MetroPlan 2045 Regional Transportation Plan

Literature Review

METROPLAN
GREATER FLAGSTAFF

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1.0 Introduction

This chapter presents a literature review of best practices and empirical research on five key elements as part of the initial development of MetroPlan's 2045 Regional Transportation Plan (RTP). They include: (1) Transportation Demand Management strategies for reducing vehicle miles traveled, (2) Emerging trends and the implications of COVID-19 on travel behavior, (3) Applications of Intelligent Transportation Systems, (4) Electric and autonomous vehicles and (5) Performance measures. The literature review will be used early in the planning process to help inform MetroPlan and their advisory committees. The five key elements of the literature review will be presented to the advisory committees in order to collect feedback and make updates accordingly. The final version of the literature review will then be used as input to the travel demand forecasting planning scenarios, as well as the development of the Performance Measures and Electric Vehicle Policy Plan.

2.0 Transportation Demand Management (TDM)

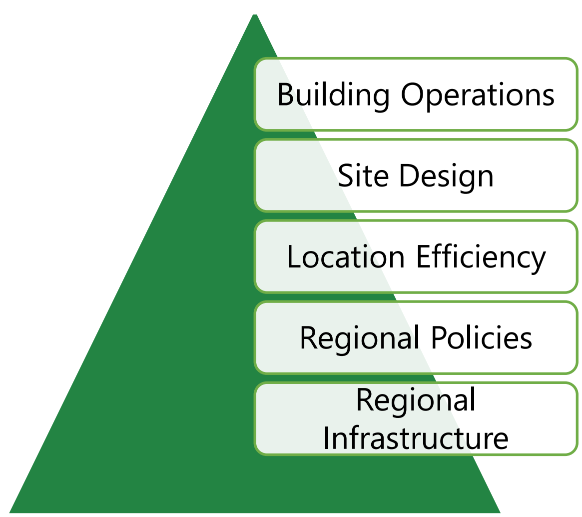
This section includes a summary of empirical research on various transportation demand management (TDM) strategies and their estimated vehicle miles travelled (VMT) benefit. The TDM menu provided in ***Table 1*** is divided into two parts: Project versus program level -including TDM's categorized by travel mode typology. The references in ***Table 1*** are derived from the Draft California Air Pollution Control Officers Association's (CAPCOA) *Quantifying Greenhouse Gas Measures, A Resource for Local Government to Assess Emission Reductions from Greenhouse Gas Mitigation Measures* (Handbook)[1]. CAPCOA prepared the handbook to provide a much-needed, common platform of information and tools to support local governments. Only those measures with literature to defensibly support emissions quantification, including micromobilty, are presented. The handbook and the evolution of climate legislation in California, including AB 32 (Global Warming Solutions Act) and SB 743 (VMT under CEQA), provide MetroPlan with a useful resource and lessons learned.

Each TDM measure includes an estimated maximum VMT benefit – depending on the quality of implementation and the observed changes in travel behavior. A combination of multiple TDM measures is not the cumulative sum of the individual VMT benefits; meaning there is a dampening effect given most of the measures are not mutually exclusive and can influence travel behavior when offered to individuals simultaneously. The Handbook of peer-reviewed empirical evidence is typically referred to during the environmental review process for new projects in California -and is considered defensible in accordance with the California Environmental Quality Act (CEQA). The body of research referenced in the Handbook is at the national scale.

The largest effects of TDM strategies on VMT are from policies related to land use, location efficiency, and infrastructure investments that support sustainable mobility -including taking transit, walking, and bicycling. While there are many TDM measures that can influence VMT related to site design and building operations (project level), those measures have smaller effects that are often dependent on final building tenants – see *Error! Reference source not found.* below.

Ultimately, TDM is about providing all individuals (*regardless of geographic location or economic status*) practical, cost-feasible, and viable options of travel other than the private vehicle.

Figure 1 – Transportation Related TDM Measures



[1] Released for public comment in August 2021:http://www.airquality.org/air-quality-health/climate-change/ghg-handbook-caleemod To be published some time in Spring 2022

Table 1 – TDM Menu with Expected VMT Benefits				
TDM Strategy		**Maximum Expected VMT Benefit** = office/ commercial = residential	**Local Considerations**	**Source(s) – From Updated CAPCOA Draft Handbook on Quantifying GHG Measures (to be released for public comment late 2021)**
Project Level				
Active Transportation				
	Provide End-of-Trip Bicycle Facilities *e.g., bike lockers or showers*	4.4% (office/commercial)	• Enhancing the user experience. Comfort is an important factor that influences travel behavior. • Suggested locations include: Downtown Flagstaff, college campuses (NAU, CCC), office campuses (i.e., Gore)	• Buehler, R. 2012. *Determinants of bicycle commuting in the Washington, DC region: The role bicycle parking, cyclist showers, and free car parking at work.* Transportation Research Part D, 17, 525–531. • FHWA. 2017a. *National Household Travel Survey – 2017 Table Designer*. Travel Day PT by TRPTRANS by HH_CBSA. • FHWA. 2017b. *National Household Travel Survey – 2017 Table Designer*. Workers by WRKTRANS by HH_CBSA.
	Provide Pedestrian Network Improvements *e.g., ensure sidewalk continuity*	6.4% (office/commercial) & (residential)	• Some neighborhoods are disconnected, with infrastructure barriers such as highways. • Opportunity to address first/last mile, as well as meeting ADA requirements. • Suggested locations include: South Milton Street between Downtown Flagstaff and the NAU campus (increasing pedestrian access to commercial spaces in between), East Butler Avenue between East Sawmill Road and Ponderosa Parkway to increase pedestrian access to these commercial centers, clusters of commercial/residential developments (i.e. North Fourth Street, South Woodlands Village Boulevard, North Humphreys Street)	• Frank, L., Greenwald, M., Kavage, S. and Devlin, A. 2011. *An Assessment of Urban Form and Pedestrian and Transit Improvements as an Integrated GHG Reduction Strategy*. WSDOT Research Report WA-RD 765.1, Washington State Department of Transportation. April. • Handy, Susan, Glan-Claudia, Sciara, and Boarnet, Marlon. 2014. *Impacts of Pedestrian Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions: Policy Brief*. September. Available: • FHWA. 2019. *2017 National Household Travel Survey Popular Vehicle Trip Statistics.* Available: https://nhts.ornl.gov/vehicle-trips. Accessed: January 2021.

Table 1 – TDM Menu with Expected VMT Benefits			
TDM Strategy	**Maximum Expected VMT Benefit** = office/ commercial = residential	**Local Considerations**	**Source(s) – From Updated CAPCOA Draft Handbook on Quantifying GHG Measures (to be released for public comment late 2021)**
Shared Mobility			
Implement Pedal Bikeshare (non-electric) Station  (Las Vegas Downtown Bikeshare launch. Source: S. Contreras, 2016).	0.02% or 0.06% for E-Bikeshare &	• Building on the lessons learned from previous experience, and best practices. • Although the VMT benefit is low, there are public health benefits. • E-bikes can help reduce some of the barriers of entry, especially for tourists. • Suggested locations include: bikeshare stations that connect residential areas to Flagstaff Medical Center, college campuses (NAU/CCC), and fulfill short distance trips to and from essential commercial centers (Downtown Flagstaff, grocery stores (Sprouts, Whole Foods)	• California Air Resources Board (CARB). 2020a. *Revisiting Average Trip Length Defaults and Adjustment Factors for Quantifying VMT Reductions from Car Share, Bike Share, and Scooter Share Services.* May. • FHWA. 2017. *National Household Travel Survey – 2017 Table Designer*. Travel Day PT by TRPTRANS by HH_CBSA. • FHWA. 2018. *Summary of Travel Trends 2017 – National Household Travel Survey.* July. • Lazarus, J., Pourquier, J., Feng, F., Hammel, H., Shaheen, S. 2019. *Bikesharing Evolution and Expansion: Understanding How Docked and Dockless Models Complement and Compete – A Case Study of San Francisco.* Paper No. 19-02761. Annual Meeting of the Transportation Research Board: Washington, D.C. • Metropolitan Transportation Commission (MTC). 2017. *Plan Bay Area 2040 Final Supplemental Report – Travel Modeling Report*. July.
Provide On-Site Car Share Parking Stalls	0.15% or 0.18% for EV Car Share &	• Suggested locations include: clustered office buildings or industrial and institutional campuses (i.e., Gore, NAU/CCC, retail land uses along East Marketplace Drive	• Cervero, R., Golub, A., Nee, B. 2007. *San Francisco City CarShare: Longer-Term Travel-Demand and Car Ownership Impacts.* January. • Lovejoy, K., Handy, S., Boarnet, M. 2013. Impacts of Carsharing on Passenger Vehicle Use and Greenhouse Gas Emissions Policy Brief. October. Available: • San Diego Association of Governments (SANDAG). 2017. *San Diego Regional Transportation Study.* Volume 1: Technical Report.

Table 1 – TDM Menu with Expected VMT Benefits			
TDM Strategy	**Maximum Expected VMT Benefit** = office/ commercial; = residential	**Local Considerations**	**Source(s) – From Updated CAPCOA Draft Handbook on Quantifying GHG Measures (to be released for public comment late 2021)**
Transit or Shuttles			
Provide Subsidized or Discounted Transit Passes  (San Francisco Street & Route 66. Downtown Flagstaff. Source: F&P, 2021)	5.5% (office/commercial & residential) Note: The elasticity of transit boardings with respect to transit fare price = -0.43. The amount of VMT reduction is dependent on how much is subsidized or discounted (50% vs. 100%).	• NAU provides passes to students • Consider as a strategy in the short-range transit plan (SRTP) • Discount fares are provided by some employers; NAIPTA may be able to provide additional information • Explore making transit free, or a tiered fare pricing system	• FHWA. 2017. *National Household Travel Survey – 2017 Table Designer*. Travel Day PMT by TRPTRANS by HH_CBSA, Workers by WRKTRANS by HH_CBSA. • Handy, L., Boarnet, S. 2013. *Impacts of Transit Service Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions.* • Litman, T. 2020a. *Transit Price Elasticities and Cross-elasticities.* Victoria Transport Policy Institute. April. • Taylor, B., Miller, D., Iseki, H., & Fink, C. 2008. Nature and/or Nurture? Analyzing the Determinants of Transit Ridership Across US Urbanized Areas. Transportation Research Part A: Policy and Practice, 43(1), 60-77.
Provide Employer-Sponsored Vanpool	3.4%-20.4% (office/commercial)	• Targeted at longer commutes, such as the City of Flagstaff to Sedona or Grand Canyon area • Private operators pre-COVID were providing commuting vanpools for residents living in Bellemont and Doney Park and working in Flagstaff • There may be an opportunity for hotels to provide shuttles for recreational (non-commuting) trips to/from Snow Bowl on US 180	• FHWA. 2017. *National Household Travel Survey – 2017 Table Designer*. Travel Day VT by HH_CBSA by TRPTRANS by TRIPPURP. • San Diego Association of Governments (SANDAG). 2019. *Mobility Management VMT Reduction Calculator Tool – Design Document.* June.
Commute Trip Reduction			

Table 1 – TDM Menu with Expected VMT Benefits

	Voluntary Commute Trip Reduction Program *e.g., carpool encouragement, preferential carpool parking, and flexible schedules for carpools*	4.0%	• Carpooling in light of COVID. • Suggested locations include: clustered office buildings or industrial and institutional campuses (i.e. Gore, NAU/CCC, retail land uses along East Marketplace Drive	• Boarnet, M., Hsu, H., Handy, S. 2014. *Impacts of Employer-Based Trip Reduction Programs and Vanpools on Passenger Vehicle Use and Greenhouse Gas Emissions*. September
	Trip Reduction Marketing *e.g., online or onsite commuter info, transit pass sales, and guaranteed ride home*	4.0%	• Opportunities here for City of Flagstaff Sustainability/Climate Program to include trip reduction marketing as part of their educational/training workshops	• Transportation Research Board. 2010. *Traveler Response to Transportation System Changes Handbook, Third Edition: Chapter 19, Employer and Institutional TDM Strategies*. June.
	Rideshare Program	8.0%	• Targeted at longer commutes, such as the City of Flagstaff to Sedona or Grand Canyon area, but can also apply to nearby residential communities such as Bellemont and Doney Park	• San Diego Association of Governments (SANDAG). 2019. *Mobility Management VMT Reduction Calculator Tool – Design Document.* June.
Parking Management				
P	Unbundle Parking Costs or Cash-Out Program	15.7% &	• Potentially focused on off-campus student housing for NAU • Apartment developments: The Grove at Flagstaff, Renew Flagstaff, Pine View Village Apartments, Flagstaff Village Apartments, University Square Apartments, Fremont Station Apartments, etc. • The Carbon Neutrality Plan has parking management goals/strategies, which can be coordinated with the RTP. For example, one identified climate action by the City is to reduce parking requirements for new apartment buildings.	• Shoup, D. 2005. *Parking Cash Out.* Planners Advisory Service, American Planning Association. • AAA. 2019. *Your Driving Costs*. September. • California Department of Transportation (Caltrans). 2002. *2000–2001 California Statewide Household Travel Survey Final Report.* • Litman, T. 2020. *Parking Requirement Impacts on Housing Affordability*. June.

Table 1 – TDM Menu with Expected VMT Benefits

TDM Strategy		Maximum Expected VMT Benefit (building icon = office/ commercial; house icon = residential)	Local Considerations	Source(s) – From Updated CAPCOA Draft Handbook on Quantifying GHG Measures (to be released for public comment late 2021)
Sustainable Vehicles				
	Provide Electric Vehicle Charging Infrastructure  (Public EV Charging Stall at Trader Joe's in Long Beach, CA. Source: F&P, 2021)	11.9% *GHG reduction* (office/commercial) or (residential)	• Fill in gaps in electric vehicle charging stations in the City: North of Townsend Winona Road, North of West Forest Avenue (potential charging location at the Museum of North Arizona, coming in from/going to the Grand Canyon)	• CARB. 2017. *Advanced Clean Cars Mid-Term Report, Appendix G: Plug-in Electric Vehicle In-Use and Charging Data Analysis, Jan 18, 2017.* • CARB. 2019. *Final Sustainable Communities Strategy Program and Evaluation Guidelines Appendices*. November. • CARB. 2020a. California Climate Investments Quantification Methodology Emission Factor Database. • CARB. 2020b. *EMFAC2017 v1.0.3*. August. • CARB. 2020c. Unofficial electronic version of the Low Carbon Fuel Standard Regulation. • Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. • U.S. Department of Energy (U.S. DOE). 2021. *Download Fuel Economy Data*. January.
Land Use				
	Provide Transit-Oriented Development (To qualify as TOD, the development would ideally be within a 10-minute walking distance -or 0.5-mile- of a high frequency transit station)	6.9%-31.0% (office/commercial) & (residential)	• Targeted at corridors with highest-frequency routes ○ Route 2 – Blue ○ Route 4 – Gold ○ Route 7 – Purple ○ Route 10 - Maroon	• FHWA. 2017a. *National Household Travel Survey – 2017 Table Designer*. Travel Day PMT by TRPTRANS by HH_CBSA. • FHWA. 2017b. *National Household Travel Survey – 2017 Table Designer*. Average Vehicle Occupancy by HHSTFIPS. Lund, H., Cervero, R., and Wilson, R. 2004. *Travel Characteristics of Transit-Oriented Development in California*. January.

Table 1 – TDM Menu with Expected VMT Benefits

	Increase Residential or Job Density	30.0% &	• Avoid sprawl land use patterns. • Continue to create commercial/office/ residential clusters	• Ewing, R., Bartholomew, K., Winkelman, S., Walters, J., Chen, D. 2007. *Growing Cooler: The Evidence on Urban Development and Climate Change.* October. • *Stevens, M. 2016. Does Compact Development Make People Drive Less? Journal of the American Planning Association 83:1(7–18), DOI: 10.1080/01944363.2016.1240044. November. Institute of Transportation Engineers (ITE). Trip Generation Manual. 10th Edition.*
Program Level				
Outreach & Engagement				
	Community-Based Travel Planning *e.g., personalized outreach and education of available options*	2.3%	• Pop-up events • Potential collaborations include education centers (NAU, CCC, High schools), CBOs (Big Brothers Big Sisters, Sustainability Program, etc.)	• Metropolitan Transportation Commission (MTC). 2021. *Plan Bay Area 2050, Supplemental Report.* (forthcoming)
Active Transportation				
	Construct/Improve Bike Facility or Expand Bikeway Network  (San Francisco Street & Aspen Avenue. Downtown Flagstaff. Source: F&P, 2021)	0.8% or 0.5% &	• Building upon existing network to/from Downtown and NAU campus • Bike infrastructure to fill distances too far to walk i.e., South Lone Tree Road to CCC, from northeastern Flagstaff (Smoke Rise Park) to central Flagstaff (Ponderosa High School) Southside Neighborhood Flagstaff • Leverage the actions identified in the City's Active Transportation Master Plan.	• CARB. 2020d. *Quantification Methodology for the Strategic Growth Council's Affordable Housing and Sustainable Communities Program*. September. • FHWA. 2017. *National Household Travel Survey – 2017 Table Designer*. Travel Day PT by TRPTRANS by HH_CBSA. • Federal Highway Administration (FHWA). 2019. *2017 National Household Travel Survey Popular Vehicle Trip Statistics.* • Pucher, J., Buehler, R. 2011. *Analysis of Bicycling Trends and Policies in Large North American Cities: Lessons for New York*. March.

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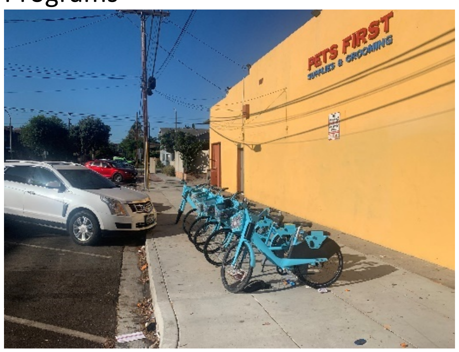
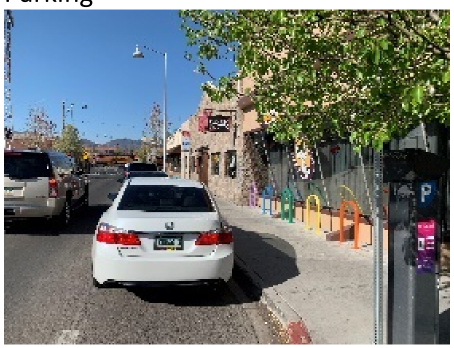
Shared Mobility				
	Implement Citywide Pedal Bikeshare Programs  (City of Long Beach Bikeshare. Source: F&P, 2021)	0.02% or 0.06% for E-Bikeshare &	• Facilitates bike infrastructure filling the gaps that cannot be walked, paired with the construction/improvement of bike/walking infrastructure. • Although the VMT benefit is low, there are public health benefits.	*Ibid*
	Implement Scootershare Program (City of Long Beach. Source: F&P, 2021)	0.07% &	• Facilitates micromobility infrastructure filling the gaps that cannot be walked, paired with the construction/improvement of bike/walking/micromobility infrastructure. • Although the VMT benefit is low, there are public health benefits.	*Ibid*
Transit or Shuttles				
	Expand Transit Network	4.6% &	• Enhancing the user travel experience, including extending service to cover new areas and times.	• Handy, S., Lovejoy, K., Boarnet, M., Spears, S. 2013. *Impacts of Transit Service Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions*. October. • Federal Highway Administration (FHWA). 2017. *National Household Travel Survey – 2017 Table Designer*. Average Vehicle Occupancy by HHSTFIPS.

Table 1 – TDM Menu with Expected VMT Benefits

	Increase Transit Service Frequency	11.3% & Note: The elasticity of transit ridership with respect to frequency of service = 0.5	• Consider as a strategy in the short-range transit plan (SRTP)	• FHWA. 2017a. *National Household Travel Survey – 2017 Table Designer*. Travel Day PMT by TRPTRANS by HH_CBSA. • FHWA. 2017b. *National Household Travel Survey – 2017 Table Designer*. Average Vehicle Occupancy by HHSTFIPS. • Handy, S., Lovejoy, K., Boarnet, M., Spears, S. 2013. *Impacts of Transit Service Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions*. October. • San Diego Association of Governments (SANDAG). 2019. *Mobility Management VMT Reduction Calculator Tool – Design Document*. June.
	Implement Transit-Supportive Roadway Treatments *e.g., transit signal priority and bus-only lanes*	0.6% &	• Consider as a strategy in the short-range transit plan (SRTP)	• FHWA. 2017a. *National Household Travel Survey – 2017 Table Designer*. Travel Day PMT by TRPTRANS by HH_CBSA. • FHWA. 2017b. *National Household Travel Survey – 2017 Table Designer*. Average Vehicle Occupancy by HHSTFIPS. • San Diego Association of Governments (SANDAG). 2019. *Mobility Management VMT Reduction Calculator Tool – Design Document*. June. • Transportation Research Board (TRB). 2007. *Transit Cooperative Research Program Report 118: Bus Rapid Transit Practitioner's Guide*.
	Reduce Transit Fares (Note: This is a different measure from the transit subsidy measure listed above, but it can be combined using the dampening formula shown in the CAPCOA Handbook. As an example, this measure would be implemented by Mountain Line, while the transit subsidy measure would be provided by the employer to its employees)	1.2% &		• FHWA. 2017a. *National Household Travel Survey – 2017 Table Designer*. Travel Day PMT by TRPTRANS by HH_CBSA. • FHWA. 2017b. *National Household Travel Survey – 2017 Table Designer*. Average Vehicle Occupancy by HHSTFIPS. • Handy, S., Lovejoy, K., Boarnet, M., Spears, S. 2013. *Impacts of Transit Service Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions*. October. • San Diego Association of Governments (SANDAG). 2019. *Mobility Management VMT Reduction Calculator Tool – Design Document*. June.

Table 1 – TDM Menu with Expected VMT Benefits				
TDM Strategy		**Maximum Expected VMT Benefit** (building icon) = office/ commercial (house icon) = residential	**Local Considerations**	**Source(s) – From Updated CAPCOA Draft Handbook on Quantifying GHG Measures (to be released for public comment late 2021)**
Parking Management				
P	Implement Market-Price Public Parking  (San Francisco Street & Phoenix Avenue, Flagstaff. Source: F&P, 2021)	30.0% (building icon) Note: The elasticity of parking demand with respect to price = -0.4	▪ The Carbon Neutrality Plan has parking management goals/strategies, which can be coordinated with the RTP. For example, one identified climate priority action by the City is to analyze and reduce or remove parking requirements – recognizing its high monetary/social costs. ▪ When pricing on-street parking, best practice is to allow for dynamic pricing to ensure approximately 85% occupancy, which helps prevent induced VMT due to circling behaviors as individuals search for a vacant parking space.	• Pierce, G., Shoup, D. 2013. *Getting the Prices Right: An Evaluation of Pricing Parking by Demand in San Francisco.* Journal of the American Planning Association, 79(1), 67-81. May.
Sustainable Vehicles				
(EV icon)	Provide Electric Vehicle Charging Infrastructure	11.9% *GHG reduction* (building icon) & (house icon)	▪ Fill in gaps in electric vehicle charging stations in the City: North of Townsend Winona Road, North of West Forest Avenue (potential charging location at the Museum of North Arizona, coming in from/going to the Grand Canyon). ▪ Carbon Neutrality Plan priority action step in first three years: Provide 14 new EV charging stations at City of Flagstaff facilities.	*Ibid*

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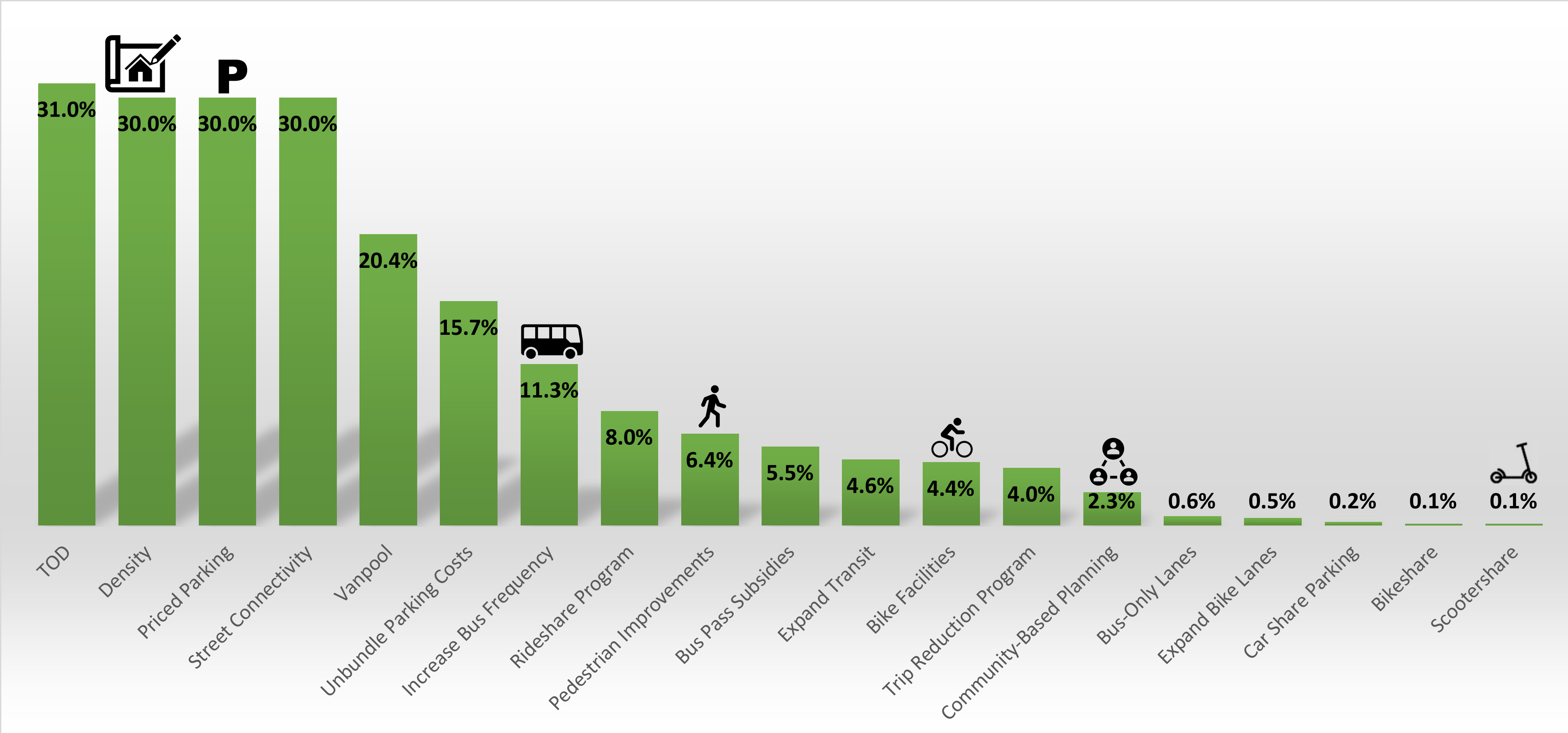
TDM Strategy	Maximum Expected VMT Benefit (building = office/commercial; house = residential)	Local Considerations	Source(s) – From Updated CAPCOA Draft Handbook on Quantifying GHG Measures (to be released for public comment late 2021)
Land Use			
Improve Street Connectivity *e.g., higher vehicle intersection density for new subdivisions and converting cul-de-sacs to grid streets to help shorten car trips.*	30.0% office/commercial & residential	▪ Neighborhoods: Bushmaster Park surrounding neighborhoods, neighborhoods surrounding Foxglenn Park, neighborhoods near commercial centers (Target, Walmart, Whole Foods, etc.) with low connectivity.	• Fehr & Peers. 2009. *Proposed Trip Generation, Distribution, and Transit Mode Split Forecasts for the Bayview Waterfront Project Transportation Study.* • Stevens, M. 2016. Does Compact Development Make People Drive Less? *Journal of the American Planning Association* 83:1(7–18), DOI: 10.1080/01944363.2016.1240044. November.

Notes:

1. (building) = office/commercial, (house) = residential
2. A combination of multiple TDM measures is <u>not</u> the cumulative sum of the individual VMT benefits; meaning there is a *dampening effect* given most of the measures are not mutually exclusive and can influence travel behavior when offered to individuals simultaneously.

Figure 2 – TDM Measures and Their VMT Benefit (% Reduction)



Source: *Fehr & Peers, 2021*. From the Updated Draft CAPCOA Handbook on GHG Reduction Strategies.

Note: A combination of TDM measures is not the cumulative sum of the individual VMT benefits; meaning there is a *dampening effect* given most of the measures are not mutually exclusive and can influence travel behavior when offered to individuals simultaneously.

2.1. TDM Case Studies

2.1.1. Bikeshare

Governing Dockless Bikeshare: Early Lessons for Nice Ride Minnesota

Dockless bikeshare systems allow for greater flexibility for riders geographically, as origins and destinations are not constrained to bikeshare stations. However, these flexible systems introduce management challenges related to maintenance, parking, and management of right-of-way. This study draws on various case studies around the US and presents recommendations to dockless bike share operation.

Key Findings

- Inconsistent sharing of data can impede successful operation of bikeshare programs
- Holding service providers accountable to address these issues reactively has proven ineffective

Policy Implications

- City authorities should proactively and transparently define right-of-way regulations before the service begins operation
- If bike share providers are utilized for the system, the City should negotiate concessions in exchange for right-of-way, such as full access to usage data and providing service in less profitable areas.
- Cities should define goals and hold the providers accountable
    - Goals can include equity/mobility justice, health, and safety outcomes
    - Providers can be held accountable through permit fees (without passing the cost down to the users) and frequent evaluation of goal performance
    -

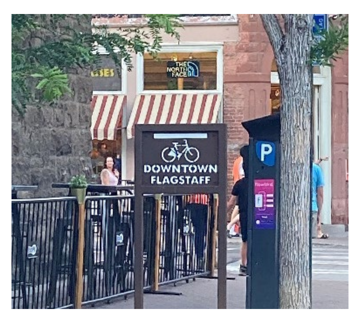
Citation: Hauf, A, Douma, F. (2019). Governing Dockless Bike Share: Early Lessons for Nice Ride Minnesota. Transportation Research Record 2019, Vol. 2673(9) 419–429. https://journals.sagepub.com/doi/10.1177/0361198119845651

The Effects of a Citywide Bike Share System on Active Transportation Among College Students: A Randomized Controlled Pilot Study

This study explores the use of a citywide bikeshare network as it relates to campus trips. The effects of providing free citywide bike share membership to university students were evaluated. As Northern Arizona University's Yellow Bike program is free to students, staff, and faculty, though is centered around the campus, the scenario presented in this study is a potential supplement to the existing bikeshare program at NAU, with citywide implementation.

Key Findings

- No significant difference in overall steps or increased biking behavior was observed between those who received the free membership and those who did not, and only two of the 29 intervention group participants redeemed their free membership
- The primary barrier cited for the lack of bikeshare usage was an unwillingness to enter credit card information into the tech platform, over fear of unwanted or overage charges
- An already-existing bus pass discount program may have dampened the demand for bike-share usage. Some participants expressed a preference for a bike share membership over the discounted bus pass or a desire for the opportunity to choose between a bus pass and a bike share membership each semester.



(Downtown Flagstaff. Source: F&P, 2021)

Policy Implications

- Bikeshare membership should allow for alternative payment methods that do not require students to enter credit/debit card information
- The interaction of bikeshare membership with other discount program should be evaluated
    - Surveys should be conducted to determine if students prefer bikeshare membership over the existing ecoPASS, or vice versa, and if students should be provided both, or have the option to choose

Citation: Grimes, A, Baker, M. (2020). The Effects of a Citywide Bike Share System on Active Transportation Among College Students: A Randomized Controlled Pilot Study. Health Education & Behavior 2020, Vol. 47(3) 412–418. https://journals.sagepub.com/doi/10.1177/1090198120914244

Factors Influencing Electric Bikeshare Ridership: Analysis of Park City, Utah

Incorporating electric bikes (e-bikes) into the bikeshare system can be especially beneficial to cities with hilly terrain, like the City of Flagstaff. This study explores factors that influence ridership of a fully-electric bike share system in Park City, Utah, which like City of Flagstaff, contains hilly terrain, seasonal tourism, and significant seasonal changes in weather.

Key Findings

- 85% of e-bike trips were made by non-regular users, most likely tourists
- Most e-bikes were rented from and returned to the same location, likely recreational trips
- The average trip distance was about 5 miles, longer than the average for non-electric bikeshare (between 1-1.25 miles)
- Weekends and summer months related to more trips than weekdays and winter months
- Stations near higher population density, public transit, bike trails, and recreation centers saw higher ridership

Policy Implications

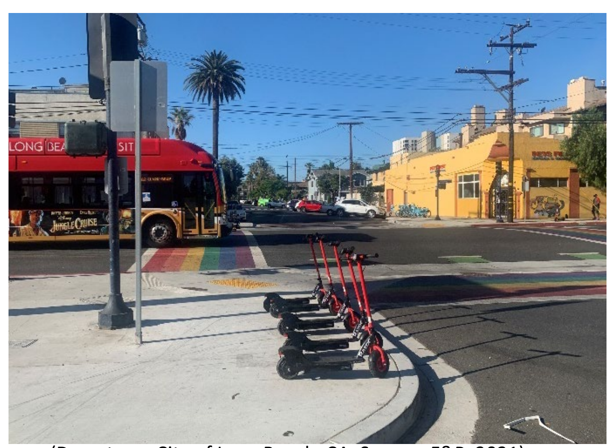
- Consider incorporating some e-bikes into a traditional pedal bike share program (similar to Washington, DC's Capital Bikeshare), or consider an all-electric bike share program if tourism is a primary indicator of usage
- Site stations near higher density areas, like Downtown, or near transit hubs, parts of the Flagstaff Urban Trails System (FUTS), and recreation centers
- Promote the system in tourism contexts, such as hotels, to capture tourist ridership

Citation: He, Y, Song, Z, Liu, Z, and Sze, N. (2019). Factors Influencing Electric Bike Share Ridership: Analysis of Park City, Utah. Transportation Research Record 2019, Vol. 2673(5) 12–22. https://journals.sagepub.com/doi/10.1177/0361198119838981

2.1.2. Micromobility

City-to-City and Temporal Assessment of Peer City Scooter Policy

In implementing and managing an electric scooter (e-scooter) share system, cities have a variety of policy dimensions and decisions to consider, ranging from equity to permitting fees. This study analyzes 12 policy dimensions regarding e-scooters over 10 mid-sized cities.



(Downtown City of Long Beach, CA. Source: F&P, 2021)

Key Findings

- Some cities capped the number of operators allowed and set minimum and maximum fleet sizes
- Most cities set performance-based thresholds for expansion or downsizing. 3 trips/scooter/day was a typical threshold for expansion, while 2 trips/scooter/day was common for downsizing
- Operation restrictions ranged from general to specific, such as "no sidewalks" or "forbidden in 16th Street Mall" (Denver, CO).
- Operator fees took a variety of structures, such as application fees, permit fees, per day per scooter license fees, or were based on an ordinance drafted by the city
- Less than half of the cities set restrictions on hours of operation
- Most cities set requirements for marketing, distribution, and accessibility to serve equity goals
- Most parking regulations were based on sidewalk clearance requirement, ranging from 3-6 feet, and about half of the cities reserved the right to fine or impound improperly parked e-scooters
- All cities required some level of data sharing, and the majority required real-time fleet information
- Austin, Denver, Minneapolis, and Seattle were dubbed "aspirational", based on mobility metrics

Policy Implications

- The City of Flagstaff should conduct stakeholder engagement surveys to determine the best policy fits for the City, particularly regarding parking, hours of operation, and areas of operation
- Policies from Austin, Denver, Minneapolis, and Seattle should be prioritized as most likely to reflect best practice
- The City should draft a micromobility ordinance that sets framework for the policy dimensions before allowing operators to enter the market

Citation: Janssen, C, et al. (2020). City-to-City and Temporal Assessment of Peer City Scooter Policy. Transportation Research Record 2019, Vol. 2674(7) 219–232. https://journals.sagepub.com/doi/10.1177/0361198120921848

A Note on Micromobility

According to Dr. Susan Shaheen of UC Berkeley[2], *Micromobility* is the shared or personal use of a bicycle, scooter, or other low-speed mode. *Shared Micromobility* is an innovative transportation alternative that enables users to have short-term access to a mode of transportation on an as-needed basis. As shown in ***Figure 3***, it includes various service models and modes that meet the diverse needs of travelers, such as station-based bikesharing (a bicycle picked-up from and returned to any station or kiosk), and dockless bikesharing or scooter sharing (a bicycle or scooter picked up and returned to any location). Early documented impacts of Micromobility include potential increases in overall mobility, reduced local greenhouse gas emissions, decreased automobile use, and health benefits.

There has been widespread growth of Micromobility vehicles in both large cities and small towns. However, these Micromobility vehicles use existing right-of-way and transportation infrastructure that was not originally designed with them in mind. As a direct result of the lack of appropriate guidance on how to design roadways to accommodate the growth in Micromobility vehicle use, the Institute of Transportation Engineers (ITE) Pedestrian and Bicycle Standing Committee developed the *Micromobility Facility Design Guide Informational Report*[3], which summarizes potential design challenges Micromobility users experience as they travel on typical roadways. The report also identifies design solutions with real-world examples to accommodate Micromobility.

[2] Shaheen, S. and Cohen, A. "Shared Micromobility Policy Toolkit." UC Berkeley California Digital Library, April, 2019. DOI 10.7922/G2TH8JW7. Retrieved on July 19, 2021 at https://escholarship.org/uc/item/00k897b5.

[3] (ITE, 2021). "Micromobility Facility Design Guide." *Institute of Transportation Engineers* (ITE) Pedestrian and Bicycle Standing Committee. Pub. No. IR-149-E. Retrieved on July 15, 2021 at https://ecommerce.ite.org/IMIS/ItemDetail?iProductCode=IR-149-E

Figure 3 shows the international taxonomy of conventional and new mobility services, such as ridesourcing (or "ride-hailing) companies like Uber and lyft. The vertical dash line indicates that an application (or "app") may be available to support the shared mode of travel.

Figure 3 – Terminology for Accessing Different Modes of Travel

Mode	Access: Personal	Access: Shared	Apps
Car	Private car	Carpool/Ridesharing, Taxi and Carsharing	Ridesourcing
Bus/Rail	**Para-transit**	**Public transit**	**Microtransit, MaaS**
Motorcycle	Private motorcycle		Ridesourcing
Bicycle	**Private bicycle**	**Bikesharing, Pedicabs**	**Micromobility**
Scooter	Private scooter		Scooter sharing
Walk			

Source: *SAE International Taxonomy, 2018*.
Notes:
1. "MaaS" = Mobility as a Service.
2. "Ridesourcing" examples include Uber and Lyft.

2.1.3. Sociopolitical Context of Transit

The Politics of Prioritizing Transit on City Streets

The implementation of sustainability-focused transportation planning policy can be highly dependent on political and community support. This study analyzes the key statements, arguments, leadership moves, and funding arrangements used to implement transit priority projects in Seattle, Portland, Denver, Chicago, New York, and Boston. While the cities in the study have a larger population than City of Flagstaff, it provides translatable insight into the options and considerations to help the City navigate transit priority projects.

Key Findings

- Messaging that framed transit priority projects as a way to accommodate growth and use limited street space efficiently was more effective than that which cited the project as a way to inexpensively improve transit
- Leadership within the city transportation agencies was more important than elected official leadership
- Building an in-house municipal transit team and pursuing strong partnerships with transit agencies was a common attribute of successful implementation – for example, marketing, maintenance, and sharing ridership data

Policy Implications

- Develop thoughtful messaging around transit priority projects, framing traffic congestion as the problem, which could get worse with increased growth, and bus rapid transit as the solution with supporting evidence/examples
    - In most cases, congestion in the adjacent travel lanes remain the same or worsen -including shifts to alternative travel routes. The benefits will only occur if there is a significant shift from private vehicle to bus travel, along with high-frequency bus service[4], which can be presented via corridor travel time for people throughput (not vehicles).
- Identify internal transit champions who build partnerships with Mountain Line and see transit priority projects from development to implementation

Citation: Singerman Ray, R. (2019). The Politics of Prioritizing Transit on City Streets. Transportation Research Record 2019, Vol. 2673(3) 733–742. https://journals.sagepub.com/doi/10.1177/0361198119837151

2.2. Long-Term (> 5 years) TDM Strategies

TDM Ordinance

The City of Los Angeles Department of Transportation (LADOT) released a draft TDM ordinance[5] for public comment in June 2021. LADOT has been working on updating their TDM ordinance for many years and they are now getting closer to implementing the update. A draft TDM Program Guidelines document accompanies the ordinance, along with a beta version of a TDM Calculator that should be used when selecting TDM measures for a project in response to the ordinance. They have been doing outreach, with the goal of taking the ordinance to Planning Commission in the Fall. The intent of the points-based program is to ensure that new development is designed to support sustainable transportation choices for residents, employees, and visitors. Implementation of the ordinance achieves the following purposes:

1. Reduce dependence on drive-alone trips and increase *sustainable mode share* to comply with the directives of SB 743, including the development of a multimodal transportation system and a diversity of land uses, and applicable requirements under South Coast Air Quality Management District (SCAQMD) Rule 2202.
2. Mitigate the transportation impacts resulting from new development by providing sustainable, accessible, and *affordable* transportation options that support the journeys of people of *all income levels* and modal choices.
3. Support the *strong link* between land use and transportation through promotion of *infill* development and mixed land uses that bring common destinations closer to people and make efficient use of infrastructure.
4. Improve *air quality, climate change*, and *public health* outcomes through encouragement of sustainable mobility options and reduction of VMT and associated greenhouse gas emissions generated by driving.

A *Transportation Management Organization*, or TMO, is one method of ensuring a successful implementation of a TDM ordinance. For example, *GoSaMo*[6] in Santa Monica, CA is a TMO that was formed to help employers and property managers comply with the local transportation regulations by providing information and resources for mobility options.

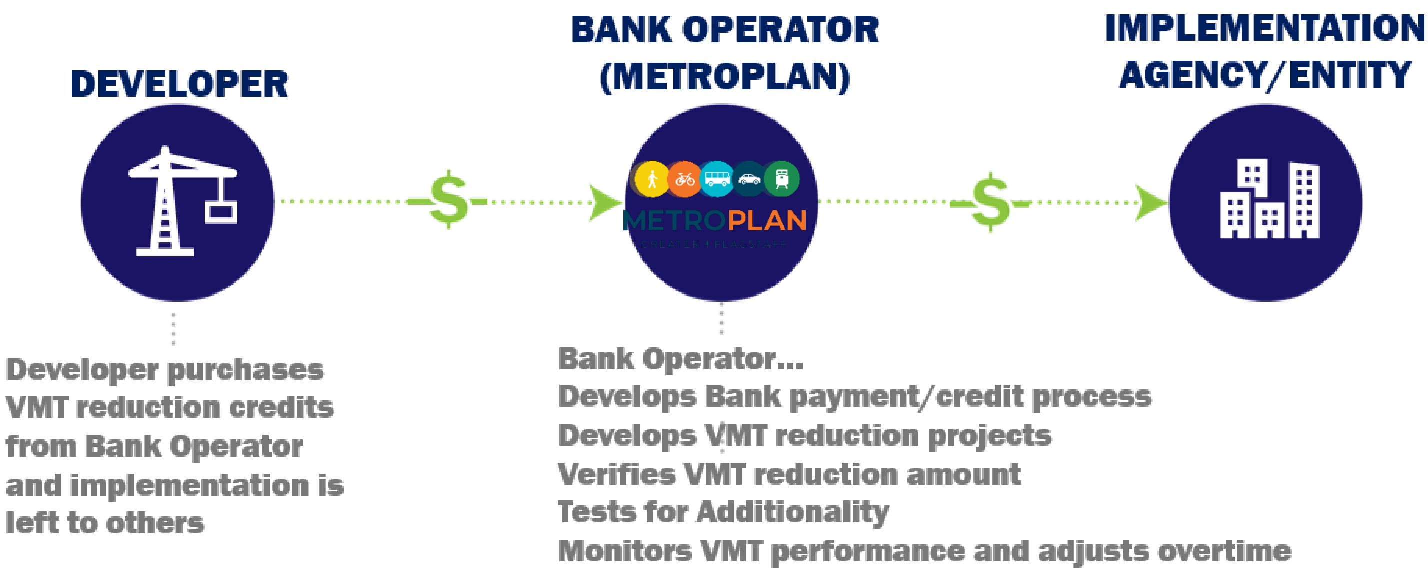
VMT Exchange Program and VMT Impact Fee/Bank Program

In addition to the conventional TDM programs described above, two new concepts that are not yet available but being explored for feasibility by other jurisdictions (such as the City of San Diego, CA) are described below.

[4] Litman, T. "When are Bus Lanes Warranted?" Victoria Transport Policy Institute. November 25, 2016. Accessed https://www.vtpi.org/blw.pdf
[5] https://planning.lacity.org/odocument/1dc924ce-b94a-403b-afe0-17ba33b3dbe1/Draft_TDM_Ordinance.pdf
[6] https://www.santamonica.gov/gosamo

- **VMT Exchange Program** – An exchange program is a concept where VMT generators can select from a **pre-approved list** of mitigation projects that may be located within the same jurisdiction or possibly from a larger area. The intent is to match the project's needed VMT reduction with a specific mitigation project of matching size and to provide evidence that the VMT reduction will reasonably occur.
- **VMT Impact Fee/Bank Program** – A VMT mitigation bank is intended to serve as an entity or organization that pools fees from development projects across multiple jurisdictions to spend on larger scale mitigation projects. This concept differs from the more conventional impact fee program approach in that the fees are directed to a few larger projects that have the potential for a more significant reduction in VMT and the program is regional in nature. See ***Figure 4*** as an example of the workflow process and responsible parties.

Figure 4 – Responsible Parties and Sample Process Flow for a VMT Impact Fee/Bank Program



Source: *Fehr & Peers, 2021*.

VMT Tax or Mileage-Based User Fee

A VMT tax, or mileage-based user fees, are distance-based fees levied on a vehicle user for direct use of a roadway system. As opposed to conventional tolls, which are facility specific and not necessarily levied strictly on a per-mile basis, these fees are based on the distance driven on a defined network of roadways. This method of revenue generation has been implemented thus far in the United States for 5,000 volunteer motorists in Oregon beginning July 1, 2015 - and for trucks.

Key Findings

- In terms of public perception, one focus group study in Minnesota[7] found that drivers may be more accepting of a change in the funding method, whether simply an increase in the existing tax or a switch to a mileage-based user fee, if the reason for the change is clearly explained.
- Privacy has been shown to be a primary concern for early adopter state departments of transportation.

[7]Minnesota DOT, 2007. "Mileage-Based User Fee Public Opinion Study." Retrieved: http://www.dot.state.mn.us/mileagebaseduserfee/pdf/opinionstudyreport.pdf

Policy Implications

- This type of levy is a state level policy, analogous to the fuel tax.
- Pilot programs have been shown to be an effective tool for testing the practicality (and potential public support) of the user fee system.

3.0 Emerging Trends – Implications of COVID-19 on Travel Behavior

What Factors are Changing?

- ***Willingness to share:*** The pandemic has resulted in a reluctance to ride transit, use transportation network company services (such as Uber and Lyft), and use shared micromobility services (such as Bird and Lime).
- ***Goods and Services Delivery:*** There has been a tremendous increase in the delivery of goods and services, which may point to sustained increases in travel related to on-demand delivery.
- ***Remote Work:*** Working from home has become the new normal for many, which could lead to a greater share of the workforce working remotely in the future.
- ***Economic Activity:*** Economic output has dropped sharply, and large questions remain about how quickly the economy will recover.
- ***Auto operating costs:*** Oil prices remain low, resulting in low automobile operating costs for now, but those may change going forward.
- ***Land use patterns:*** There could be an increased trend of suburban migration and decentralization.
- ***Other trends:*** Patterns such as increased remote learning, reduced business and tourism travel, and the level of government funding for infrastructure also stand to affect travel demand in the future.

3.1. Work from Home (WFH)

With respect to long-range transportation planning, the COVID-19 pandemic has raised two common questions from decision makers:

1. *How much will people continue to work from home once offices are all reopened?* and,
2. *How will the trend of additional working from home (or otherwise remotely) affect their way of doing business?*

3.1.1. Travel Behavior

As noted in a recent paper from Harvard Business School, the biases and distortions documented by behavioral economics affect our commutes as well, including:

- ***Status Quo Bias:*** Most of us rely on habit to choose when and how we travel, and we rarely make those decisions with perfect information about our different travel options. This force of habit also means that we are most likely to shift commute modes when moving to a new home or starting a new job, making the return to work an opportunity to encourage transit, carpooling, and bicycling for commuters.

- ***Loss Aversion:*** When thinking about trying a new commute mode, we often pay more attention to the possible downsides than the possible upsides. Events like Bike to Work Day provide a social incentive to try out a new commute, which can help us get past our concerns about a new travel mode.

- ***Social Norms:*** We tend to do what we observe others doing or what we think most people do – and since most people in the U.S. drive alone to work, most of us think of driving to work as the normal thing to do. TDM programs that feature peer-to-peer education, like Stanford's Commute Club, can help overcome this barrier.

3.1.2. Work from Home Studies

- A recent survey of professionals by Harvard Business School found that 27% would like to continue working remotely full-time and 18% would like to go back to working in the office full time. 60% of respondents want to work 2-3 days a week from home. It is not hard to find additional surveys with similar results that indicate that workers appreciate flexibility in where they work.

3.2. E-Commerce/Online Shopping

Online shopping, or E-commerce, in the United States has grown substantially in recent years; and was accelerated further amidst the onset of the COVID-19 pandemic. For the first time ever, it surpassed the 10% mark of the total share of US retail sales in 2019[8]. This is also evident in the growing number of fulfillment centers and last-mile delivery facilities from retailers such as Amazon and Walmart. The implications of these trends can help guide municipalities and agencies in developing policy strategies that can maximize the potential efficiencies with respect to VMT.

At the *100th Annual Meeting of the Transportation Research Board* in Washington, D.C., in January 2021, Professor Cara Wang of the Rensselaer Polytechnic Institute presented a nationwide, data-driven study that showed there was an overall increase in delivery vehicle VMT during the COVID-19 pandemic in 2020, while at the same time a decrease in person miles traveled. The study focused exclusively on shopping trips and home deliveries across the United States, including retail and groceries, with the purpose of assessing the potential to decarbonize goods movement.

3.3. Trip Generation Adjustments

This section assess potential adjustments (1-3 methodologies: business as usual, moderate change, & substantial change) to trip generation rates -as inputs to the travel demand model- to reflect lasting effects of COVID-19 on travel behavior, including work-from-home (WFH), alternate work schedule (AWS), and e-commerce. A total of three scenarios were considered using *Trendlab+ 2020*[9], an online tool to explore how the COVID-19 pandemic and its impacts on the economy may affect short- and long-term travel behavior, including traffic levels and transit use. The three hypothetical prediction scenarios include: *Business as usual* (pre-pandemic), *moderate change*, and *substantial change*.
See ***Table 2*** below for a list of the prediction parameters for each of the three scenarios. The final predicted VMT per capita percent reductions for 2030, with respect to year 2019 (pre-pandemic), for each of the three scenarios are shown at the bottom of the table. The VMT percent reductions are being treated as a proxy for adjusting the trip generation rates for the different RTP model scenarios. This is one limitation since VMT is the product of one vehicle trip and the distance traveled. However, the majority of the prediction parameters for the scenarios are travel behavior-dependent, such as telecommuting and online shopping. Based on literature review, 37 percent of jobs in U.S. could be performed at home, 30% for Coconino County.

Work-From-Home Prediction Parameters:

- Business as usual (5-10% WFH factor)
- Moderate change (10-20% WFH factor)
- Substantial change (20-30% WFH factor)

[8] US Census Bureau News, Quarterly Retail E-Commerce Sales Quarter 2, 2021. Retrieved on 8/26/21 at https://www.census.gov/retail/mrts/www/data/pdf/ec_current.pdf
[9] https://fpgisdevweb01.fehrandpeers.com/trendlab-2020/

Table 2 – 2030 Scenario-Planning Data Inputs			
Prediction Parameter	**Business as Usual**	**Moderate Change**	**Substantial Change**
Percentage of workforce telecommuting & Working-From-Home	5%-10%	10%-20%	20%-30%
Percentage of home-based shopping trips replaced by home deliveries	0%	15%	30%
Bikeshare & Micromobility	Pre-pandemic levels	Increase in personal ownership of e-bikes & scooters	20% increase in bike & scooter use (owned or shared)
Percentage of students at schools & universities remote learning/rotating attendance	0%	20%	50%
Bicycle & Pedestrian environments	Pre-pandemic streets	Expansion	Significant expansion
Transit service & Fares	Pre-pandemic levels	Minor reduction	Major reduction
Total VMT per Capita % Reduction in 2030 Relative to 2019	**2%**	**15%**	**32%**

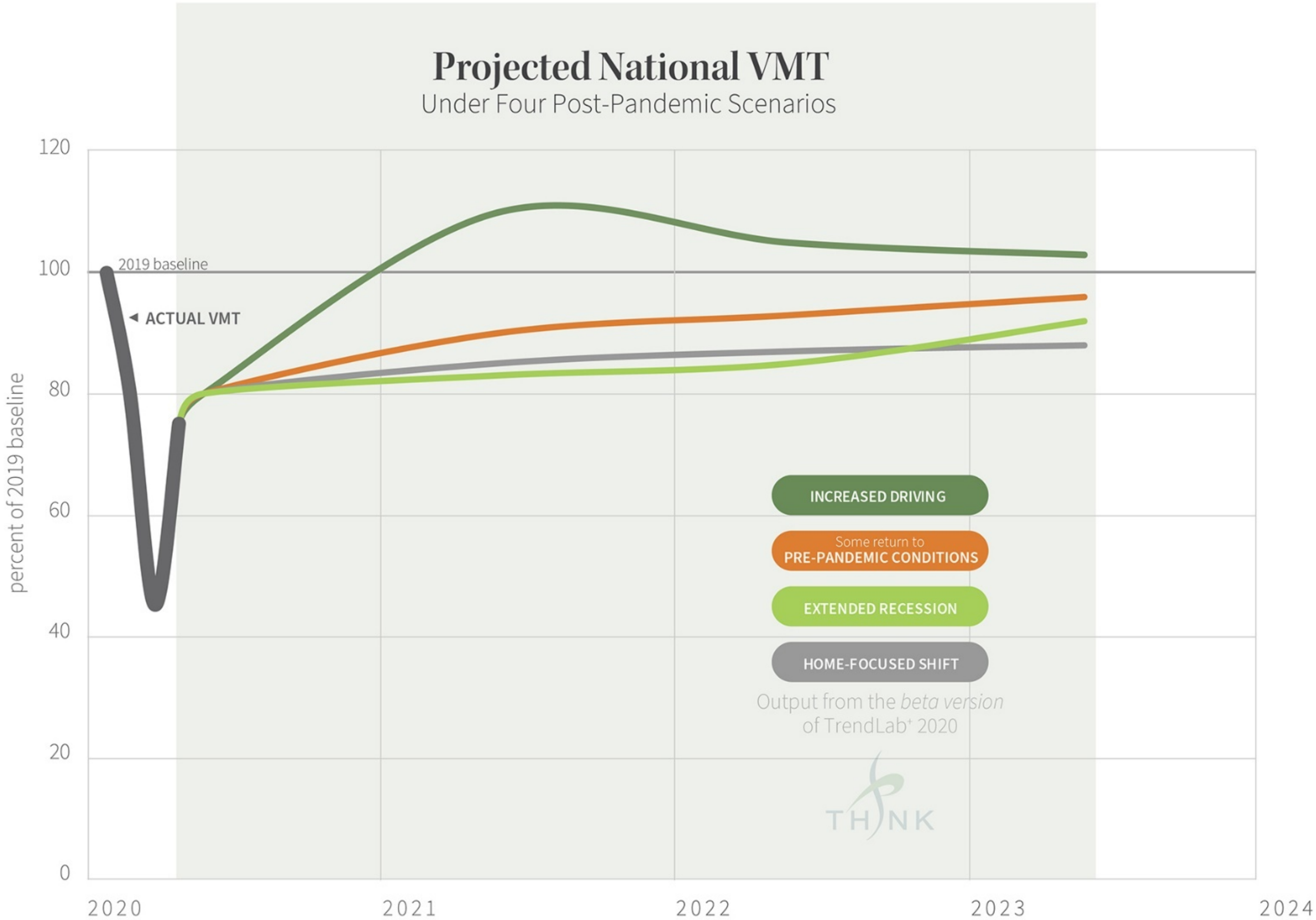
Source: *Fehr & Peers Trendlab+ 2020*

3.3.1. VMT Trends: Post-Pandemic Travel Demand

Much has been written in the last year about how travel patterns have changed due to the COVID-19 pandemic. There have been some startling trends, including dramatic decreases in transit usage, where some systems saw ridership decline by 95% or more. There were also large decreases in the overall amount of driving, with reductions in vehicle miles traveled (VMT) averaging about 50% or more nationwide, though those have since started increase. Walking and bicycling activity has increased, resulting in booming bicycle sales around the country.

Originally developed in 2014, Fehr & Peers' *TrendLab+* tool examines future trends and their resulting impact on driving activity and VMT. The current pandemic has changed many aspects of travel resulting in a new *TrendLab+* 2020 scenario-planning version. The new version of the tool accounts not only for previously considered factors, such as demographic and socioeconomic trends, but also current factors affecting travel demand in new ways – such as the option or requirement to work from home. Four potential post-pandemic scenarios were identified for how travel demand could change over the next three years – see ***Figure 5***.

Figure 5 – *TrendLab+* 2020 Post-Pandemic National VMT Projections



Source: *Fehr & Peers, 2020.*

What are the Results?

There are several potential outcomes over the next few years:

- **Total VMT** could remain well below 2019 levels, or it may <u>increase</u> by 5-10% if more people choose to drive rather than take other travel options.
- The ***Home-Focused*** and ***Extended Recession*** scenarios would see VMT remaining relatively flat over time, at around 10-15% below previous 2019 demand.
- Under an ***Increased Driving*** scenario, a VMT "peak" may occur in 2021 and then moderate slightly as the preferences for other non-driving modes increase in subsequent years.
- **Transit** may rebound from current historic lows, though the magnitude of the rebound and duration of the recovery period is uncertain. Under a ***Some Return to Pre-Pandemic Conditions*** scenario, we could be back above previous transit ridership levels by 2023, but under other scenarios a full rebound could take longer.
- The transit recovery period also depends in part on actions taken by the transit agencies to weather severe revenue declines and assure riders of their safety.

An example of the *Trendlab+* tool in a *user-friendly version* is provided here for the City of Tigard in Oregon: https://apps.fehrandpeers.com/tigard-trendlab/

4.0 Intelligent Transportation Systems (ITS)

4.1. Managing Travel Demand and Congestion Using ITS

Intelligent Transportation Systems (ITS) technology can be used for bus progression, such as transit signal priority, in addition to managing passenger cars. ITS strategies can also improve accessibility and safety for bicyclists and pedestrians. Developing a transportation systems management and operations (TSMO) arm within the City of Flagstaff metro area would support implementation of ITS solutions.

ITS has improved rapidly in the past few years through the advancements in connectivity, data processing, big data availability, and technological adaptations to new transportation priorities. ITS has been used to support a wide variety of policy goals including managing travel demand, decreasing VMT, encouraging mode shifts away from private vehicles, and addressing safety.

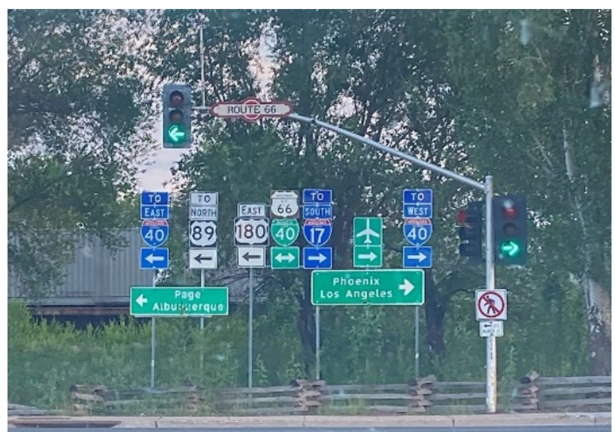
4.1.1. Transportation Systems Management and Operations Agency Coordination

Regional Concept for Transportation Operations: A Tool for Strengthening and Guiding Collaboration and Coordination

Effective TSMO in multi-jurisdictional metro areas, such as the Flagstaff region, relies on coordination across agencies. This study discusses the importance of establishing a regional concept for transportation operations (RCTO) and describes considerations and opportunities.

Key Findings

- An RCTO presents a mutual vision for regional operations, garners commitment from agencies, and strengthens the relationship between planners and multimodal operators
- Development of an RCTO involves traffic operators, engineers, and planners, emergency response officials, emergency managers, port authority managers, and bridge and toll facility operators
- An RCTO may include congestion management, road weather management, traffic incident management, and other operational categories -including evacuation routing during extreme weather events.
- An RCTO helps to guide and enable the development of a regional ITS architecture



(Route 66 in Flagstaff. Source: F&P, 2021)

Policy Implications

- MetroPlan should examine FHWA documentation on developing an RCTO to determine if developing this framework is a useful complement to the RTP or regional ITS architecture development
- Regional operators, such as the City of Flagstaff, the Arizona Department of Transportation, Coconino County, the Navajo Nation Division of Transportation, and Mountain Line should discuss interest in and feasibility of developing an RCTO, with a focus on pursuing regional ITS architecture

Citation: Berman, W, et al. (2005). Regional Concept for Transportation Operations: a Tool for Strengthening and Guiding Collaboration and Coordination. Transportation Research Record: Journal of the Transportation Research Board, No. 1925, Transportation Research Board of the National Academies, Washington,D.C., 2005, pp. 245–253.

Congestion Relief Based on Intelligent Transportation Systems in Florida: Analysis of Triple Bottom Line Sustainability Impact

ITS can be an effective solution to congestion issues and their impact on economic and environmental losses. This study examined the sustainability impacts of ITS congestion relief (freeway incident management systems, ramp metering, arterial signal coordination, and arterial access management) in Florida. While geographically distant from the City of Flagstaff, the rapid population growth and popularity of tourism in Florida make this applicable to Northern Arizona's context.

Key Findings

- The state saw both direct and indirect environmental savings from ITS congestion management in the areas of GHG emission, energy consumption, toxic releases, water consumption, and ecological footprint
- In an economic lens, annual delay was reduced, but profitability and employment in some industries (such as oil refineries) dropped as a result of the fuel savings -which is a natural outcome when attempting to reduce fossil fuel emissions.

Policy Implications

- In ITS implementation for congestion management, it is important to first understand the region's congestion issues and apply the appropriate ITS technology. For example, the City should identify congestion hot spots to determine which ITS investments are most relevant before pursuing any specific ITS infrastructure. Focus areas may include:
  - Ramp metering at interchanges with Interstates 40 and 17
  - Congestion at signalized arterial intersections, such as those along US-180 or S Milton Road
  - Locations prone to incidents or congestion during inclement weather, such as steep grades or sharp curves

Citation: Berman, W, et al. (2013). Congestion Relief Based on Intelligent Transportation Systems in Florida Analysis of Triple Bottom Line Sustainability Impact. Transportation Research Record: Journal of the Transportation Research Board, No. 2380, Transportation Research Board of the National Academies, Washington, D.C., 2013, pp. 81–89. DOI: 10.3141/2380-09

4.2. ITS Applications

The sections below provide an overview of ITS applications. ***Table 3*** provides a summary of the ITS applications discussed, their potential benefits, and local considerations. Documents cited for the sections below are referenced in ***Table 3***.

4.2.1. ITS and Transit

Transit Signal Priority with Connected Vehicle Technology

Using connected vehicle (CV) technology for transit signal priority (TSP) can improve upon traditional TSP by reducing shortcomings, such as delay for passenger cars, other bus routes, and pedestrians and bicyclists on side streets. This study examined a potential application of transit signal priority with connected vehicle technology (TSPCV), which would consider the number of riders on a bus in the reallocation of green time and deliver more accurate location tracking and arrival prediction. TSPCV is not yet ready for implementation but is recognized as a high potential and dynamic, innovative application of emerging mobility technology by AASHTO and USDOT. The policy implications are not exclusive to a particular application of TSPCV, but rather touch on the importance of considering ITS in TSP.

Key Findings

- TSPCV greatly reduced bus delay at signalized intersections without negatively affecting side streets
- TSPCV out-performed both traditional TSP and no-TSP scenarios during simulation runs at all congestion levels
- Implementation of TSPCV is a great starting point for incorporating CV technology into a transportation system, as deployment cost is lower than many other CV applications and only requires modification of buses and traffic signal controllers

Policy Implications

- While TSPCV is still considered emerging technology, it points to the importance of integrating ITS technology in both City systems (traffic controllers) and transit operator fleets (buses). As previously noted in the TSMO ***Section 4.1.1***, regional operators such as the City of Flagstaff, the Arizona Department of Transportation, Coconino County, the Navajo Nation Division of Transportation, and Mountain Line should discuss interest in and feasibility of developing a regional concept for transportation operations (RCTO), with a focus on pursuing and integrating a regional ITS architecture. For example, a multi-agency traffic management center (TMC) similar to Southern Nevada's TMC[10].
- As TSPCV or similar transit-priority ITS technology develops, the City of Flagstaff and Mountain Line should begin conversations about the feasibility of pursuing traffic signal-bus communications and set the policy framework necessary for this coordination -including setting multimodal travel time goals.

Citation: Hu, J, et al. (2014). Transit Signal Priority with Connected Vehicle Technology. Transportation Research Record: Journal of the Transportation Research Board, No. 2418, Transportation Research Board of the National Academies, Washington, D.C., 2014, pp. 20–29. DOI: 10.3141/2418-03

4.2.2. Traffic Signal ITS

Automated Traffic Signal Performance Measures

ATSPM are a toolbox of data analytical tools that automatically collect and process high-resolution controller data into actionable performance measures. ATSPM requires traffic signal controllers to be fitted with detection hardware and connection to a central system to store highly detailed traffic data. Connected traffic signals can then provide real time demand data at different locations. ATSPM processes data using analytical tools that identify a plethora of signal performance measures such as arrivals on green, red light running, pedestrian delay, signal offset coordination, identifying split failures, and detecting sensor malfunctions. These analytical tools give agency professionals the information needed to proactively identify and correct deficiencies in the traffic signal controller network.

Implementation Considerations

ATSPM provides a means to better manage infrastructure to achieve policy goals. The many applications of ASTPM allows holistic maintenance programs that can account for many occurring issues within the same traffic controllers. Managing traffic signals in this way allows controllers to operate in the context of the existing conditions and will improve traffic congestion, safety, and quality of service to pedestrians. Currently there is little infrastructure in place to support ATSPM in the City of Flagstaff, investments in this technology could be prioritized along more congested corridors that serve high vehicle volumes and are important to transit lines – a corridor like Milton Road would be a good place to start. Infrastructure for ATSPM can also be applicable to other ITS deployments such as Bus Signal Priority, Bicycle Signal Heads, and Leading Pedestrian Intervals.

Transit Signal Priority

TSP is used to improve the quality of transit services by allowing buses to communicate with signal controllers to alter phasing and allow buses to pass through on green. The main objective of TSP is to reduce transit time, reduce travel time variability, and improve schedule and headway adherence. Deployments of TSP by transit agencies in other regions have achieved desired outcomes – especially in reducing intersection delay, reducing travel times, and improving schedule adherence. These same agencies generally reported challenges in maintaining long-term TSP operations in the context of financial pressures and coordinating with jurisdictions that manage the traffic signals.

TSP increases the attractiveness of using transit. Research conducted by the Transit Cooperative Research Program (TCRP) found that when riders experience fewer delays and have higher confidence in the arrival time of the bus, they

[10] https://www.rtcsnv.com/news/southern-nevada-traffic-management-center-keeps-traffic-flowing-safely-and-efficiently/

will choose transit more often. Applying ITS technology like TSP will be in line with policy goals focused on shifting travel modes away from passenger vehicles and more towards transit.

Implementation Considerations
Intersections along corridors where transit lines overlap will be the most efficient places to deploy TSP such as Milton Road and Butler Avenue. A major challenge reported by other transit agencies of implementing TSP is interagency coordination. Butler Avenue traffic signals are owned, maintained, and operated by the City of Flagstaff whereas the traffic signals along Milton Road fall under Arizona Department of Transportation (ADOT) jurisdiction. Maintaining effective TSP operations will depend heavily on the interagency cooperation of City of Flagstaff, ADOT, and Mountain Line, which may prove difficult over long periods of time and shifting priorities of these agencies.

Bicycle Signal Heads
Bicycle signal heads are additional traffic control signals that provide clarity and special instruction specifically to cyclists during bicycle only movements or leading bicycle intervals. They have the same green, amber, red colored lenses as traditional traffic signal heads but instead of solid circles the signal shows a bicycle icon. Bicycle signal heads are intended to be used in conjunction with regular traffic signals or hybrid beacons and should never be deployed alone. They are best deployed at facilities with identified safety or operation problems or to indicate bicycle signal phases or other timing strategies (such as leading intervals). Typically bicycle signal heads reap the most benefits when used where bike paths or multi-use paths intersect streets, especially at intersections where the major bicycle movement conflicts with the main motor vehicle movement.

Implementation Considerations
Bicycle signal heads could be considered at key intersection along the Flagstaff Urban Trail System or near the university. Increasing signal capabilities for bicycle specific movements will increase the safety and convenience of crossing vehicle-dominated intersections. According to the National Association of City Transportation Officials (NACTO), for many people, the real and perceived risks of crossing a signalized intersection on a bicycle are a major deterrent to choosing to travel by bike. Bicycle signal heads will support policies designed to encourage mode shifts to bicycles as well as general safety.

Leading Pedestrian Interval
A leading pedestrian interval (LPI) is when the pedestrian walk signal activates before the corresponding vehicle signal turns green in the same direction of travel. LPIs typically give pedestrians three to seven seconds head start depending on the crossing width. Allowing pedestrians to enter the intersection first increases their visibility and reinforces their priority over the turning vehicles. LPIs are most beneficial at intersections with heavy turning traffic in conflict with crossing pedestrians. NACTO reports LPIs reduce pedestrian related collisions by up to 60%, however the Federal Highway Administration (FHWA) reports typical reductions of about 13%.

Implementation Considerations
Perceived comfort and safety of travel modes is an important influence over travel mode choice. LPIs are a very low-cost method to enhance safety and comfort at traffic signals for pedestrians. The safer people feel in City of Flagstaff crossing intersections the more likely they'll leave their car at home for short trips. LPIs require only the cost associated with adjusting traffic signal timing and are consistent with policies promoting safety and multimodal travel.

4.2.3. Travel Demand Management ITS

Real-Time Bus Arrival Information
The recent proliferation of smart phone ownership and the increased reliance on web-based information among the public has driven many metro transit organizations to create applications that provide transit users with real-time bus arrival information. Researchers have found that providing accurate real-time bus arrival information decreases the

perceived wait time by riders and leads to greater rider satisfaction with the transit system. Case studies in New York City and Chicago both found that providing real-time bus arrival information increased average ridership by 2% per route.

Implementation Considerations
Mountain Line has a web-based and smart phone accessible app that provides real-time bus arrival information. Users without a smart phone can also receive real time information on bus arrivals by texting their stop code to the Mountain Line number or by using any other web accessible device. Researchers have found that these kinds of information systems increase the frequency of existing riders' use of the transit system while new riders are often uncomfortable using the app when they aren't already familiar with how to use the transit system. Education efforts to increase public awareness of these services should also include information of how to use the transit system in general to encourage new ridership.

Variable Message Signs
Variable Message Signs (VMS) are traffic control devices that provide travelers with enroute information. VMS are typically installed on full-span overhead bridges or post mounted on roadway shoulders. Messages can be changed remotely, from a central location, or at the site. The messages can vary in purpose such as giving current travel time information to certain destinations, warnings of conditions ahead, directions to change lanes or take a detour, reminders of safety, warnings of police enforcement, and any other relevant information. Researchers have found that VMS are taken seriously regarding safety, though the effect diminishes among drivers under 30.

Implementation Considerations
The Flagstaff region's weather and high tourism make VMS an attractive ITS solution. The City of Flagstaff conducted a study into the demographics of Flagstaff's tourists and found that many come from the greater Phoenix area. These drivers are unlikely to be familiar with Flagstaff's weather conditions or know alternative routes should a detour become necessary. A case study conducted in Maryland found that VMS deployments were effective in rerouting recreational motorist to alleviate critical bottlenecks. This approach could be applied to City of Flagstaff's snow-day tourism problems along US-180.

Free Web-based Travel Information Apps
Free web-based apps accessible from smart phones, such as Waze, provide real time traffic conditions information and live map crowdsourced incident reports. Users can check routes before leaving and plan accordingly if disruptions are present along their planned route. Free web-based apps also provide carpool matching services where users can advertise their desired departure time and destination to see if a potential driver or passenger will match to that plan.

Implementation Considerations
The City of Flagstaff has a relatively youthful population, so it may be expected a web-based app such as Waze will be more readily adopted by the populace. The more users of the app the more incidents that will be reported to the live-map increasing its accuracy while also increasing the likelihood of matching with a carpooler. Better travel information will help drivers avoid congestion while carpool matching will help reduce the number of vehicles on the road.

Table 3 – ITS Menu with Expected Advantages

Traffic Signal ITS

ITS Strategy	Benefits	Local Considerations	Source(s)
Automated Traffic Signal Performance Measures	• Real time travel demand information • Detects arrivals on red and green which helps adjust signal timings to increase arrivals on green • Detects red light running • Tracks pedestrian signal delay • Identifies split failures and assists timing adjustments • Locates detector malfunctions • Locates pedestrian push button malfunctions • Allows holistic maintenance programs of traffic signal network • Signal controllers are maintained to operate in the context of dynamic conditions • Improves traffic congestion • Increases quality of service for pedestrians • Enhances safety for all users of intersection	• City of Flagstaff has minimal infrastructure in place for ATSPM • Prioritize ATSPM along high volume/high congestion corridors (e.g., Milton Road) • Requires interagency coordination to quickly enact ATSPM findings • Requires dedicated city staff to be trained in managing ATSPM infrastructure, managing large volumes of high-resolution data, and interpreting data to apply a solution at signal level	• Bullock, D., Clayton, R., Mackey, J., Misgen, S., Stevens, A., Sturdevant, J., Taylor, M. (2014). "Automated Traffic Signal Performance Measures". *ITE Journal*, March 2014, 33-39. • *Day, C., Taylor, M., Mackey, J., Clayton, R., Patel, S., Xie, G., Li, H., Sturdevant, J., Bullock, D. (2016). "Implementation of Automated Traffic Signal Performance Measures". ITE Journal, August 2016, 27-34.* • *Lattimer, A. (2020). "Automated Traffic Signal Performance Measures". FHWA-HOP-20-002. http://www.ntis.gov*

Table 3 – ITS Menu with Expected Advantages				
Traffic Signal ITS				
ITS Strategy		**Benefits**	**Local Considerations**	**Source(s)**
	Transit Signal Priority	• Reduces intersection delay for buses • Improves schedule and headway adherence • Increases public confidence and reliability in buses arriving on time	• Most efficiently deployed along corridors with overlapping bus routes such as Milton Road and Butler Avenue	• Anderson, P., Simek, M., National Academy of Sciences, Engineering, and Medicine (2020). "Transit Signal Priority: Current State of the Practice." Washington, DC: The National Academic Press. https://doi.org/10.17226/25816. • Rathwell S., Stephens D., Borsuk I. (2006). Transit Priority and Traffic Operations: Striking the Right Balance, ITE Annual Meeting Proceedings
	Bicycle Signal Heads  (Bicycle Signal Head. Source: NACTO, 2013)	• Reduces conflicts between bicyclist and vehicular traffic • Simplifies bicycle movements through complex intersections • Protects bicyclist in the intersection • Improves real and perceived safety of cycling public at high-conflict areas	• Bicycle Signal heads could be considered at key intersections along the Flagstaff Urban Trail System or around the NAU Campus	• Fitzpatrick K., et al. "Evaluation of Pedestrian and Bicycle Engineering Countermeasures" Federal Highway Administration. Report No. FHWA-HRT-11-039. Washington, DC. • Hunter W., Stutts T., Jane C. "Bikesafe Bicycle Countermeasure Selection System." BIKESAFE, Federal Highway Administration, Office of Safety, Washington, DC. • Ryus P, Tanaka A., Monsere C., McNeil N., Schultheiss W. "Bicycle Facility Evaluation: Washington, DC." District Department of Transportation, District of Columbia, Washington, DC.

Table 3 – ITS Menu with Expected Advantages

Traffic Signal ITS

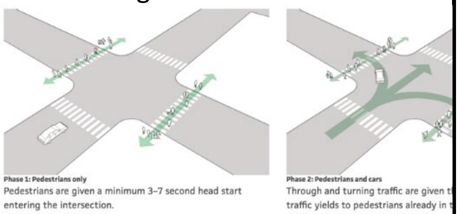
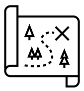
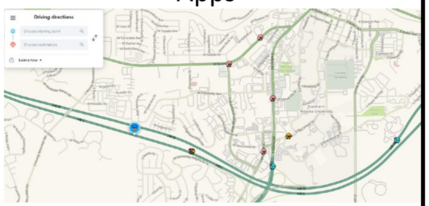
ITS Strategy		Benefits	Local Considerations	Source(s)
	Leading Pedestrian Interval  (Lead Pedestrian Interval. Source: NACTO, 2013)	• Allows pedestrians to enter intersection first • Increases pedestrian visibility • Maximum pedestrian collision reduction observed 60% • Typical Pedestrian collision reduction 13% • Low implementation cost	• Most useful at intersections with heavy turning traffic in conflict with pedestrians (e.g., around NAU, near high ridership bus stops, and downtown)	• Fayish, Aaron C & Frank Gross. "Safety Effectiveness of Leading Pedestrian Intervals Evaluated by a Before-After Study with Comparison Groups." Transportation Research Record, Journal of the Transportation Research Board 2198 (1), 15-22, Washington, DC. • Goughnour, E., Carter, D. Lyon, C., Persaud, B., Lan, B., Chun, P., Signor, K. (2018). "Safety Evaluation of Protected Left Turn Phasing and Leading Pedestrian Intervals on Pedestrian Safety", Federal Highway Administration. Report No. FHWA-HRT-18-044. Washington, DC. • Russo, Ryan, et al. "Don't Cut Corners: Left Turn Pedestrian & Bicyclist Crash Study." New York City Department of Transportation, New York. • Van Houten, Ron, Richard Retting, Charles Farmer, Joy Houten. "Field Evaluation of a Leading Pedestrian Interval Signal Phase at Three Urban Intersections." Journal of the Transportation Research Board 1734, 86-92, Transportation Research Board, Washington, DC.

Table 3 – ITS Menu with Expected Advantages

Travel Demand Management ITS

ITS Strategy		Benefits	Local Considerations	Source(s)
	Real-Time Bus Arrival Information	• Riders perceive the wait time to be longer without real time information • Increases overall satisfaction with transit experience • 2% Median increase in ridership observed in New York City and Chicago per bus route after introducing Real-Time information app • Riders reported feeling an increased sense of security while waiting for bus	• Riders unfamiliar with transit system less likely to appreciate app as much as frequent riders due to unfamiliarity with transit network • Education efforts on using the Mountain Line app should coincide with education of using the transit system to encourage infrequent riders	• *Brakewoor,C. (2014) Quantifying the Impact of Real-Time Information on Transit Ridership. PhD thesis, Georgia Institute of Technology, Atlanta.* • *Brakewood, C., Macfarlane, G.S. & Watkins, K. (2015). The impact of real-time information on bus ridership in New York City. Transportation Research Part C: Emerging Technologies, Vol. 53, pp. 59–75.* • *Ferris, B., Watkins, K., & Borning, A. (2010). OneBusAway: Results from Providing Real-Time Arrival Information for Public Transit. Proceedings: CHI,1807–1816.* • *Watkins, Kari & Ferris, Brian & Borning, Alan & Rutherford, G. & Layton, David. (2011). Where Is My Bus? Impact of mobile real-time information on the perceived and actual wait time of transit riders. Transportation Research Part A: Policy and Practice. 45. 839-848. 10.1016/j.tra.2011.06.010.*
	Variable Message Signs (VMS)	• Travel time information effectively induces route changes • Driver perception of travel time and environmental benefits are high even if actual benefits may be relatively small • Assertive safety related messages (e.g., monetary fine and number of accidents/deaths) are taken seriously • Younger drivers (less than 30) are less likely to consider safety messages on VMS seriously	• NAU related traffic may respond better to road condition and safety warnings from web connected mobile app information • VMS found effective rerouting tourist on recreational routes (applicable to snow-day tourism along US 180)	• Boyle L., Cordahi G., Grabenstein K., Madi M., Miller E., Silberman P. (2014) *Effectiveness of Safety and Piblic Service Announcemet* (PSA) Messafes on Dynamic Message Signs (DMS), Report No. FHWA-HOP-14-015. • Hughes W. (1982) Recreational Traffic Management Strategies. ITE Journal, September 1982 • Kiron Chatterjee & Mike Mcdonald (2004) *Effectiveness of using variable message signs to disseminate dynamic traffic information: Evidence from field trails in European cities*, Transport Reviews, 24:5, 559-585, DOI: 10.1080/0144164042000196080 • Thill, J., Rogova G., Yan J. (2004*) Evaluating Benefits and Costs of Intelligent Transportation Systems Elements from a Planning Perspective*. Economic Impacts of Intelligent Transportation Systems: Innovations and Case Studies Research in Transportation Economics, Volume 8, 571-603

Table 3 – ITS Menu with Expected Advantages				
Travel Demand Management ITS				
ITS Strategy		**Benefits**	**Local Considerations**	**Source(s)**
	Web Based Travel Information Apps  (Waze live-map. Source: Waze, 2021)	• Real time roadway conditions information available on free public mobile app • Crowd sourced incident reports to give drivers chance to reroute around incidents • App pairs passengers and drivers in carpool matching feature	• Carpooling app potentially useful for NAU students carpooling to Phoenix • Young demographic of City of Flagstaff may participate in reporting to travel information apps more readily than an older population	• *Pack, M., Ikanov K. (2017) Are You Gonna Go My Waze? Practical Advice for Working with 3rd Party Data Providers. ITE Journal, February 2017.*

5.0 Electric Vehicles and Autonomous Vehicles

Electric vehicles (EV) are consistent with the Flagstaff region's environmental visions of a more sustainable future. A literature review was conducted to establish the current penetration of EVs at the national, state, and regional levels. Other aspects of EV technology were also reviewed within the City of Flagstaff to explore what has been done to encourage EV ownership and what challenges EV adaption still face.

Connected and Autonomous Vehicle (CAV) technology is a promising avenue to improve transportation systems, but the technology remains in its nascent stages and there is still much yet to come. This literature review highlights the levels of automation as well as their general market penetration on roads today.

5.1. Electric Buses for Transit

In late 2020, Mountain Line completed a Zero Emissions Bus (ZEB) Transition Plan[11]. Phase One modeled battery electric and fuel-cell electric buses on Mountain Line routes and hours of service and incorporated Flagstaff's topography, climate, and utility rate structure. This information was then used to outline each fleet technology's impact on greenhouse gas emissions, transit operations, costs, and infrastructure needs compared to the current hybrid electric buses. At the June 2021 Mountain Line Board meeting, the Directors approved pursuing a battery electric fleet on a policy level, with implementation of battery electric buses occurring project by project, bus by bus as funding and interest allows. Phase Two of the ZEB Transition Plan provided a detailed implementation plan of battery electric buses. To ensure maximum penetration of electric vehicles, whether it be private or public fleets, there are several barriers for the region to consider. ***Table 4*** below provides a summary of the common barriers to adopting electric buses for use by mass transit agencies (Sclar, R. et al, 2019).

Table 4 – Main Barriers to Adopting Electric Buses	

Technological Barriers	• Shortage of information and data needed to determine:
	  ○ Proper inputs for an initial cost-benefit analysis of e-buses and infrastructure
	  ○ Best initiate and operate e-bus project
	  ○ Operational characteristics, limitations, and maintenance requirements to be completed prior to adoption
	• Technical limitations of the e-buses and charging infrastructure:
	  ○ Vehicles/batteries produce limited range and power relative to conventional buses
	  ○ Agencies/operators lack the knowledge needed to adopt new operation models to accommodate for the limitations of e-buses
	  ○ Grid/charging infrastructure are new and evolving technologies that face limitations and stability strategies
	  ○ For Mountain Line, improvements in technology are expected, but there is no indication of when the market may see e-bus technology improve to the point of 1-for-1 replacement of internal combustion engine vehicles regardless of duty cycle

Financial Barriers	• Difficulties for agencies in changing procurement processes:
	  ○ E-bus programs can be unique in cost structure with uncertain risks, and it is common for new tasks (compared to conventional buses) like maintaining batteries and grid infrastructure to be neglected
	  ○ For Mountain Line, there is no indication of when the cost of fuel cell or hydrogen fuel will decrease to cost-competitive levels
	• Lack of long term, scalable financial options:
	  ○ Scaling e-bus projects requires a large, risk-tolerant capital investment, both to procure vehicles and to supply charging infrastructure and grid updates

[11] Mountain Line Zero-Emission Bus Implementation Plan. December 2020. Accessed at https://mountainline.az.gov/about-us/reports-plans/ on 10/18/21.

Institutional Barriers	• Lack of leadership and pragmatic public policy: ○ No laws or roadmaps to provide a strategy plan or financial backing for implementing e-buses ○ Mountain Line's Board approval gave staff direction for how to proceed and assumptions to make on a variety of projects, but does not commit the agency to implementing the ZEB 100% moving forward • Lack of institutional authority, funding, and land: ○ Not enough resources or jurisdictional authority to coordinate an e-bus project. E-bus projects need land to install and manage charging infrastructure, especially while scaling up

Source: Sclar, R., Goruinpour, C., Castellanos, S., and Li, X. "Barriers to Adopting Electric Buses." Federal Ministry of Economic Cooperation and Development, May 2019. And the Mountain Line Zero-Emission Bus Implementation Plan, December 2020.

5.2. Private Electric Vehicles

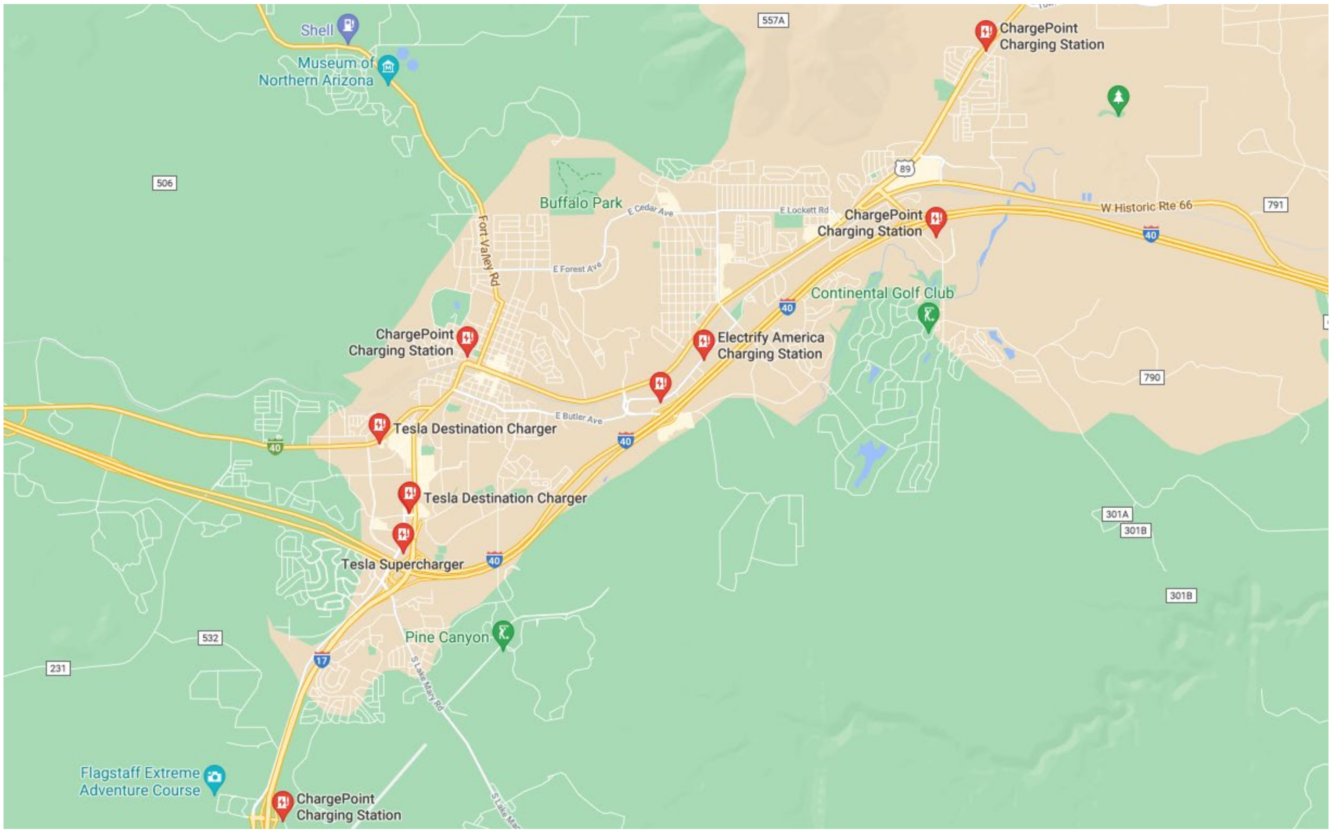
5.2.1. EV Charging Station Location Best Practices

A major hurdle to EV sales is public concern over the availability and convenience of charging stations. Charging electric vehicles at home may take the entire night; while public fast chargers may take only twenty minutes, they are still much slower than gas pumps and much less common. The typical range of an EV is 250 miles, which is sufficient for a typical commuter use but drivers have concerns whether a charging station will be available over long trips. The U.S. Department of Energy estimates the country has about 41,400 EV charging stations, only 5,000 of these are considered fast chargers, compared to the roughly 150,000 gas stations estimated in the U.S. by the National Association of Convenience Stores (NACS).

The City of Flagstaff currently has nine electric vehicle public charging stations, mostly concentrated at municipal buildings such as City Hall. ***Figure 6*** below shows a snapshot pulled from Google Maps with the City of Flagstaff's current charging stations pinned. EV owners can access information on the internet through sources like Google to find not only the location of the charge stations but also the charge level and station owner. The City of Flagstaff owns two publicly available dual charge stations at City Hall. The city is currently constructing four more at the Aquaplex on the east side of town and planning another six to ten stations at the airport.

Mountain Line already operates all service through the Downtown Connection Center (DCC), thus a central location for charging is already available. In addition, the master planning is currently underway to replace and modernize the current DCC facility.

Figure 6 – City of Flagstaff Charging Station Locations



These City of Flagstaff owned charging stations were part of the Arizona Public Service (APS) Take Charge AZ pilot program, which offers free electric vehicle charge station installments to non- single-family residential APS customers. All charging stations installed by APS under this pilot are Level-2, meaning they provide 10-20 miles of range per hour. The program is intended to supply EV charging opportunities to fleet vehicles, employees, and multifamily communities. Applicants of the program do not pay for the equipment or installation costs, just the cost of the electricity used.
An EV manufacturer, Tesla, has charging stations in the City of Flagstaff at a few hotels. These Tesla stations use a proprietary plug; users without Teslas would have to purchase Tesla adapters to use the Tesla charging stations. There are two kinds of Tesla charging stations: Destination Charger and Super Charger. The Destination chargers are Level-2 and are typically installed in hotel parking lots. Super Charger stations are the DC fast charge type and can recharge 80% of an EV in 20 minutes. The City of Flagstaff has one fast charging station owned by Tesla, meaning non-Tesla EV drivers must have a Tesla adapter to use it.

To help accommodate an increase in electric vehicles in the region, the following locations are suggested in ***Table 5***.

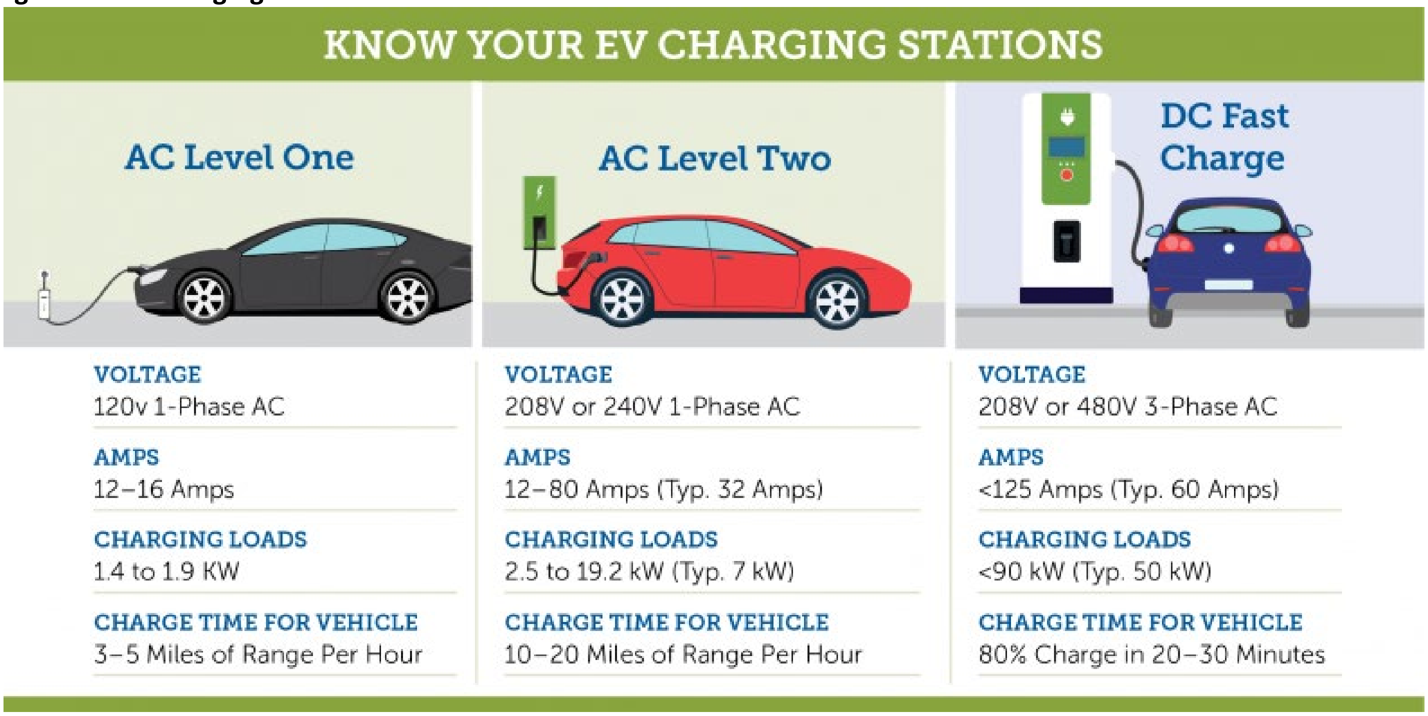
Table 5 – Optimal Locations for EV Charging Stations

Medical Campus	○ Tend to have a largely car-dependent workforce, shift workers who have few/less frequent off-hours public transit options ○ Potential locations in the City of Flagstaff: Flagstaff Medical Center, Sacred Hearts Health Center, North County HealthCare, Rehabilitation Hospital of Northern Arizona
Higher Education	○ Higher education campuses tend to draw employees and students from across the region. Some campuses are isolated from public transit and have higher proportions of auto commuters ○ Potential locations in the City of Flagstaff: Northern Arizona University and Coconino Community College
Public Sector	○ Public sector employees tend to drive at higher rates than private sector employees. Municipal office locations are often places far away from transit options, making them more likely to be car-dependent. ○ Potential Locations in the City of Flagstaff: Somewhere central to public sector buildings in Downtown Flagstaff, Coconino County Office, Coconino County Public Works ○ Mountain Line is currently in the master planning stage of replacing and modernizing the current DCC facility, which could be a prime central location for charging e-buses
Neighborhood Center	○ Neighborhood centers are often a mix of commercial and residential uses. Neighborhoods with more of one or the other uses, cars are left parked on the street needing charging ○ Potential Locations in the City of Flagstaff: Neighborhood near the Whole Foods on E Butler Ave, neighborhood near WF Killip Elementary School, similar neighborhoods on the west end of the City of Flagstaff
Leisure Destination	○ Parks, public pools, cultural institutions, stadiums, and other major leisure attractions ○ Potential locations in the City of Flagstaff: Museum, Northern Arizona, Snowbowl, Thorpe Park, Foxglenn Park, Buffalo Park, and Duck Lake

Source: "Electric Vehicles Are on the Rise. Is Your Community Ready?" Vock, D.C., 2021. *Planning Magazine*, American Planning Association (APA).

Single family homes are the best equipped for EVs as they typically provide easy outlet access for Level-1 EV charging. Level-2 charging requires the homeowner to install a special utility hookup usually costing in the range $800 to $1200 while the cost of the charging station itself will cost an additional $400 to $2000 depending on the vendor and rate of charge. Residents living in multi-family homes like apartment complexes will find it especially challenging to adopt EV. Some apartment complexes do have EV charging stations but typically only one or two plugs. ***Figure 7*** explains the levels of EV charging stations.

Figure 7 – EV Charging Station Levels



Market Share in the City of Flagstaff

As of 2020, the market share of EVs remains low in the City of Flagstaff with only about 300 total EVs. Roughly half of these are battery electric vehicles (BEV), and the other half are plug-in hybrid electric vehicles (PHEV).

City Incentive Program Results

The City of Flagstaff encourages people to buy EVs through the Power Up Flagstaff tax rebate program. This program rebates a portion of the local tax paid for purchases of fuel-efficient automotive vehicles. The current local transaction privilege (sales) tax rate on the purchase of vehicles is 2.281%; with this incentive program the City of Flagstaff will take off 2% for fully electric vehicles, 1.6% for PHEVs, and 0.7% for fuel efficient vehicles. Since the program's inception in April 2021 to August 2021, 14 applications have been processed for the purchase of 12 PHEVs and two fully electric vehicles. There are also 15 pre-order fully electric vehicles currently being processed through this program.

5.2.2. Consideration for Global Influence

The global environmental benefits of electric vehicles remain hotly debated though ample research has been conducted into the lifecycle Green House Gas (GHG) emissions of EVs versus Internal Combustion Engine Vehicles (ICEVs); it is better understood now that EVs have lower overall life cycle GHG emissions than ICEVs but the distribution of GHG emissions throughout the vehicle lifecycle varies as well as where the GHGs are emitted. EV emissions during their use phase are highly dependent on the carbon intensity of the local electric grid. Battery powered EVs have lower life cycle GHG emissions than the average ICEV, but a plug-in hybrid EV can produce just as many GHGs as an efficient ICEV if the electric grid is carbon intensive.

Generally, EVs produce very few GHG emissions during their use phase and have comparable emissions to ICEVs in their vehicle manufacturing phase. Unlike ICEVs, EVs use powerful ion batteries whose manufacturing process emits a comparable amount of GHGs as the manufacturing process for the vehicle itself. EVs produce far less GHGs locally where they are used but externalize the GHG cost of the battery production elsewhere. The total amount of GHGs produced over the course of an EV's lifecycle is substantially lower than an average ICEV especially given the City of Flagstaff's Carbon Neutrality Plan goal for reduced carbon dependency.

There are concerns regarding the true benefits of converting from conventional gas-powered vehicles to electric vehicles, especially when it comes to the source of electricity used for charging. The City of Flagstaff adopted a Carbon Neutrality Plan[12] in June 2021 that outlines a goal for 100% renewable electricity for the municipality by 2025, including two solar power installations: 50MW at Red Gap Ranch and 10MW at the landfill. The Arizona Public Service has also committed to a 100% carbon-free electric grid by 2050. Lastly, there is a proposed wind and solar farm to be built in Coconino County approximately 30 miles north of the City of Flagstaff that would generate 160 megawatts of energy[13]. With these transition efforts to renewable energy sources, electric vehicles could play a major role in the decarbonization of the City of Flagstaff.

5.2.3. Fundamental Steps in Planning for Electric Vehicles[14]:

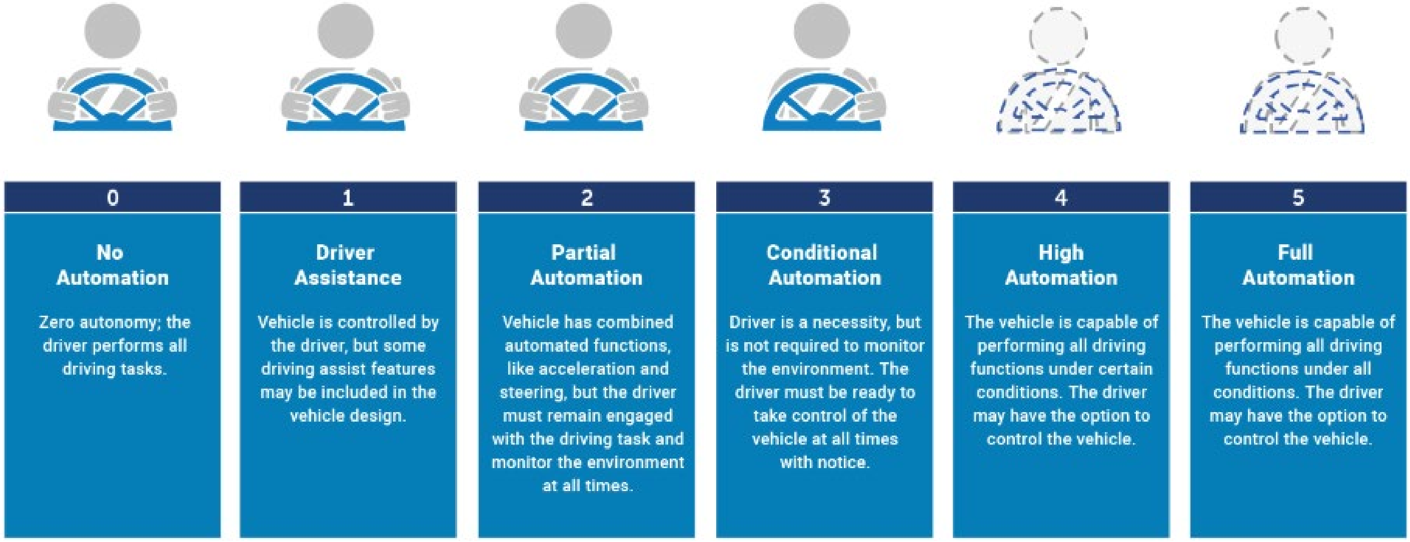
- Start by focusing on vehicles that the City has the most control over (buses, municipal fleets, and taxis for example) and plan charging infrastructure around these fleets
- Determine the type of chargers needed throughout the city (Level 1 (120V) for at-home charging, Level 2 (240V) for public charging, Direct current/fast charging (480+V)), based on where, when, and what types of electric vehicles drivers will be charging
  - Make sure that partners in EV infrastructure deployment have a clear understanding of which types of chargers are included in the City's plans
- Update local policies and incentives to encourage/require others to build charging infrastructure, including:
  - Shift cost to developers
  - Encourage investment from electric vehicle manufacturers and energy companies
  - Secure investments from local companies
- Choose a ZEB transition scenario that maintains fleet size due to space constraints:
  - Due to limited vehicle storage space at the Kaspar Drive Maintenance Facility, the number of buses required to maintain current Mountain Line fixed-route service levels would exceed the facility's indoor capacity for storing and charging e-buses.

5.3. Autonomous Vehicles

While still an evolving technology, autonomous vehicles (AVs) come in a range of automation levels. The Society of Automotive Engineers (SAE)-defined levels of vehicle automation are shown in ***Figure 8***.

[12] https://www.flagstaff.az.gov/DocumentCenter/View/66105/Flagstaff-Carbon-Neutrality-Plan_for-adoption_6-15-21?bidId=
[13] https://azdailysun.com/news/local/wind-and-solar-farm-planned-north-of-flagstaff/article_29a7c05d-3764-5289-85f0-c70fa5fa8f7c.html
[14] https://www.c40knowledgehub.org/s/article/How-to-build-an-electric-vehicle-city-deploying-charging-infrastructure?language=en_US

Figure 8 – Society of Automotive Engineers (SAE) Automation Levels



Source: https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety#topic-road-self-driving, 3/12/20

Most vehicles currently sold are at **Level 1**, with basic driver assistance features such as cruise control or a back-up camera. A recent report notes that as of early 2018 at least one ADAS feature was available on over 90% of new vehicles sold in the U.S[15]. Vehicles with more advanced driver assistance systems, such as Subaru's Eyesight[16], Mercedes Benz' Intelligent Drive[17], or Toyota's Safety Sense[18], are at **Level 2**. Such systems can control two functions at once, such as combining adaptive cruise control, collision avoidance, and lane-keeping assistance to keep the vehicle in its lane and prevent it from hitting the vehicle in front.

Very few vehicles, such as Teslas with Enhanced Autopilot[19], are at **Level 3** and can operate without driver intervention for extended periods. These vehicles still require the driver to monitor vehicle operation and the operating environment. The well-publicized accidents involving Teslas in self-driving mode illustrate the need for driver attention at the current state of the art, and the potential consequences of not having that attention.

The most advanced passenger vehicles being tested are at **Level 4**, with roughly private 1,400 test vehicles operating on U.S. roadways. Based on the literature reviewed to date, all of the "autonomous" vehicles and taxis being demonstrated or tested by Waymo, Google, et al, have active human monitors in the driver's position or elsewhere in the vehicle at all times. These drivers or monitors cope with "disengagements" when the autonomous vehicle encounters conditions with which it cannot cope. Based on disengagement reports filed with the State of California[20], these conditions may include:

- Non-standard intersections (e.g. roundabouts).
- Missing or indecipherable roadway markings.
- Construction or work zones.
- Unrecognizable items or obstructions in the road.
- Weather conditions, such as ice, snow, mud, or heavy rain that obscure roadway markings.

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[15] AAA, (2019). Advanced Driver Assistance Technology Names.
[16] https://www.subaru.com/engineering/eyesight.html
[17] https://media.daimler.com/marsMediaSite/en/instance/ko/Mercedes-Benz-Intelligent-Drive-Assistance-systems-for-safety-and-comfort.xhtml?oid=9904983
[18] https://www.toyota.com/safety-sense/
[19] https://www.tesla.com/support/autopilot
[20] CBS News. (2020). *Automated Trucking, A Technical Milestone That Could Disrupt Hundreds of Thousands of Jobs, Hits the Road website.* Retrieved March 16, 2020

Given the City of Flagstaff's snowy climate, special care will be required to reduce the number of disagreements in autonomous vehicles. Lane centering features are increasingly prevalent on today's roads and depend heavily on lane striping. Any degradation or obstruction of the lane striping will diminish the convenience and safety benefits of lane centering technology. Frequent snow plowing and deicing techniques like spreading salt or cinders on roads can obscure lane markings from lane centering sensors.

The only road vehicles reportedly operating at **Level 5**, without a driver or monitor on board, have been restricted to test tracks or closed courses, such as corporate campuses. "Sidewalk robots" and other small delivery vehicles have been operating with human monitors, remote or on-site. Thus, based on the documentation reviewed to date, the state of the art for on-road AVs in general can be placed at Level 3, requiring a human to be 1) actively monitoring operation and environment; and 2) capable of assuming control with little or no notice. The current cutting edge of development is at Level 4, with some vehicles (e.g. Waymo taxis) operating for extended periods without human intervention, but only in well-defined, bounded (geo-fenced) areas. There are as yet no free-running Level 4 vehicles.

In practice, autonomy has come to mean self-driving operation with remote monitoring, which is technically Level 3 or 4. As technology improves and monitoring practices transition from constant supervision to management by exception, the distinction between Level 4 and Level 5 becomes semantic rather than functional.
Modeling – Fehr & Peers published a technical paper in 2019 at the annual TRB meeting that assessed implications of AV's on modeling and forecasting future travel demand[21]. The AV planning scenarios included (1) privately owned AVs, as well as (2) half of all future shared ride trips made by AVs similar to potential MAAS offerings. The models confirmed that **making vehicle travel more convenient has the potential to significantly increase vehicle use and reduce transit ridership**.

VMT associated with AVs is very nascent topic for implementation in forecast models. Most models (including the MAG model) show an increase in trips from mostly zero occupancy vehicles (zombie trips). WFH and EV implications in a model environment are still evolving.

Public Perception of Autonomous Shuttles
Based on a study of a one-year pilot of an autonomous shuttle in Downtown Las Vegas in 2018[22], the results of the passenger survey showed that the majority were in favor of the new technology given its (1) slow speed, (2) no transit fare, and (3) *less anxiety* given passengers were sharing the ride and not riding alone. In other words, the riders were sharing the journey/risk with other riders. Similarly, young, highly educated, males felt more positively about autonomous vehicles than their respective counterparts. Agency coordination, including between the public agencies and private operator, was also an important lesson learned.

Within Arizona, the Maricopa County Department of Transportation (MCDOT) was exploring use of an autonomous shuttle prior to COVID-19. This may be explored by MCDOT post COVID.

[21] https://www.fehrandpeers.com/wp-content/uploads/2020/01/Milam_Islam_Johnson_Fong_Donkor_Xu_AV-Modeling_TRB_2020.pdf
[22] https://www.tandfonline.com/doi/abs/10.1080/10630732.2021.1879606

6.0 Performance Measures Review

Performance measures provide a way to quantitatively measure progress towards a defined goal. A goal is a desired outcome, and best practice is to develop SMART goals: Specific, Measurable, Achievable, Relevant, and Time-bound. This section presents an initial list of specific, measurable, and mobility-related performance measures for potential application and evaluation in the RTP, as shown in ***Table 6***. This is not an exhaustive list and does not preclude MetroPlan from exploring additional performance measures or removing as appropriate. Additionally, the federal performance measures that MetroPlan has to follow are included in ***Table 7***.

Figure 9 shows the three main categories of the performance measures: *Environmental* measures such as VMT and GHG, *Equity* measures of mobility justice and accessibility, and *Efficiency* measures via travel time – which all connect to the ultimate vision of the RTP to "create the finest transportation system in the country." What makes a good performance measure is typically one that has data characteristics of being retrievable, reliable, and robust (or the three "R's"). A target is the desired benchmark to gauge whether the defined goal is achieved. For example, one of the primary goals of the 2045 MetroPlan RTP is to reduce the emphasis on single occupant vehicles. The performance measure is VMT, and the target is a 17% reduction. The targets noted below are derived from other local and state plans, such as the Carbon Neutrality Plan, and could be used with Scenario 2. Additional performance measures and targets will be vetted with advisory members and community stakeholders. ***Table 8*** shows the existing commute mode split in the City of Flagstaff.

Table 6 – Potential Performance Measures

Performance Measure		Target and Baseline	Target Reference	Other Notes
	Vehicle miles traveled (VMT)	17% reduction by 2030 compared to business as usual (BAU) projections (i.e., maintain VMT at 2019 levels)	• 2030 Carbon Neutrality Plan	• Consider **VMT per capita** as the metric, instead of total VMT. This will help account for expected future population growth.
	Total (%) share of electric vehicles (EVs)	30% of internal VMT comes from EVs by 2030	• 2030 Carbon Neutrality Plan	• Includes both passenger vehicles and e-buses.
	Greenhouse Gases (GHGs) from Transportation in Metric tons of carbon dioxide equivalent (MTCO2e)	Reduce GHGs from transportation by 35% compared to 2030 BAU	• 2030 Carbon Neutrality Plan	• Primarily represents emissions from the type of fuel currently being used.
	Total (%) share of fossil fuel car trips[A]	To be established	• To be established	• The target would be 70% if the measure is fossil fuel VMT.

Notes:
[A] Rows highlighted in light blue do not originate from an existing plan but are under consideration for the RTP.

Table 6 – Potential Performance Measures

Performance Measure	Target and Baseline	Target Reference	Other Notes
Total (%) mode share of walking/biking/ transit trips	76% mode share by 2030	• 2030 Carbon Neutrality Plan	• Otherwise known as the "Big Shift." • From 26% in the base year to 76% in 2030
Bicycle Comfort Index (BCI) and Bicycle Level of Service (BLOS)	BCI for Title VI areas meet or exceed regional average and/or regional average for different development types	• This was previously performed for Blueprint 2040 using BLOS, and analyzed by TAZ for urban, suburban, & rural areas	• BCI refers to a specific road segment facility, while BLOS is systemwide. • Both can be reported side-by-side
Equity Ranking Index[A] (1-10 score)	For example, all new projects/policies in the 2045 RTP capture census tracts that have an equity ranking index score of 5 or higher	• To be determined	• Derived from Portland's Equity Matrix[23] • Uses 3 demographic variables: Race, income, & limited English proficiency • Fehr & Peers developed a Mobility Hubs Site Suitability Tool that incorporates an EPA Equity Index Score[24]
Person hours of travel	To be established	• To be determined	
Unequal Commute[A] (i.e., Accessibility)	For example, residents in disadvantaged areas live within a comparable commute to the region average	• To be determined	• Derived from the Urban Institute Unequal Commute Tool[25]
Bus Service Frequency	Increase Route 5 frequency to every 30 minutes, and Route 7 to every 20 minutes on weekdays	• NAIPTA Mountain Line Short-Range Five-Year Transit Plan	• Targets based on adopted 2017 Plan. • Consider coordinating with ongoing SRTP update

Notes:
[A] Rows highlighted in light blue do not originate from an existing plan but are under consideration for the RTP.

[23] PBOT Equity Matrix - https://www.portland.gov/transportation/justice/pbot-equity-matrix
[24] https://fehrandpeers.maps.arcgis.com/apps/webappviewer/index.html?id=0c6cff9987934305b6870c6f4e007d42
[25] Urban Institute Unequal Commute Tool - https://www.urban.org/research/publication/access-opportunity-through-equitable-transportation

Table 6 – Potential Performance Measures

Performance Measure		Target and Baseline	Target Reference	Other Notes
	Single Occupant Vehicle Trips	Reduce by 11% compared to 2019 baseline (69% mode share – see Table 7)	• 2030 Carbon Neutrality Plan	• The CNP has a 34% target of commute trips taken by walk, bike, & transit, inclusive of carpool programs
	Residential Density	Increase density in residential neighborhoods by 20% in 2030 compared to BAU	• 2030 Carbon Neutrality Plan	• Based on achieving the VMT target of 2019 levels

Notes:
[A] Rows highlighted in light blue do not originate from an existing plan but are under consideration for the RTP.

Table 7 – Federal Performance Measures

Performance Measure		Target and Baseline	Target Reference	Other Notes
	Number of Fatalities	2% increase	• ADOT Performance Targets	
	Rate of Fatalities/100 Million Vehicle Miles Travelled	2% increase	• ADOT Performance Targets	
	Number of Serious Injuries	7% decrease	• ADOT Performance Targets	
	Rate of Serious Injuries/100 Million Vehicle Miles Travelled	8% decrease	• ADOT Performance Targets	
	Number of Non-motorized Fatalities and Serious Injuries	1% decrease	• ADOT Performance Targets	
	Percent of National Highway System (NHS) Bridges classified in good condition based on deck area	52%	• ADOT Performance Targets	
	Percent of NHS Bridges classified in poor condition based on deck area	4%	• ADOT Performance Targets	
	Percent of Interstate Pavements in good condition	44%	• ADOT Performance Targets	
	Percent of Interstate Pavements in poor condition	2%	• ADOT Performance Targets	
	Percent of Non-Interstate NHS Pavements in good condition	28%	• ADOT Performance Targets	

Table 7 – Federal Performance Measures				
Performance Measure		Target and Baseline	Target Reference	Other Notes
	Percent of Non-Interstate NHS Pavements in poor condition	6%	• ADOT Performance Targets	
	Freight Reliability on the Interstate (Truck Travel Time Reliability Index)	1.35	• ADOT Performance Targets	
	Percent of person-miles that have reliable travel times on the Interstate	85.8%	• ADOT Performance Targets	
	Percent of person-miles that have reliable travel times on the Non-Interstate NHS	74.9%	• ADOT Performance Targets	

Figure 9 – Performance Metric Categories

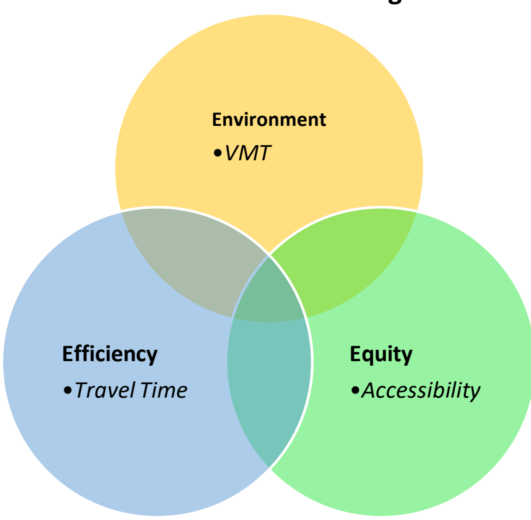

Table 8 – City of Flagstaff Commute Mode Split

	Flagstaff Metro Area
Drive Alone--	69%
Carpool--	12%
Transit--	1.5%
Walk--	9%
Other--	3.5%
Work at Home--	5%

Source: *2015-2019 American Community Survey (AC*