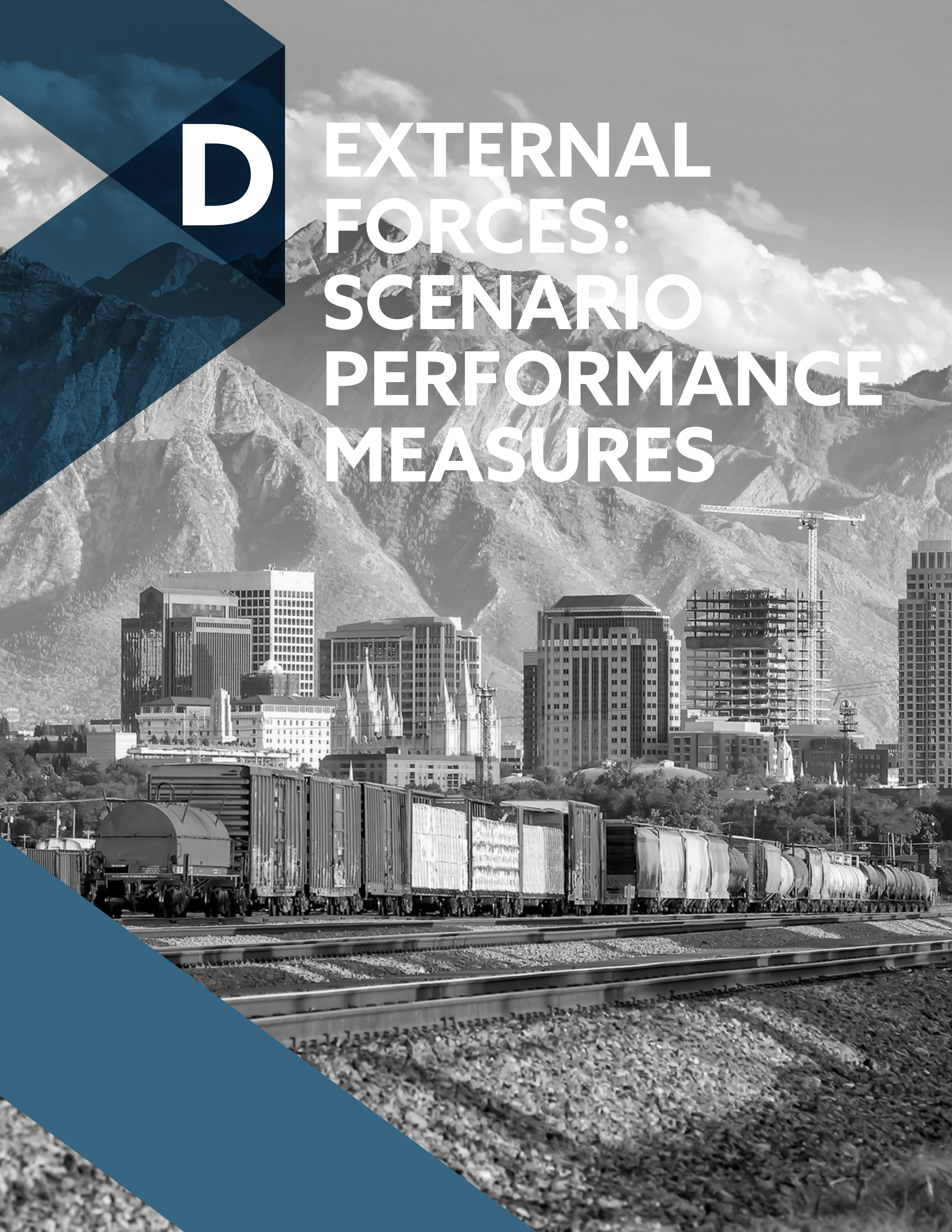
D EXTERNAL FORCES: SCENARIO PERFORMANCE MEASURES



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LIST OF ABBREVIATIONS

AV	Autonomous Vehicles
CAV	Connected and Autonomous Vehicles
CV	Connected Vehicles
E-bikes	Electric Assisted Bikes
E-commerce	Electronic Commerce
E-living	Electronic Living
E-scooter	Electric Scooters
MAG	Mountainland Association of Governments
MPO	Metropolitan Planning Organization
RTP	Regional Transportation Plan
SOV	Single Occupancy Vehicle
TDM	Travel Demand Model
TNC	Transportation Network Company
TSC	Traffic Signal Coordination
TSP	Transit Signal Priority
UDOT	Utah Department of Transportation
UTA	Utah Transit Authority
VMT	Vehicle Miles Traveled
WFRC	Wasatch Front Regional Council

INTRODUCTION

Throughout the 2023-2050 Regional Transportation Plan (RTP) development process, the Wasatch Front Regional Council (WFRC) has been focusing on exploring and understanding external forces - transportation technologies and shifts in market and consumer demand that may impact transportation, land use, and economic development decisions. The intent of this approach is to elevate the discussion of these planning uncertainties and understand these changes statewide, regionally, and locally. Overall, this is a starting point for local communities, transportation agencies, and other stakeholders to come together to discuss how the Region should move forward, address future uncertainty, and become more resilient in the face of change.

Initial research and literature reviews focused on 11 external forces: connected and autonomous vehicles (CAV), e-bike adoption, electric vehicle adoption, freight disruptions, high-tech transit systems, internet shopping, inter-regional high-speed transit, new micromobility adoption, on-demand travel and sharing services, passenger drone and drone taxis, and telecommuting. This list was refined into six forces through discussions with staff from local governments, transportation and state agencies, and businesses whose work is directly tied to, or may be heavily influenced by, the identified forces. More discussion on the process and forces can be found in a revised external forces guidebook.

Table 1. External Forces Included in Scenarios

CONNECTED AND AUTONOMOUS VEHICLES	**HIGH-TECH TRANSIT SYSTEMS**	**MICROMOBILITY AND E-BIKES**	**ON-DEMAND TRAVEL AND SHARING SERVICES**	**E-COMMERCE AND DELIVERY**	**TELECOMMUTING**
Autonomous vehicles (AV) are capable of driving without human intervention. Connected vehicles (CV) communicate with other vehicles, infrastructure, and other road users via wireless technology.	High-tech transit systems utilize technology within their fleet, such as Transit Signal Priority (TSP), Traffic Signal Coordination (TSC), and connected and autonomous shuttles and buses.	Lightweight devices that are typically used for shorter-distance transport. Can include standard bicycles, electric assisted bicycles (e-bikes), electric scooters (e-scooters), and other mobility devices that have improved electric motor technology.	Mobile applications that enable users to call/secure individual and shared transportation services. Often called Transportation Network Companies (TNCs). **Was not included in scenario technical analysis.*	A series of changes that are occurring in how people purchase goods and how those goods are delivered. These include, but are not limited to, internet shopping, food delivery, truck automation and platooning, and last-mile delivery logistics, including the use of drones.	A work arrangement in which an employee works outside the office, often working from home or a remote location.

The official Wasatch Front Travel Demand Model (TDM) version 8.3.1 was used for this work, and the "base scenario" was run without modification to serve as a comparison to the modified forces scenario tests. For each force, the TDM was modified to account for how the forces and policies would change travel behavior and demand. A low, medium, and high rate of implementation was developed for each force, as shown in Table 2. WFRC tested the impact on the transportation system from five forces, both individually and together in three scenarios. Model modifications and outcomes for individual forces can be found in a technical assumptions memo.

Table 2. 2050 External Forces Implementation Range Summary

EXTERNAL FORCE	BASE SCENARIO	LOW IMPLEMENTATION	MEDIUM IMPLEMENTATION	HIGH IMPLEMENTATION
Connected and Autonomous Vehicles	0%	15% of Level 3/Level 4 Automation for all new vehicle sales; 60% of all roads have CV roadside units	25% of Level 3/Level 4 Automation for all new vehicle sales; 80% of all roads have CV roadside units	50% of Level 3/Level 4 Automation for all new vehicle sales; 100% of all roads have CV roadside units
High-Tech Transit Systems	0% of technology in the system	20% of technology in the system	55% of technology in the system	85% of technology in the system
Micromobility and E-Bikes	3% of trips under three miles are by bicycle	8% of trips under three miles are by micromobility	20% of trips under three miles are by micromobility	40% of trips under three miles are by micromobility
E-Commerce and Delivery	Minimal	25% of total retail sales	45% of total retail sales	65% of total retail sales
Telecommuting[2]	5% of regional jobs telecommute	15% of regional jobs telecommute	20% of regional jobs telecommute	25% of regional jobs telecommute

WFRC tested three scenarios that combined all five forces while placing emphasis on a key characteristic of the future - automation, shared mobility, and e-living. In addition, WFRC tested a plausible external forces scenario based on conversations with and surveys of elected officials and the External Forces Peer Group about the reasonability of implementation. Table 3 shows the four scenarios and the level of implementation for each external force.

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[1]As the designated Metropolitan Planning Organization (MPO) for Davis, Salt Lake, Weber, and southern Box Elder Counties, WFRC is responsible for coordinating the Wasatch Choice Vision and the RTP planning process, which is updated and adopted every four years. The RTP informs, and is the transportation element of, the Wasatch Choice Vision. Several partners are involved in the development of the RTP and the Vision, including the Mountainland Association of Governments (MAG), the Utah Department of Transportation (UDOT), the Utah Transit Authority (UTA), and county and city governments, along with other agencies, stakeholders, and the public.The exploration of external forces will inform the 2023 Unified Transportation Plan in addition to being addressed in WFRC's RTP planning process.

[2] Telecommuting includes both office-based jobs that are at least partially remote and home-based jobs.

Table 3. External Forces Scenarios Summary

EXTERNAL FORCE	BASE SCENARIO	SCENARIO 1 HIGH AUTOMATION	SCENARIO 2 HIGH SHARED MOBILITY	SCENARIO 3 HIGH E-LIVING	PLAUSIBLE EXTERNAL FORCES SCENARIO
Connected and Autonomous Vehicles	⊘	H	M	L	L/M
High-Tech Transit Systems	⊘	H	M	L	M
Micromobility and E-Bikes	VL	M	H	L	L
E-Commerce and Delivery	⊘	L	M	H	M
Telecommuting	VL	L	M	H	L

The purpose of this Scenario Performance Measures Memo is to summarize the impact of how combining the external forces might affect our transportation system. Each scenario was assessed under a variety of performance measures, both quantitative and qualitative, as shown in Table 4.

Table 4. Scenario Performance Measures

GOAL	MEASURE	EXPLANATION
Livable and healthy communities	**Livable neighborhoods**	Qualitative assessment of the ability of neighborhoods to meet our daily needs
Access to economic and educational opportunities	**Access to opportunities**	Number of jobs and households that are accessible within a typical commute
Manageable and reliable traffic conditions	**Freight delay**	Total truck delay per day
	Vehicle hours of travel	Total time per day that the average person spends in a vehicle
Quality transportation choices	**Walk and bike trips**	The number of trips per day taken by foot or bike
	Transit trips	The number of trips per day taken by transit
	Drive alone to work trips	The number of trips per day that residents travel to work in single-occupant vehicles
Safe, user-friendly streets	**Safety**	Qualitative assessment of impacts to safety
Clean air	**Vehicle miles of travel**	Vehicle miles of travel, regional total
Housing choices and affordable living expenses	**Equity and affordability**	Qualitative assessment of impacts to equity and Equity Focus Areas
Fiscally responsible communities and infrastructure	**Community resiliency**	Qualitative assessment of the ability for communities to respond to changes in travel behavior

Table 5 shows a summary of the qualitative results of the performance measures. The results are indicating the differences based on each of the scenarios as well as the most likely, or plausible external force scenario.

All measures have a higher access to opportunities (ATO) for both auto and transit than the 2050 Base Scenario. The auto and transit ratio is the number of jobs an individual can access by car to the number of jobs an individual can access by transit. All scenarios result in a lower ratio, which indicates less of an imbalance for transit.

Freight delay stays the same for High E-Living (Scenario 3) as this has higher levels of e-commerce as compared to the Base Scenario but is significantly lower when compared to the High Automation (Scenario 1) and High Shared Mobility (Scenario 2). Vehicle hours of travel (VHT) helps estimate the hours of travel in the region, and the results indicate that in all scenarios this goes down, particularly in High Shared Mobility (Scenario 2).

Walking and biking trips increase in all scenarios, but the transit trips are a mix, with the High Shared Mobility (Scenario 2) resulting in a smaller share, likely because of the high levels of micromobility trips replacing transit trips. The number of trips where individuals drive alone decreases in all scenarios, meaning less trips are reliant on single occupancy vehicles. The total vehicle miles of travel is the mileage of travel for cars across the region per day. In High Automation (Scenario 1) this number increases with more connected and autonomous vehicles contributing to more people living further distances, but with the two other scenarios, this number decreases when compared to the 2050 Base Scenario.

For more details about the measures and the explanation that can describe the results for each scenario, please refer to the sections found below.

Table 5. Scenario Forecasting Results Summary

MEASURE	BASE SCENARIO	**SCENARIO 1** HIGH AUTOMATION	**SCENARIO 2** HIGH SHARED MOBILITY	**SCENARIO 3** HIGH E-LIVING	**PLAUSIBLE EXTERNAL FORCES SCENARIO**
Access to opportunities (auto)	242,000	272,000	269,000	255,000	256,000
Access to opportunities (transit)	15,600	18,700	18,200	17,300	18,000
Auto:transit ratio	15.5	14.6	14.8	14.8	14.2
Freight delay (hours)	33,000	26,500	26,900	33,000	31,800
Vehicle hours of travel	1,629,000	1,572,000	1,485,000	1,575,000	1,610,000
Walk and bike trips (mode split)	1,481,000 (10.5%)	2,585,000 (19.0%)	4,048,000 (30.1%)	1,749,000 (13.2%)	1,783,000 (13.1%)
Transit trips (mode split)	341,000 (2.4%)	272,000 (2.0%)	216,000 (1.6%)	282,000 (2.1%)	304,000 (2.2%)
Drive alone to work trips (commute mode split)	12,250,000 (87.1%)	10,776,000 (79.0%)	9,181,000 (68.3%)	11,226,000 (84.7%)	11,546,000 (84.7%)
Vehicle miles of travel	60,136,000	62,269,000	58,857,000	59,911,000	61,413,000

HIGH AUTOMATION SCENARIO

This scenario explores the impacts of robust adoption of connected and autonomous vehicles and high-tech transit systems. It assumes high levels of implementation of AV/CAV and high-tech transit, low levels of implementation of telecommuting and e-commerce, and medium levels of implementation of micromobility options.

Force Implementation

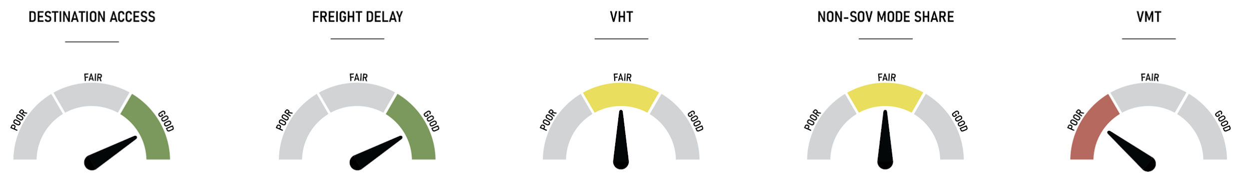
CONNECTED AND AUTONOMOUS VEHICLES	H
HIGH-TECH TRANSIT SYSTEMS	H
MICROMOBILITY AND E-BIKES	M
E-COMMERCE AND DELIVERY	L
TELECOMMUTING	L

SCENARIO PERFORMANCE

High implementation of autonomous vehicles increased roadway capacity on limited-access facilities. This increased efficiency led to a reduction in travel time, even though vehicle miles of travel increased. The overall number of auto trips decreased by 12 percent in this scenario, but the average trip length increased with higher implementation of autonomous vehicles. Higher travel speeds led to increased access to opportunities - over 12 percent for auto access and almost 20 percent for transit access. This was the highest access-to-opportunities gained across the three forces scenarios.

Overall non-auto mode split increased over 60 percent from the base scenario. This was due to an increase in the number of trips less than three miles taken by micromobility. Despite high levels of high-tech transit implementation, the total number of transit trips decreased by almost 70,000 trips, or 20 percent from the base scenario.

High Automation Scenario Compared to the 2050 Base



LIVABLE NEIGHBORHOODS

These technologies are expected to hold a potential for reduced pollution in urban areas along with a certain degree of change in the appearance and allocation of space across the built environment. By optimizing on-road behavior across trips, CAVs may prove helpful in trimming away excessive emissions and power usage which result from the typical stop-and-go driving patterns, idling, and sub-optimal driving speeds of drivers in congested urban areas. Additionally, the majority CAVs are expected to transition away from fossil fuel technologies towards low or no-emission vehicles, further eating away at the impact of vehicles on the urban environment. Through efficient CAV route finding, inter-vehicular coordination, and communication with infrastructure and policy, cities may find a greater control in their levels of noise pollution, driving speeds, and the degree to which traffic bleeds off major arterials during peak congestion times, creating more comfortable and predictable traffic dynamics for all travelers and community residents. Even a modest uptick in vehicle automation across a region may prove sufficient to nudge driving behavior towards slower travel speeds and routing towards more sensitive areas, such as residential neighborhoods (Riggs 2020).

CAVs may also change the distribution and allocation of space across communities (as explored further below), which opens up opportunities for cities to use this recaptured land to improve right of way opportunities for other travel modes, create space for public and private redevelopment and reuse, and for the provision of things such as affordable housing. With a reshaping of street and curbside patterns, comes a reshaping of usage and a near limitless potential for the reimagining of streetlife and neighborhood livability. That said, the benefits of optimization will likely find their upper limit and CAVs will likely exhibit many of the same challenges associated with single-occupant vehicles (SOVs). Finally, the results of the TDM indicate a higher opportunity for choice in terms of living and working, especially when accounting for the costs of distance in travel, which may come at the expense of more localized community placemaking goals, as populations adjust their willingness to travel farther between home, work, and other activities.

SAFE, USER-FRIENDLY STREETS

The increasing role of automation in transportation systems has wide implications for safe and user-friendly streets. There are many many potential benefits of connected vehicle and transit technology, including the potential for reducing crashes. Likewise, the main safety benefit of autonomous vehicle systems is the potential for reducing human operating error. Full automation would help to minimize the risks created by human errors and could hold long-term benefits for pedestrians and cyclists as it would reduce the potential for dangerous interactions between all travelers and design of the transportation system. One caveat here is the expectation that such benefits will not be experienced until CAVs fully encompass the market and the transportation system experiences an all-autonomous condition. Until then, tangible outcomes for improved safety are expected to be murky at best.

However, one of the most commonly predicted negative effects of CAVs is on cyclist and pedestrian safety especially during the transitional period where technology may not be able to accurately detect pedestrian and cyclist movements. This is a safety concern, especially when vehicles are being tested more frequently on public streets. This could create further transportation mode separation and put additional constraints on pedestrian and bike travel, the opposite of the goal of creating safe, user-friendly streets. Just like today, if priority movement is given to vehicles, whether connected and autonomous or not, over other road users, streets will only be safe and user-friendly for those in vehicles.

Additionally, the adoption of new technologies is often accompanied by growing pains and fruitful trials by error. But when considering the health and safety of CAV users themselves, there remain questions which communities should grapple with as far ahead of implementation as possible, rather than struggling with their results in hindsight. Communities will benefit from working together to get ahead of the curve by gauging the issues surrounding the safety of minors and other users within autonomous systems in the context of shared mobility, their strategies to assist the elderly and those affected by a range of health issues during emergencies and normal operations, and a range of other risks as soon as possible. Utah has made some small steps towards regulating the CAV ecosystem, with the passing of House Bill 31 in 2021, but there remains much to be considered as CAV technologies increasingly weave themselves through the regulatory framework and into everyday life. As of yet there remains no federal regulatory framework for autonomous vehicles, only guidance. Therefore, while states and communities may look upwards for next steps, internal work must be undertaken in order to codify the environment surrounding these new technologies until a deeper federal framework is ratified.

EQUITY + AFFORDABILITY

Without policy intervention, CAVs are likely to generate equity concerns, primarily centered around inclusion and affordability. While they may offer substantial benefits to disadvantaged individuals and society at large, policymakers must critically evaluate these assumptions when setting investments and priorities that generate high degrees of inertia.

CAVs possess a special capability to restore the personal mobility of aging and transportation disadvantaged individuals. In today's transportation system, disabled people and the increasing share of aging adults who are unable to drive are often left with few transportation options. As suburban populations age in place, greater numbers of aging adults will live in areas with limited possibilities for public transit service and poor bicycle and pedestrian infrastructure. Along with this comes a significant deterioration in quality of life and health, leading to higher rates of depression, isolation, and mortality. Even limited automation affords these aging drivers the chance to remain behind the wheel longer by reducing the risk of crashing, improving their independence and quality of life well into the future in the context of an auto-dominated urban environment.

With CAV technology comes the hope of reduced individual costs, especially in a context of shared mobility. While the true outcomes remain to be seen, as CAVs emerge at scale, the costs per passenger are expected to drop relatively quickly as these technologies become more ubiquitous in filling the roles of shared mobility currently provided by TNCs, traditional taxi companies, and even transit services. This is primarily evidenced as a result of the expected optimized routings, interim travel, and the cost savings associated with a lack of driver wages. Unfortunately, these benefits remain conjectural, with cost savings that may

exist only on a relative rather than equitable scale to each user and an optimization of routing and travel patterns which may be reliant on coinciding investments in data infrastructure.
Communities and policymakers would do well to initiate the development of localized frameworks to help them evaluate their own versions of equity and affordability, especially in the context of a high automation and shared mobility scenario. Adopting measures from the Spatial, Temporal, Economic, Physiological, and Social (STEPS) barrier evaluation methodology retooled from transit accessibility may be a recommended first approach, but localities would benefit from critical self-evaluation and local engagement in order to paint the best picture of autonomy in their community.

COMMUNITY INFRASTRUCTURE

AVs also promise to influence the design of cities, and vice-versa. A willingness of some commuters to travel further, for example, could encourage sprawl and reinforce trends of auto-oriented development, and in the process increasing energy consumption and income-based segregation. Design choices planners make with regard to the allocation of street space, meanwhile, will ultimately govern interactions between different modes. AVs also potentially require less space than their human-operated counterparts, reducing the need for parking as a result of a shared-travel-induced reduction in car trips and a redistribution of vehicles elsewhere to park themselves. This would liberate land currently occupied by parking lots and structures for alternative uses. Further, they may drive a trend of narrowing lane widths, right of way recaptures, and road dieting. But these outcomes—positive and negative—remain conjectural.

Much like TNCs, CAVs may exhibit significant impacts on public transit systems, albeit to a greater degree. CAVs may supplant transit agencies by eating up transportation market shares or, alternatively, support routes by providing important first and last mile options for travelers into spaces where transit cannot operate or shifting scarce resources away from low-performing routes. Additionally, the integration of these vehicles into transit fleets could play heavily in reducing operating costs and the impact of staffing shortages (a significant cost incurred by agencies), increasing the operating capacity for the agency across its service region.

As essential players in determining the direction of CAV shocks, cities hold key regulatory powers, such as managing most of the public right-of-way and articulating land-use policy, and can make CAV technology work to community benefit. Recently cities have begun to leverage their policy making capacities in order to adjust for the influx of these new technologies. For example, last year, Chandler, Ariz., became one of the first U.S. cities to rewrite its zoning code to facilitate the future of autonomous vehicles. Developers may now qualify to build less parking — a major cost saving — if they provide curbside passenger loading zones with benches and trees for shade, creating space to replace parking lots with more attractive options, such as open space and parks.

With implementation comes a broader set of impacts to consider. Often, governments are to a degree reliant on parking tickets, speeding fines, vehicle registration, and fuel taxes as funding sources, and could lose revenues, challenging cities to find alternatives. Making plans to account for this loss should be integrated into the planning and policy process as autonomous technologies expand across communities.

HIGH SHARED MOBILITY SCENARIO

This scenario imagines the impacts of high use of shared mobility options such as micromobility and on demand and ridesharing services. It assumes high levels of implementation of micromobility such as e-bikes, and medium levels of implementation of all other forces.

Force Implementation

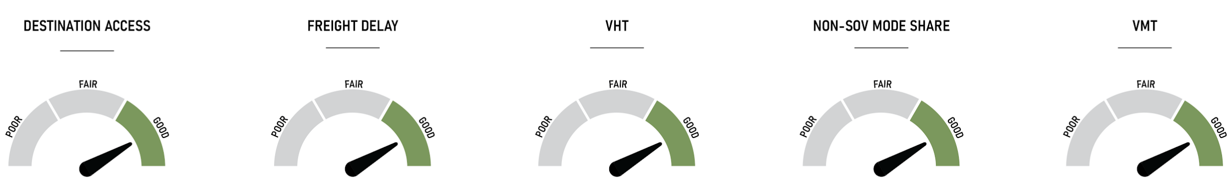
CONNECTED AND AUTONOMOUS VEHICLES	M
HIGH-TECH TRANSIT SYSTEMS	M
MICROMOBILITY AND E-BIKES	H
E-COMMERCE AND DELIVERY	M
TELECOMMUTING	M

SCENARIO PERFORMANCE

High implementation of shared mobility, including micromobility and e-bikes, led to a very significant increase in walk and bike trips, which led to both a significant decrease in single-occupant commutes and reduced transit use. In this scenario, the walk and bike mode split increased from 10.5 percent in the base scenario to 30.1 percent, while single-occupant commute mode split decreased from 87.1 percent in the base scenario to 68.3 percent.

The increased use of active transportation also resulted in reduced vehicle miles traveled by two percent, reduced vehicle hours of travel by nine percent, and reduced freight delay by 18 percent.

Scenario Compared to the 2050 Base



LIVABLE + HEALTHY COMMUNITIES

Transportation is one of the most underappreciated but significant determinants of health and well-being for communities. With the advent of shared and micromobility, cities have been offered a chance to address long-standing public health transportation issues that affect health equity within their communities at large, especially within the US where historical sprawl has been broadly correlated with a multitude of significant health issues. By offering the chance for residents to engage in a more diverse array of travel options, these new mobilities provide benefits that have been previously relegated to traditional forms of active transportation, such as biking and walking.

Residents now have new and potentially more inclusive means of transportation that are shown to help improve their physical mobility and cardiovascular health, reduce anxiety and depression, and benefit a host of other key health metrics via the use of electrical assistance and shared fleets. Electric assisted mobility especially offers elderly and differently abled residents the opportunity to participate in active transportation within their communities, opening up a new range of physical, social, and economic opportunities that they otherwise may have been excluded from due to physical limitations. The availability of such options may also persuade other users, who would have otherwise chosen a different mode of travel, to enjoy these considerable benefits.

Moving beyond individual health, in the scenario run within the TDM under the assumption of high levels of micromobility implementation, there was a projected increase in destination accessibility and share of trips made without SOVs. Such results allow broad conclusions about which benefits communities would experience. Reduced congestion as a result of personal auto trips, an increased diversity of lifestyle choice, and a more dynamic urban fabric are just some of the benefits communities could enjoy when electricity reduces distances and shared fleets provide near instant transport options. This is especially evident during times where shared mobility offers opportunities for travel outside of standard transit service hours, especially weekends and evenings or within low-service areas. Because ridesharing reduces the number of automobiles needed by travelers, it provides communities with even broader benefits, including reductions in energy consumption and emissions, congestion mitigation, and reduced parking infrastructure demand.

Areas with a high density of shared mobility service, especially micromobility, may also create a more welcoming environment for visitors. Micromobility services provide the ability for a city’s transport system to catch newcomers who do not yet know how to navigate the intricacies of its transit networks or dense downtown environments. In providing a rapid response mobility option which affords exploration and flexible routing, visitors have the ability to more deeply interact with their new environment, allowing spontaneous visits to the businesses, amenities, and other destinations across the city. As shared mobility expands across urban regions, more benefits are likely to reveal themselves.

SAFE, USER FRIENDLY STREETS

Despite low travel speeds, there are a few critical safety implications surrounding high shared mobility and micromobility implementation, specifically surrounding their use on streets where pedestrians, active travelers, and automobiles all interact and share space. For example, a tracker of e-scooter fatalities, maintained by the University of North Carolina's Highway Safety Research Center, shows that 20 of the 24 e-scooter fatalities in the United States involved motor vehicles, including some heavier vehicles and trucks. And with the rise in e-bike purchases and trips, there is also a coinciding degree of injury severity and rates of hospitalization. Higher speeds, older users, and increased rider utilization of shared street networks provide some of the factors behind the degree of damages, alongside the usual interactions with moving automobiles (Berk et al., 2022). As new mobility creates a greater permeability between different users and environments, cities must critically consider how their streets could be reshaped or optimized to accommodate all users safely and pleasantly. While shared mobility has the ability to replace car trips and help clear the streets for a diversity of users, the issue of dangerous interactions between pedestrians, automobiles, and new mobility users remains.

Shared mobility does offer the chance to induce shifts in infrastructural priorities, as a result of an increased number of users who bring new eyes and new pressure to supporting improved street design and policy. For shared services, cities can respond by setting service areas, determining maximum safe micromobility device speeds, creating geofenced slow speed and restricted access zones, and restricting vehicle speeds or times of operation in areas with dense micromobility ridership—and exploring approaches to incentivize helmet use. More broadly, many areas may lack necessary infrastructure to support safe use. Cities can begin prioritizing and expanding the types of street design which encourage greater degrees of safe, comfortable active transportation utilization, leveraging the spillover effects that result in the increased public acceptance and use of shared fleets and micromobility. While such efforts and the influx of shared mobility may be a difficult transition in some places, policy makers can manage this by regularly engaging their communities to help support solutions built around consensus.

By regularly engaging the public, many are seeking to build a culture of safety through micromobility ambassador programs, rider training, and programs designed to support safe tourism and micromobility use during special events and festivals. By building program evaluation plans, conducting pilot studies, establishing data requirements and data use agreements, and partnering with diverse agencies, communities are beginning to develop protocols and training for injury reporting and incident management and learning about how to improve the safety of all road users. As demonstrated, cities and their residents have many opportunities to improve their communities in order to best leverage the benefits of these mobilities and help improve the safety and convenience for all users of the local transportation system.

EQUITY + AFFORDABILITY

E-bikes and e-scooters can help many people overcome barriers that would otherwise prevent them from taking active forms of transportation, excluding them from its well-demonstrated benefits. As previously stated, mobility becomes less dependent on ownership of often expensive transport assets, there could be benefits for social inclusion, reduced isolation and improved access to services, education, employment and social interaction. At the same time, there is a need to be mindful of who benefits from these systems, who may be harmed or excluded, and how micromobility systems can be designed to meet their full potential in supporting safe, equitable, and resilient communities.

There are lower rates of shared mobility use among the poor which have many plausible explanations, including lack of availability in low-income neighborhoods, usage pricing, and limited Internet, smartphone, and credit/debit card access. Many shared mobility services require debit/credit cards for payment and, in some cases, collateral for vehicles or equipment. This can be a barrier for the 15 percent of US consumers who are under-banked or unbanked, raising equity challenges as a disproportionate share of minorities are under and unbanked (Pew Research Center, 2016). Furthermore, bikesharing typically requires an equipment deposit hold on a bank account or credit card. This can be cost prohibitive for users that could otherwise afford the membership and usage fees. A more elusive reason given for lack of shared mobility use among low-income households and minorities are social barriers. Community-based organizations and public sector experts highlighted a lack of culturally inclusive marketing and outreach when shared mobility services launch in a particular market. There is a sentiment among low-income communities and minorities that despite being technically able to access shared mobility, the services have not been designed with their needs in mind (Schmitt, 2012). For limited English proficiency users, lack of outreach in the appropriate language is often cited as a reason these users are less likely to access shared mobility (Kodransky, 2014). Finally, there exist social barriers as a result of the digital divide, where currently around 10% of adults don't use or have access to the internet, or may often find it difficult to use. While this is changing as a result of the increasing rates of internet adoption, the process is not fully complete and therefore policymakers should take this into consideration when supporting and implementing shared services.

Some cities have made concerted efforts to remediate at least part of these issues. For example, San Francisco mandates that at least 20% of its bikeshare stations be located in low-income neighborhoods, whereas GREENbike in Utah offers a $5 annual pass to Utah residents with a household income at or below 200 percent of the federal poverty guidelines. Other regions have experimented with schemes that help subsidize the purchase of automobile-replacing electric micromobility devices, such as e-scooters and e-bikes, with varying levels of success. Cost and distances are barriers, but cities and operators have concrete opportunities to make strides in opening up inclusive service levels to their residents.

Cities also are investigating micromobility parking needs in relation to concerns about sidewalk accessibility. Vehicles that are parked or toppled across sidewalks pose safety hazards for the general public, and create barriers to movement for people with disabilities. In Santa Monica, CA, and Alexandria, VA, for example, 42% and 75% of program complaints/citations were for improperly parked vehicles blocking sidewalks. These present an ongoing challenge for many cities. Curbside management offers a significant opportunity to improve the success of implementation for these services while maintaining the quality of accessibility for pedestrians.

COMMUNITIES + INFRASTRUCTURE

There are a multitude of ways communities can integrate shared mobility into the public process. Many cities were blindsided by the influx of new service providers in the past decade, as they entered the market before the vast majority of regions had any regulations in place to accommodate them. As a result, unclear policies have had a direct impact on community response, sometimes quite negative.

Many created bans and an opaque regulatory framework, resulting in market conditions that operators found difficult to navigate. Others were innovative and proactive in providing predictable regulations alongside community and mobility stakeholders, resulting in programs and services that found high rates of usage and approval, delivering net benefits to their communities. As mentioned previously, shared mobility and an uptick in micromobility usage has the potential to increase demand for these supportive infrastructures and policies, which could spill over and broadly benefit focus and investment around AT options. There are several spaces which cities could focus on in order to catch the benefits most effectively, as well as piggybacking off these mobilities to find other benefitting opportunities throughout the built environment. Cities have an inherent interest in shifting the demand of their communities to these modes, as they can take advantage of those benefits widely recognized as being also derived from active transportation. A reduction in traffic congestion and infrastructure maintenance costs along with improved resident and environmental health are just a few of these consistently demonstrated benefits.

One of the most important ways cities can manage a surge in shared and e-mobility is by cultivating an environment that supports the ability to physically grow shared fleets. Research shows that utilization rates for bike shares go up with system size, so by providing space or investing in infrastructure for operators, cities can gently improve the kinds of transportation market conditions which support shared-fleet growth. In partnership with providers and community members, cities can also physically support the implementation of shared mobility by integrating slow down zones or restricted areas via geofencing. For example, Austin maintains degrees of geofencing requirements around vulnerable facilities such as the Texas School for the Blind, in response to community safety concerns that resulted from multiple near misses, broken canes, and other dangerous events impacting blind students learning to navigate the environment. This offers a demonstrated example how municipalities can effectively address shared mobility challenges in an ad hoc and flexible manner.

Another way cities can promote better integration across the built environment is by ensuring that services mesh with transit modes and infrastructure. This can be done by promoting physical proximity between transit and these new mobilities, but also by ensuring that the necessary technological infrastructure for seamless use and mode expansion are aligned. Currently, technological infrastructure which supports micromobility may have a harder time integrating with the older and less flexible systems used in the public world, especially in the transit context. For example, by focusing on updating public general specification feeds by expanding their documentation to include GTFS-flex or intermodal options such as bikeshares, agencies can support trip planning services to promote flex routes, demand response services, and multiple forms of public shared mobility. Additionally, developing data metrics, models, planning platforms, and formal methodologies to measure the travel and economic impacts of shared mobility within a community's region is essential for transportation planners and policymakers. As of yet, there is no means for cities to easily obtain shared mobility data from private sources in order to integrate them into planning. The synergistic relationship between shared mobility systems and smartphone applications presents new opportunities to enhance understanding of shared mobility and to incorporate this insight into local transportation planning and operations activities. The individual mobility apps of service providers and mobility aggregators (apps that provide routing, booking, and payment functions) collect an array of data points that are useful to public agencies for both static planning and analysis and real-time network management and response Developing these tools will also enable public agencies to forecast the economic and travel behavior impacts of shared modes and guide public policy development related to urban and spatial planning, rights-of-way, parking, and zoning.

Finally, governments and public agencies can support shared mobility by providing marketing and administrative assistance. For example, municipalities can engage in joint marketing campaigns with shared mobility operators and ensure that programs have visibility on public agency websites and in newsletters, outreach materials, and press releases. Governments can allocate funds, share risk to support service via partnership, supply right of way, and initiate new services via requests from residents, essentially helping champion a shift in transportation mode choices across their communities.

As shared and micromobility grows across the world, decision makers should consider how many potential preferred mode trips are substituted by car-based trips via shared mobility and how an increase in these services can help cities achieve their future goals. Therefore, public authorities need to engage to ensure that shared mobility is contributing to their policy goals when considering the different ways they can aid implementation into their communities. This may be a difficult process, due to the aggressive growth approach of many service providers and the breadth of expertise needed to evaluate them. But by working closely with stakeholders and mobility providers, cities can leverage micro and shared mobility in many new and exciting ways. For example, in Denver, private developer Avanti proposed a development made up of eight shipping containers where local chefs and restaurateurs could test food concepts without the risk involved in opening their own establishments. The project was permitted to proceed through a partnership with BCycle to build a 30-dock on-site bike sharing station (Hendee 2015), which helped meet minimum parking requirements within the municipality. In September 2010, the City of New York enacted a Carsharing Zoning Text Amendment. The amendment defines carsharing, permits car sharing vehicles to occupy public parking garages (not to exceed 40 percent of total spaces), and allows the conversion of up to 15 general-use parking spaces to carsharing parking in existing buildings, with additional carsharing parking provisions dependent on other applicable zoning categories and regulations. This helps meet city desires in reusing wasted space for alternative functions. Examples like these have helped cities align themselves with shared mobility to help advance their broader goals.

Cities may also find that shared mobility has brought familiar challenges, as SOV on-demand services still create some of the issues associated with the ownership and use of private vehicles. While in some instances, cities found services such as Uber and Lyft complemented their transit agencies by increasing ridership, other studies found variations in that the implementation of sharing services increased rail ridership, but decreased bus ridership. Overall, findings show that the implementation of TNCs and sharing services increase vehicle miles traveled (VMT) and generally lower transit ridership. A substitution of walking and cycling trips with public transport as well as a shift from public transport to car-sharing, taxi or taxi-like services, thus towards car-based modes, is typically considered unfavorable from a city perspective.

HIGH E-LIVING SCENARIO

This scenario investigates the impacts of lifestyle shifts that favor telecommuting and e-commerce and delivery. It assumes high levels of implementation of telecommuting and e-commerce and low levels of implementation of all other forces.

Force Implementation

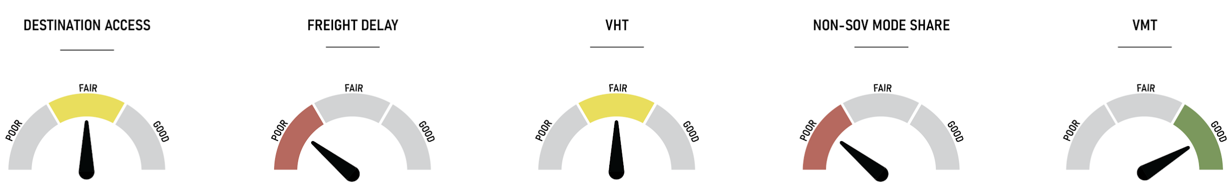
CONNECTED AND AUTONOMOUS VEHICLES	L
HIGH-TECH TRANSIT SYSTEMS	L
MICROMOBILITY AND E-BIKES	L
E-COMMERCE AND DELIVERY	H
TELECOMMUTING	H

SCENARIO PERFORMANCE

Although high levels of e-commerce increased total hours and vehicle miles of travel over the base scenario, high levels of telecommuting counteracted these disbenefits. Combined together in this scenario, vehicle hours of travel nominally decreased by three percent and vehicle miles of travel decreased by less than a percent.

While this scenario reduced drive alone trips to work by over a million daily trips, transit use also declined by roughly 60,000 daily trips.

Scenario Compared to the 2050 Base



LIVABLE + HEALTHY COMMUNITIES

The rise of e-living holds interesting possibilities for our communities and infrastructure, including radical new uses for civic spaces, shifts in transportation demands and behavior, and a host of other important outcomes that cities and their residents must start thinking about seriously. The impact of the COVID-19 pandemic has not only catalyzed the uptake of such forces, pushing individuals and communities towards implementation, but has brought a degree of lasting normalcy to them that begs us to consider how they may shape our society in the coming decades.

Telecommuting especially has tangibly reshaped the lives of many individuals, and in aggregate had a considerable effect on communities as a whole. During the onset of the pandemic in 2020, a transformation that has gradually occurred over decades was suddenly accelerated, resulting in the near-total digitalization of many office activities. Coupled with the advent of 5G networks, fully remote work has come to seem like a feasible option for many employers. Major companies expect an increasing share of their employees to become fully remote in the coming decade and coworkers across all fields continue to express interest in either remaining remote or maintaining some degree of remote option in their work schedules. With this transformation comes an expected host of benefits and downsides. The most visible are the demonstrated benefits felt by individual workers. Generally, employees operating in some remote capacity experience less stress, more happiness, cost savings associated with the absence of a commute, and a greater degree of flexibility in their lives. Employers have found that productivity has improved, money is saved on office space, the pool of potential employees is much expanded, along with higher degrees of employee satisfaction and retention. With more workers spending time remotely, family life, local businesses, neighborhood amenities are subject to increasing demand and emphasis. Additionally, the more time workers spend remotely, the more they are likely to advocate for a range of activities within walking distance, whether green space or entertainment options, as well as the infrastructure to make it happen. These new demands have the potential to organically encourage the mixing of uses and a shift in the environmental character of communities areas. This may allow cities to rethink the very concept of zoning that has underlaid urban planning for the past century, expanding the range of possibilities of what communities can envision for themselves. Communities can also likely expect some disadvantages resulting from higher rates of remote work. There will be impacted businesses, especially those restaurants and shops catering to workers, and by proxy, the families who rely on these incomes. Dealing with the challenges of reduced business levels, or potentially even relocation, would likely present a significant hurdle for those affected. There are also likely to be changes in the environmental character of previous job clusters if said amenity providing businesses gradually drain out of the area. While the empirical research on the spatial effects of the adoption of e-commerce by retailers and consumers is limited, these potential impacts are still worth considering across communities everywhere.

The impacts of workplace digitalization will be paralleled and reinforced by the digitalization of entertainment, education, and shopping. The online purchase and delivery of basic goods will become more fully entrenched, with brick-and-mortar stores more likely devoted to so-called experiential retail. With regard to space needs, Romm (2002) estimated that e-commerce could reduce the need for one-and-a-half billion square feet of retail space in the US – about 5% of the total – and up to one billion square feet of warehouse space. As retail space opens up, communities once again have the opportunity to reconsider what they envision the future of such spaces as being. And as services shift more and more to an online format, communities can expect to find ample opportunities to reconfigure office space, storefronts, public property, and local infrastructure such as parking to best meet their new needs. Combined these trends may result in a lot of obsolete asphalt. Even if it takes a few more decades for increased active transportation, transit, and autonomous vehicles to take over roadways, the ideas for repurposing parking areas that have circulated in recent years may be implemented sooner rather than later. For example, as parking requirements are based on the Christmas rush, which has become an increasingly online phenomenon, cities can redefine their requirements, making space for alternative land uses for the excess asphalt, from affordable housing to urban forests.

SAFE, USER FRIENDLY STREETS

Shifts in commuting patterns could hold some notable benefits for the safety of all street users. As workers find themselves commuting less, peak PM travel is likely to find some decreases. Alongside this phenomenon, communities will likely experience an increase in safety outcomes with the reduction of vehicles on their roads. Alternatively, as seen during the pandemic, many people drive more aggressively, including unlawful speeding, when fewer vehicles are on the road. However, additional benefits may also be seen through reduced congestion and increased on-street comfort, lowering levels of stress, noise and air pollution. But while communities may experience less commuter and short trip traffic on their streets, e-commerce has increased freight volumes and shifted freight vehicles to local streets and arterials, creating conflicts as deliveries compete with bicycle lanes, on street parking, transit stops and bus lanes, as well as with passenger pickup and drop off. These conflicts are not limited to business districts and commercial areas; they also occur in residential neighborhoods that rely on on-street residential parking. Outdated curb regulations and pricing policies and ineffective enforcement are ill-suited to an era in which commercial demands for curb space are growing so rapidly. In response, communities should start questioning the future of their curb space and consider how they may manage it in order to provide space or encourage a shift towards smaller, safer options across delivery fleets. Improvements in technology and a gradually more widespread adoption of smaller delivery vehicles, such as e-cargo bikes, quadricycles, drones, and more offer tangible benefits to cities as they try to balance the needs of residents and the logistics of providing them goods and services. These benefits are primarily experienced in the first and last mile context of supply chains, which inherently is the chainlink impacting cities most heavily.

As an additional safety concern, the exponential growth in e-commerce is bolstering last-mile deliveries and associated drivers, which include many individuals without previous commercial driving experience. This might especially be an issue in situations where drivers work non-traditional hours or experience high volume workloads, increasing the risks of drowsy driving. While the impacts of this and resulting data are harder to evaluate, there poses an increased risk of accident incidence throughout urban areas as less experienced drivers face the challenge of navigating complex environments.

EQUITY + AFFORDABILITY

E-living holds significant implications for historically isolated communities, who may otherwise not have the same access to opportunities, services, and goods that they would by digital provisioning. This may hold true both for geographically isolated communities, such as rural towns, and for historically marginalized neighborhoods that have experienced disinvestment and lack of service rather than geographic limitations, which has cut them off from the benefits associated with a centering of goods and services. Now, residents can connect to jobs, education, medical appointments, healthier food, and more without having to traverse the barriers which have traditionally blocked their access. This argument, expressing an ‘end of geography’ view, is aligned with ideas stated by some commentators arguing that space and place are becoming meaningless in the digital era. In theory, living near a shopping location becomes less important when it is possible to have everything delivered to the home or to engage in the full span of professional activities from the comfort of one's home office. Broadly speaking, these benefits may be impactful enough to integrate their considerations into the planning process, but as of yet there remains little research on the degrees of long-term benefits and adoption of e-living across communities. Whether or not communities spread geographically, necessitating changes in how to approach service or infrastructure provisioning, or maintain their current degrees of clustering remains to be seen, but nonetheless remains a useful question as decision makers consider planning in general, especially when examining issues of equitable access.

Yet, as more and more employees across cities are embracing remote options and the level of e-services expands, there still remain many issues with e-living in its current form, especially when its impact on lower-income communities is examined. Many find themselves excluded from the benefits of e-living, be those from remote work or from increased digital commerce. The brunt of such limitations center around the costs associated with deliveries, especially of food. Costs for deliveries remain high, inherently limiting the lifestyles of lower-income families and individuals, and potentially reinforcing the health impacts and lifestyle constraints associated with food deserts, where more often than not, lower income communities find themselves trapped in. Finally, the reality is that many jobs, especially lower earning professions, remain jobs that require a physical presence and don't have much chance of becoming remote in any capacity in the near future. While this is changing within some service sectors, there remains a glass ceiling for the share of those workers who work in fields that have no chance of a transition towards remote options or for those whose professions aren't keeping pace culturally or technologically with the rates of digitalization across the wider job market. This means that workers, their families, and their communities are unlikely to experience some of the direct and tangential benefits associated with higher rates of remote adoption. These include the aforementioned health and social benefits, and potential environmental changes across all communities, further creating disadvantages to them and their opportunities for advancement.

There remain many avenues to explore how e-living can either help or hinder disadvantaged communities. For example, model results communicate a decrease in overall VMT, something to expect as more workers choose remote options. With this comes a lesser need to cater the transportation system to peak time commuters. Instead resources could be directed towards benefitting the wider mass of people who travel outside of typical peak times, either for daily tasks or to access jobs that exist outside of traditional commute times. This is a large pool and they stand to experience significant benefits from increased investment in their transportation choices. That said, telecommuting could hold a significant impact on municipal budgets and the resources cities have to address long standing equity and affordability issues. For example, Manhattan's 400 million square feet of office space provides 10 percent of the city's tax revenue, putting question to the viability of the municipal budget (Creswell, 2020). As a result, whether or not resources are to be freed up remains to be seen. Therefore, community engagement is a crucial component when addressing the potential surplus and resources, and more so, when addressing how e-living will impact communities equitably. Decision makers need to not only know how goods move, but how people consume and commute to assemble effective strategies and plans. And the best way to do this is to directly involve communities in finding solutions.

COMMUNITIES + INFRASTRUCTURE

E-living is expected to have significant changes in both the degree and type of impact on cities, much of it centered around community infrastructure. For example, the most obvious and direct mobility effect of e-commerce on freight transport is that the last segment of the supply chain is modified when trucks deliver the purchased goods either to a pick-up point or to the home of the customer. Earlier research has identified the following three commonly used supply chains in e-commerce retailing: retailers that are only active in the online segment with dedicated vehicles for delivery to customers, retailers using a parcel carrier's existing distribution network to deliver the goods to the customer, and click-and-mortar retailers (retailers selling through brick-and-mortar stores as well as through an online channel) sometimes using a dedicated fleet of vehicles for delivery to customers. By working to understand the local market conditions, cities can better understand how to address this diversity of delivery options. Widely speaking, city logistics needs to be afforded greater importance in the planning process and political agenda, and related city structures need to be retrofitted to accommodate the different supply chain patterns. Changing regulations or zoning at the macro level also can be a tool to encourage or reinforce the development of e-commerce and create space for its physical needs. One such example is the encouragement of integrated pick-up points and parcel lockers. These are often located at key nodes in the public transport system and allow consumers to collect products that have been ordered online. Generally, outdated transportation plans, improper traffic rules, and insufficient infrastructure all contribute to today's e-commerce challenges and do little to address ways that the benefits of e-commerce can be leveraged. To do so requires more inventive and holistic partnerships between city governments and private companies to formulate scientific and data-driven resolutions that integrate well into each community's urban fabric.

Having said that, the problems that the rise of e-commerce presents are undeniably complex. There is no doubt that a great endeavor from all stakeholders, more in-depth research, and innovative thinking are required to identify workable answers for the future. Much could likely center around the leverage provided by advances in data technologies. Because e-commerce companies are basically algorithm-driven, city governments can seek collaboration with tech giants to find opportunities for integration and collaboration of private endeavors and the public realm. Hangzhou, China and the tech giant Alibaba created such a partnership, by building a big-data platform to make delivery across the urban space more efficient while also expanding its application to other services. Called ET City Brain, its format has been replicated in multiple cities across the region and has sought to minimize some of the impacts associated with the interlacing of travel demand, commercial logistics, and city services. It has helped reduce congestion, improve transit efficiency, scheduled medical trips, improved accident and construction reporting, shortened emergency response times, and prioritized freight patterns, among other things.

Such expansion and integration of technology and partnerships promises to hold substantial benefits for communities, but with some caveats. With these technologies come significant issues related to privacy and security, both for the individual and the municipal system as a whole. In light of highly publicized hacking and ransomware problems, communities are more aware of data security issues and the risks they pose to infrastructure. Additionally, with the increase in remote work, systems may face greater risks than main offices as employees navigate the digital world. Special care should be taken to ensure that equipment and connections are protected across public and private domains. Private individuals also face individual risks as their travel and shopping habits, medical needs, and more, become recorded and transmitted across the digital ecosystem, providing a ripe chance for breaches in personal privacy and security. More and more, as public services and personal patterns become electronic, governments and their residents should consider how to coordinate and tackle the risks of a fully remote world.

Finally, whether or not an increased implementation of e-living has positive impacts on the system as a whole. Counterintuitively, an increase in the e-living scenario implementation hasn't indicated a drop in VMT as expected. This may be because it is difficult to determine the extent to which e-commerce deliveries may be replacing vehicle trips for shopping. In theory, a consolidated delivery system of e-commerce could reduce VMT as compared to individual households making their own shopping trips in cars. But, the reality can be more complex. A single online order may arrive in multiple shipments. If 30 percent of online orders are returned, and 15 percent never make it to the correct address on the first delivery attempt, e-commerce can lead to an incidental bump in VMT. Unfortunately, building this into the scenario evaluation process can be difficult, due to the proprietary nature of logistics data, keeping the share of extra VMT generated by these logistics unseen. Increased partnership between communities and the private entities reliant on their infrastructure will be crucial to understanding the stresses, needs, and outcomes of an increasingly digitized system.

PLAUSIBLE EXTERNAL FORCES SCENARIO

Following review and input, the following Plausible External Forces Scenario was developed as shown in Figure 14: connected and autonomous vehicles implementation at a low/medium rate; high-tech transit systems implementation at a medium rate; micromobility and e-bikes implementation at a low rate; e-commerce and delivery implementation at a medium rate; and telecommuting implementation at a low rate.

Force Implementation

CONNECTED AND AUTONOMOUS VEHICLES	L/M
HIGH-TECH TRANSIT SYSTEMS	M
MICROMOBILITY AND E-BIKES	L
E-COMMERCE AND DELIVERY	M
TELECOMMUTING	L

SCENARIO PERFORMANCE

The Plausible External Forces Scenario produced the following measures compared to the 2050 Base Scenario. Non-SOV mode share increased two percentage points, mostly due to an increase in bicycle and pedestrian usage. There were modest benefits to vehicle hours of travel and freight day.

Scenario Compared to the 2050 Base