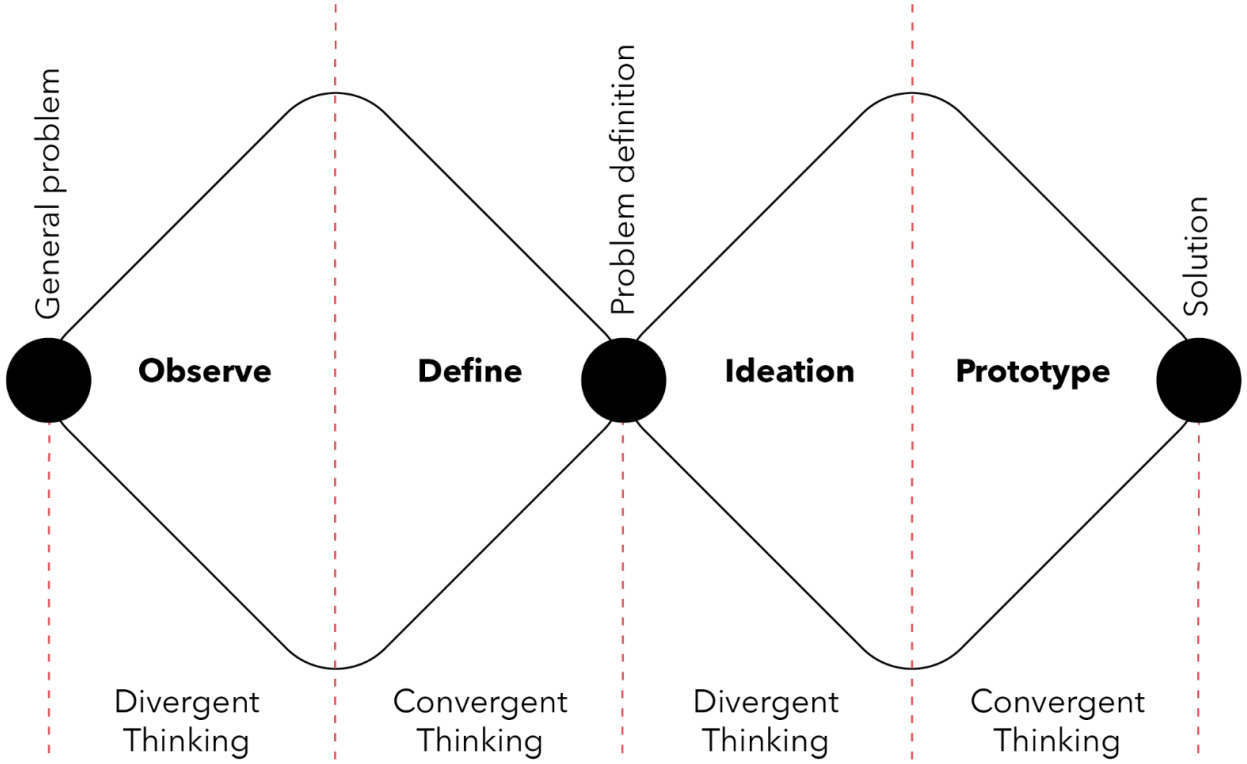
- Binary response: Yes/ No
    - Were you able complete the purpose of visit (use) today?

Reference: Anderson, D. (n.d.). The 4 Most Important Customer Experience Metrics.

Data Creation & Collection

Double Diamond Process

- Design Thinking Perspective
- Case Example: EMT Madrid (City Bus)
- Method: Double Diamond Process
  - 4-phase development process created by the British Design Council in 2005
- 4 Phases:
  1. Mapping out: Plan and define a framework
  2. Exploring: Empathize (users – environment) and visualize data
  3. Developing: Brainstorm a lot but prototype one solution
  4. Delivering: Test with users, iterate if necessary, and deliver to the client

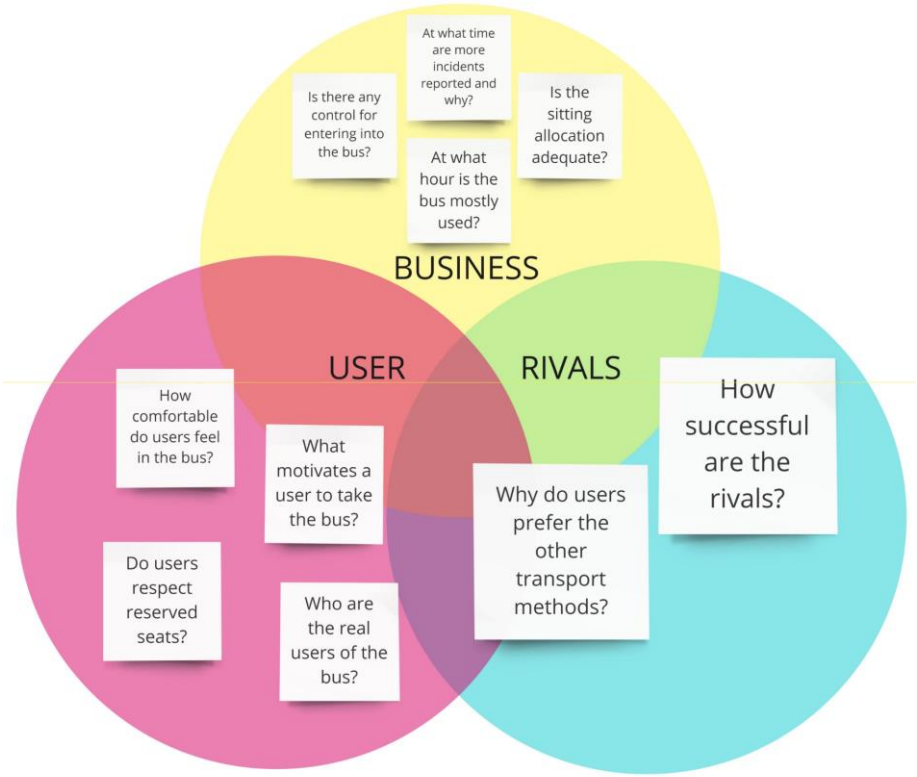


Reference: Giménez, M. (2018, November 04). Double-diamond strategy for Madrid´s public citybus.

Data Creation & Collection

Phase 1: Mapping Out

- Individual Desk Research about the business, users, and rivals (alternatives) using web pages that could offer information need
- Qualitative Research: collected opinions and comments from users in blogs/ social networks



Phase 2: Empathize

- Safari to the Buses
- Online questionnaire (Google Forms)
- Personal interview at bus stop
- User Persona Creation and Journey Map

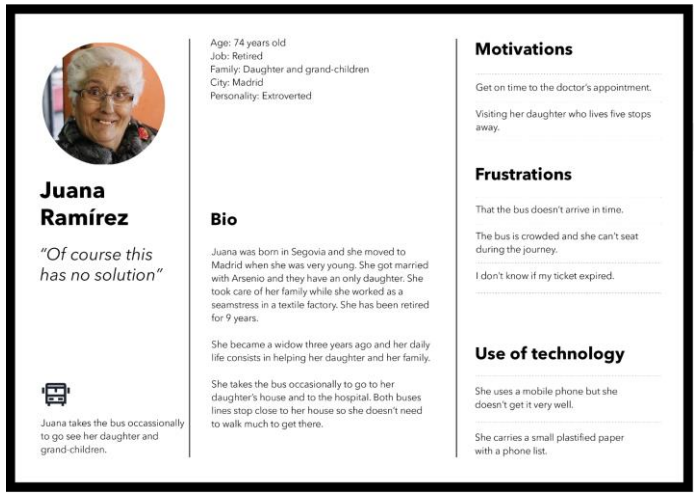
Findings:

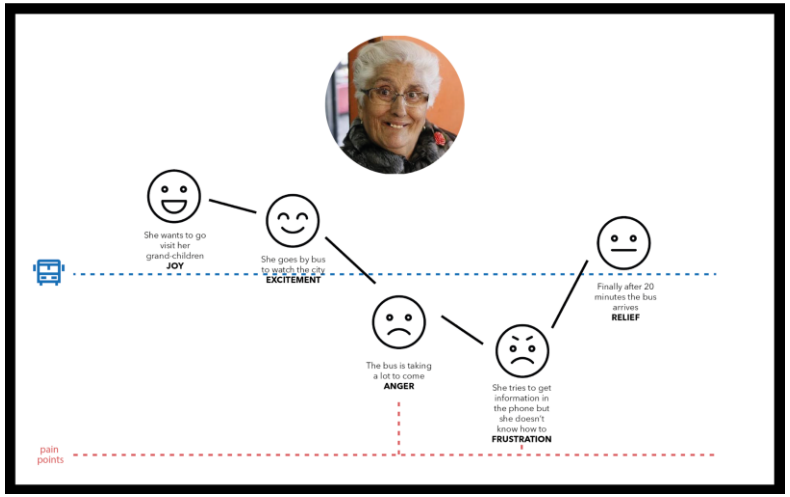
- **Older people** use the bus **mostly** because of habit or close location to the bus station and destination.
- **Metro** is the **most used** public transit method and users feel **safer** there.
- Standing in the bus is a real trouble.

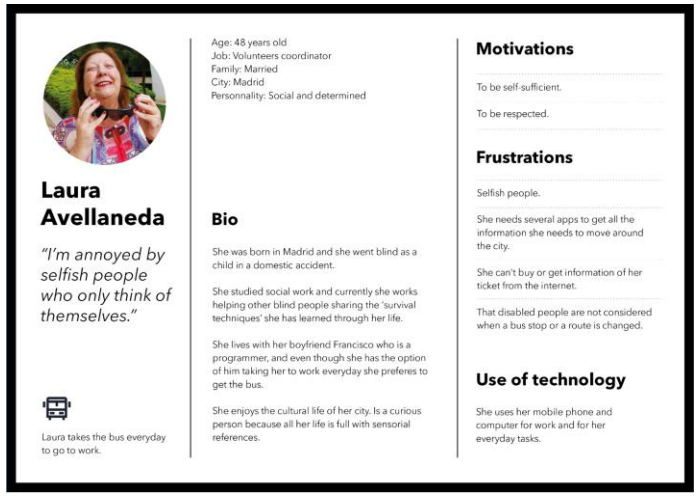
Reference: Giménez, M. (2018, November 04). Double-diamond strategy for Madrid´s public citybus.

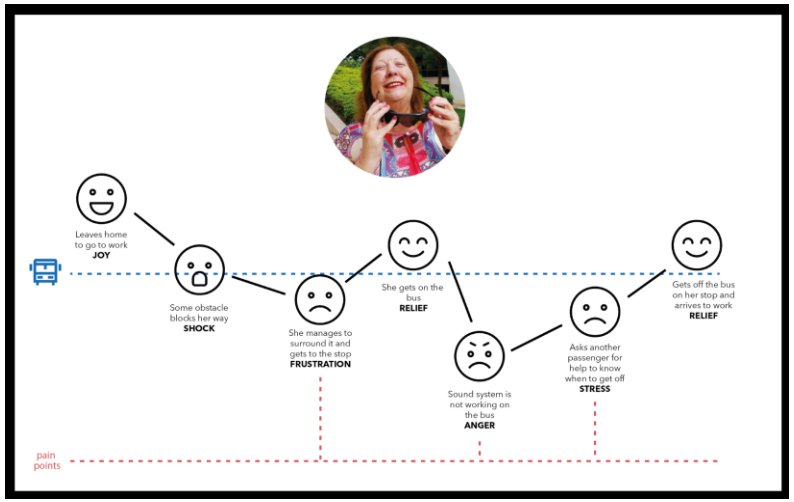
Data Creation & Collection

- **Phase 2: Empathize**
  - User Persona Creation and Journey Map









Reference: Giménez, M. (2018, November 04). Double-diamond strategy for Madrid´s public citybus.

Findings:

1. Users suffer a lack of space in the bus.
2. Users do not use the backside of the bus because it is difficult to exit from there.
3. Users are unstable when standing inside the bus (especially the old people).
4. Users prefer metro because they can sit down or hold on steadily.

Opportunities:

Enhance:

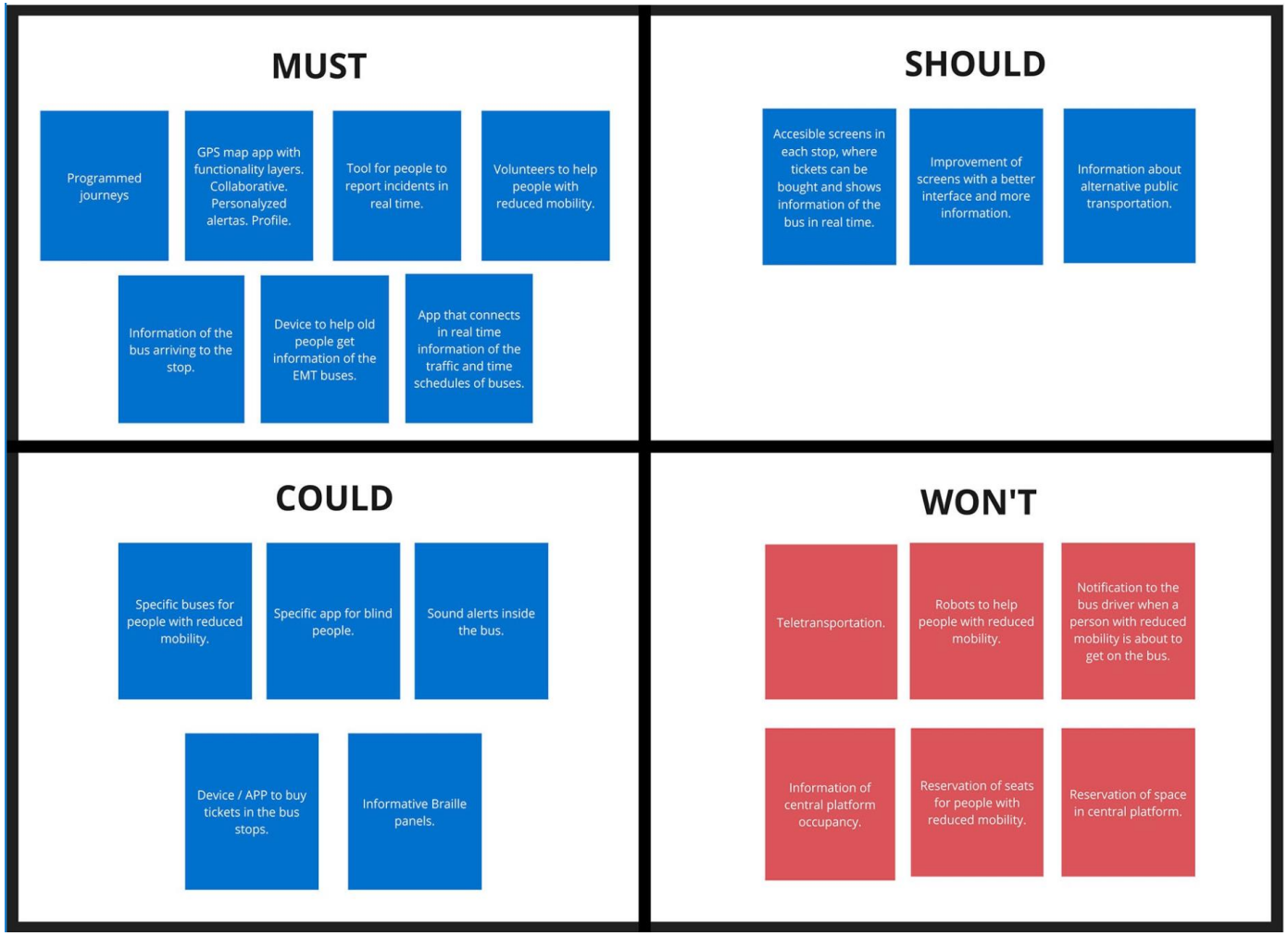
- Space
- Comfort
- Security
- Smooth flow o users

Insight:

We found that our users (based on our proto-persona Amalia) feel uncomfortable when standing inside the bus.

Data Creation & Collection

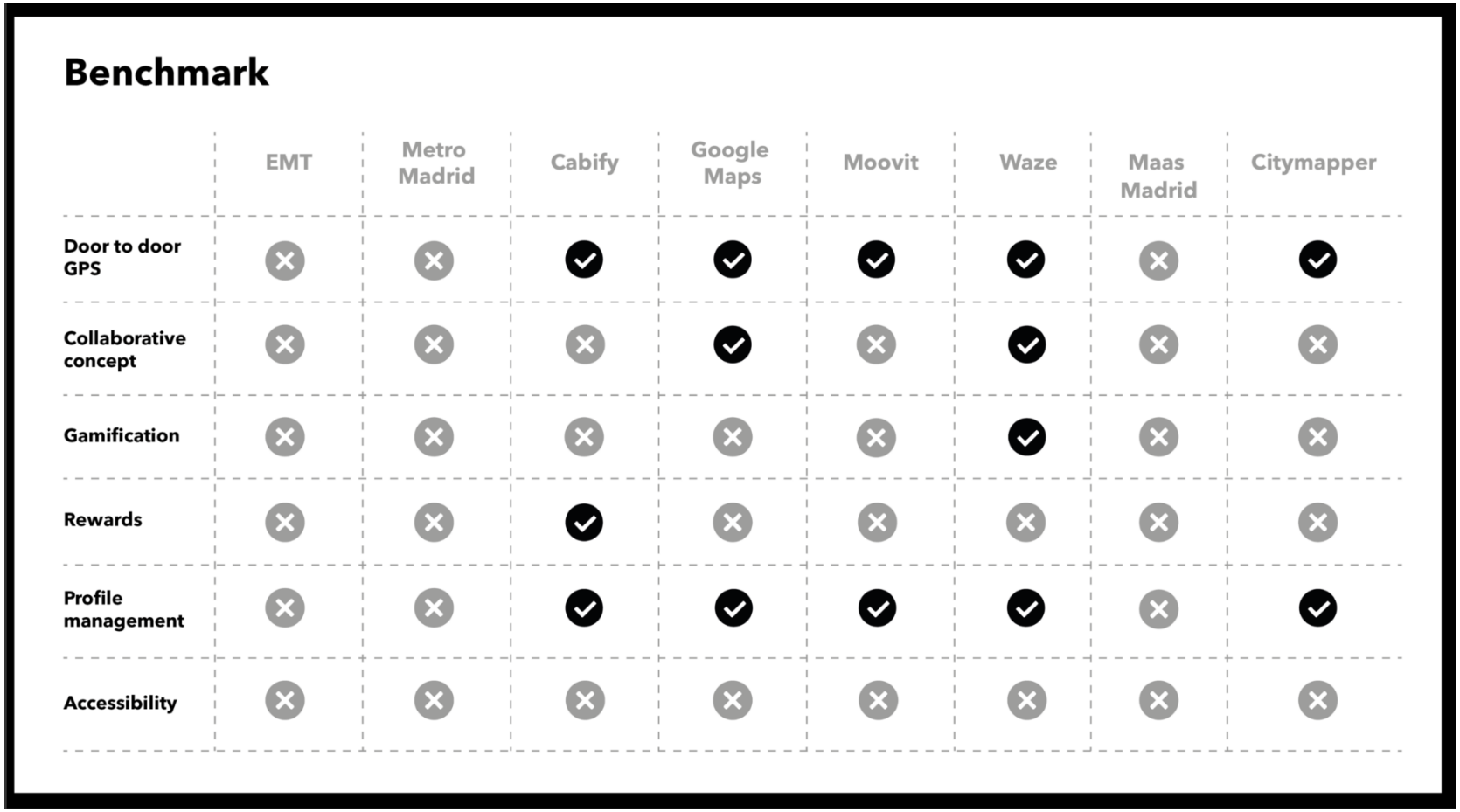
- **Phase 3: Brainstorm a lot of ideas but prototype on one**
  - Ideas divided according to priority:
    - MUST: crucial to solution
    - SHOULD: very important
    - COULD: could dismiss
    - WON'T: completely dismissed



Reference: Giménez, M. (2018, November 04). Double-diamond strategy for Madrid´s public citybus.

Data Creation & Collection

- **Phase 3: Brainstorm a lot of ideas but prototype on one**
  - Benchmarking

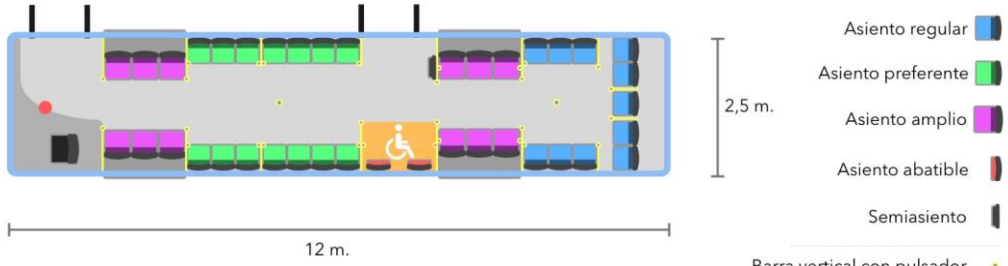


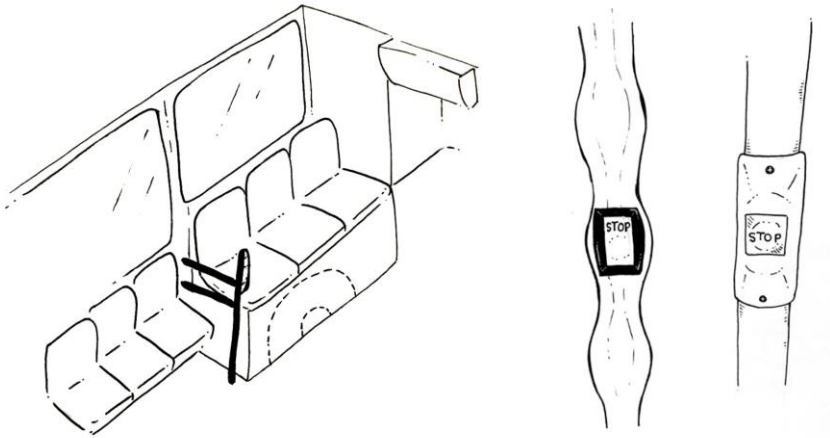
Reference: Giménez, M. (2018, November 04). Double-diamond strategy for Madrid´s public citybus.

Data Creation & Collection

- **Phase 3: Brainstorm a lot of ideas but prototype on one**

	COMFORT	MORE SEATS	MORE CAPACITY	SECURITY	VIABILITY
INFORMATIVE PANEL AT THE MARQUEE DISPLAYING INTERIOR INFORMATION OF THE BUS (CAPACITY, ...)	✗	✗	✗	✗	✓
SYSTEM THAT KEEPS ADEQUATE DISTANCE BETWEEN BUSES OF THE SAME LINE	✗	✗	✗	✗	✓
RESTRUCTURATE THE INSIDE OF THE BUS	✓	✓	✓	✓	✗
EASE THE PAYMENT METHOD	✗	✗	✗	✗	✓
DOUBLE-FLOOR BUS	✗	✓	✓	✗	✗



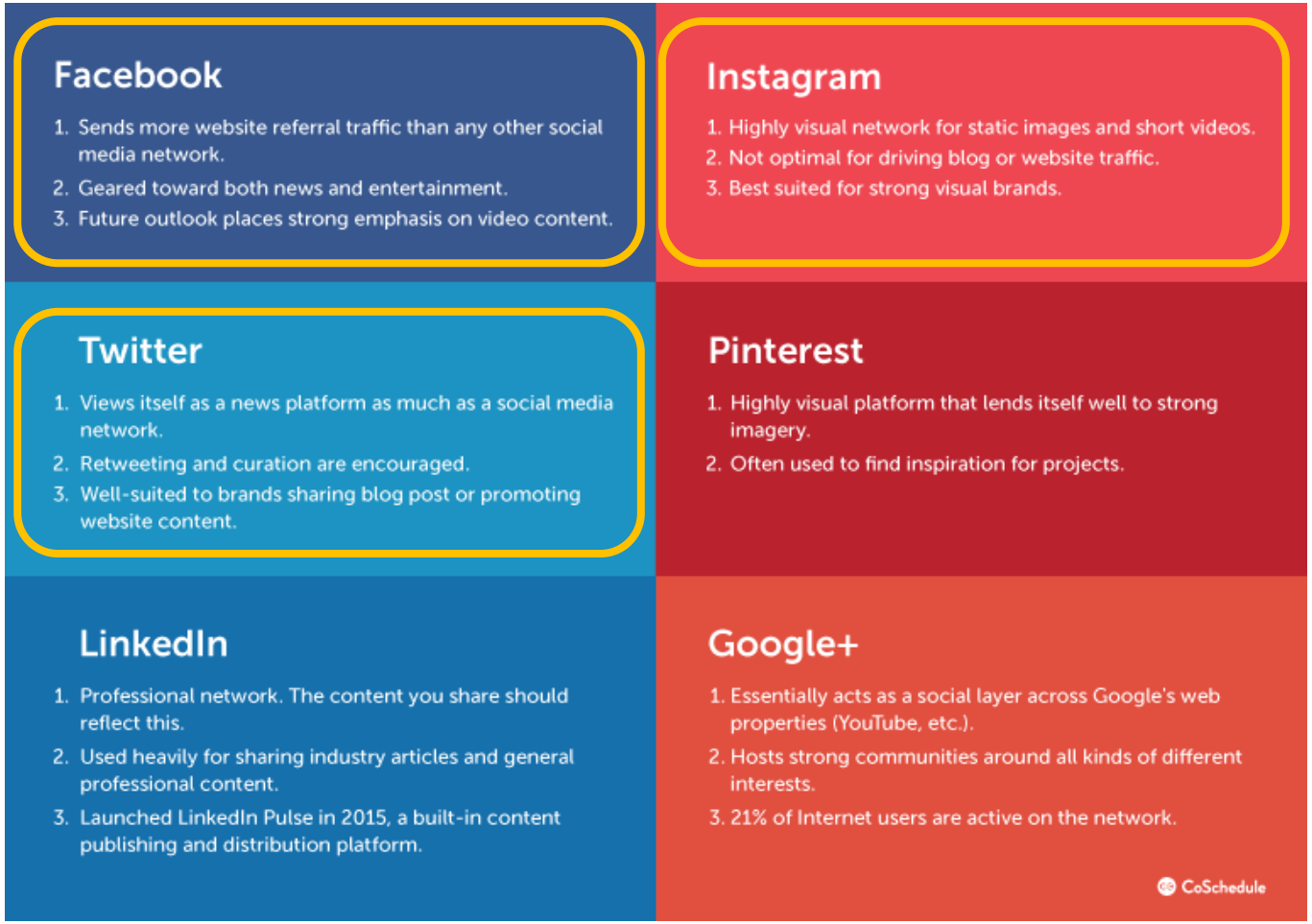


Solution:
Transmit a similar allocation experience of the metro on the bus

Reference: Giménez, M. (2018, November 04). Double-diamond strategy for Madrid´s public citybus.

Data Creation & Collection

Social Media Engagement



It is important to select the appropriate social media platform for the intended function. Based on the descriptions of the different social media platforms, Facebook and Twitter would be the most appropriate choices for the Shared Autonomous Vehicles. Instagram should also be considered though given the developing analytical applications in machine learning.

Reference: Sailer, B., & Sailer, B. (2017, July 26). How To Use Social Media Analytics To Create The Best Content.

Data Creation & Collection

Facebook Analytics

Post-Level Metrics	
Likes/ Reacts	Quick indication that the post resonated; people may not take time to comment; take not of other emotions expressed (humor, anger, sadness)
Comments	Positive comments indicate that the post hits the mark but take note as well of negative comments for possible improvement
Shares	Measure of virality; more shares generally reflects greater interest in content
Referral Traffic	Moving users from Facebook to the website helps get content read
Reach	Important metric used to determine how many people see the posts

Page-Level Metrics	
Page Views	Relates to exposure of service/ product
Engagement Rate	Calculated by weighing the number of people who like, comment on, or share posts against the total number of people seeing the content; the higher the number, the more interesting users find the content
Video Metrics	How long the videos posted are being viewed
Page Fan Growth	More fans means more people seeing the content, which in turn builds authority and even drives conversions
Conversions	Tells whether the messaging in the Facebook posts matches the messaging on destination pages (websites)

Reference: Sailer, B., & Sailer, B. (2017, July 26). How To Use Social Media Analytics To Create The Best Content.

Data Creation & Collection

Twitter Analytics

Post-Level Metrics	
Retweets	The more retweets, the more content spreads
Replies	Gauge of audience engagement
Referral traffic	Driving traffic back to blogs and websites
Tweets linking to you	Measures the number of people talking about your content and sharing your links on Twitter
Tweet likes	Measure of content appreciation; the more likes, the better
Tweet impressions	Getting content seen, not necessarily earning engagement

Page-Level Metrics	
Profile Visits	Indicates interest in the service/ product and what it's about
Follower Growth	Measure of people who find the content valuable

Reference: Sailer, B., & Sailer, B. (2017, July 26). How To Use Social Media Analytics To Create The Best Content.

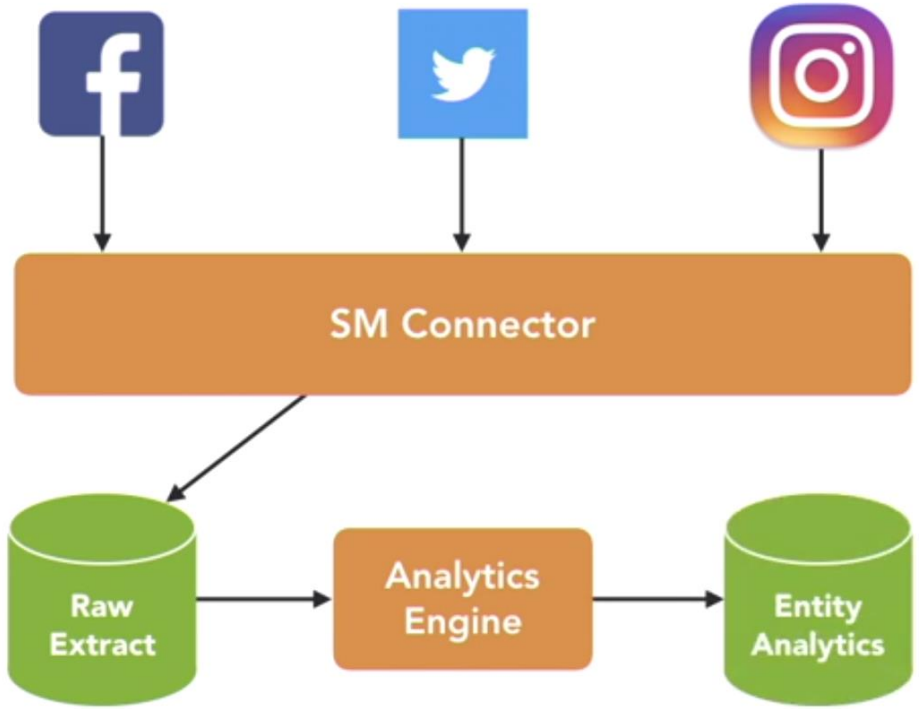
Data Creation & Collection

Social Media Analytics

Options:

- **Google Analytics** – free, powerful
- **In-App Analytics** – internal analytics
- **Cyfe** – for data aggregation/ building custom data dashboards
- **Simply Measured** – social media tasks

Social Media Connector



Store in **MongoDB** as nested JSON docs. MongoDB has good querying capability. JSON docs contain info on text, likes, links, and shares. Indexes are created by hashtags.

Cassandra can be used as database:

- Entities: users, hashtags, links, media
- By entity summaries
- Constant updates
- Sentiment analytics scores

References:

Ponnambalam, K. (2019, July 18). Lecture. Retrieved from https://www.lynda.com/Data-Science-tutorials/Complete-ecommerce-platform/647675/754828-4.html

Sailer, B., & Sailer, B. (2017, July 26). How To Use Social Media Analytics To Create The Best Content.

Data Creation & Collection

Behavioral and Psychological Metrics

Unprompted Verbal Expressions

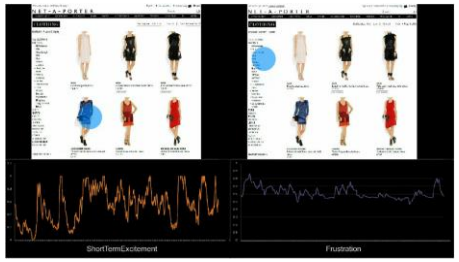
- Catalog all verbal expressions or comments and then categorize each one as positive, negative, or neutral
- Look at ratio of positive to negative comments
- Compare ratios across different design iterations
- If ratio has increased significantly with each design iteration, this would be one indication of an improved design
- Make good use of video recording – best note takers can take something important
- View comments within a larger context (negative comments but with positive comments on other aspect)

Eye Tracking

- Infrared video camera: infrared light sources create reflections on the surface of the participant's eye (corneal reflection) and the system compares the location of that reflection to the location of the participant's pupil
- Useful in a usability test: enabling observers to see where the participant is looking in real time is extremely valuable
- Most common way to analyze eye-tracking data is by measuring visual attention on specific elements or regions/ areas of interest (AOI)
- Other metrics:
    - Dwell time: total amount of time spent looking within an AOI; the greater the dwell time, the greater the level of interest in AOI
        - A dwell time greater than 500 msec generally means the participant had an opportunity to process the information
    - Number of fixations: total count of fixations with an AOI
    - Fixation duration: average time for fixations; measures relative engagement with object; typically ranges from 150 to 300mm
    - Sequence: order or sequence in which each AOI is first fixated; tells the researcher the relative prominence of each AOI within the context of a given task
    - Time to first fixation: how long it takes users to first notice a particular element
    - Revisits: number of times that the eye fixates within an AOI, leaves the AOI, and returns back to fixate within the AOI; indicate "stickiness" of the AOI
    - Hit ratio: percentage of participants who had at least one fixation within the AOI

Reference: Tullis, Tom, and Bill Albert. *Measuring the User Experience Collecting, Analyzing, and Presenting Usability Metrics*. 2nd ed. Amsterdam

Data Creation & Collection



Emotional Engagement

- **Facial expressions**
  - ThirdSight (Blue Bubble Lab): Emovision – application that allows the researcher to understand the participants' emotional state while pinpointing what they are looking at; uses a webcam to identify the facial expressions at any moment in time and then classifies it into one of seven unique emotions: neutral, happy, surprised, sad, scared, disgusted, and puzzled
  - Facial Action Coding System – includes 46 specific actions involving the facial muscles
  - Classified and associated with six basic emotions: happiness, surprise, sadness, afraid, disgust, anger
- **Skin conductance**
  - Measures level of arousal
  - Q sensor – device worn on the wrist that measures the electrical conductance of the skin known as electrodermal activity (EDA). EDA increases when you sweat – small increases in moisture are associated with increased sympathetic nervous system activity indicating emotional activation or arousal
  - Does not tell however researcher whether the experience that triggered an increased level of arousal was positive or negative
- **EEG**
  - Measures brain wave activity with unique signatures tied to specific emotional responses
  - combines electroencephalography and eye-tracking data
  - Seren uses an EEG device developed by Emotiv
  - EEG measures brain waves, specifically the amount of electrical activity on different parts of the participant's scalp. Electrical activity is associated with cognitive and emotional states.
  - Electroencephalography data are extremely useful in monitoring the emotional engagement of a participant throughout a session. Results can be used to prompt additional questions or to create "emotional heatmaps" that identify areas that led to a change of the emotional state.

Stress

- Heart rate variability: measures the time intervals between heart beats
- Having a certain level of variability in heart rate is healthier than not having any variability at all
- Smartphone apps (Azumio)/ mobile technology
  - User gently places finger over camera and software is able to detect heart rate and calculate HRV
  - HRV is calculated after about 2 minutes, and a stress score is calculated
- Skin conductance and heart rate were used to assess the stress level induced by the response times for web pages to load – there is evidence of physiological stress associated with longer response times
- Pilot technologies: Pressure Mouse, Posture Analysis Seat

Reference: Tullis, Tom, and Bill Albert. *Measuring the User Experience Collecting, Analyzing, and Presenting Usability Metrics*. 2nd ed. Amsterdam

Data Analysis

- **Via graphs**
  - Coding: R, Python, JavaScript
  - Applications: Tableau, Qlik, Excel
- **Exploration**
  - Single distribution
  - Joint distributions
  - Unusual cases
  - Errors in data
  - Missing data

DASHBOARD / REPORTS (OPTIONAL)

Key DATA

- Distance covered
- Energy use
- Passengers transported
- Avg. Speed
- Temperature (outdoor/indoor)

Monitoring tools

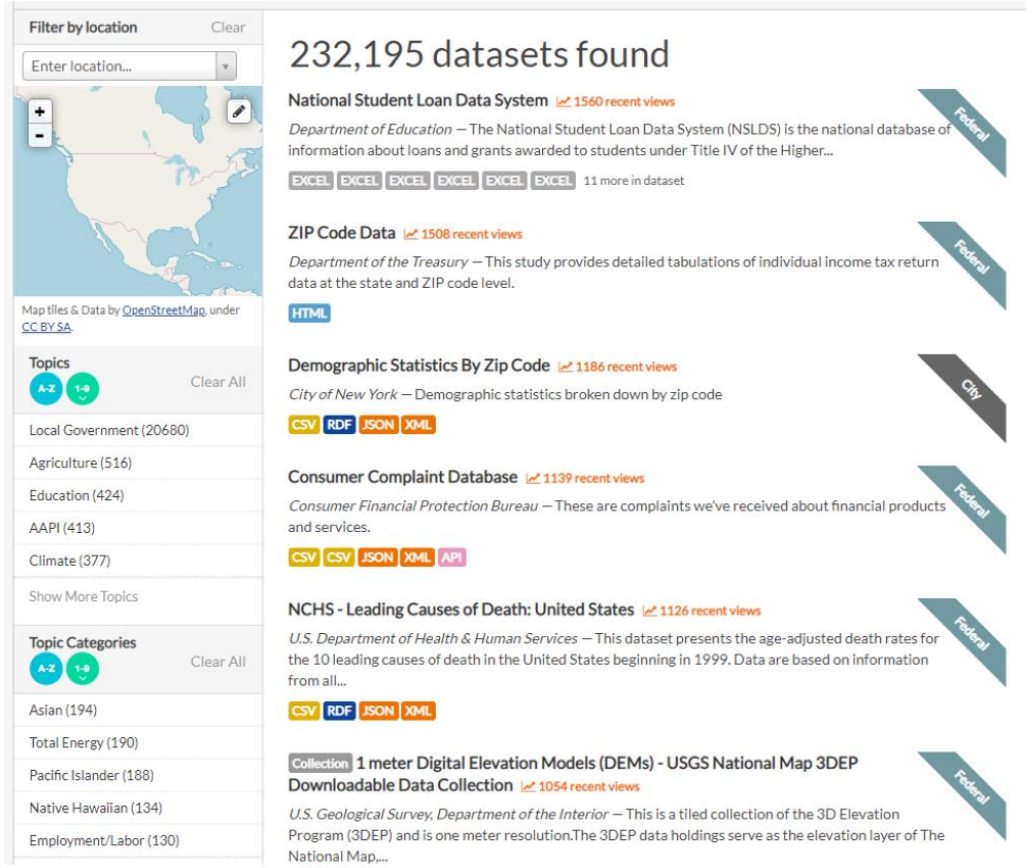
- Visualize: Graph or analytics
- Explore: All Fleet or vehicle
- Display : Daily, weekly,…

nauya

Reference: Data Governance Best Practices and Recommendations Report (Rep.). (2019).

Data Archiving

- The data set catalog may be as simple as a web page with a set of links to the data set. Information included are:
  - Data set description
  - Owner
  - Date of publication or activation
  - Access methods
  - File and data format
  - Data descriptions
- Data catalogs tend to post data in a standardized format, like GTFS, where data and file formats and data definitions are specified in an open, published standard.
- File formats:
  - CSV (comma separated values)
  - JSON
  - XML
  - Feature Services (OGIS format)
- A data dictionary including data formats may be a published interface document like NTCIP 1211 for Signal Control and Prioritization or GTFS

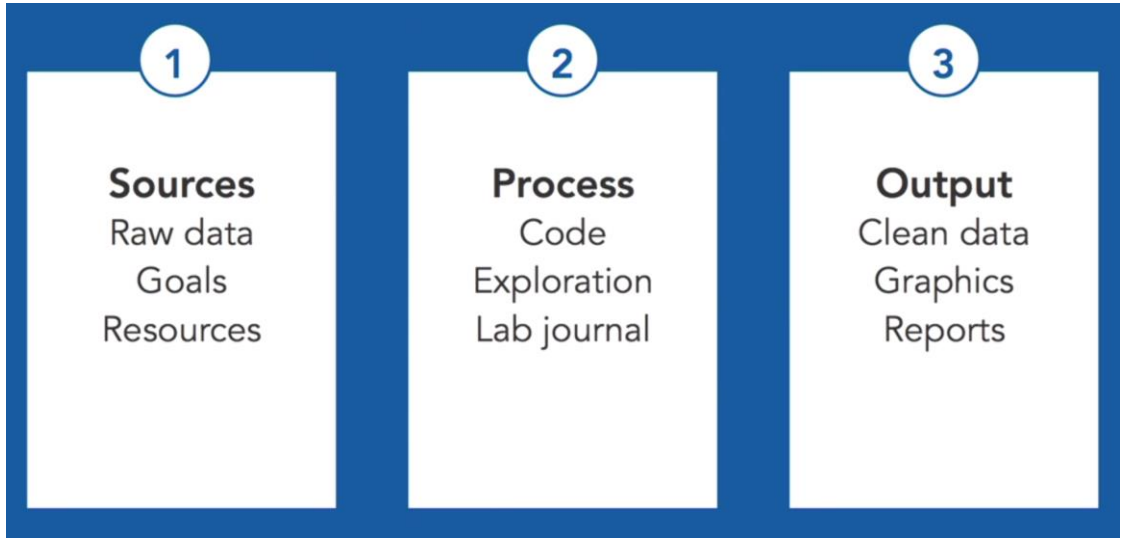


The Federal government has an online data catalog that is a simple list of data sets and their available formats.

Reference: Data Governance Best Practices and Recommendations Report (Rep.). (2019).

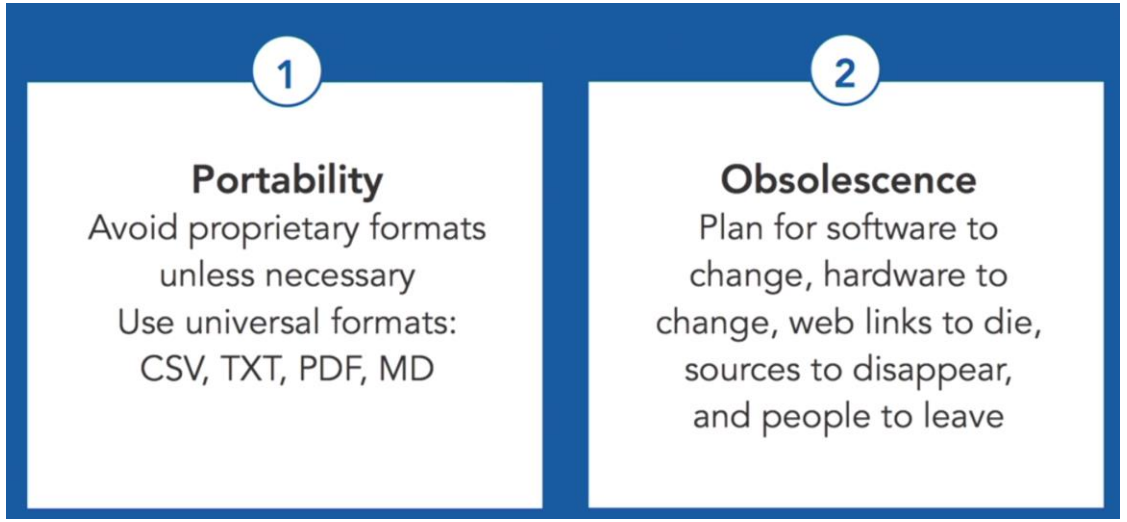
Data Archiving

Digital Trail:



Records

- Lab notebook with narrative
- Commented code
- Appropriately titled files and folders



Reference: Poulson, B. (2016, July 27)

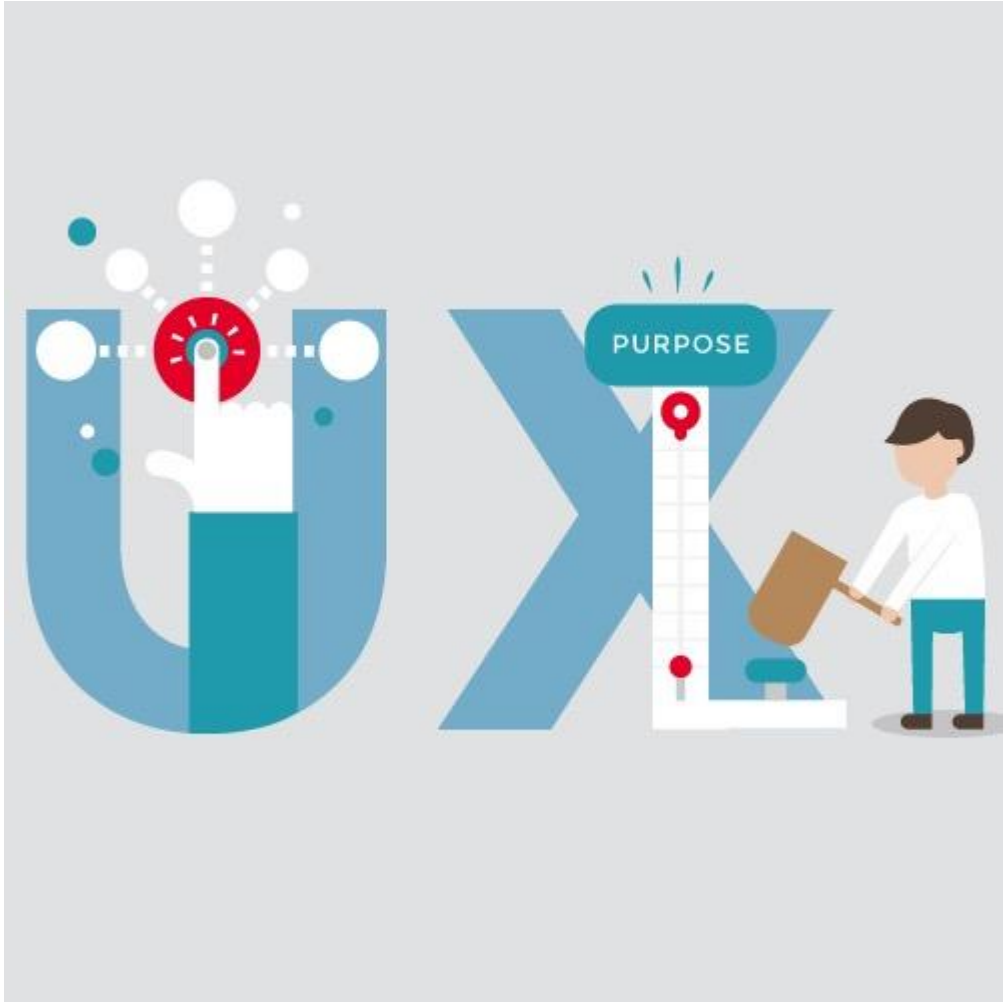
User Experience (UX) Metrics

User Experience Defined
Getting to
Waiting For
Riding On

4

User Experience Defined

- A user is involved
- That user is interacting with a product, system, or really anything with an interface
- The users' experience is of interest, and observable or measurable
- Usability: ability of the user to use the thing to carry out a task successfully; vs. user experience: looks at individual's entire interaction with the thing, as well as the thoughts, feelings, and perceptions that result from that interaction
- A UX metric reveals something about the interaction between the user and product:
    - Effectiveness: being able to complete a task
    - Efficiency: amount of effort required to complete the task
    - Satisfaction: degree to which the user was happy with his/ her experience while performing the task
- For the SAV project, uer experience is classified as follows: getting to, waiting for, and riding on.



Reference: Tullis, Tom, and Bill Albert. *Measuring the User Experience Collecting, Analyzing, and Presenting Usability Metrics*. 2nd ed. Amsterdam

Getting To

Best Practices	Measures	Alternative Data Collection Methods
Integrate AV shuttles into larger transit and pedestrian networks	Seamless transition between transit systems	GoogleMaps Platform (Distance Matrix API)
	Single payment card/ app	Open Data (DOT)
	Shared station stops for transit modes	
	Improved walkability per stop (1/2 to ¾ mile from stop)	
	Sidewalks	
	Safety/ comfort – trees, lighting, benches	Customer Safari
Expand “last mile” multi-modal access to and from AV shuttle stops	Multi-modal access	Open Data (DOT)
	Street’s average daily traffic count	
	Lane extension/ utilization	
	Bike/ slow/ local lane	
Increase safety and trust with more “eyes on the street” near shuttle stops	New technologies: sensors, call buttons	
	Culture of friendly, sociable interaction around AV system	
	Walkability per stop	Journey Map Walk-Score
	Green cover density within radius of stops	
	Gravity and reach to retail and dining	
	Housing units within depth N	

Waiting For

Best Practices	Measures	Alternative Data Collection Methods
Exceed user's expectations on providing them with safety, comfort, and respect	Shelter from sun and rain	
	Comfortable seating setback from street	Customer Safari Journey Map Survey
	Handicap/ stroller access	
	Real time information	
	360 view of surroundings – digital or physical	
	Budget for high levels maintenance and cleaning of shelters, emptying of trash	
	Crime prevention	Camera live feed
	Vehicle communication to bus stop	
Provide real-time information about the status of the system	Real-time information displays	
	Mobile application (OneBusAway)	
Design AV shuttle stops to celebrate the identity of both the AV shuttle system and each stop's local neighborhood	Visual/ audial means of providing bus stops w/ distinctive identity	

Waiting For

Best Practices	Measures	Alternative Data Collection Methods
Integrate activities and information into the bus stop to make it a community hub	Design shelter to accommodate diverse community gatherings	
	Community billboards for flyers	
	Parking for bikes, scooters, cars	
	Community engagement for new developments	
Enable waiting to become active time	Wifi connectivity (solar powered?)	
	Opportunities to learn about neighborhood	
	Community garden	
	Productive waiting time	
	Recharging stations	
	Additional furnishings	
	Wait time more playful for users – interactive play	
Support pop-ups and small businesses catering to bus stops	Zone of low regulation Multi-use arcade bus stop	
	Vehicle Availability	Ride Trends – Time, Location
	Published Schedules Availability	

Riding On

Best Practices	Measures	Alternative Data Collection Methods
Consider rider comfort	Ergonomics, comfort	Posture Analysis Seat Survey
	Accessibility, atmosphere, security	Survey/ Interview Customer Journey Map
	Lighting, hard seats, cleanliness	Customer Journey Map
	Creating the right scale	
	Safe to ride alone – easy to read facial expressions and body language	ThirdSight (Emovision)
	Clear and dynamic information	
	Vehicle care incentives	Survey/ Interview
Role of people on the shuttle	Docents and attendants	Social Media Engagement – real-time assessment of quality
	Preventing empty vehicles – minimum single rider	API: Number of Passengers
	External accountability	
	Social riding environments	
Create Equality	Free to access – remove financial barrier	
	Digital payment and access	
	Revenue from convenience (premium for preferential routing)	
	Revenue from specialization (specialize vehicle environment)	
	Minimum value of time (value of time aboard in vehicle)	

Riding On

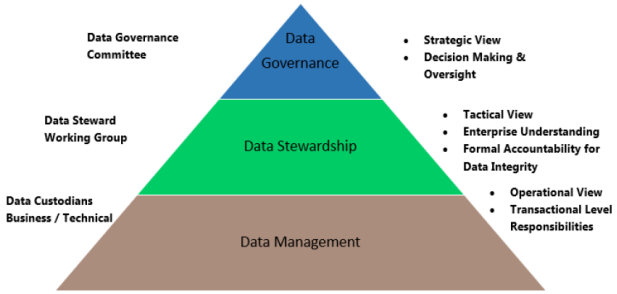
Best Practices	Measures	Alternative Data Collection Methods
Ride Efficiency/ Satisfaction	Ride Satisfaction	Social Media Analytics Survey Double Diamond Process Mobile App – star rating
	Repeat Transaction	Number of ride requests
	Security	
	Handicapped-friendliness	API: Ramp state
	Speed Reliability	Mileage Speed
	Breakdown Occurrence	API: Door state

5

Conclusion

Recommended Next Steps for Chamblee Resources

Recommended Next Steps for Chamblee



AV Partner Selection:

Define Data Governance Organization and Framework

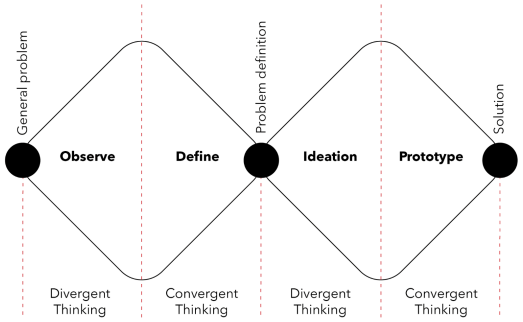
SAV Implementation:

Data Collection via APIs

Recollection of User Feedback via Survey/ Interview/ Social Media

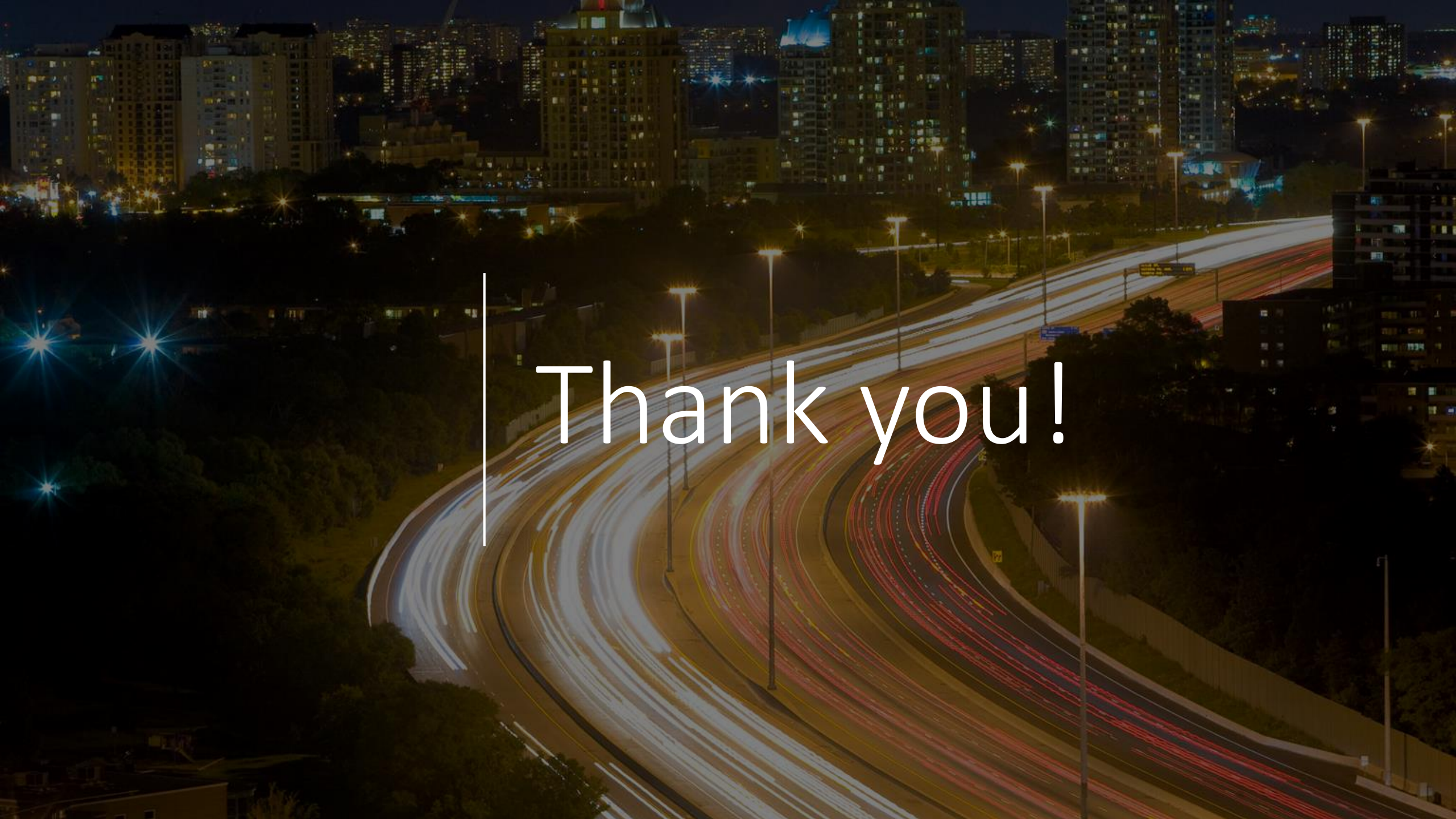
SAV Pilot:

Double Diamond Process



Resources

- Anderson, D. (n.d.). The 4 Most Important Customer Experience Metrics. Retrieved from https://www.iperceptions.com/blog/most-important-customer-experience-metrics
- *Data Governance Best Practices and Recommendations Report* (Rep.). (2019). ICF International.
- Demographics: Chamblee, GA - Official Website. (n.d.). Retrieved from https://www.chambleega.com/404/Demographics
- Giménez, M. (2018, November 04). Double-diamond strategy for Madrid´s public citybus. Retrieved from https://uxdesign.cc/double-diamond-strategy-for-madrid-s-public-citybus-e73b0a0374d8
- *Managing Mobility Data* (Rep.). (2019, April). Retrieved https://nacto.org/2019/05/30/managing-mobility-data/
- *Objective-Driven Data Sharing for Transit Agencies in Mobility Partnerships* (Rep.). (2019). Chicago, IL: Shared-Use Mobility Center. doi:https://learn.sharedusemobilitycenter.org/overview/white-paper-objective-driven-data-sharing-for-transit-agencies-in-mobility-partnerships/
- Ponnambalam, K. (2019, July 18). Lecture. Retrieved from https://www.lynda.com/Data-Science-tutorials/Complete-ecommerce-platform/647675/754828-4.html
- Poulson, B. (2016, July 27). Existing data. Retrieved from https://www.lynda.com/Big-Data-tutorials/Existing-data/420305/505120-4.html
- Poulson, B. (2016, July 27). Reproducible research. Retrieved from https://www.lynda.com/Big-Data-tutorials/Reproducible-research/420305/505160-4.html?autoplay=true
- Poulson, B. (2018, April 02). Predictive modeling of public opinion. Retrieved from https://www.lynda.com/Data-Science-tutorials/Predictive-modeling-public-opinion/630612/687402-4.html
- Sailer, B., & Sailer, B. (2017, July 26). How To Use Social Media Analytics To Create The Best Content. Retrieved from https://coschedule.com/blog/social-media-analytics/
- Tullis, Tom, and Bill Albert. *Measuring the User Experience Collecting, Analyzing, and Presenting Usability Metrics*. 2nd ed. Amsterdam, Netherlands: Elsevier, 2013. Interactive Technologies. Web.


Thank you!