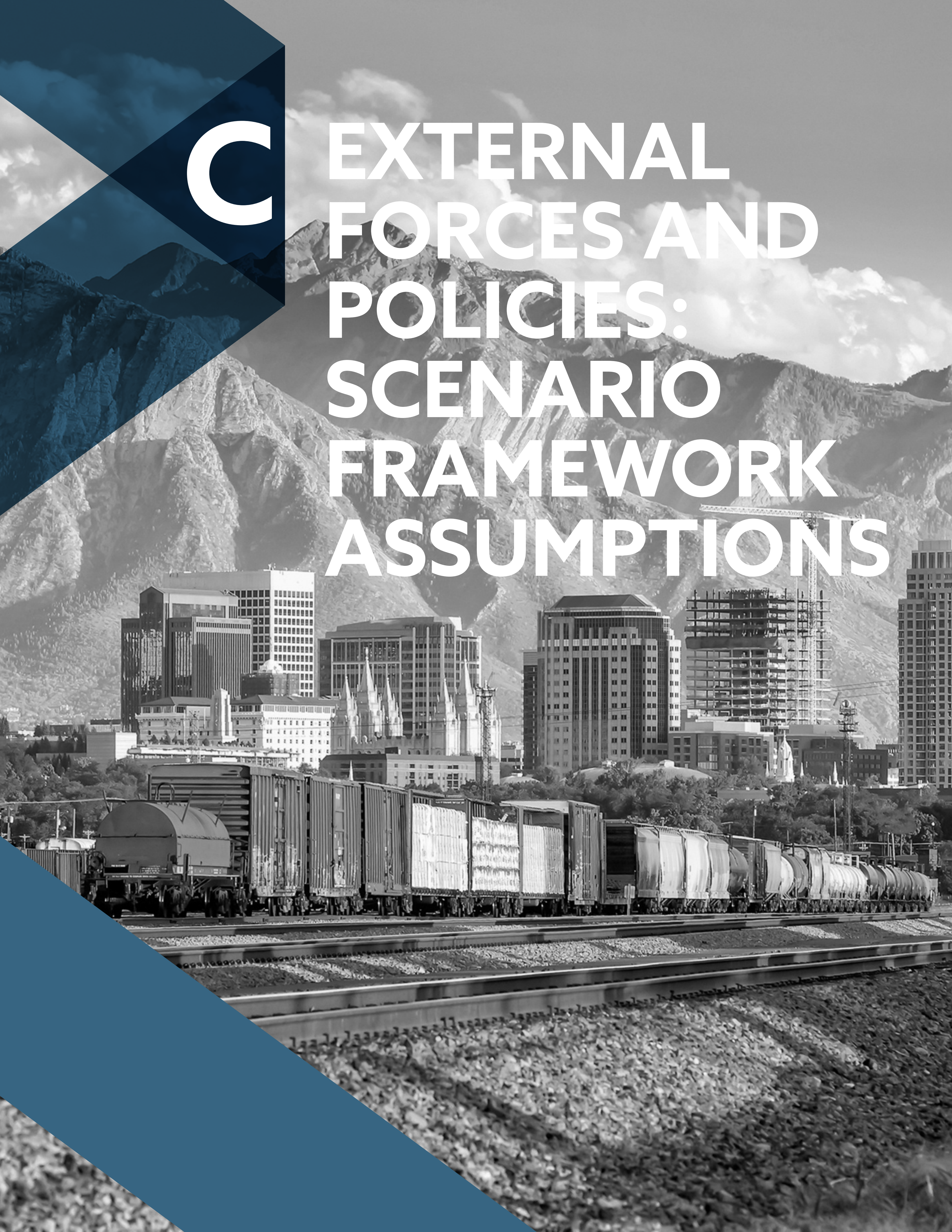
C EXTERNAL FORCES AND POLICIES: SCENARIO FRAMEWORK ASSUMPTIONS



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LIST OF ABBREVIATIONS

AGRI	Agriculture
AV	Autonomous Vehicles
BRT	Bus Rapid Transit
CACC	Cooperative Autonomous Cruise Control
CAV	Connected and Autonomous Vehicles
CONS	Construction
CV	Connected Vehicles
E-bikes	Electric Assisted Bikes
E-scooter	Electric Scooters
FOOD	Food and Accommodation
FSD	Full Self-Driving
GPI	Kem C. Gardner Policy Institute
GVED	Government and Education
HBJ	Home-Based Jobs
HCM	Highway Capacity Manual
HLTH	Health Care
HOT	High-Occupancy Toll
HOV	High-Occupancy Vehicle
ITS	Intelligent Transportation System
MAG	Mountainland Association of Governments
MANU	Manufacturing
MING	Mining
MPH	Miles per Hour
MPO	Metropolitan Planning Organization
MPR	Market Penetration Rate
NACTO	National Association of City Transportation Officials
OBU	On-Board Units
OFFI	Office
OTHR	Other
PC/HR/LN	Passenger Cars per Hour per Lane
RETL	Retail Trade
RSU	Roadside Units
RTP	Regional Transportation Plan
SOV	Single-Occupancy Vehicle
TAZ	Traffic Analysis Zone
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
UVX	Utah Valley Express
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Technology
VHT	Vehicle Hours of Travel
VMT	Vehicle Miles of Travel
WFRC	Wasatch Front Regional Council
WSLE	Wholesale and Transportation

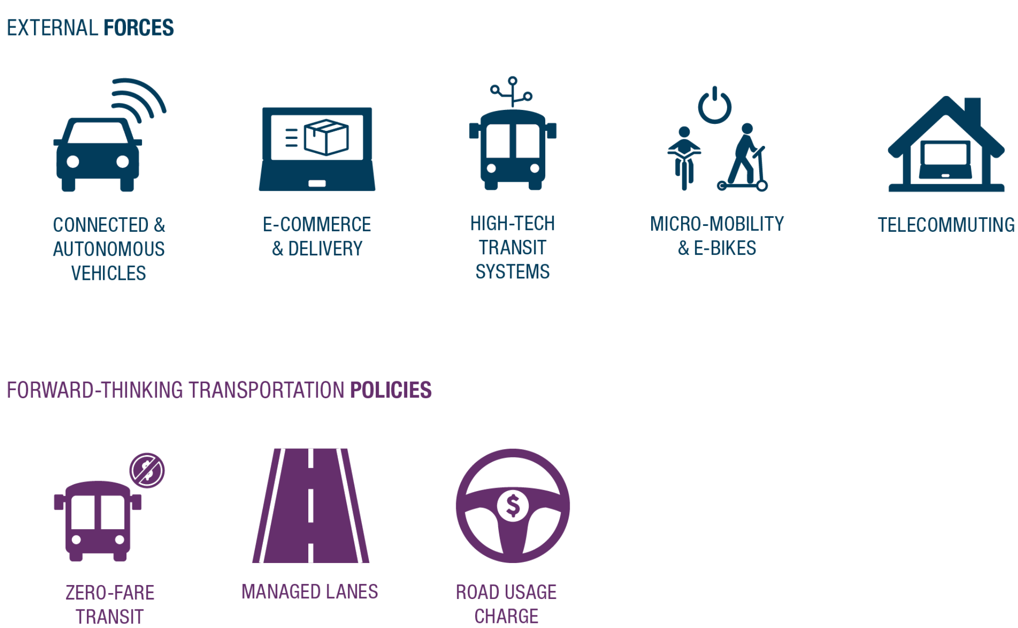
INTRODUCTION

Throughout the 2023-2050 Regional Transportation Plan (RTP) development process, the Wasatch Front Regional Council (WFRC) has had a focus on exploring and understanding external forces and future-thinking transportation policies — transportation technologies, shifts in market and consumer demand, and local and regional policies that may impact transportation, land use, and economic development decisions. Ultimately, this work 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 to change.

Initial research and literature reviews focused on over 20 external forces and future-thinking transportation policies. A guidebook was created for discussion in a series of peer groups composed of staff from local governments, transportation and state agencies, and businesses whose work is directly tied to, or may be heavily influenced by, these planning uncertainties. The peer groups helped refine this initial list into six forces and nine policies for further conversation and exploration. More discussion on the forces and policies can be found in revised external forces and policies guidebooks.

WFRC has been testing the impact on the transportation system from the following forces and policies: connected and autonomous vehicles, high-tech transit systems, micromobility and e-bikes, on-demand travel and sharing services, e-commerce and delivery, telecommuting, zero-fare transit, managed lanes, and road usage charge.

Figure 1. External Forces and Forward-Thinking Transportation Policies Considered in Technical Process



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 and policies tests. For each external force or future-thinking transportation policy, 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 external force and future-thinking transportation policy tested. As a beginning step, each external force and future-thinking transportation policy was evaluated independently to determine individual impacts. Future work will create and test scenarios, composed of each force at various implementation rates, to evaluate how the forces interact together. This technical document, External Forces and Policies: Scenario Framework Assumptions Tech Memo, is meant to provide further insight into trends, provide rationale for ranges of implementation, and document integration of each force or policy into the travel demand model environment. These assumptions were developed and carried out with travel demand modeling experts and based on research findings from WFRC and other partner agency staff.

As the designated Metropolitan Planning Organization (MPO) for Salt Lake, Davis, 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. This planning process looks several decades into the future to anticipate needed transportation investments. The current four-year planning cycle began in 2019 and will be completed in 2023, leading to the adoption of the 2023-2050 RTP. 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.

WFRC also works with the Cache MPO, Dixie MPO, MAG, UDOT, and UTA on Utah's Unified Transportation Plan. The exploration of external forces will inform the 2023 Unified Transportation Plan in addition to being addressed in WFRC's RTP planning process.

Table 1 provides more detail to the topic areas that were explored as part of the 2023-2050 RTP process that began by looking at external forces and forward thinking transportation policies.

Table 1. Topic Areas

External Forces *Each topic area is linked to its section in the document*	Connected and Autonomous Vehicles (CAV)	Autonomous vehicles (AV) are vehicles capable of driving without human intervention (also called self-driving or driverless vehicles). A connected vehicle (CV) is one that communicates with other vehicles (V2V), infrastructure (V2I), and other road users (V2X) via wireless technology.
	High-Tech Transit Systems	High-tech transit systems integrate technology within their fleet, often utilizing Intelligent Transportation Systems (ITS) to become more efficient through Transit Signal Priority (TSP), Traffic Signal Coordination (TSC), and other technologies. This also encompasses connected and autonomous shuttles and buses.
	Micromobility and E-Bikes	Micromobility refers to the use of lightweight devices typically used for shorter-distance transportation. These can include standard bicycles, electric assisted bicycles (e-bikes), electric scooters (e-scooters), and other mobility devices that have improved electric motor technology. Micromobility devices can be either personally owned or shared among users, such as GREENbike in Salt Lake City.
	On-Demand Travel and Sharing Services (TNC)	The use of technology in the form of a mobile application that enables users to call/secure individual and shared transportation services. These services are often called Transportation Network Companies (TNCs).
	E-Commerce and Delivery	E-commerce and delivery refers to a series of changes that are occurring in the purchase and delivery of goods. These include, but are not limited to, internet shopping, food delivery, truck automation and platooning, and last-mile delivery logistics, including drones.
	Telecommuting	Telecommuting is the act of partially or entirely replacing out-of-home work activities by working at home or at locations close to home.

Future-Thinking Transportation Policies	App Development	A tech service on smart phones that allows users to plan, order, share, and pay for a wide variety of transportation.
	Congestion Pricing	Tolling to enter a cordoned area within a city. Does not include traditional toll lanes and roads.
	Curbside Management	Managing the curb by improving allocation of space for pedestrians, drivers, bicycle infrastructure, transit services, transportation network companies, micromobility devices and stations, and personal delivery services.
	Zero-Fare Transit	Zero-fare transit is a policy decision to remove the barrier of paying for transit services. This may be done system wide or within designated zones.

	Local Street Design Modifications	Modifications to the design and speeds of local streets which can improve the suitability of roads for all modes of travel, especially as new technologies such as connected and autonomous vehicles and micromobility continue to evolve.
	Managed Lanes	Managed lanes are operational strategies that optimize the carrying capacity of existing transportation facilities[1].
	Parking Modernization	Modernization of parking systems, including elimination of parking minimums, adoption of paid parking, and unbundled parking costs.
	Road Usage Charge	A road usage charge is a usage-based fee based on a certain rate per mile traveled, replacing or supplementing taxes imposed on fuel consumption.
	Street Connectivity	Connectivity can be defined as multiple routes and connections serving the same origins and destinations.
	Subsidized E-Bike Purchases	Subsidized or discounted purchase programs and trial use programs aimed at accelerating the adoption of electric assisted bicycles for transportation use.
	Transit Priority	The movement from a direct connect system to a connected network system utilizing lower tech improvements including queue jumping, dedicated lanes, bus-only lanes, intersection improvements, bus stop spacing considerations, bus bulbs, and other spot improvements. Creating a system where transit is the priority and it is fast and frequent.

Tables 2 and 3 below indicate the ranges of implementation for the external forces and policies within the model framework. For the external forces, a low, medium, and high implementation rate was identified for each force. For the future-thinking policies, the range applies to zero-fare transit while the two other policies do not have a range of implementation. Only the forces and policies being tested in the WFRC travel demand model are included in the summaries below. More information about which forces and policies were tested within the travel demand model are discussed further in this document.

[1] UDOT's Statewide Managed Lanes Study finding is available to access on the project website https://utah-managed-lanes-study-uplan.hub.arcgis.com/

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 mile are by micromobility
E-Commerce and Delivery	Minimal	25% of total retail sales	45% of total retail sales	65% of total retail sales
Telecommuting	5% of regional jobs telecommute	15% of regional jobs telecommute	20% of regional jobs telecommute	25% of regional jobs telecommute

Table 3. 2050 Future-Thinking Transportation Policy Implementation Range Summary

EXTERNAL FORCE	BASE SCENARIO	POLICY TEST
Zero-Fare Transit	Fare structured for system-wide regular and premium bus and rail service and zoned-based commuter rail	Three tests: region-wide zero-fare, region-wide zero-fare with no route transfer penalty, and 50% reduced fare
Managed Lanes	No implementation of tollways	Test select tollways on limited access freeways
Road Usage Charge	Auto operating cost per mile for autos and light, medium, and heavy trucks	20% increase in auto operating costs per mile

After determining the ranges of implementation for the external forces and forward-thinking transportation policies, WFRC and partners determined how to test these ranges in the WFRC Travel Demand Model Version 8.3.1. Table 4 provides a description of the model integration in order to simulate the implementation ranges in Table 3. Once these integrations were tested, they were used as a proxy for evaluating the external forces and forward-thinking transportation policies.

Table 4. Model Integration Summary

EXTERNAL FORCE	MODEL INTEGRATION
Connected and Autonomous Vehicles	Test an increase of freeway capacity using a series of capacity adjustment factors.
High-Tech Transit Systems	Test an increase in frequency and speed of Bus Rapid Transit (BRT), Core Service 15, and Core Service 5 routes. Speed will be adjusted for all BRT routes and select Core Service 15 routes.
Micromobility and E-Bikes	Test impact on the transportation network by manually assigning a certain percentage of trips that are three miles or less to non-motorized modes.
E-Commerce and Delivery	Test an increase in truck trips based on different truck types and destinations.
Telecommuting	Test a reduction of employment per Traffic Analysis Zone (TAZ).
Zero-Fare Transit	Test a reduction and removal of transit fares.
Managed Lanes	Test select tollways on limited access freeways by converting HOV lanes from the model network into general purpose lanes. All lanes on freeways and access-controlled facilities were then modeled as tolled facilities (with the exception of I-15, I-215, and I-80).
Road Usage Charge	Test an increase in the auto operating costs per mile as a proxy for a road usage charge.

FORCES

CONNECTED AND AUTONOMOUS VEHICLES (CAV)

Autonomous vehicles (AVs) are vehicles that are capable of driving without human intervention (also called self-driving or driverless vehicles). A connected vehicle (CV) is one that communicates with other vehicles (V2V), infrastructure (V2I), and other road users (V2X) via wireless technology. The Connected and Autonomous Vehicles (CAV) external force is a combination of connected and automated technologies, and can be applied to vehicle technology separately.

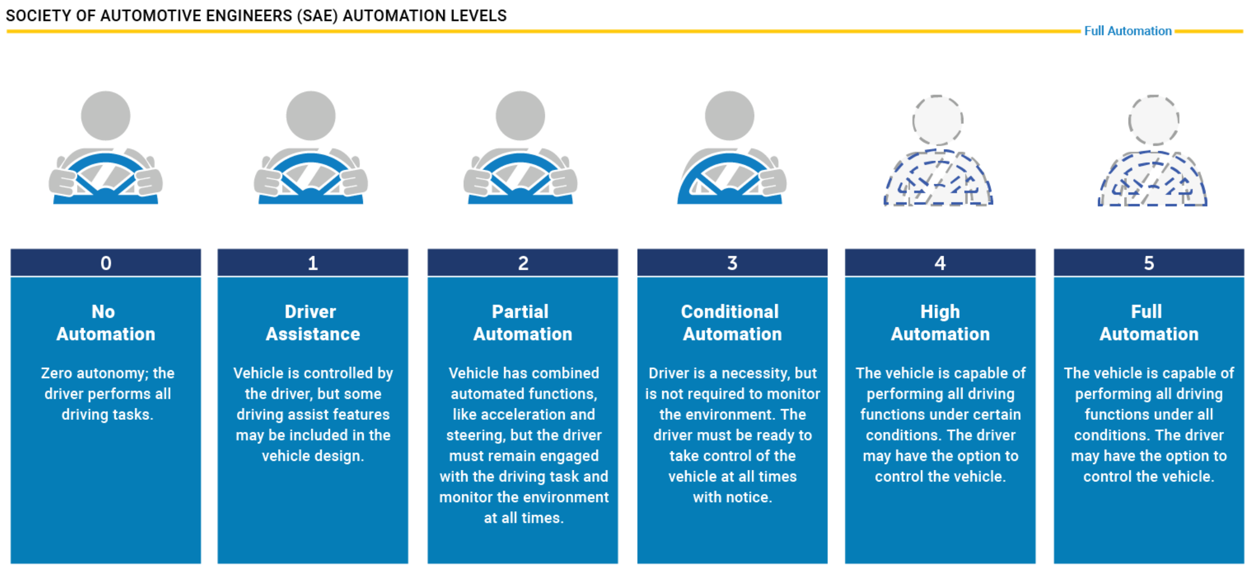
GENERAL TRENDS

CAV has six levels of automation which are rated on a zero-to-five scale, as indicated in Figure 2. The levels of vehicle automation are significant because they will influence how these technologies can be implemented and deployed in the near- and long-term and how these types of technologies will affect the built environment. Most vehicles on the road today are on the spectrum of automation. Level 1 automation may include technologies such as automatic transmission, lane-keeping technologies, and assisted cruise control. Level 2 includes some of these technologies working in conjunction (such as in Tesla's Full Self-Driving (FSD) autopilot mode) with the driver. When FSD is engaged on a Tesla, the vehicle can change lanes, navigate, and change speed without driver intervention. However, the driver must still hold the steering wheel and monitor traffic for safety.

UDOT has prioritized connected vehicle technology research and programming. UDOT and Panasonic launched a partnership in 2019 to further expand V2X technology in the state[2]. The state transportation department has also sponsored CV technology studies, with roadside units (RSUs) installed on some corridors to allow for transit and snowplow pre-emption. Additional studies are underway to increase the deployment of RSUs in the Region, as well as the number of state-owned vehicles with on-board units (OBUs), which allows vehicles to collect and gather important information on road conditions, weather, congestion, and other factors which may be of interest to the passenger and vehicle to make routing decisions[3].

[2]UDOT. Cirrus by Panasonic CV Innovation Platform. 2021. https://transportationtechnology.utah.gov/connected-vehicle-data-ecosystem/
[3] US Department of Energy. “Connected and Automated Vehicles Capstone Report”. 2020. https://www.energy.gov/sites/prod/files/2020/08/f77/SMART-CAVS_Capstone_07.22.20.pdf

Figure 2. Levels Of Automation



Source: National Highway Traffic Safety Administration, Levels of Vehicle Automation: https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety

IMPLEMENTATION

Implementation of CAV will rely on several factors. Many industry experts have different timelines for AV market penetration and full adoption that vary between the upcoming decades. Regardless of the uncertainty in technology implementation, one of the touted benefits of CAV, in addition to safety improvements, is increased capacity on highways through the vehicles' ability to communicate with each other and perform Cooperative Adaptive Cruise Control (CACC) that will allow for the platooning of vehicles. Benefits like reducing headways and increasing safety can occur with vehicle platooning potential, especially on separated facilities such as highways.

All telematic applications fall under the overall transportation system concept of ITS. Wireless communication of CVs is made possible through the evolution of OBUs in vehicles that are able to communicate wirelessly with other vehicles and RSUs. With this technology, vehicles are able to capture information about road conditions, speed, weather events, highway debris, and other necessary information about the roadway which can be shared with other vehicles[4].

Although future development of connected and autonomous vehicles will have some level of connectability— either with the infrastructure, network, or other vehicles— it is not automatically guaranteed that all future vehicles will have these capabilities. Although CV and AV technology are related, a vehicle can have automation functions and not communicate with the road infrastructure technology. Connected vehicle technologies are readily implemented on roadways today, but a larger range of uncertainties exist with regards to when full automation of connected vehicles will be adopted in the United States. WFRC staff initially discussed with partners and other experts the potential to separate connected vehicles from vehicle automation, but ultimately determined to analyze CAV as one external force.

[4] Li Chang et al. "Effects of on-Board Unit on Driving Behavior in Connected Vehicle Traffic Flow". 2019. https://www.hindawi.com/journals/jat/2019/8591623/

Table 5. Connected and Autonomous Vehicle Implementation Ranges

SCENARIO	RANGE	JUSTIFICATION
2020 Existing	Minimal	Based on on-going UDOT/UTA TSP studies on Redwood Road and Utah Valley Express (UVX) transit routes and in preparation for future expansion projects in the Region (as of December 2020). Regarding automation specifically within vehicles, there are some vehicles which currently operate on the Wasatch Front roadway network that have some level of automation (i.e., Teslas). However, this number is negligible.
Base Scenario	0%	Not currently included in the Wasatch Front TDM Version 8.3.1.
Low Implementation	V2X/I2V/V2V: 100% adoption of in-vehicle infotainment, wireless capabilities in all new vehicles; RSUs installed on 60% of all roads. 15% of Level 3/Level 4 Automation for all new vehicle sales; 100% Level 2 Automation for all new vehicle sales.	Based on initial findings from Todd Litman's Autonomous Vehicle Implementation Predictions[5]. WFRC Long Range Planning met with Blaine Leonard, UDOT, on January 30, September 14, and October 8, 2020 to discuss these implementation rates. UDOT confirmed that the rate of adoption is appropriate and in alignment with UDOT's assumptions.
Medium Implementation	V2X/I2V/V2V: 100% adoption of in-vehicle infotainment, wireless capabilities in all new vehicles; RSUs installed on 80% of all roads. 25% of Level 3/Level 4 Automation for all new vehicle sales; 100% Level 2 Automation for all new vehicle sales.	
High Implementation	V2X/I2V/V2V: 100% adoption of in-vehicle infotainment, wireless capabilities in all new vehicles; RSUs installed on 100% of all roads. 50% of Level 3/Level 4 Automation for all new vehicle sales; 100% Level 2 Automation for all new vehicle sales	

[5]Litman, Todd. Victoria Transport Policy Institute. "Autonomous Vehicle Implementation Predictions". June 5, 2020. https://www.vtpi.org/avip.pdf

MODEL INTEGRATION

The approach for integrating CAV in the model for testing scenarios is based on research by transportation industry experts that are studying the increased capacity of freeways with the implementation of CAV. The initial model is based on a UDOT-sponsored pooled fund study that explores capacity adjustment factors for CAV based on the Highway Capacity Manual (HCM)[6].

The research showed that freeway lane capacity, measured in passenger cars per hour per lane (PC/HR/LN), increased for basic freeway segments as the proportion of CACC-capable vehicles of the overall vehicle fleet, identified as the market penetration rate (MPR), increased. Higher MPRs have a compounding effect that increased capacity exponentially. The capacity rate increase, however, is dependent on the freeway's initial capacity. Facilities with a high initial capacity have a lower capacity-increasing rate. Facilities with a lower initial capacity have a much higher rate.

The study estimated two sets of freeway-capacity adjustment factors, one for two-lane freeway segments and one for three-or-more-lane freeway segments. Table 6 presents the adjusted freeway lane capacity by MPR for 2 lane facilities, and Table 7 presents the adjusted freeway lane capacity by MPR for 3+ lane facilities.

Table 6. Adjusted Freeway Lane Capacities by Market Penetration Rate (MPR) for 2 Lane Facilities

PORTION OF CACC-CAPABLE VEHICLES IN TRAFFIC STREAM (MPR - %)	ADJUSTED SEGMENT CAPACITY			
	2,400 PC/HR/LN	**2,100 PC/HR/LN**	**1,800 PC/HR/LN**	**1,500 PC/HR/LN**
0%	1.00	1.00	1.00	1.00
20%	1.02	1.07	1.14	1.22
40%	1.07	1.15	1.27	1.43
60%	1.13	1.25	1.43	1.65
80%	1.22	1.37	1.60	1.90
100%	1.34	1.52	1.81	2.20

Source: Kittelson and Associates. "White Paper: HCM Capacity Adjustment Factors (CAFs) for Connected and Autonomous Vehicles (CAVs)." April 14, 2020. WFRC Analytics 2021.

[6] Abby Morgan et al. 7 Key Insights from the Automated Vehicles Symposium in Orlando, FL. 2019. https://www.kittelson.com/ideas/seven-key-insights-from-the-automated-vehicles-symposium-in-orlando-fl/

Table 7. Adjusted Freeway Lane Capacities by Market Penetration Rate (MPR) for 3+ Lane Facilities

PORTION OF CACC-CAPABLE VEHICLES IN TRAFFIC STREAM (MPR - %)	ADJUSTED SEGMENT CAPACITY			
	2,400 PC/HR/LN	**2,100 PC/HR/LN**	**1,800 PC/HR/LN**	**1,500 PC/HR/LN**
0%	1.00	1.00	1.00	1.00
20%	1.02	1.07	1.13	1.18
40%	1.07	1.15	1.25	1.36
60%	1.12	1.23	1.37	1.55
80%	1.21	1.36	1.56	1.80
100%	1.36	1.54	1.79	2.10

Source: Kittelson and Associates. "White Paper: HCM Capacity Adjustment Factors (CAFs) for Connected and Autonomous Vehicles (CAVs)." April 14, 2020. WFRC Analytics 2021.

The study did not assume CAV-dedicated or CAV-only CACC-enabled lanes. Complex and multimodal urban systems are less likely to see the high levels of capacity increases from CAV since autonomous vehicles are programmed to be more conservative and safe than human drivers.

The empirical data from the research was smoothed and extrapolated to create a set of capacity multiplier lookup curves that were then integrated into TDM Version 8.3.1 (see Figures 3 and 4).

Figure 3. Smoothed CAV Capacity Multiplier by Market Penetration Rate for 2 and 3+ Lane Facilities

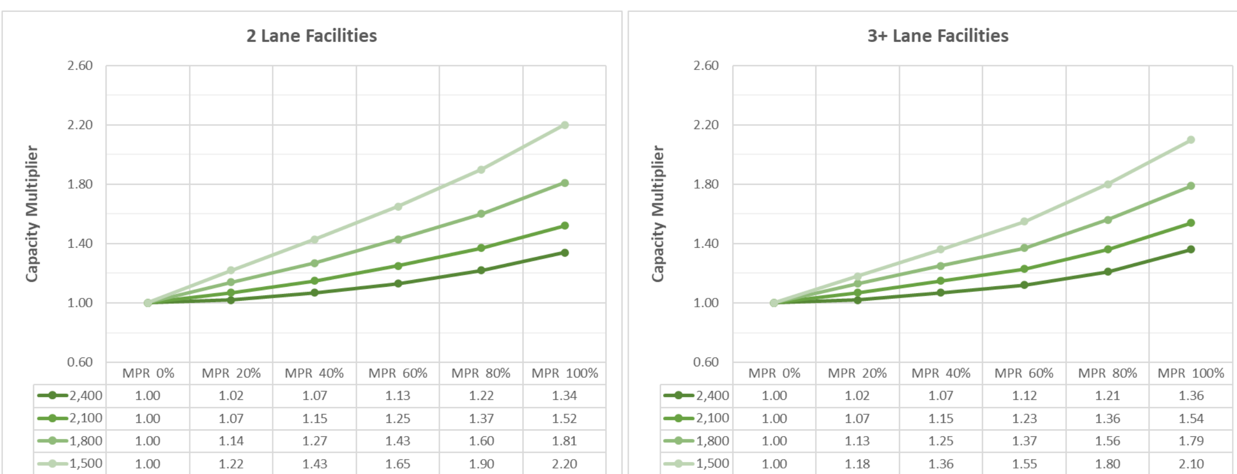
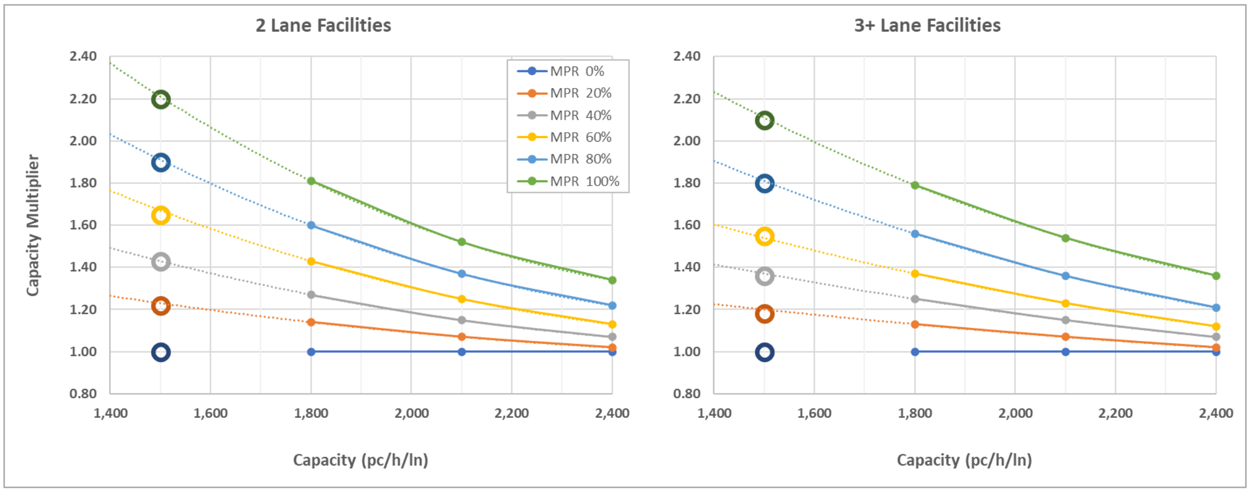


Figure 4. Extrapolated CAV Capacity Multiplier by Freeway Lane Capacity for 2 and 3+ Lane Facilities



Users specify the CAV MPR for each travel model scenario. The travel model then uses the user-specified MPR and attributes of the freeway to look up a capacity multiplier, which is then used to adjust the per-lane capacity for the freeway segments in the model.

For the first round of scenario testing for CAV, the WFRC team applied the following low, medium and high ranges to test.

Ranges for Initial Model Testing

Low: 30% MPR
Medium: 60% MPR
High: 90% MPR

WFRC and the transportation partners also considered managed lanes and what it could mean for CAV. In the TDM 8.3.1, managed lanes are part of the base scenario. With managed lanes in the base scenario, there are some inherent operational improvements in the freeway capacity. Concerns were brought up by transportation partners on how the inclusion of the managed lanes would impact testing with CAV. However, since all other testing of external forces included managed lanes in their base scenarios, the team determined that the testing of CAV in the TDM 8.3.1 should also include managed lanes and subsequently moved forward with this testing approach.

FORECASTING RESULTS

As indicated in the previous section, CAV was tested on the TDM v.8.3.1 by increasing roadway capacities.

- Low: 30% MPR
- Medium: 60% MPR
- High: 90% MPR

Initial model results indicate that there is an overall reduction in delay on Vehicle Hours of Travel (VHT), illustrating that travel delay would go down with more autonomous vehicles able to platoon on freeways and other limited access roadways. The model shows a decrease in VHT as the MPR increases from 30 percent to 90 percent. This is supported by research findings which indicate that overall travel time is reduced with CAV and that there is greater reduction with more CAV in the transportation network.

Modeling of CAV implementation indicates both an increase in vehicle miles traveled (VMT) and vehicle hours of travel (VHT). Based on the model testing, at a market penetration rate of 90 percent there is a 7.2 percent increase in VMT and a 2.1 percent increase in VHT. CAV implementation results in more automobile travel time and distance traveled.

Table 7. 2050 Daily VHT and VMT by Implementation Range for CAV

		BASE	LOW IMPLEMENTATION	MEDIUM IMPLEMENTATION	HIGH IMPLEMENTATION
VHT	Hours	1,633,000	1,638,000	1,645,000	1,667,000
	Change	-	*0.3%*	*0.7%*	*2.1%*
VMT	Miles	60,223,000	61,526,600	62,754,400	64,573,900
	Change	-	*2.2%*	*4.2%*	*7.2%*

Table 8. 2050 Daily Trips and Mode Share by Implementation Range of CAV

		BASE	LOW IMPLEMENTATION	MEDIUM IMPLEMENTATION	HIGH IMPLEMENTATION
Non-Motorized	Trips	1,481,000	1,470,000	1,461,000	1,451,000
	Change	-	*-0.7%*	*-1.3%*	*-2.0%*
Transit	Trips	321,000	319,000	317,000	312,000
	Change	-	*-0.6%*	*-1.2%*	*-2.8%*
Auto	Trips	12,269,000	12,280,000	12,289,000	12,301,000
	Change	-	*-0.1%*	*-0.2%*	*-0.3%*
Total	**Trips**	**14,459,000**	**14,457,000**	**14,456,000**	**14,456,000**
	Change	-	*-0.0%*	*-0.0%*	*-0.0%*

The total number of daily trips on transit with CAV implemented in the system decreased as the implementation increased. This may be a result of less congested freeways attracting trips from transit, reducing the overall number of transit trips.

HIGH-TECH TRANSIT SYSTEMS

High-tech transit systems integrate technology within their fleet, often utilizing ITS to become more efficient through Transit Signal Priority (TSP), Traffic Signal Coordination (TSC), and other technologies. This also encompasses connected and autonomous shuttles and buses.

GENERAL TRENDS

ITS is becoming more commonplace. Autonomous shuttle/bus technology is emerging rapidly and is anticipated to be integrated within existing transportation systems. These systems are already being implemented in projects throughout the Wasatch Front Region and elsewhere. UDOT and UTA have partnered on an autonomous shuttle pilot program that is being tested at multiple locations throughout the Region.

In addition, TSP data for the Wasatch Front Region is becoming more readily available through studies, as described in the CAV section of this report. TSP is a technology that reduces wait times at traffic signals. There are a few ways that TSP is implemented — detection systems on transit vehicles, priority request generators, and installation of overall TSP management systems. Research has shown that TSP optimizes schedule adherence, and therefore, waiting time. Evaluating TSP implementation for buses along major arterials have been found to reduce travel time by more than 40 percent — which is translated into faster arrival time, lower transit delay, and more reliable transit service. TSP has also been shown to have minimal impact on overall traffic performance.

IMPLEMENTATION

Table 9. High-Tech Transit System Implementation Ranges

SCENARIO	RANGE	JUSTIFICATION
2020 Existing	5%	Some TSP exists in the Wasatch Front in various locations, but it is minimal. This technology is now coming online more rapidly with additional studies finding the travel benefits.
Base Scenario	0%	None currently exists in the TDM.
Low Implementation	20%	Utilizing higher performing transit routes, low and medium implementation will be identified after analysis of high implementation outputs. The low and medium ranges will utilize the same project list changes. These percentages were informed by research and conversations with transit professionals.
Medium Implementation	55%	
High Implementation	85%	

MODEL INTEGRATION

Autonomous transit is not currently a mode included in the TDM version 8.3.1. To test the benefits of this technology, frequencies for bus rapid transit (BRT), Core Service 15, and Core Service 5 routes for each implementation range will be increased. Increased frequency is based on the assumption that if there is fully autonomous transit, the operational cost of the driver can be applied to other things, such as adding more buses to a route. It is hypothesized that the analysis will show an increase in ridership and trips for each mode.

To model TSP benefits, the speed of select routes will be increased. Projects selected for an increase in speed included BRT projects and projects identified in projected congested corridors.

All Core Service 15 and BRT modes will have increased frequency in the model. Core Service 5 will stay the same frequency. Core Service 15 will move from 15-minute peak frequency to ten-minute peak frequency. BRT will move from a ten-minute peak frequency to a seven-minute peak frequency. BRT and select Core 15 received a ten percent increase in speed on their prospective routes.

Table 10. Frequency adjustments to select transit routes

	ADJUSTED FREQUENCY (PEAK/OFF-PEAK, IN MINUTES)	
MODE	EXISTING	NEW
Core Service 5	5/15	5/15
Core Service 15	15/15	10/15
Bus Rapid Transit	10/15	7/10

FORECASTING RESULTS

As stated above, the low, medium, and high scenarios were run through the TDM Version 8.3.1 with changed frequencies associated with transit mode. It was anticipated that each of these scenarios would increase ridership, and this was found following the final outputs of each scenario. Overall, each scenario had a total increase in ridership from the base scenario. When comparing the scenarios, it was found that some modes had a decrease in ridership. This is because the Core 5 projects did not have a change in frequency and are located in areas with competing transit projects with a mode that had updated frequency, therefore making them more attractive within the model itself.

These results show that increased frequency and speed are more attractive to transit users, emphasizing the need for better technology to create more reliable transit service.

Table 11. Low, Medium, and High Scenario Results for High-Tech Transit

		BASE[1]	LOW IMPLEMENTATION	MEDIUM IMPLEMENTATION	HIGH IMPLEMENTATION
Core 5	Ridership	41,740	42,040	41,740	36,490
	Change	-	*0.7%*	*0%*	*-13%*
Core 15	Ridership	63,570	72,420	82,930	84,890
	Change	-	*14%*	*30%*	*34%*
Bus Rapid Transit	Ridership	61,440	61,180	61,860	97,320
	Change	-	*-0.4%*	*0.7%*	*58%*
Total	**Ridership**	**166,750**	**175,640**	**186,530**	**218,700**
	Change	-	*5%*	*12%*	*31%*

1. For comparison purposes, the base model run for the high-tech transit implementation tests include select unfunded projects that were also included in the low, medium and high scenario testing.

MICROMOBILITY AND E-BIKES

Micromobility refers to the use of lightweight devices typically used for shorter-distance transport. These can include standard bicycles, electric assisted bicycles (e-bikes), electric scooters (e-scooters), and other mobility devices that have improved electric motor technology. Micromobility devices can be either personally owned or shared among users, such as GREENbike in Salt Lake City.

GENERAL TRENDS

According to the North American Bike Share Association's 2020 State of the Industry Report, 36 percent of shared mobility trips replaced a vehicle trip. There were 157 million shared mobility trips in 2019 with an average trip length of 1.3 miles per trip[7]. E-scooters have a higher utilization rate than bikes, while bikes have longer trip distances and durations. A National Association of City Transportation Officials (NACTO) report[8] states that a survey in six cities indicates 45 percent of micromobility trips replaced a vehicle trip, while 28 percent replaced a walking trip. When introduced in 2018, dockless device trips quickly overtook docked device trips due to huge fleets of scooters being deployed rapidly across cities. The growth in the number of dockless devices has slowed as companies have exited the market due to regulation, competition, or the COVID-19 pandemic. However, due to the clear popularity of shared mobility devices, as evidenced by the number of trips taken in 2018 (84 million[9]) and 2019, there is a market for companies that can survive the pandemic and navigate local regulation moving forward. If cities embrace micromobility as a legitimate mobility strategy, current trends indicate that many car trips will be replaced by 2050.

[7] North American Bikeshare Association. "2020 State of the Industry Report". September 3, 2020. https://nabsa.net/about/industry/nabsa-2020-state-of-the-industry-report/
[8] National Association of City Transportation Officials. "Shared Micromobility in the US: 2019". https://nacto.org/shared-micromobility-2019/
[9] National Association of City Transportation Officials. "Shared Micromobility in the US: 2018". https://nacto.org/wp-content/uploads/2019/04/NACTO_Shared-Micromobility-in-2018_Web.pdf

Table 12. Micromobility Implementation Ranges

SCENARIO	RANGE	JUSTIFICATION
2019 Existing	See base scenario	See base scenario
Base Scenario	3% of trips under three miles are by bicycle	Current assignment of bicycle trips in the Wasatch Front TDM Version 8.3.1; based on the 2012 Household Travel Survey.
Low Implementation	8% of trips under three miles are by micromobility	Many surveys and research indicate the majority of micromobility trips are less than three miles, about an 18-minute traditional bicycle ride. Lime micromobility surveys indicate anywhere from 20% to 40% of trips replace a vehicle trip[10], while a McKinsey article indicates 8% to15% of vehicle trips under five miles will be replaced by micromobility, even though about 50% of all passenger miles are under five miles.[11] For low implementation, we modestly increased micromobility trips under three miles from the base scenario. Medium implementation reflects the moderate vehicle trip replacement reflected in user surveys. High implementation reflects the majority of micromobility potential being realized. Walking trips are not accounted for in these percentages. Technology improvements, safe riding conditions (protected infrastructure for bike and scooter users), and policies promoting the competitiveness of micromobility devices against private vehicles will all play a major role in the adoption rate of micromobility.
Medium Implementation	20% of trips under three miles are by micromobility	
High Implementation	40% of trips under three miles by micromobility	

[10] Lime. "Year End Report 2018". https://www.seattlebikeblog.com/wp-content/uploads/2018/12/Lime_Year-End-Report_2018.pdf
[11] McKinsey & Company. "Micromobility's 15,000 Mile Check-up." January 29, 2019. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/micromobilitys-15000-mile-checkup

MODEL INTEGRATION

The current TDM version 8.3.1 does not have a direct input tied to shared micromobility devices. This being the case, a number of model inputs were adjusted to replicate the effects, or act as proxy, of micromobility implementation. Walking trips are presumed to maintain a consistent percentage of trips under three miles in every scenario.

Current model mode choice parameters for biking:

- Speed: 10 miles per hour (MPH)
- Time to travel one mile: 6 minutes
- Biking only allowed for trips less than six miles or up to 36 minutes
- All bike trips weighted two times in-vehicle time

Potential model modifications include:

- Change default travel speed for bikes from 10 MPH to 13 MPH to reflect e-bike and e-scooter speeds.
- Manually change bicycle trips under three miles to reflect low, medium, and high ranges of micromobility implementation.
- Adjust time weights for biking in order to reflect more competitive travel times with vehicles and transit. Time weights, or time penalties, affect a user's decision to take a given travel mode.

Trip Tables with Ranges of Implementation:

The tables below show how trip type changes by increasing bicycles trips while holding steady total trips, trips under three miles, and walking trips.

Table 13. 2019 Base Scenario Total Trips for Micromobility

		WALK		BIKE		NON-MOTORIZED	
	TOTAL TRIPS	TRIPS	%	TRIPS	%	TRIPS	%
Less than 3 miles	5,049,000	844,000	16.7%	**151,000**	**3.0%**	995,000	19.7%
3 to 6 miles	1,876,000	0	0.0%	35,000	1.9%	35,000	1.9%
Total Person Trips	9,559,000	844,000	8.8%	195,000	2.4%	1,039,000	10.9%

Table 14. 2050 Low Scenario Total Trips for Micromobility

		WALK		BIKE		NON-MOTORIZED	
	TOTAL TRIPS	TRIPS	%	TRIPS	%	TRIPS	%
Less than 3 miles	5,049,000	844,000	16.7%	**419,000**	**8.3%**	1,263,000	25.0%
3 to 6 miles	1,876,000	0	0.0%	35,000	1.9%	35,000	1.9%
Total Person Trips	9,559,000	844,000	8.8%	453,000	4.8%	1,298,000	13.6%

Table 15. 2050 Medium Scenario Total Trips for Micromobility

		WALK		BIKE		NON-MOTORIZED	
	TOTAL TRIPS	TRIPS	%	TRIPS	%	TRIPS	%
Less than 3 miles	5,049,000	844,000	16.7%	**1,010,000**	**20.0%**	1,854,000	36.7%
3 to 6 miles	1,876,000	0	0.0%	35,000	1.9%	35,000	1.9%
Total Person Trips	9,556,000	844,000	8.8%	1,045,000	10.9%	1,888,000	19.8%

Table 16. 2050 High Scenario Total Trips for Micromobility

		WALK		BIKE		NON-MOTORIZED	
	TOTAL TRIPS	TRIPS	%	TRIPS	%	TRIPS	%
Less than 3 miles	5,049,000	844,000	16.7%	**2,020,000**	**40.0%**	2,863,000	56.7%
3 to 6 miles	1,876,000	0	0.0%	35,000	1.9%	35,000	1.9%
Total Person Trips	9,559,000	844,000	8.8%	2,054,000	21.5%	2,898,000	30.3%

FORECASTING RESULTS

Out of the three potential model modifications described above, manually changing trip percentages for bicycle trips under three miles to reflect low, medium, and high ranges of micromobility implementation was the best course of action. Once those targets were set, the model was run and trip assignments were made across the other modes as well. Trip output is shown in the tables below, for all non-motorized modes. One notable difference from the tables above is that when the model was run, it did not hold walking trips constant. Therefore, as the model assigned mode choice, many walking trips were reassigned as bicycling trips. However, bicycling trips were assigned from other modes as well, indicating that strategies focused on increasing bicycling trips under three miles could have significant influence on single-occupancy vehicle (SOV) trips. Tables showing the non-motorized trip numbers and the resulting VMT and VHT are below.

Table 17. 2050 Base Scenario Trips for Micromobility

		WALK		BIKE		NON-MOTORIZED	
	TOTAL TRIPS	TRIPS	%	TRIPS	%	TRIPS	%
Less than 3 miles	7,371,000	1,202,000	16.3%	**202,000**	**2.7%**	1,404,000	19.0%
Total Person Trips	14,459,000	1,210,000	8.4%	271,000	1.9%	1,404,000	10.2%

Table 18. 2050 Low Scenario Trips for Micromobility

		WALK		BIKE		NON-MOTORIZED	
	TOTAL TRIPS	TRIPS	%	TRIPS	%	TRIPS	%
Less than 3 miles	7,371,000	1,100,000	14.9%	**590,000**	**8.0%**	1,689,000	22.9%
Total Person Trips	14,459,000	1,106,000	7.6%	727,000	5.0%	1,833,000	12.7%

Table 19. 2050 Medium Scenario Trips for Micromobility

		WALK		BIKE		NON-MOTORIZED	
	TOTAL TRIPS	TRIPS	%	TRIPS	%	TRIPS	%
Less than 3 miles	7,371,000	906,000	12.3%	**1,474,000**	**20.0%**	2,380,000	32.3%
Total Person Trips	14,459,000	911,000	6.3%	1,754,000	12.1%	2,665,000	18.4%

Table 20. 2050 High Scenario Trips for Micromobility

		WALK		BIKE		NON-MOTORIZED	
	TOTAL TRIPS	TRIPS	%	TRIPS	%	TRIPS	%
Less than 3 miles	7,371,000	655,000	8.9%	**2,949,000**	**40.0%**	3,603,000	48.9%
Total Person Trips	14,459,000	657,061	4.5%	3,466,000	24%	4,123,000	28.5%

Table 21. 2050 Daily VHT and VMT by Implementation Range for Micromobility

		BASE	LOW IMPLEMENTATION	MEDIUM IMPLEMENTATION	HIGH IMPLEMENTATION
VHT	Hours	1,633,000	1,615,000	1,586,000	1,532,000
	Change	-	*-1.1%*	*-2.9%*	*-6.2%*
VMT	Miles	60,223,000	59,906,000	59,260,000	58,156,000
	Change	-	*-0.5%*	*-1.6%*	*-3.4%*

ON-DEMAND TRAVEL AND SHARING SERVICES

The use of technology in the form of a mobile application that enables users to call/secure individual and shared transportation services. These services are often called Transportation Network Companies (TNCs).

GENERAL TRENDS

Currently there are about 600 cities with TNCs. TNCs utilize mobility-as-a-service, which integrates all available options for transportation into a single mobility service that allows users to order, track, travel, and pay for transportation.

Highly dependent on population size, existing transportation network, geography, and other variables, TNCs' impact on transit systems can vary greatly. In some instances, cities found services such as Uber and Lyft complemented their transit agencies by increasing ridership. Other studies found the implementation of sharing services increased rail ridership, but decreased bus ridership. Overall, findings show that the implementation of TNCs and sharing services increase VMT and generally lower transit ridership.

MODEL INTEGRATION

The integration of TNCs into the TDM requires a significant amount of assumptions given both the nature of the variability in TNC impacts to transportation systems and a lack of robustness in the TDM to model TNC behavior. Therefore, this external force was not continued through the technical process.

E-COMMERCE AND DELIVERY

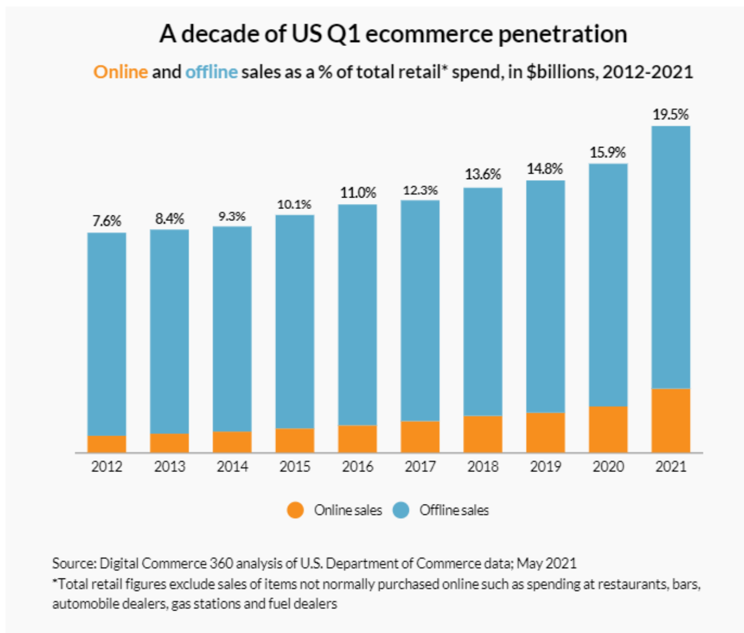
E-commerce and delivery refers to a series of changes that are occurring in the purchase and delivery of goods. These include, but are not limited to, internet shopping, food delivery, truck automation and platooning, and last-mile delivery logistics, including drones.

GENERAL TRENDS

E-commerce represents a growing share of the retail market and is most commonly associated with online shopping of retail products including clothing, consumer electronics, furniture, and beauty products. The increase of e-commerce and local delivery is directly related to freight and goods movement, and highlights the importance of providing more options for how people make purchases and travel to get to these purchases.

Online spending accounted for approximately 15 percent of total retail sales in 2019. According to the US Census Bureau, total e-commerce sales for 2019 were estimated at $601.7 billion. US online sales increased by 40 percent in August 2020 when compared to August 2019. With COVID-19 restrictions in place, internet shopping grew exponentially. According to the Utah State Tax Commission report for March 2020, non-store retail (internet) purchases were up 76 percent in the state from the previous year. Additionally, many brick and mortar shops rapidly moved their business online to continue serving clients during the pandemic. Figure 7 indicates the percentage share of online sales in the last ten years.

Figure 7. Historic E-Commerce Sales



Due to demand for fast delivery, the number of warehouses between 70,000 and 120,000 square feet rose more than 34 percent in five years across the United States. Businesses have been adding smaller fulfillment and distribution center locations that put inventory closer to customers to have items delivered in two days or less. Companies also are adapting existing buildings, such as empty malls, for warehousing, while more retailers are using their stores as fulfillment centers for online customers.

Although e-commerce growth has varied greatly by retail category and price points, there has been an increase in growth within online orders for grocery and food items and curbside delivery of these goods. According to a Gallup study, 11 percent of consumers said they buy groceries online— for pickup or home delivery— at least once per month, up from nine percent in 2017. In 2019, four percent of consumers said they buy groceries online at least once per week, unchanged from 2017. Downloads of Instacart, Walmart mobile grocery app, and Shipt increased 218 percent, 160 percent, and 124 percent respectively on March 15, 2020, compared to the year prior.

IMPLEMENTATION

Although internet shopping has been around for decades, the exponential growth of e-commerce in recent years has been fueled by major online marketplace platforms and widespread use of smartphones. Based on existing data and research of the online market, a range for future implementation of future total retail sales was identified.

Table 22. E-Commerce and Delivery Implementation Ranges

SCENARIO	RANGE	JUSTIFICATION
2020 Existing	E-commerce accounts for approximately 15.9% of total retail sales in the United States (total retail figures exclude sales of items not normally purchased online such as spending at restaurants, bars, automobile dealers, gas stations, and fuel dealers).	Based on retail data from the U.S. Census on the Quarterly E-Commerce Report[12].
Base Scenario	Minimal	Wasatch Front TDM Version 8.3.1.
Low Implementation	25% (of total retail sales)	According to Digital Commerce 360 in Figure 6 above, the average percentage of online sales as part of total retail spending has grown approximately one percent each year since 2012 with the exception of the increase in 2020 caused by the pandemic. If this average of one percent growth continues for 30 years, it is projected that in 2050, 45.9% of the total retail sales will be online sales. The project team rounded this 45.9% to 45% and stated that this would be a reasonable medium implementation rate. The project team developed the low implementation after making the assumption that the annual one percent growth rate could be diminished to a 0.5% growth in online sales for the next 30 years.
Medium Implementation	45% (of total retail sales)	
High Implementation	65% (of total retail sales)	

[12] US Census. 2020. https://www.census.gov/retail/index.html

MODEL INTEGRATION

The primary method for integrating e-commerce in the TDM version 8.3.1 is through increasing the truck trip generation. This method of integration is described further below.

Truck Trip Generation

In the TDM version 8.3.1, truck trip generation is divided into three areas: light-, medium-, and heavy-weight trucks. Within these three subcategories, there are many destination areas: households, retail, food, manufacturing, office, health, agriculture, mining, government and education, and others. Based on the research findings, most e-commerce and delivery trips increased primarily to household destinations, but there may also be some smaller increases to industrial employment centers, retail, and other spaces.

Table 22 shows the truck trip generation increases based on truck type to destination locations based on the length of the trucking vehicles. For industrial, retail, and other employment trips of light-trucking vehicles (i.e., box trucks), there is a low range of 10 percent and a high range of 15 percent. For all three truck weight types, however, although there may be an overall slight increase in trips to destinations, the WFRC team has chosen to specifically emphasize the trips made to households. Therefore, rates of different truck types to household destinations are slightly higher (e.g., 20 percent low, 25 percent medium, 30 percent high implementation rates on light-weight trucks).

Based on research conducted, more deliveries are occurring directly to households. With e-commerce and the rise of fast shipping and delivery, WFRC staff assume that the truck trip generation increases overall.

Table 23. Light Truck Trip Generation Increases to Destination Locations

	IMPLEMENTATION				NEW TRIP GENERATION		
	LOW	MEDIUM	HIGH	LIGHT TRUCK RATE	LOW	MEDIUM	HIGH
Industrial Employment	10%	12.5%	15%	0.320	0.352	0.360	0.368
Retail Employment	10%	12.5%	15%	0.303	0.333	0.341	0.348
Other Employment	10%	12.5%	15%	0.149	0.164	0.168	0.171
Total Households*	20%	25%	30%	0.086	0.103	0.107	0.111

Table 24. Medium Truck Trip Generation Increases to Destination Locations

	IMPLEMENTATION				NEW TRIP GENERATION		
	LOW	MEDIUM	HIGH	MEDIUM TRUCK RATE	LOW	MEDIUM	HIGH
Industrial Employment	10%	12.5%	15%	0.426	0.469	0.479	0.490
Retail Employment	10%	12.5%	15%	0.445	0.490	0.501	0.512
Other Employment	10%	12.5%	15%	0.120	0.132	0.135	0.138
Total Households*	20%	25%	30%	0.174	0.209	0.218	0.227

Table 25. Heavy Truck Trip Generation Increases to Destination Locations

	IMPLEMENTATION				NEW TRIP GENERATION		
	LOW	MEDIUM	HIGH	HEAVY TRUCK RATE	LOW	MEDIUM	HIGH
Industrial Employment	10%	12.5%	15%	0.266	0.293	0.299	0.306
Retail Employment	10%	12.5%	15%	0.166	0.183	0.187	0.191
Other Employment	10%	12.5%	15%	0.023	0.025	0.026	0.026
Total Households*	10%	12.5%	15%	0.097	0.107	0.109	0.112

WFRC recognizes the increasing importance of goods movement within and through the Region and freight mobility is a key component of the Wasatch Choice Vision. With the rise of e-commerce and changing shopping habits, WFRC realizes there is a need to foster the development of an integrated and coordinated multimodal freight network and supports communities in facilitating goods movement while maintaining livability. WFRC is regularly convening an Urban Freight Stakeholder Group to advance freight planning.

In November 30, 2020, a WFRC Urban Freight Stakeholder Workshop occurred and participants were asked about the comments received from industry stakeholders during the WFRC Freight Stakeholder Meeting on November 30, 2020 also indicated that stakeholders are seeing a disproportionately greater increase in the number of trucks than the total weight and volume of goods transported.

Home-Based Shopping Trips

Home-based shopping trips take into account the shopping trips that begin from the home. As more people opt for direct delivery to their home and choose to not make the trip to the store, there may be potential to adjust home-based shipping trips in the model. Traditional travel demand models account for destination shopping trips by assuming that individuals will make trips to stores for purchases. With the growth of e-commerce, delivery of goods has become much more complex. Individual trips may be replaced by home deliveries by retailers, or other third-party carriers. Goods may also be delivered to designated locations (i.e., Amazon lockers) or at the retail store itself for individuals to pick up. This will result in individual trips continuing[13]. For example, during the COVID-19 pandemic, there was a substantial increase in demand for curbside delivery and households are still choosing to pick up an item, making a trip despite not entering the shop.

According to existing UDOT traffic data, traffic volumes at end of 2020 have almost returned to 2019 pre-pandemic levels[14]. This indicates that people and households are continuing to travel and make local trips, despite the pandemic. The rise of e-commerce has shown that although people are ordering goods and having these goods delivered, the delivery transaction may still require some travel for individuals to either pick up their goods at location or have it delivered to their homes. The WFRC team has taken the initial approach of evaluating e-commerce through the truck generation trip increase, as mentioned earlier as the first step of integrating e-commerce and delivery in the model.

Home-based shopping trips may be another area that can be further researched and considered for adjustment within the travel modeling space as e-commerce and delivery continues to grow.

[13] Suel, Ezra. "Incorporating online shopping into travel demand modeling: challenges, progress, and opportunities" Transport Review, 2017. https://www.tandfonline.com/doi/full/10.1080/01441647.2017.1381864
[14] UDOT. "Daily Volume Summary". 2022, https://app.powerbigov.us/view?r=eyJrIjoiNzJhMzQ5YWEtNjNmMy00NGM4LTlhNzMtOThmMDE0MTYyMmMyIiwidCI6ImFkZjY2ZWIyLWZjY2YtNDE3My1iZjQ0LTNmNzY3MzBhYTg5ZSJ9

FORECASTING RESULTS

As indicated in the previous section, the e-commerce and delivery external force was tested in the TDM Version 8.3.1 by increasing truck trips to various destinations based on the different truck type. This analysis showed that as truck trips increased, VHT and VMT also increased.

Table 26. 2050 Daily VHT and VMT by Implementation Rate for E-Commerce and Delivery

		BASE	LOW IMPLEMENTATION	MEDIUM IMPLEMENTATION	HIGH IMPLEMENTATION
VHT	Hours	1,633,000	1,666,000	1,690,228	1,698,000
	Change	-	*2.0%*	*3.5%*	*4.0%*
VMT	Miles	60,223,000	60,970,00	61,336,000	61,660,000
	Change	-	*1.2%*	*1.8%*	*2.4%*

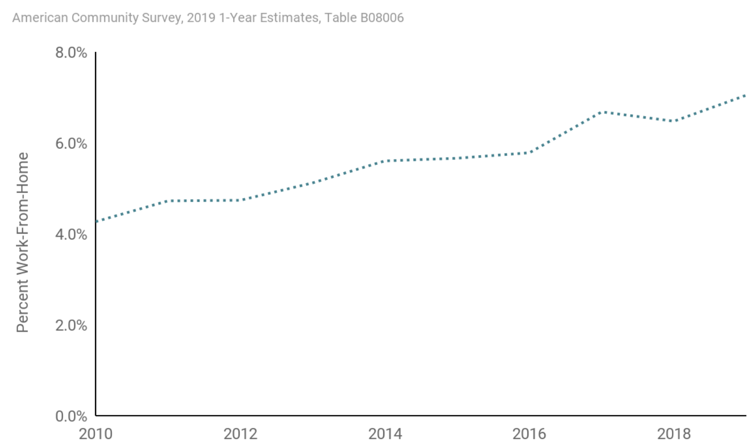
TELECOMMUTING

Telecommuting is the act of partially or entirely replacing out-of-home work activities by working at home or at locations close to home. This has the potential to reduce network congestion and vehicular emissions, specifically during rush hours.

GENERAL TRENDS

Prior to COVID-19, the Wasatch Front Region's work-from-home commute mode share was steadily increasing from 4.3 percent in 2010 to 7.0 percent in 2019[15]. However, the world is undergoing an unparalleled experiment in telecommuting in the midst of COVID-19, the long-term effects of which are unknown. There is a significant opportunity during the pandemic to accelerate long-term adoption of telecommuting. Nationally, just over a third of employed Americans worked mostly or entirely from home by late summer 2020[16].

Figure 8. Regional Percentage Work-From-Home



Telecommuting adoption rates differ by job sectors and it is unclear how this might evolve over the long-term. Although many are currently teleworking, employers throughout the country have expressed concerns related to collaboration, creativity, and burnout of employees[17]. Data-wise, it can be difficult to quantify how many employees are actually working from home as Census data related to work-from-home includes both telecommuters and home-based businesses and the Census generally asks about typical work commutes, missing those who telecommute only one or two days a week.

IMPLEMENTATION

The ranges in Table 27 show the percentage of regional jobs that are home-based and include both workers who telecommute and those whose home is their primary place of employment.

[15] American Community Survey, 1-year Estimates, 2010-2019, Table B08006, "Sex of Workers by Means of Transportation to Work."
[16] Utah Foundation. "The Way Home: The Shift to Telework and its Air Quality Ramifications." January 2021. https://www.utahfoundation.org/wp-content/uploads/rr783.pdf
[17] Utah Foundation.

Table 27. Telecommuting Implementation Ranges

<table>
<tr><th>SCENARIO</th><th>RANGE</th><th>JUSTIFICATION</th></tr>
<tr><td>2020 Existing</td><td>7%</td><td>American Community Survey, 2019 1-Year Estimates, Table B08006</td></tr>
<tr><td>Base Scenario</td><td>5%</td><td>Wasatch Front TDM Version 8.3.1</td></tr>
<tr><td>Low Implementation</td><td>15%</td><td rowspan="3">To determine Region-wide implementation rates, there are three key factors:
1. Telecommuting preference of the workforce,
2. Telecommuting ability of economic sectors, and
3. Frequency of telecommuting.

Recent survey data on the preference of employees to work from home post-COVID-19 indicated that about 15% of employees would prefer to work from home all of the time, 45% would prefer to work from home two to three times per week, and 25% would prefer to work from home one to two times per week, and 15% would not work from home[18]. However, a more detailed look at this survey reveals that although 85% of employees responded that they would like to work remotely in the long-term, only 16% were currently working remotely, wanted to continue, and had the support of their employer to do so in the long-term. Other surveys that focused on traditional office workers indicate upwards of 75% to 85% would like to work remotely for at least two or more days per week[19,20]. However, traditional office and government jobs represent just under a third of the employment in the Region.

Economic sectors have different capacities to work from home. For instance, surveys indicate that over 40% of the healthcare industry employers are unwilling or very unwilling to accommodate telecommuting, while 86% of architecture, engineering, and planning employers were willing or very willing to accommodate telecommuting[21]. In the Model Integration section below, the variation in telecommuting by economic sector is noted.

It is also important to note that the Wasatch Front Travel Demand Model represents a typical day, and is unlikely that all full-time and all part-time telecommuters would work remotely on the same day.

For these reasons, implementation rates varied by economic sector, as shown in the Model Integration section that follows. Table 24 illustrates the individual economic sectors and the overall regional implementation rate.</td></tr>
<tr><td>Medium Implementation</td><td>20%</td></tr>
<tr><td>High Implementation</td><td>25%</td></tr>
</table>

[18] Kittelson and Associates, Inc.. "Will COVID-19 Permanently Alter Teleworking and Commuting Patterns? Here's What 1,000 Commuters Told Us." August 2020. https://www.kittelson.com/ideas/will-covid-19-permanently-alter-teleworking-and-commuting-patterns-heres-what-1000-commuters-told-us/

[19] Utah Foundation.

[20] CBRE. "Workforce Sentiment Survey." September 2020. https://www.cbre.com/thewayforward/Workforce-Sentiment-Survey?article=%7B9DD4F9D7-60E8-4B40-B4E8-4357ECD0A9E0%7D

[21] Kittelson and Associates, Inc. "Will COVID-19 Permanently Alter Teleworking and Commuting Patterns?"

MODEL INTEGRATION

To test telecommuting within the travel demand model structure, the amount of employment attractions within each traffic analysis zone (TAZ) was reduced. This approach would keep overall employment within the model at the control-total level, but would reduce work-based trip generation by shifting employment to home-based jobs (HBJ).

The TDM version 8.3.1 stratifies employment into eleven primary employment fields:

1. Retail (RETL): retail trade
2. Food and accommodation (FOOD): Accommodation and food service
3. Manufacturing (MANU): Manufacturing
4. Wholesale and transportation (WSLE): Utilities, wholesale trade, transportation, and warehousing
5. Office (OFFI): Information, professional services, technical services, and management
6. Government and education (GVED): Education, military, federal government, and state and local government
7. Health care (HLTH): Health care and social assistance
8. Other (OTHR): Finance and insurance, real estate, administrative and waste services, arts, entertainment, recreation, and other services
9. Agriculture (AGRI): Agriculture, forestry, fishing, hunting, and farm
10. Mining (MING): Mining, quarrying, and oil and gas extraction
11. Construction (CONS): Construction

The TDM version 8.3.1 assumes a portion of employment is at the household location and does not attract trips in the same way that employment at the jobsite would. These home-based jobs are removed from each of the Kem C. Gardner Policy Institute (GPI) sectors into a new category, HBJ, before the GPI data is aggregated into the 11 travel model categories. The existing model assumes a reduction in employment and addition to HBJ based on the following percentages:

- Retail 2.5%
- Accommodations and Food 2.5%
- Manufacturing 1.0%
- Utilities 1.0%
- Wholesale 1.0%
- Transportation and Warehousing 1.0%
- Information 8.0%
- Professional and Technical Services 8.0%
- Management 8.0%
- Education 8.0%
- Military 2.5%
- Federal Government 2.5%
- State and Local Government 2.5%
- Health 8.0%
- Finance and Insurance 2.5%
- Real Estate 2.5%
- Administrative and Waste Services 8.0%
- Arts, Ent, Rec 8.0%
- Other services 8.0%
- Agriculture 0.0%

- Farm 20.0%
- Mining 0.0%
- Construction 1.0%

Each employment category, with the exception of agriculture, mining, and construction, was modified on a low, medium, and high level based on these existing home-based work percentages:

Table 28. Telecommuting Implementation Rates by Employment Category

EMPLOYMENT CATEGORY	LOW IMPLEMENTATION	MEDIUM IMPLEMENTATION	HIGH IMPLEMENTATION
RETL	-2.5%	-5.0%	-7.5%
FOOD	-2.5%	-5.0%	-7.5%
MANU	-1.0%	-3.0%	-5.0%
WSLE	-1.0%	-3.0%	-5.0%
OFFI	-20.0%	-30.0%	-40.0%
GVED	-15.0%	-20.0%	-25.0%
HLTH	-15.0%	-20.0%	-25.0%
OTHR	-15.0%	-20.0%	-25.0%
OVERALL HBJ	**15.6%**	**20.2%**	**24.7%**

FORECASTING RESULTS

As indicated in the previous section, telecommuting was tested in the TDM Version 8.3.1 by reducing work-based trip generation. This reduction in commute trips led to fewer overall daily trips being forecasted in 2050 - between three and five percent depending on implementation rate, as shown in Table 29. Mode share remained similar between the base and each of the three scenarios, with non-motorized at about ten percent, transit at about two percent, and auto at about 85 percent.

Table 29. 2050 Daily Trips and Mode Share by Telecommuting Implementation Rate

		BASE	LOW IMPLEMENTATION	MEDIUM IMPLEMENTATION	HIGH IMPLEMENTATION
Non-Motorized	Trips	1,481,000	1,448,000	1,434,000	1,420,000
	Change	-	*-2.2%*	*-3.2%*	*-4.1%*
Transit	Trips	321,000	301,000	292,000	284,000
	Change	-	*-6.2%*	*-9.0%*	*-11.6%*
Auto	Trips	12,269,000	11,888,000	11,721,000	11,552,000
	Change	-	*-3.1%*	*-4.5%*	*-5.8%*
Total	**Trips**	**14,459,000**	**14,027,000**	**13,837,000**	**13,647,000**
	Change	-	*-3.0%*	*-4.3%*	*-5.6%*

As expected, the majority of the reduction in trips, about 80 percent, were home-based work trips, even though home-based work trips account for less than 20 percent of trips forecasted in the model.

These reductions in daily trips led to significant reductions in VHT forecasted, as well as reductions in VMT, that mirrored the reductions in daily trips. This is not surprising as telecommuting reduces trips mainly in periods of the day with the greatest congestion.

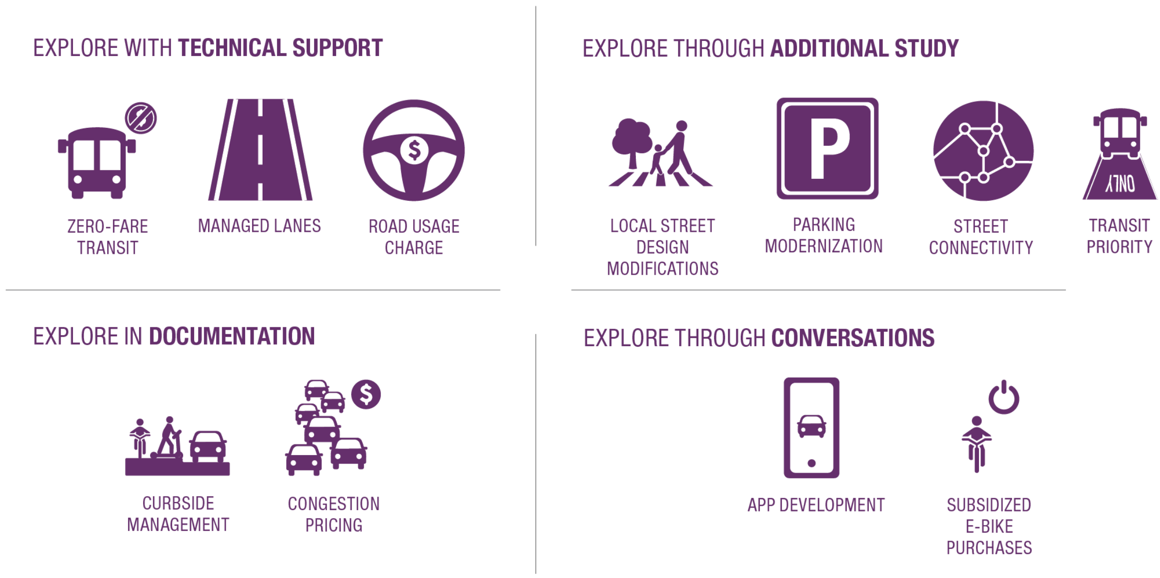
Table 30. 2050 Daily VHT and VMT by Telecommuting Implementation Rate

		BASE	LOW IMPLEMENTATION	MEDIUM IMPLEMENTATION	HIGH IMPLEMENTATION
VHT	Hours	1,633,000	1,573,000	1,545,000	1,520,000
	Change	-	*-3.7%*	*-5.4%*	*-6.9%*
VMT	Miles	60,223,000	58,698,000	58,027,000	57,365,000
	Change	-	*-2.5%*	*-3.6%*	*-4.7%*

POLICIES

WFRC conducted initial research on 11 forward-thinking transportation policies. Through discussions with WFRC analytics staff and peer groups, only three of these policies were moved forward to explore with technical support: zero-fare transit, managed lanes, and road usage charge. The remainder of the policies, some of which were unable to test within technical tools, will either be explored through a larger, additional study; through conversations with local communities and stakeholders; or simply be included in documentation as policies that were initially explored.

Figure 9. Forward-Thinking Transportation Policy Exploration



After additional analyses and proxy tests were conducted with the TDM on zero-fare transit, managed lanes, and the road usage charge, it was determined that no forward-thinking transportation policies would be further evaluated within or permanently incorporated into the TDM.

ZERO-FARE TRANSIT

CURRENT IMPLEMENTATION AND GENERAL TRENDS

UTA currently operates a Free-Fare Zone in Downtown Salt Lake City where passengers may ride for free when entering and exiting a fixed-route bus, paratransit vehicle, or TRAX train within the boundaries identified by UTA. Several universities in Utah, in partnership with UTA, provide transit passes as part of their enrollment. In February 2022, UTA operated Fare-Free February, where the entire UTA system operated without charging fares. Further, in the 2022 Utah Legislative Session, two bills were run - one in the House and one in the Senate - that would prohibit UTA from charging fares. Later this year, WFRC, MAG, UDOT, and UTA will begin a zero-fare transit study looking at financial, social, and ridership impacts of various zero-fare scenarios.

POLICY TEST CASE

Payment for transit has been an identified barrier for riders, and the removal of such a barrier has been shown to increase ridership. The question was then asked, “how would removing or reducing fares affect transit ridership?” There were three policy test cases for zero-fare transit: system-wide zero-fare, system-wide zero-fare with removal of the modeling transfer penalty, and system-wide reduced fare by 50 percent.

MODEL INTEGRATION

To test zero-fare transit in the TDM, fares needed to be changed for three different fare systems. System 1 sets fares for regular service such as all bus and TRAX, system 2 sets fares for premium service such as express bus, and system 3 sets fares for commuter rail. System 3 is the only fare system that uses zones to establish fare amounts. Table 9 shows fares for existing and the three policy test cases by fare system.

Table 31. Zero-Fare Test Cases

	ADJUSTED		
EXISTING	ZERO-FARE	ZERO-FARE (NO TRANSFER PENALTY)	REDUCED FARE
Fare System 1 - Regular Service (All bus + TRAX) $1.15 **Fare System 2** - Premium Service (Express Bus) $2.50 **Fare System 3** - Commuter Rail Zone 1 - $1.15 Zone 2 - $1.42 Zone 3 - $1.69 Zone 4 - $1.97	**Fare System 1** - Regular Service (All bus + TRAX) $0 **Fare System 2** - Premium Service (Express Bus) $0 **Fare System 3** - Commuter Rail Zone 1 - $0 Zone 2 - $0 Zone 3 - $0 Zone 4 - $0	**Fare System 1** - Regular Service (All bus + TRAX) $0 **Fare System 2** - Premium Service (Express Bus) $0 **Fare System 3** - Commuter Rail Zone 1 - $0 Zone 2 - $0 Zone 3 - $0 Zone 4 - $0	**Fare System 1** - Regular Service (All bus + TRAX) $0.58 **Fare System 2** - Premium Service (Express Bus) $1.25 **Fare System 3** - Commuter Rail Zone 1 - $0.58 Zone 2 - $0.71 Zone 3 - $0.85 Zone 4 - $0.99

Zone 5 - $2.24 Zone 6 - $2.52 Zone 7 - $2.79 Zone 8 - $3.07 Zone 9 - $3.34 Zone 10 - $3.62 Zone 11 - $3.89 Zone 12 - $4.17 Zone 13 - $4.44 Zone 14 - $4.72	Zone 5 - $0 Zone 6 - $0 Zone 7 - $0 Zone 8 - $0 Zone 9 - $0 Zone 10 - $0 Zone 11 - $0 Zone 12 - $0 Zone 13 - $0 Zone 14 - $0	Zone 5 - $0 Zone 6 - $0 Zone 7 - $0 Zone 8 - $0 Zone 9 - $0 Zone 10 - $0 Zone 11 - $0 Zone 12 - $0 Zone 13 - $0 Zone 14 - $0	Zone 5 - $1.12 Zone 6 - $1.26 Zone 7 - $1.40 Zone 8 - $1.54 Zone 9 - $1.67 Zone 10 - $1.81 Zone 11 - $1.95 Zone 12 - $2.09 Zone 13 - $2.22 Zone 14 - $2.36

FORECASTING RESULTS

Reducing fares, whether removing fares completely or reducing them, improved transit ridership by 14 to 35 percent. The two zero-fare policy test cases out-performed the reduced fare case by 65,000 to 85,000 additional transit trips.

Table 32. Zero-Fare Modeling Results

		BASE	ZERO-FARE	ZERO-FARE (NO TRANSFER PENALTY)	REDUCED FARE
Total	**Ridership**	401,731	521,345	540,867	456,342
	Change	-	*30%*	*35%*	*14%*

ROAD USAGE CHARGE

A road usage charge is a usage-based fee based on a certain rate per mile traveled, replacing or supplementing taxes imposed on fuel consumption.

CURRENT IMPLEMENTATION AND GENERAL TRENDS

There has been a road usage charge pilot program in Utah since the start of 2020. SB 136 (2018) and SB 72 (2019) directed UDOT to implement this pilot program. Currently, the pilot program allows electric and hybrid vehicle owners to have an option to pay a road usage charge in lieu of their annual alternative fuel vehicle fee. At the end of 2020, there were a total of 3,648 drivers enrolled in the program - 1,469 electric vehicles; 446 plug-in electric hybrids; and 1,773 gas hybrids. The Utah State Legislature has passed SB 150 (2020) requiring UDOT to enroll all vehicles registered in the State in the road usage charge program by 2031. Nationally, there has yet to be a pilot program, although the federal government is interested in exploring this concept at a broader scale.

POLICY TEST CASE

Road usage charges have been shown to alter travel behavior and reduce vehicle miles traveled. This is because the road usage charge program can effectively match user impacts to the fees users pay. However, this elasticity is not able to be modeled in the current travel demand modeling framework. Thus, the question was asked, “What does an overall increase in auto operating cost do to travel demand and mode choice?” The policy test case for the road usage charge policy was essentially changed to an increased cost of driving test case.

MODEL INTEGRATION

In the travel demand model version 8.3.1, auto operating cost is defined for four user types: personal auto, light trucks, medium trucks, and heavy trucks. Auto operating costs are composed of the price of motor fuel per gallon, maintenance costs, and tire replacement costs. To test an increased cost of driving, all auto operating costs were increased by 20 percent, as shown in Table 33.

Table 33. Increased Auto Operating Cost Test

		BASE	20% INCREASE POLICY TEST
Auto	cents/miles	18.3	22.0
Light Trucks	cents/mile	24.6	29.5
Medium Trucks	cents/mile	47.8	57.4
Heavy Trucks	cents/mile	63.7	76.4

FORECASTING RESULTS

Increasing the auto operating costs by 20 percent had minimal impact on daily auto trips, while slightly decreasing transit trips and slightly increasing non-motorized trips. In theory, an increase in the cost of driving would reduce auto trips and increase transit and non-motorized trips, having more impact the higher the cost of driving. It is unclear why transit trips declined. Additionally, changes in mode share led to very minor changes in VHT and slightly decreased VMT.

Table 34. 2050 Daily Trips for Increased Auto Operating Cost

		BASE	INCREASED AUTO OPERATING COST TEST
Non-Motorized	Trips	1,481,000	1,535,000
	Change	-	*3.7%*
Transit	Trips	341,000	333,000
	Change	-	*-2.3%*
Auto	Trips	12,250,000	12,202,000
	Change	-	*-0.4%*
Total	**Trips**	**14,460,000**	**14,458,000**
	Change	-	*-0.0%*

Table 35. 2050 Daily VHT and VMT for Increased Auto Operating Cost

		BASE	INCREASED AUTO OPERATING COST TEST
VHT	Hours	1,629,000	1,615,000
	Change	-	*-0.9%*
VMT	Miles	60,136,000	58,653,000
	Change	-	*-2.5%*

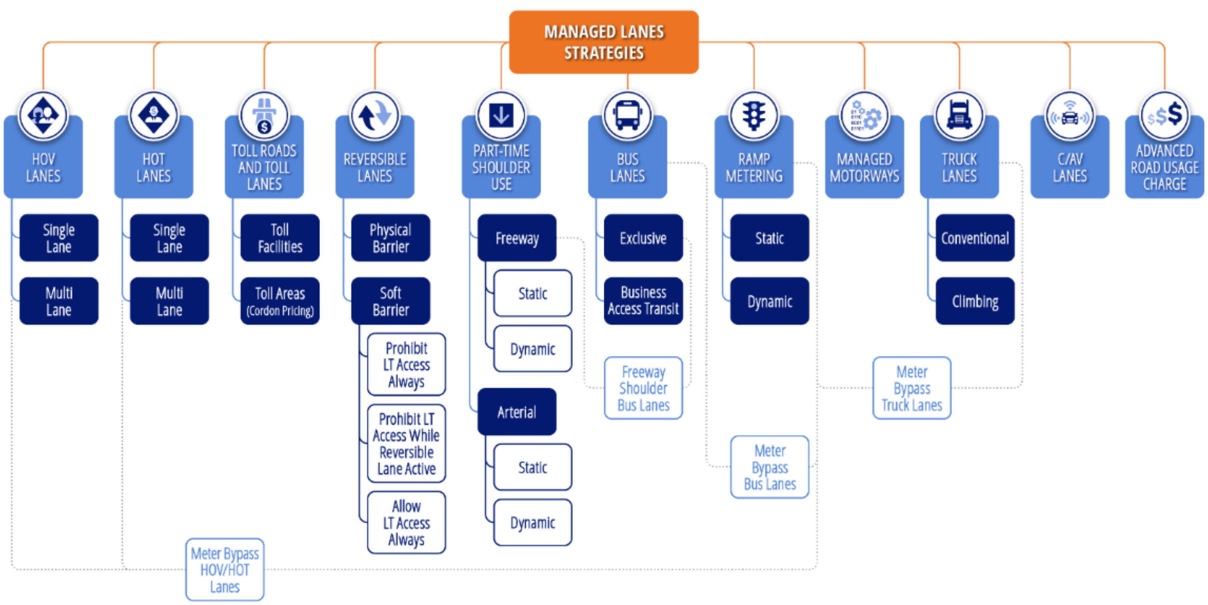
MANAGED LANES

Managed lanes are operational strategies that optimize the carrying capacity of existing transportation facilities[22]. There is a comprehensive package of strategies which include coordinated ramp signaling, lane use management, congestion pricing, and variable message signing that UDOT has explored as part of its broader Managed Lanes Study conducted in 2021.

CURRENT IMPLEMENTATION AND GENERAL TRENDS

According to UDOT, three main benefits can be achieved through managed lanes strategies, including congestion management, demand management, and potential revenue source. There are a suite of strategies which fall under the managed lanes concept. Figure 10 illustrates the types of managed lanes strategies UDOT explored through the study:

Figure 10. Managed Lanes Strategies



Some of the managed lane strategies, such as road usage charge, high-occupancy toll lanes, and reversible lanes are already in practice in Utah, but UDOT's study seeks to find other potential road segments that may qualify for these potential strategies.

POLICY TEST CASE

Managed lanes can increase mainline throughput, network productivity, and overall travel time reliability depending on which type of strategy is applied. Toll roads and toll lanes generate revenues to help cover construction, operations, and maintenance needs of transportation systems. They can also help manage congestion and travel demands through the economic influence of congestion pricing. Due to the large

[22] https://utah-managed-lanes-study-uplan.hub.arcgis.com/

number of managed lane strategies and time constraints, there were some challenges in incorporating all strategies into the current travel demand modeling framework. Thus, the WFRC team and partners determined that certain policies should be prioritized for testing.

The following table describes the reasoning for testing the different strategies within the TDM Version 8.3.1. In a few cases, the managed lane strategy may already be covered within another external force considered by WFRC. The WFRC team determined that it was best to test tolling, and ask the policy test question: "what would happen if our Region created a fully connected toll road transportation system?" Toll roads are a congestion management, demand management, and revenue generator and thus were selected to be evaluated. Utah does not currently have any full toll facilities.

Table 36. Managed Lane Test Cases

UDOT MANAGED LANE STRATEGY	MODEL CAPABILITY	TESTING (Y/N)	REASONING
Bus Lanes	Yes	No	Difficulty in incorporating within the TDM 8.3.1 due to time and other constraints.
CAV Lanes	No	No	CAV is already being considered in greater detail as a stand-alone external force that evaluates CAV lanes on the freeway.
High-Occupancy Vehicle (HOV) Lanes	Yes	No	The TDM 8.3.1 model has this in current practice, particularly on freeway facilities.
High-Occupancy Toll (HOT) Lanes	Yes	No	The TDM 8.3.1 model has this in current practice, particularly on freeway facilities. In addition, this is currently implemented on the I-15 facility.
Managed Motorways	Yes	No	Through the research and TDM 8.3.1 model adjustments for the CAV external force, the WFRC team has already taken into account making freeway capacity adjustments. The managed motorways strategy will not be tested to reduce redundancy.
Part-time shoulder use	Yes	No	Difficulty in incorporating within the TDM 8.3.1 due to time and other constraints.
Ramp metering	No	No	Through the research and TDM 8.3.1 model adjustments for the CAV external force, the WFRC team has already taken into account making freeway capacity adjustments created and supported by ramp metering. The ramp metering strategy will not be tested to reduce redundancy.
Reversible Lanes	Yes	No	Difficulty in implementation in the TDM 8.3.1 to test the reversible lanes.

Toll Lane	Yes	No	Toll lanes were not tested because the setup in the travel model would be similar to HOV. The WFRC and UDOT team determined it would be more effective to test the viability of a tolled road rather than a lane.
Truck lanes	No	No	There is precedent in Utah for restricting truck traffic from the leftmost lanes on certain highways and freeways. However, truck-exclusive lanes are not currently in place in the state. Currently, there is low interest from stakeholders to review truck-specific lanes.
Toll Roads	Yes	Yes	This policy has never been tested within the existing model framework and there is ease in incorporation within the model to test. This will be evaluated on the freeway and limited access facilities.

MODEL INTEGRATION

The following roads were identified for testing for toll road facilities. These projects were largely identified in the UDOT Managed Lanes Study, but with some augmentation. Although toll roads were identified in Big Cottonwood Canyon (SR-190) and Little Cottonwood Canyon Canyon (SR-210) in UDOT's initial research on qualified segments, the WFRC team removed these from the testing in the model and focused on projects that were not primarily associated with recreational uses. I-15, I-215, I-84, and I-80 were not tested for tolling capabilities due to the fact that general purpose lanes built by federal funds cannot be transitioned to tolling facilities.

Table 37. Toll Roads Implementation Testing in Model

ROADWAY	TO EXTENT	FROM EXTENT	COUNTY
Legacy Highway	I-15	I-215	Davis
Mountain View Highway	I-80	Pioneer Crossing	Salt Lake
Bangerter Highway	I-80	I-15	Salt Lake
SR-201	8400 West	I-15	Salt Lake
Lehi 2100 North	Mountain View	I-15	Utah
Pioneer Crossing	Mountain View	I-15	Utah
Cory Wride Freeway	End of Road (Fairfield)	Mountain View	Utah

Foothill Freeway	Pioneer Crossing	Redwood	Utah
Utah Lake Bridge Crossing	Redwood Road	Parallel I-15 Road	Utah

FORECASTING RESULTS

To test full toll roads in the existing modeling framework, the WFRC team removed the HOV lanes from the model network and converted them to general purpose lanes. All lanes on freeways and access-controlled facilities were then modeled as tolled facilities (with the exception of I-15, I-215, and I-80). The project team did not toll any arterials since it was not recommended in the UDOT Managed Lanes study. The outcome was an overall increase in delay on non-freeway facilities such as local streets and arterials. There was an overall increase in delay by 85% for the entire transportation network.

Table 38. 2050 Daily VHT, VMT and Delay for Tolled Freeway Facilities

		BASE	TOLLED FREEWAY FACILITIES TEST
VHT	Hours	1,629,000	1,869,000
	Change	-	*15%*
VMT	Miles	60,136,000	59,781,000
	Change	-	*-1%*
Delay	Hours	202,000	373,000
	Change	-	*85%*

For non-freeway facilities in particular, delay increased by 17 percent in the managed lanes toll roads scenario. There was a 129 percent increase in overall delay for non-freeway and limited access facilities, indicating that there will be a desire to remain on facilities that have no cost burden rather than utilize tolled facilities. This shift increased vehicle hours traveled by 28 percent for non-freeway facilities and reduced vehicle hours of travel on freeway facilities by 12 percent.