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Planning Indicators: Non-Auto Mobility

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16. Abstract
Cities and transit agencies, including the Los Angeles County Metropolitan Transportation Authority (LA Metro), are interested in shifting travel from solo driving to more sustainable modes, including transit, biking, walking, and other non-auto modes. As LA Metro and other agencies collect more data about their system and its users, there are many opportunities to apply that data to productively improve the system and drive policy. In this project, our primary goal was to identify a set of specific indicators Metro and other agencies could use to measure their success in the creation and provision of a high-quality non-auto mobility system for both existing users reliant on these modes as well as future users who shift from driving.

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The Institute of Transportation Studies at UCLA acknowledges the Gabrielino/Tongva peoples as the traditional land caretakers of Tovaangar (the Los Angeles basin and So. Channel Islands). As a land grant institution, we pay our respects to the Honuukvetam (Ancestors), 'Ahiihirom (Elders) and 'Eyoohiinkem (our relatives/relations) past, present and emerging.

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EXECUTIVE SUMMARY

Cities and transit agencies, including the Los Angeles County Metropolitan Transportation Authority (LA Metro), are interested in shifting travel from solo driving to more sustainable modes, including transit, biking, walking, and other non-auto modes. As LA Metro and other agencies collect more data about their system and its users, there are many opportunities to apply that data to productively improve the system and drive policy. In this project, our primary goal was to identify a set of specific indicators Metro and other agencies could use to measure their success in the creation and provision of a high quality non-auto mobility system for both existing users reliant on these modes as well as future users who shift from driving.

Our research process included a review of academic literature on the factors that influence travel behavior, interviews with relevant community-based organizations (CBOs) and advocacy groups, and identification of best practices from transit agencies nationwide. Once our research process concluded, we synthesized our findings in an analysis, and created a framework to form our recommendations. We conclude this report with recommendations for specific indicators, as well as additional recommendations relevant to, and useful for, achieving more meaningful and effective outcomes. Our recommended indicators will help LA Metro and other agencies measure success towards reaching the goals of shifting travel behavior towards non-auto modes through a focus on riders' and users' experiences and perceptions of the system.

Through our analysis process, we focused our research by using the following criteria for potential indicators. The indicators had to be: supported by the engagement process and literature, relatively easy data collection and measurement, and fall within the purview of LA Metro. Based on these criteria, we selected three primary categories of indicators: Transit Dependability, Transit Safety, and Multi-Modal Network Quality.

Transit Dependability is an umbrella term that includes all indicators relevant to the tracking and improving of a transit rider's ability to depend on transit as their primary mode of transportation. Relevant indicators include service frequency, service reliability, and speed.

Transit Safety describes how safety informs and influences what mode of transportation people use, across race, class, and gender. Our engagement process with CBOs and policy organizations have shown us that concerns about safety focus on different solutions among black and brown riders, female riders, and lower-income riders.

Multi-Modal Network Quality refers to the ability for active transportation users to access their destinations using high-quality, safe infrastructure. Through our interview process, we heard from community organizations that potential active mode users must feel they have a feasible option to which they can shift from other modes. We also found support for this idea in our literature review, including one report which highlighted how bicycle mode share rose in all eight cities studied after each city significantly expanded their bicycle facilities network. Cities and agencies must plan for a more cautious user before the use of active modes, including cycling and micro-mobility, will increase.

Within each of these categories, we researched the most effective and most commonly-used indicators and explored both empirical indicators that measure success using quantitative data and perception indicators that directly track user experiences through methods such as transit rider surveys. Tracking both empirical and perception indicators will both help improve service for existing non-auto mode users and help identify factors that encourage mode shift away from the automobile. In our recommendations section, we pulled out what we believe to be the indicators that make the most sense for LA Metro to use. We include more details on the calculation of these indicators in the Recommendations section of this report.

Dependability Indicators

Empirical: Additional Bus Stop Time - We recommend LA Metro measure service reliability using *Additional Bus Stop Time* which compares the average added time customers wait at a stop for a bus and their scheduled wait time. For routes with frequent service, the indicator is designed to capture headway consistency, and for routes with less frequent service, the indicator should capture schedule adherence.

Perception: Perceived Wait Time - We recommend tracking riders' perceptions of how long they wait for a bus or train using rider survey methods at the stop/station level. This will allow for a comparison between perceived wait times and actual wait times based on real-time tracking data, revealing stops with conditions that make the perceived wait times relatively longer.

Transit Safety Indicators

Empirical: Effectiveness of Transit Ambassadors - As LA Metro rolls out its future transit safety ambassador program, we recommend tracking the ratio of the number of ambassador interactions where police are requested by ambassadors to the total number of ambassador interactions. This is based on our community engagement interviews and reports from numerous advocacy organizations, which showed that the relationship police on Metro have with riders of color is strained and does not always contribute positively to their safety. Additionally, our review of academic literature and safety reports from community organizations showed that the presence of armed officers can escalate violent incidents especially when lower-income and/or riders of color are involved. This indicator would help to elucidate how often armed police officers are actually required resolve incidents on Metro.

Perception: Perceived Comfort - Perceptions of safety are varied and holistic and are informed by built environment features as well as the presence of Metro personnel on the system. We recommend LA Metro track the percent of riders who would feel safer from safety interventions. For each stop/station, as well as at the system-wide level, Metro could track the percent of riders who would feel safer or more comfortable based on factors including brighter lighting, more seating, and an increased presence of Metro personnel at stops and stations.

Multi-Modal Network Quality Indicators

Empirical: Bicycle Network Buildout - *Bicycle Network Buildout* is measured as the percent of total miles of Metro's MAT Program Cycle 1 Priority Active Transportation Corridors that have been built with bicycle facilities. As a regional priority list, the MAT Program Corridors provides a county-wide assessment of the health of bicycle infrastructure improvements and is used to create a baseline to measure progress toward a complete bicycle network. With a focus on regional connectivity, this indicator will help Metro provide system users with the increased confidence that they can safely reach their destinations.

Empirical: First/Last Mile Bicycle Connectivity - *First/Last Mile Bicycle Connectivity* is calculated through the total bicycle network connections over the total road network connections at qualified intersections within a three mile radius of rail and BRT stations, weighted by station points from Metro's MAT Program Cycle 1 First/Last Mile Ranked Locations List. An intersection qualifies if it falls within a three mile radius of a rail or BRT station and features three or more feeder streets with vehicle volumes of at least 3000 vehicles per day (VPD). Each station's weighted First/Last Mile Bicycle Connectivity score can be added together county-wide to provide a single aggregate metric for overall county-wide first/last mile bicycle connection health.

Perception: Rider-identified Level of Stress - We recommend LA Metro track *Rider-Identified Levels of Stress* as a perception indicator for Multi-Modal Network Quality. Our literature review revealed a strong correlation between the number of cyclists on a route and how safe cyclists feel while biking. If users do not feel that a safe non-auto route exists to their destination, they are less likely to use a non-auto mode regardless of the infrastructure that does exist. Cities and researchers have identified methods for directly surveying cyclists about their levels of stress and perceived safety levels in their neighborhoods or on their commute. To measure rider-identified levels of stress, LA Metro could mimic what other cities/agencies are doing and ask cyclists to give a qualitative description of stressful parts of their non-auto trips with open-ended responses.

Additional Recommendations

Finally, we include additional recommendations that emerged from our engagement process and literature review that we feel are important but did not incorporate into any of our indicator categories. One such recommendation is for LA Metro to collect data often enough for indicator progress to be sufficiently measured. While this may be relatively easy for empirical indicators that rely on existing data, some of the perception indicators may require additional and more frequent surveys and outreach methods. Additionally, we recommend LA Metro develop avenues for riders, CBOs, and other relevant groups to track the agency's progress themselves. This can encourage greater participation in outreach efforts, leading to better service and more efficient allocation of resources, as well as a greater understanding by CBOs of where their efforts are most needed. This could take the form of a public data dashboard that highlights progress in certain indicators, as well as ensuring public access to data soon after it is collected.

Source: LA Metro

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INTRODUCTION

PROJECT PURPOSE

Cities and transit agencies, including the Los Angeles County Metropolitan Transportation Authority (LA Metro), are interested in better understanding how to shift travel from solo driving to more sustainable modes, including transit, biking, walking and other non-auto modes. As LA Metro and other agencies collect more and more data about their system and their riders, many methods exist to measure mode share and the factors that influence travel behavior, including metrics about the transit system itself and the broader mobility and land use context. In this project, our primary goal is to identify a set of specific indicators Metro and other agencies could use to measure their success in the creation and provision of a high quality non-auto mobility system for both existing users reliant on these modes as well as future users who shift from driving.

RESEARCH APPROACH

Our research approach included a review of academic literature related to indicators and travel behavior, identification of best practices from transit agencies nationwide, interviews with relevant community-based organizations (CBOs) and advocacy groups, multiple discussions with LA Metro staff members, and conversations with our project advisor.

LITERATURE AND PLANS REVIEW

To begin our research process, we conducted a thorough literature review of over sixty academic articles and plans created by transit agencies and city planning departments. Our goals were to better understand the factors that influence travel behavior and how indicators can assess these factors, to provide a conceptual background on indicator use, and to identify examples and best practices of indicators used to track progress towards a city or transit agency's goals. We also identified best practices in the use of location-based services data for transportation planning purposes. Finally, we included examples of mode-shift results from relatively cost-effective non-auto mobility interventions in other cities to help illustrate the potential impacts of these interventions in Los Angeles. Our full literature review can be found in Appendix B.

EXTERNAL ENGAGEMENT

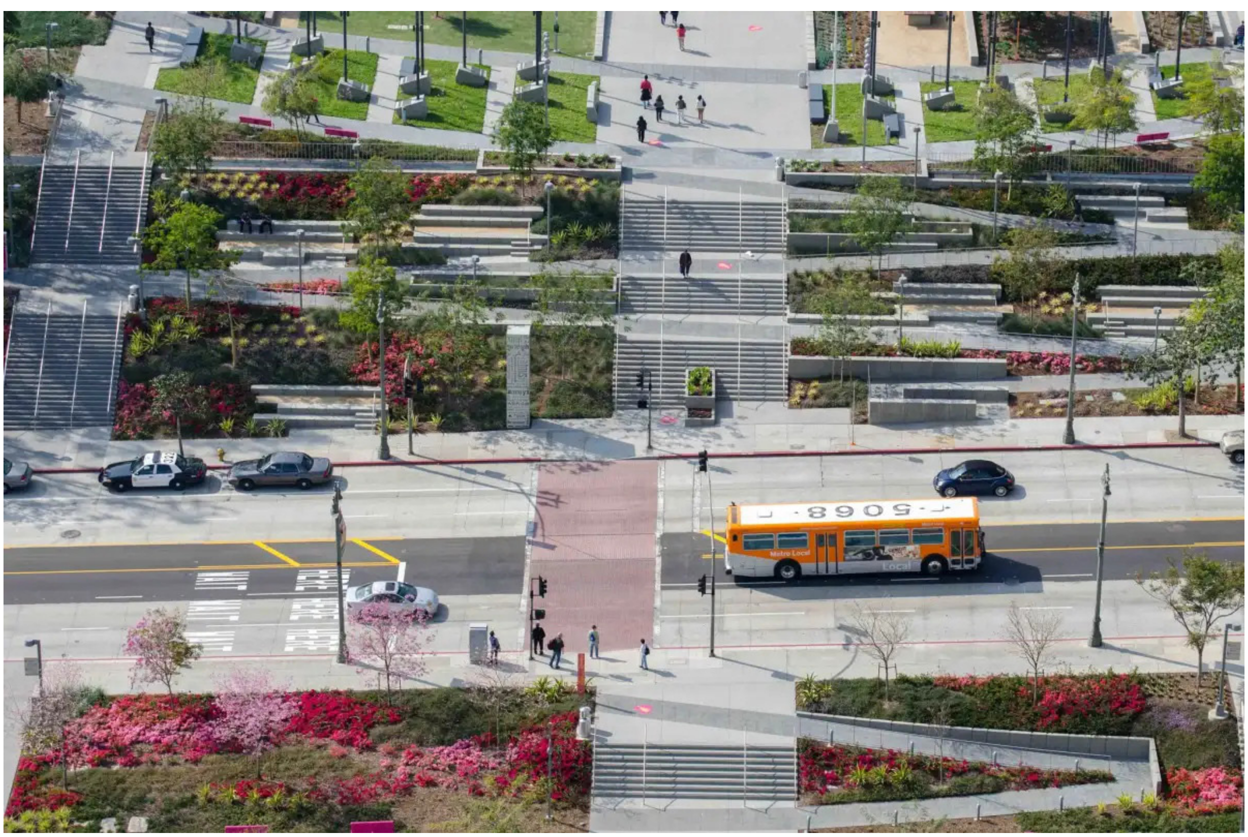
To complement our literature and plans review, we interviewed local community-based and political organizations that focus on non-auto mobility and prioritize the lived experiences of transit users, cyclists, and pedestrians. In total, our team reached out to ten organizations and performed one-hour interviews with seven of them, with the guiding question, "What does your organization find to be a good indication of a well-functioning transportation system unreliant on private vehicles?" In these interviews, we also discussed each organization's perspective on indicators that would best measure improvement in the organization's focus area, as well as each organization's preferred ways LA Metro could implement best practices we found in the literature review. See Appendix A for a full list of questions we asked during interviews.

CLIENT INPUT

Throughout the course of our research and analysis, we met with representatives from LA Metro's Office of Extraordinary Innovation (OEI) as well as Metro's service planning office. In these meetings, we shared interim results and received feedback on the strengths and potential drawbacks of our recommended indicators. We also learned about how OEI, service planning, and other LA Metro divisions currently use indicators, which helped us understand how well the agency could implement our recommendations.

RESEARCH ADVISOR INPUT

Beyond these three research areas, we had several internal discussions with our research advisor to help shape our analysis and develop our recommendations into actionable indicators for LA Metro.



Source: LA Metro

ENGAGEMENT

To complement our literature and plans review, we interviewed local community-based organizations that focus on non-auto mobility and prioritize the lived experiences of transit users, cyclists, and pedestrians. We also met with the Los Angeles Mayor's Transportation Team for relevant policy perspectives.

METHODOLOGY

In total, our team reached out to ten CBOs and conducted hour-long interviews with representatives from seven of these organizations. With the goal of ultimately synthesizing community priorities into relevant indicators, we focused our interviews on the following topics:

- How current practices are perceived by the communities that LA Metro serves
- Whether these communities feel their non-auto mobility needs are addressed by existing indicators
- How changes in LA Metro's practices could better address the needs of these communities while building a closer tie between the agency and residents

To focus our engagement efforts, our team developed an overarching guiding question that would best consolidate our goals, a set of internal questions to help ourselves prepare for the interviews, and a set of interview questions to use as appropriate with interviewees to inform our internal questions. Our overarching guiding question was: What does your organization find to be a good indication of a well-functioning transportation system, unreliant on private vehicles? Appendix A contains our full list of questions. For organizations concerned with both mobility and access outcomes, we coordinated engagement efforts with another UCLA research team, Access to Opportunities, as this team is researching access indicators in detail.

FINDINGS

The findings from these interviews can be grouped into the following subcategories: dependability, safety, non-auto mobility quality, and other considerations relevant to LA Metro.

DEPENDABILITY

Bus and rail dependability issues were often raised by the community-based organizations we interviewed. Four out of seven organizations stated that transit service should be more reliable and three out of seven stated that it should be more frequent. A suggested indicator from a CBO is wait time and the traveler's perception of wait time for transit. Two organizations believe that the LA Metro board should be more representative of bus riders; three believe

LA Metro should prioritize bus riders in particular; and five organizations believe bus service needs to be improved. An advocacy organization representative stated, "Don't forget about bus riders. Bus riders make up 70 percent of the system. Putting so much money towards rail is great, but if bus service remains as bad as it is, it speaks to how agencies continue to neglect the core base of their ridership." They elaborated that the bus rider operator shortage is contributing to the decline in service. Several advocacy groups also stated that unreliable and inconsistent service are under-emphasized barriers.

SAFETY

Five out of seven organizations stated that Metro could do a better job of understanding the daily experience of the rider, and that there needs to be increased and more nuanced engagement with community organizations. Three organizations agree that police on Metro are a barrier to mobility, one of which stated that police on Metro is specifically a barrier to Black riders. One potential indicator suggested by an organization is to compare the racial demographics of people being arrested with ridership demographics over time. Additionally, two organizations stated that safety is a nuanced concept that must be treated thoughtfully and that the amount of money going to police is an issue of equity. In terms of cycling, one advocacy organization pointed out that bike counts are often inaccurate because they take place during business hours and ignore cyclists who commute either very early in the morning or late at night. These are typically lower-income, essential workers who bike out of necessity and not by choice. The same organization also brought up how unhoused and low-income cyclists are disproportionately harassed by police for not having lights or riding against traffic. Finally, this organization stated that bike planning should be done for riders who are the least comfortable riding on the street in order to increase cycling.

MULTI-MODAL NETWORK QUALITY

Three out of seven organizations agree that politics are a major barrier to mobility and non-auto infrastructure. Four organizations stated that walking and biking should be made easier and more accessible, that a singular non-auto mode will not be the answer to ending car dependency and investments need to be made in multiple mobility alternatives. A policy organization suggested that bus service and reliability should be emphasized over other innovations to improve ridership. Rail and bus only lanes were also suggested, along with shelter being critical to riders waiting for transit. A suggested indicator from an advocacy organization is to track People Miles Traveled (PMT) over Vehicle Miles Traveled (VMT). Four organizations also agree that mode share is important to measure. Three out of seven organizations agree that adopting fare free transit would reduce barriers to non-automobility.

OTHER CONSIDERATIONS

Two out of seven organizations have stated that they collect their own data related to non-automobility and would value greater transparency from LA Metro. Four out of seven organizations interviewed have stated that LA Metro should be prioritizing low-income riders and community members. Three out of seven organizations indicated that Metro needs to involve community members more and suggested paying community-based organizations to do engagement rather than hiring external consulting firms. Additional suggestions about Metro improving their outreach claimed that existing surveys are insufficient for understanding the needs of underserved riders and Metro needs to expand their on the ground efforts on engagement.

Based on the findings across seven interviews, there are multiple recurring themes to highlight. Organizations brought up quality and expansion of transit service, increased and improved methods of community engagement, the complexity of safety in and on transportation systems, and more direct consideration of how politics informs our transportation system. Prioritization of bus service and vulnerable riders were a consistent theme in what these organizations understand to be positive indicators of non-automobility. Cycling and walking infrastructure and how safe and accessible they are came up as major concerns for a shift to non-automobility as well. Socioeconomic status and racial identity seem to also show that different factors influence who chooses to take non-auto transportation and when.

Source: LA Metro

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ANALYSIS

BACKGROUND

Transit agencies typically collect significant amounts of data about their systems, operations, and riders, and therefore have countless options to measure 'success' as an agency. Agencies, as well as state and federal entities that fund transit, have traditionally used indicators such as ridership and farebox recovery ratio to measure success. Increasingly, transit agencies are taking a more holistic view of mobility within their operating territory and are attempting to measure overall travel mode share and establish goals based on this metric. In Vision 2028, for example, LA Metro set forth an ambitious overarching vision to "double the percent usage of transportation modes other than solo driving, including taking transit, walking, biking, sharing rides, and carpooling" (Los Angeles County Metropolitan Agency, 2018, p. 2).

Shifting mode share away from solo driving and towards more sustainable modes is an important goal for the future of Los Angeles County (LA County), not only because cars and trucks are responsible for 33 percent of LA County's greenhouse gas emissions, but also because of the vast amount of valuable public and private land consumed by automobile storage and multi-lane roadways that might otherwise become green space, housing, or public spaces (A Greater LA: Climate Action Framework, 2017). Shifting mode share to transit, other forms of shared mobility, and active transportation will promote both environmental and economic sustainability. Shifting mode share to active transportation modes like walking and biking could also promote other societal goals, such as improving physical and mental health outcomes.

However, the challenge of using mode share as a transit agency's key performance indicator is that the interventions with the greatest potential to alter mode share are most often outside of a transit agency's immediate sphere of influence, as we uncovered through our literature review (see Appendix B). While new rail lines, bus lanes, or first/last mile connections can certainly spur localized mode share changes, these changes are small relative to the impact of other factors such as parking regulations, land use, and fuel and vehicle prices. For example, researchers found access to parking to have three times the effect on transit use as living in an area with good transit access, a good Walk Score, or a good Bike Score (Millard-Ball et al., 2021). Further, other academic research on parking revealed that residential areas with scarce parking were correlated with a 37 percent reduction in solo vehicle commutes and a 25 percent reduction in solo vehicle grocery store trips (Chatman, 2013). Despite large investments in transit in LA County over the past 25 years, LA Metro ridership has been falling since 2013 (LA Metro, 2021), which researchers ascribe to the substantial increase in vehicle access in Southern California since 2000 (Manville et al., 2018).

Source: LA Metro

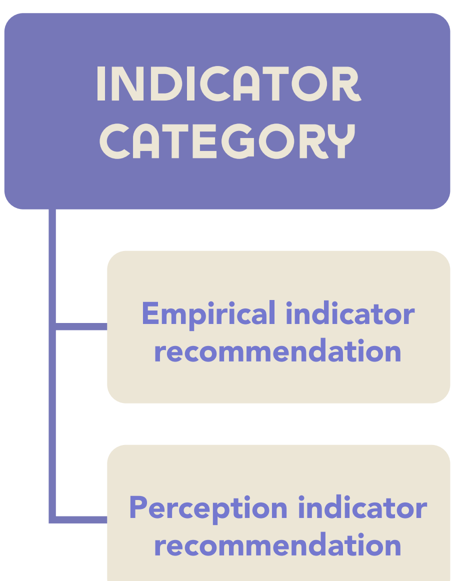
While LA Metro's influence over land use is limited, it is possible for the agency to play a role in certain areas. For example, LA Metro could draft their Transit Oriented Communities (TOC) policy to condition the receipt of regional discretionary funds for transit expansion, enhancement, and improvement projects on removing parking minimums and allowing shared and unbundled parking. Similar proposed TOC policy in the Bay Area requires parking maximums for residential and commercial properties near rail or bus rapid transit stops (Joint MTC Planning Committee with the Association of Bay Area Governments Administrative Committee Agenda Item 5b, 2022). Additionally, LA Metro could create policies to charge drivers for the true cost of driving, including the social, environmental, and personal costs, through congestion pricing measures. When London implemented congestion pricing, a virtuous cycle ensued: as bus speeds improved, more people rode public transit, and the increased ridership made service improvements more feasible, which further increased ridership (Small, 2005).

Most authority over land use and parking, however, still resides with local jurisdictions. Mode share, therefore, could be considered a system performance indicator for a much larger system than the transit agency alone. While system performance indicators are important to help stakeholders understand the overall system's performance, knowing the travel mode share in LA County at any given time is not the most important factor to an individual traveler. For an indicator program to achieve its full potential, indicators must be appropriate in scope and clearly associated with a policy or set of possible actions (Innes and Booher, 2000). Additionally, using mode share as a measure of LA Metro's success could imply that significant responsibility for shifting mode share away from driving solely belongs with Metro. This could take away focus from other actors, such as local jurisdictions and the state, whose decisions on land use, parking, and the costs of driving have great influence on mode share. Finally, a significant focus on mode share within LA Metro could divert resources from interventions to improve service for existing transit-reliant riders.

Given the multiple purposes indicators serve—as learning tools, planning tools, and communication tools—as well as the factors associated with mode share that are outside the agency's control, LA Metro should prioritize using indicators relevant to delivering high-quality service to existing transit riders and users of other non-auto modes. While attempts to capture new riders may induce small changes in mode share, LA Metro's ridership base is primarily made up of transit-reliant riders who are disproportionately low-income and people of color (LA Metro, 2020). Immediate improvements to the most heavily used bus and rail lines, bike routes, and sidewalks will benefit these riders the most, while simultaneously proving to people currently unreliant on transit that non-auto modes can indeed be feasible alternatives to solo driving.

EMPIRICAL AND PERCEPTION INDICATOR FRAMEWORK

Improving the quality of non-auto modes for both current and future users requires a set of indicators that capture a holistic perspective of the transportation system and measure success towards a city or transit agency's goals. Our research has uncovered several indicator concepts cities and agencies use to track the benefits of improvements to transit and non-auto mode networks. Many of these include empirical methods to measure transit system and mobility network performance, such as frequency and reliability for transit modes or the number of collisions involving cyclists or pedestrians. Tracking indicators such as these make sense given the importance of such factors in travel behavior and satisfaction. At the same time, our research uncovered the importance of perception in influencing travel mode choice, especially for non-auto modes. For example, researchers found that the perception of safety was more important to potential cyclists than crash statistics (Blanc and Figliozzi, 2016). For this reason, we have explored empirical indicators that attempt to get closer to measuring the perception of riders or users than traditional metrics. For example, agencies can measure bus reliability from the perspective of riders rather than vehicles. In the subsequent analysis sections, we refer to indicators that rely on anything other than customer feedback as empirical indicators. Additionally, we have explored qualitative indicators that measure perception directly from riders and users, through means such as surveys. We refer to these as perception indicators.



> ***…PERCEPTION OF SAFETY WAS MORE IMPORTANT TO POTENTIAL CYCLISTS THAN CRASH STATISTICS***

While perception can be more difficult to measure than empirical performance, such a qualitative perspective must be included in any analysis of transportation system quality and effectiveness. Additionally, empirical and perception indicators can be used in tandem to examine the relative importance of empirical indicators and identify areas of particular concern. For example, a large difference between the measured and perceived wait times at a bus stop could indicate the presence of factors that make the waiting experience undesirable, such as a lack of shade or lighting. LA Metro, other transit agencies, and researchers have a variety of methods for measuring perceptions of transportation systems, including customer experience surveys, aggregating feedback from several sources, and crowdsourcing through mobile phone apps.

LA Metro has solicited feedback from riders annually through the Customer Experience (CX) survey, and published its first Customer Experience Plan in 2020, which provided an honest and comprehensive look at riders' experiences (LA Metro, 2020). The agency sought the responses of thousands of riders through surveys, social media, complaints, and community meetings. The survey asked riders several questions including demographic information, reasons for riding Metro or other modes, and their trip purpose. In addition to riders, LA Metro also interviewed Board members and bus operators. In the plan, LA Metro identified ten priority areas for improvement: bus reliability, accuracy of real-time information, bus frequency, bus stops, ease of payment, speed, crowding, personal security, homelessness, and cleanliness. Prior to the COVID-19 pandemic, the overall satisfaction for LA Metro riders was very high, with 90 percent of riders stating they were satisfied with LA Metro. According to the CX Plan, ridership dropped by 50 percent during the COVID-19 pandemic (with internal estimates nearing an 80 percent reduction), and riders during this time wanted to see enhanced cleaning, reduced crowding, and more work to address homelessness. The CX Plan discusses each of the ten priority areas and concludes with section-specific and overarching recommendations.

Other transit agencies have taken steps recently to incorporate qualitative measures of perceptions of transit network quality. For example, San Francisco Municipal Transportation Agency (SFMTA) incorporates customer satisfaction information, broken down by time of day, into a larger set of empirical metrics they track at the neighborhood level and by individual transit line, such as on-time performance and service gaps (TransitCenter, 2021). This approach helps the agency identify geographically and temporally specific interventions, such as addressing service gaps that lead to crowding on a specific bus line through Chinatown during peak hours (TransitCenter, 2021). SFMTA aggregates qualitative data from a variety of sources, including field surveys, 311 comments, feedback via elected officials, and engagement with community-based organizations (CBOs) (SFMTA, 2020). Other agencies have also taken steps beyond traditional survey approaches when measuring perceptions and experiences of transit, such as Metro Transit in Minneapolis-St. Paul, which provides funding to CBOs to conduct outreach (TransitCenter, 2021), who may hold more trust within the local community than the agency itself.

Researchers have explored new methods for measuring perceptions of transportation modes through rapid feedback mechanisms and app-based surveys. For example, in terms of measuring perceptions of quality or safety of different modes, Misra et al. reference 'crowdsourcing' as a potential method for involving a "large group of stakeholders in transportation planning and operations" (2014, p.1). In one example, researchers at Carnegie Mellon University created an app called Tiramisu Transit, which allows users to submit information about their experience riding the bus such as bus crowding, which can help people with disabilities choose which bus to board (Misra et al., 2014). Many transit agencies across the country, including LA Metro, have partnered with the Transit App, which measures rider satisfaction as well as the level of agreement with specific statements such as, "My stop/station provided a good place to wait" (Transit App, 2021). Additionally, researchers at George Mason created an accessibility mapping system for crowd-sourced identification of barriers or obstacles in pedestrian networks that need repair (Lee and Sener, 2020). Such an approach could help incorporate Americans with Disabilities Act (ADA) accessibility requirements into measures of sidewalk quality, as recommended by TransitCenter (2021).

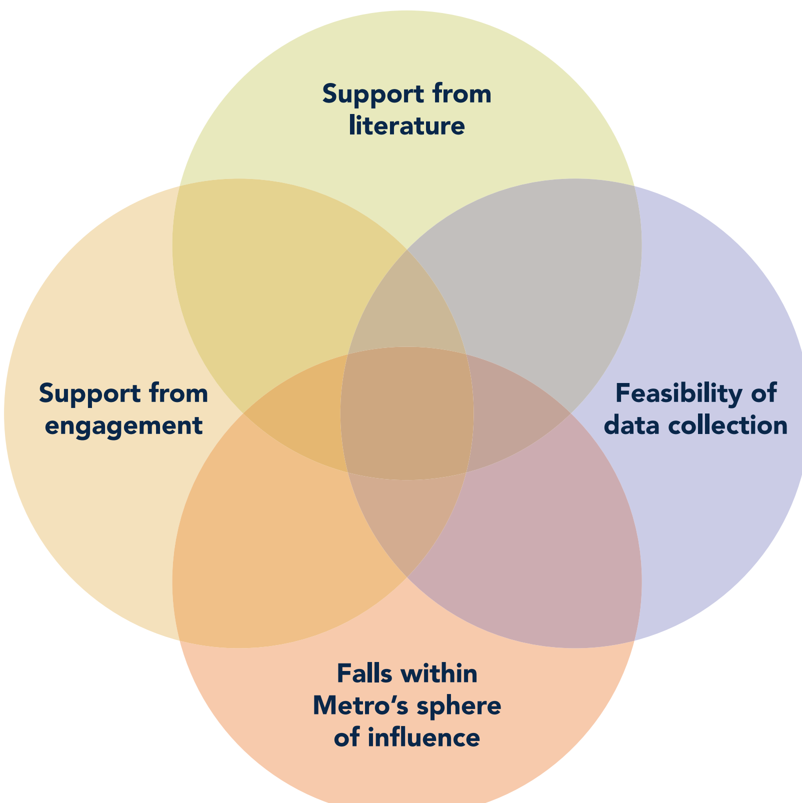
As LA Metro makes targeted improvements to the transit system and active mobility network, it will be important to measure performance using empirical indicators. At the same time, it will be critical to measure perceptions of non-auto mode performance to understand the extent to which these improvements are noticeably improving the experiences of transit riders and active mode users. Over the next several years, as LA Metro, the state, and local governments implement policies to better manage automobile demand, such as congestion pricing, higher-density land uses, and eliminating minimum parking requirements, improved perceptions of the non-auto mode network will mean that current drivers feel they have more viable non-auto options.

SELECTED INDICATOR CONCEPTS

In order to arrive at indicator categories, our team reviewed and discussed both the results of our community engagement efforts and the findings from our literature review. In this analysis, we use the following criteria to evaluate potential areas of focus: (1) the degree to which the measured phenomena fall under LA Metro's sphere of influence, (2) the feasibility of consistent data collection, (3) the support for a measurement category based on community engagement, and (4) the support for a measurement category based on academic literature. We also identify examples of similar measures used by other agencies, where applicable. In applying these criteria, three key themes emerged as especially worthy of further consideration, each with sub-indicators pertaining to both empirical and perceived measures:

1. **Transit Dependability**
2. **Transit Safety**
3. **Multi-Modal Network Quality**

Using these categories and their relevant indicators to measure success as a transit agency will help create a better transportation network for people most reliant on the system as it exists today, as well as prepare the system for the future influx of users as policies to manage automobile demand come to fruition. The following sections will introduce these themes in more detail, discuss their relation to both empirical performance and perception, and analyze the value of developing more specific planning indicators to track progress and communicate outcomes to the public.



TRANSIT DEPENDABILITY

JUSTIFICATION + IMPORTANCE

A dependable transportation system is one that users can rely on to work for them when they need it. This is especially helpful for those users who do not have access to a car and is also important in encouraging users to make sustainable transportation choices by opting out of car ownership. Our focus on dependability came out of our conversations with community leaders in transportation advocacy in Los Angeles. During our outreach experience, we heard several overarching themes related to transit service improvements. Overall, we heard that bus service was an especially important area of consideration to community organizations as bus riders make up a majority of the transit ridership in the City of Los Angeles and are significantly lower-income than those who drive and those taking the train (Anonymous Interview, 2022). A majority of the organizations that we talked to expressed some sentiment related to bus service improvements. Within bus service improvements, several factors came up regularly:

- Service frequency (short headways)
- Reliability (schedule adherence)
- Speed of transit
- Travel delay

According to the organizations we interviewed, all of these factors, when improved, make bus service more dependable for bus-reliant transit riders. This is consistent with the stakeholder and public outreach sessions performed for the NextGen Bus Study, in which the public identified faster service, more frequent service, and more reliable service among the most important network characteristics (Metro Transit Service Policies and Standards, 2020). Additionally, Metro outlines these factors as important in Vision 2028 which references average travel speeds and adherence to implementation schedules as important measures (Los Angeles County Metropolitan Agency, 2018). The LA Metro CX Plan also names bus reliability, accuracy of real-time information, bus frequency, and speed as priority areas for improvement based on feedback collected for the plan.

Our research into the academic literature on transportation service indicators and travel behavior supported the importance of these factors. Jarrett Walker argues that frequency is important for three reasons: it reduces wait times, it makes connecting easier, and it reduces reliability issues (if a bus breaks down but another one is coming soon, it's less of an issue; Walker, 2011). In this way, a transit system that increases vehicle frequency also sees an increase in service reliability. Other research supported the importance of bus frequency in transit behavior. One study by the Institute for Transportation Development and Policy (ITDP) used twelve mobility indicators (such as share of population, jobs, or low-income households with proximity to transit, or the share of opportunities accessible within 30 or 60 minutes) and found the most influential of those indicators was the share of population within close proximity to frequent transit (ITDP, 2019). In Portland, Oregon, when bus service-hours were streamlined into twelve core routes to increase frequency, ridership on these routes increased 18.2 percent, while ridership on the routes that lost service-hours decreased only 0.7 percent (Litman, 2021). Similarly, in 2015, Houston METRO re-designed its bus network to create a gridded network of frequent lines (Binkovitz, 2016). Houston METRO also increased service on high-frequency routes and expanded weekend service (Binkovitz, 2016). As a result, bus ridership increased across the board by 1.2 percent, though there was a much greater increase in weekend trips, especially on Sundays where the increase was 34 percent (Binkovitz, 2016). While the literature supports the importance of transit vehicle speed, Jarrett Walker argues that what matters most to riders is not speed, but delay and that shifting the planning focus results in not only greater speeds, but also more reliable service for riders (Walker, 2011). In practice, both speed and delay are vehicle-based metrics that must be weighted by route ridership or per-stop boarding delay. The importance of these transit attributes may guide the development of indicators for LA Metro related to transit dependability.

EMPIRICAL INDICATORS

A variety of service performance metrics could be considered related to the dependability of public transit service. Some general considerations related to bus dependability include:

- How many scheduled buses actually run?
- How many buses arrive according to schedule?
- How often are passengers turned away when buses are full?
- How fast do the buses travel?
- How often do the buses come?
- How consistent are the intervals between buses?
- How many passengers are affected by the performance of each bus?

Source: LA Metro

Other transit agencies attempt to track the answers to questions like these through service quality metrics, which are often communicated to the public through an online dashboard. For example, in New York City, the Metropolitan Transportation Authority (NYC MTA) tracks and reports *Service Delivered*, or the share of scheduled buses that are actually provided during peak hours (MTA Bus Performance Dashboard, 2022). Similarly, the San Francisco Municipal Transportation Agency (SFMTA) tracks the *Percent of Scheduled Service Hours Delivered* (SFMTA Strategic Planning Metrics: Service Quality, 2022). The NYC MTA also measures *Average Speed* along a route. Faster average bus speeds matter for dependability because they help passengers trust that they will be able to get to their destinations quickly. The SFMTA is also beginning to measure the *Percent of Trips Above Capacity* (SFMTA Strategic Planning Metrics: Service Quality, 2022). Such metrics play at least some role in capturing and representing the dependability of the transportation system as a whole or at the route level to identify problems and allocate resources most efficiently.

With regard to schedule adherence, many transit agencies measure average *On-Time Performance*. For example, AC Transit tracks and reports the share of buses leaving stops no more than one minute early and no more than five minutes late (AC Transit Key Performance Indicators, 2022). The SFMTA uses a vehicle-locating system to measure on-time performance as within four minutes late or one minute ahead of schedule, based on vehicle departure times, and reports the percent of on-time performance on a monthly basis (SFMTA Strategic Planning Metrics: Service Quality, 2022). The SFMTA is noteworthy here for having recently switched to using stop departure times, which may be more important to users, rather than arrival times. Another SFMTA metric is the *Percent of Trips Meeting Headway Adherence* based on the number of “gaps” in service, or times a vehicle arrives more than five minutes later than the scheduled headway (SFMTA Strategic Planning Metrics: Service

Source: LA Metro

Quality, 2022). Measuring the number of gaps in service is one way to capture information about bus bunching, or inconsistency in headways. This metric reports headway adherence based on the share of gaps in vehicle trips; it does not distinguish between major or minor delays as experienced by passengers waiting at each stop.

The MBTA publishes a similar *Bus Reliability* percentage, based on the share of buses arriving more than three minutes after the scheduled interval since the last bus, for routes with frequent service, or for other routes, more than six minutes after the scheduled arrival time (MBTA Dashboard, 2022). This example is noteworthy for using different reliability metrics for routes with frequent and infrequent service, because when service is expected to be frequent, riders are less concerned with schedules and more likely to show up with mental estimates of how long they might wait based on typical intervals between buses on the route. For routes with frequent service, riders care about headway consistency. When service is less frequent, riders are more likely to rely on their schedules to plan their trips. These riders care about schedule adherence. For example, if buses were scheduled to arrive every ten minutes, customers expect to board shortly upon arrival at a stop. If all the buses got off schedule, but the headways remained consistent, riders would still be likely to consider the service reliable. On the other hand, for infrequent routes, schedule adherence is more important than headway consistency. If buses come only every 30 minutes, and the buses get off schedule and consistently arrive 20 minutes later than the scheduled times, riders would likely be dissatisfied despite the consistent headways.

The NYC MTA also considers waiting time differently based on the frequency of service along a route. In the past, they used a *Wait Assessment* indicator somewhat similar to the MBTA's bus reliability metric, but the agency now considers this a "legacy metric" and explains that it did not account for the number of customers waiting at different stops or distinguish between minor gaps in service and major delays (MTA Bus Performance Dashboard, 2022). Instead, the NYC MTA now measures *Additional Bus Stop Time*, defined as the average added time customers wait at a stop for a bus, compared with their scheduled wait time. It assumes customers arrive at the stop uniformly for routes with frequent services and closer to the scheduled stop time for routes with longer headways. Riders' card swipes are combined with GPS tracking data for the bus (MTA Bus Performance Dashboard, 2022). This indicator accounts for different customer behavior and expectations for different routes according to the frequency of service. Additionally, unlike SFMTA's *On-Time Performance* or MBTA's *Bus Reliability* metric, which are both vehicle-based metrics, it accounts for the number of passengers at each stop, so bus performance that affects a larger number of people is weighted more heavily. Measuring *Additional Bus Stop Time* is considered an industry best practice worldwide (MTA Bus Performance Dashboard, 2022). Research using data collected by the International Bus Benchmarking Group compares four alternatives and recommends this type of metric, also known as *Excess Wait Time*, as best reflective of the customer experience of service regularity (Trompet et al., 2011).

Other passenger-based dependability indicators used by the NYC MTA include *Additional Travel Time* and *Customer Journey Time Performance*. *Additional Travel Time* measures the difference between the average time customers spend on board the bus and their scheduled travel time (MTA Bus Performance Dashboard, 2022). It relies on riders' card swipes and GPS tracking data. *Customer Journey Time Performance* combines the results of *Additional Bus*

INDICATOR	AGENCY	WHAT IT MEASURES	INDICATOR TYPE
Service delivered	NYC MTA	Share of scheduled buses that are actually provided during peak hours	Vehicle-based
Service-hours delivered	SFMTA	Percent of scheduled service hours delivered	Vehicle-based
Average speed	NYC MTA	Average bus speeds along a route	Vehicle-based
Percent of trips above capacity	SFMTA	(Dashboard still in development)	Vehicle-based
On-time performance	AC Transit	Share of buses leaving no more than one minute early and no more than five minutes late	Vehicle-based
	SFMTA	Share of buses leaving no more than one minute early and no more than four minutes late	Vehicle-based
Percent of trips meeting headway adherence	SFMTA	"Gaps" in service, defined as times when a vehicle arrives more than five minutes later than the scheduled headway	Vehicle-based
Bus reliability	MBTA	Share of buses arriving more than three minutes after the scheduled interval since the last bus (for routes with frequent service) or more than six minutes after the scheduled arrival time (for routes with infrequent service)	Vehicle-based
Additional Bus Stop Time	NYC MTA	Average added time customers wait at a stop for a bus, compared with their scheduled wait time (assuming uniform rider arrivals for routes with frequent service and arrivals closer to the scheduled stop times for routes with longer headways)	Passenger-based
Additional Travel Time	NYC MTA	The difference between the average time customers spend on board the bus and their scheduled travel time	Passenger-based
Customer Journey Time Performance	NYC MTA	The percentage of customers whose journeys are completed within five minutes of the scheduled time	Passenger-based

Table 1. Selected methods for measuring bus system dependability

Stop Time and *Additional Travel Time* to calculate the percent of customers whose journeys are completed within five minutes of the scheduled time (MTA Bus Performance Dashboard, 2022).

Decreasing the discrepancies between scheduled service and provided service can help riders trust that bus service is reliable, and indicators that measure these discrepancies can help agencies identify stops or routes that require additional attention, track their overall progress, and communicate the results with the public. However, discrepancy measures of reliability do not fully capture the idea of dependability. A dependable transportation system is one that users can rely on to work for them when they need it. From our literature review and public engagement, it became clear that in order for the public to come to see public transit as a dependable mode of transportation, buses must come not only reliably according to schedule and with consistent headways, but also frequently. In the long run, providing better service to transit-dependent riders and allowing vehicle owners to feel they can give up car ownership, or at least to see transit as an attractive option for many of their trips, will require particular focus on increasing the frequency of service.

Despite the significant influence of bus frequency on travel behavior choices, transit agencies rarely use frequency as a standalone performance measure for the system. This is likely because agencies also care about coverage, and, at a certain point, continuing to streamline frequency into certain routes would no longer improve overall system quality or increase total ridership. Although frequency may not make sense as a system performance indicator, frequency measurements could still be valuable to track internally, so service planners have the data to better understand the effects of route headways on ridership. Frequency of service may be the most important factor related to dependability, but due to the difficulty of determining the optimal trade-off with coverage, we limit the scope of this analysis to evaluating other possible measures related to dependability.

One important way to distinguish between bus system indicators is whether they are based on vehicle performance alone or are also weighted by the number of passengers. Tracking performance weighted by passengers will provide the most accurate picture of how users experience the system and can help planners prioritize the service improvements that will improve the transit experience for the greatest number of people. LA Metro has both Automatic Passenger Counting (APC) data and TAP card data that, when combined with General Transit Fleet Specification - Real Time (GTFS-RT) vehicle-tracking

> **"THE ONLY WAY TO TRULY UNDERSTAND PERCEPTIONS OF FREQUENCY AND RELIABILITY IS TO ASK RIDERS DIRECTLY."**

data, could enable the use of passenger-based performance indicators. Even indicators that are traditionally vehicle-based, such as vehicle speeds, could be improved by weighting speed data by the number of passengers on board at a given time. Vehicle-based indicators could misrepresent how people experience the system, if vehicles with few riders in periods of uncongested traffic are weighted the same as vehicles with many riders in peak travel periods. We encourage the use of passenger-based indicators.

Another difference between the indicators in Table 1 is whether they treat minor delays and major delays differently. Many indicators simply show whether a delay occurred, without accounting for its length. The *Additional Bus Stop Time* indicator stands out as particularly strong for capturing both the length of delays and how many passengers were affected. It compares the average added time customers wait at a stop for a bus with their scheduled

STRENGTHS OF USING ADDITIONAL BUS STOP TIME

- **Takes into account route frequency**
- **Treats major and minor delays differently**
- **Passenger-based rather than vehicle-based**

wait time. The "scheduled wait time" could be based on headways for routes with frequent service, and based on scheduled departures for infrequent routes. For frequent routes, for each passenger, the difference between scheduled and actual wait time is calculated as the difference between the actual and scheduled headway, divided by two (assuming uniform arrivals to the stop). For infrequent routes, for each passenger, the difference between scheduled and actual wait time could be the number of minutes behind the actual schedule a bus departs. If a scheduled stop is skipped entirely, it could be assumed that half of the passengers boarding the next bus had been waiting since the previous scheduled departure time. The *Additional Bus Stop Time* indicator can capture both headway consistency and schedule adherence. It also partially captures the discrepancy between scheduled service hours and provided service hours, because running fewer buses will increase actual wait times. Tracking performance according to the Additional Bus Stop Time metric could help LA Metro focus on improving dependability for as many riders as possible. This could be complemented with a similar passenger-based metric that captures the excess time riders actually spend on the bus, such as *Additional Travel Time*.

Some transit agencies, including LA Metro, track bus speed as an additional indicator related to transit dependability. While bus speed does not necessarily translate directly into more frequent or reliable service, faster bus speeds can allow an agency to schedule more frequent service without increasing service hours. Additionally, increasing bus speed likely requires some form of transit priority to avoid traffic congestion, such as bus lanes, which can make headways more consistent. We ultimately did not include bus speed as one of our key recommended indicators, as we have focused primarily on aspects of wait time as they relate to dependable transit service. Researchers have found that transit riders perceive one minute of waiting time to be 2.5 times as long as one minute of in-vehicle time (Fan et al., 2016), highlighting the need to prioritize indicators that specifically focus on wait times. That said, bus speed is an important metric that can be used to understand the effectiveness of transit priority interventions.

Additionally, wait time is one component of *Transit Competitiveness*, a broader indicator concept employed by agencies including LA Metro and the MBTA to measure the percent of all trips in each agency's service area in which transit is competitive with driving (Gartsman et al., 2020). For example, the MBTA measures scheduled and actual service frequencies (which impact wait times) and the reliability and variability of travel times as components of their transit competitiveness metric (Gartsman et al., 2020). LA Metro uses the idea of transit competitiveness primarily in relation to travel time, and considers a transit trip to be competitive with driving if the transit travel time is less than about 2.5 times the drive time. While such a competitiveness analysis is useful for a transit agency engaged in service planning or a bus network redesign intended to increase ridership, it may be less relevant as a public-facing measure of success. Furthermore, one conceptual strength of the transit competitiveness metric is its ability to shift a traveler's focus on the structural advantages of driving, and therefore better realize the need for interventions to speed up transit, such as bus lanes. However, because these structural advantages of driving are largely outside LA Metro's power to reduce, this indicator's strength is also its weakness when under consideration as a measure of LA Metro's success. Transit dependability, on the other hand, matters to all riders and puts more focus on the transit system itself. For this reason, we prioritize actual and perceived wait time as a specific focus area for LA Metro to track over time.

PERCEPTION INDICATORS

While the empirical indicators described in the previous section can get close to transit riders' experience of dependability, the only way to truly understand perceptions of frequency and reliability is to ask riders directly. Measuring perception is important for understanding dependability, as researchers have found the perception of waiting time to be more directly related to transit rider satisfaction than actual waiting time (Carrel et al., 2016). Additionally, riders typically perceive wait times to be longer than they actually are, with researchers estimating the perceived wait time to be about 1.2 times the actual wait time (Fan et al., 2016). Riders also tend to perceive unreliable services as taking longer to arrive (Fan et al., 2016).

AGENCY	SOURCE	RELEVANT QUESTIONS/ STATEMENT	CHOICES
LA Metro	Transit App Survey	My agency is on-time and reliable	Agree / Disagree (1-5 scale)
		I was able to get to my destination in the amount of time I expected	Agree / Disagree (1-5 scale)
LA Metro	Customer Experience Survey (2019)	THIS bus/train is generally on time (within 5 minutes)	Strongly Agree - Strongly Disagree
		How many minutes did you wait for [the] FIRST bus or train [on this trip]?	Minutes
SFMTA	Survey (2018)	Respondents presented with hypothetical 20-minute wait and four different information scenarios: • Bus shelter sign says 20-minute wait • Bus shelter sign displays earlier-arriving alternative a short walk away • Check smartphone prior to departing and see 20-minute wait • Smartphone app (e.g., Google Maps) advertises Uber and Lyft	Take original MUNI route Take alternative MUNI route Walk or other modes
SF - Berkeley researchers	San Francisco Travel Quality Study (2013)	How satisfied were you with the in-vehicle travel times, wait times, transfer times (if applicable) and overall reliability experienced today?	5-point scale (happy to sad face)
King County Metro	Rider Survey (2019)	Satisfaction level with many aspects of transit, including frequency of service and on-time performance	Very satisfied to very dissatisfied
Minneapolis	University of Minnesota Researchers (2016)	How many minutes do you think you waited at the station/stop before you boarded this train/ bus?	Minutes

Table 2. Selected methods for measuring perceptions of wait time and frequency (De La Loza, 2020; King County Metro Transit, 2020; Los Angeles Metro, 2022; SFMTA Board of Directors, 2018)

Transit agencies typically measure perception using customer satisfaction surveys, which are the "most direct way of capturing the customers' perspective" (Carrel et al., 2016). Surveys, both by transit agencies and researchers, vary in their approaches to asking riders about perceptions of wait times and frequency. Some, including LA Metro and researchers in Minneapolis, simply ask passengers directly how long they believe they waited at a stop (see Table 2). Others, such as SFMTA, have created more specific hypothetical scenarios to see how riders may react to different information scenarios given a potential long wait time.

Ultimately, researchers find that perceptions of wait times can vary significantly depending on stop factors including "surroundings, perceived security, and amenities such as enclosed waiting areas, seating or restrooms" (Fan et al., 2016). Therefore, it is important to measure the average perceived wait times at a stop and compare it to average actual wait times to reveal stops with large gaps between actual and perceived wait times. Customer satisfaction surveys are often most useful when the agency can make a direct link between satisfaction and specific service quality measures (Carrel et al., 2016). Tracking the difference between actual and perceived wait times at the stop level could help identify stations in need of shelter, lighting, or other amenities. Benches, for example, were associated with reductions in perceived wait time based on a study of Minneapolis transit riders (Fan et al., 2016).

To track the perceived wait time, Metro could continue to ask survey respondents the number of minutes they waited for a given bus/train, and ask respondents to state the stop at which they boarded. Researchers have also found that real-time arrival information can reduce perceived headways from ten to eight minutes (Fan et al., 2016). Without real-time information, "riders perceived wait times to be greater than the true wait times, whereas with real-time information, they did not." (Carrel et al., 2016). As SFMTA has done, Metro could also test with riders hypothetical scenarios in which they have access to real-time arrival information, as well as other real-time information such as nearby service heading in a similar direction that will arrive sooner. That said, real-time information must be reliable, as the perceived wait time is larger than the actual wait time when the real-time information is perceived to be inaccurate.

Finally, Metro could examine the differences between actual and perceived wait times broken down by demographic groups. For example, Fan et al. found that women were more likely to report longer wait times in stops perceived to be relatively unsafe (2016). We examine safety in more detail in the next section.

TRANSIT SAFETY

JUSTIFICATION + IMPORTANCE

Safety in transportation can be understood based on the mode of transportation used by an individual and external factors and stressors that shape the individual's perception of their personal safety. As our focus is on encouraging non-auto mobility, this section will explore empirical indicators and perceptions of safety for transit users. One indicator framework proposed by Innes and Booher (2000) consists of system performance indicators, policy and program indicators, and rapid feedback indicators. System performance indicators look at the big picture and should measure the performance of the system as a whole. Consensus about the type of system desired by the community is important when developing system indicators; however, this does not mean it is best to avoid controversy and settle on lowest-common-denominator indicators with minor influence. These indicators provide a shared sense of direction, helping people see the whole system and anticipate changes. Policy and program indicators have a narrower focus and do not require the same level of consensus as system indicators. These indicators allow decision-makers to analyze subsystems, and it is often beneficial to create multiple policy or program indicators for a given topic or goal. In the case of individual safety, considering how travelers prioritize their safety by mode and their lived socio-economic realities can lead to a safer transportation network for all people. There is resounding evidence that perceptions of safety by travelers indicate which mode of transportation they choose, but because what informs their safety varies, a holistic approach to safety from Metro would benefit non-auto mode users and Metro operators and employees alike.

In a 2010 study, researchers asked Los Angeles transit users to rate the importance of various features related to access, reliability, information, amenities, and safety on a scale from "not important" to "very important" and their level of satisfaction with the feature, from "strongly disagree" to "strongly agree" (Iseki and Taylor, 2010). The three most important factors for riders were safety at night, safety during the day, and schedule adherence.

A holistic framework can inform more equitable strategies towards safety for all transit riders, with different needs. A 2021 TransitCenter report found that 29 percent of former LA Metro riders cited safety as a primary reason they stopped taking transit (TransitCenter, 2021). But how riders of color define safety concerns are different from white riders. Black adults are five times as likely to be stopped by police (outside or inside a transit system) and transit dependent undocumented riders always put their personal security at risk when using transit with police presence (TransitCenter, 2021). Asian-Americans post COVID-19 have faced increased harassment on transit, while transit operators feel unsafe from rider harassment while working. Valuing safety while understanding how armed policing actively makes transit more hostile for a

Source: LA Metro

large percentage of transit dependent people in Los Angeles could change how former and current riders perceive their safety while traveling. How Metro currently chooses to define safety deeply impacts the individual experiences on transit of their riders of color, LGBTQ, and female riders (ACT-LA, 2021). When considering the different safety needs of different riders across demographic groups, the same conclusion can be drawn which is that the status quo of transit safety must be changed.

EMPIRICAL INDICATORS

According to an LA Metro Survey result report from 2019, only 8 percent of Metro bus riders are white and nearly 90 percent are people of color. Of rail users, 21 percent are white, while 75 percent are people of color. ACT-LA has also found that LA Metro has been steadily increasing their police budget over time, with their current budget reaching $768 million. Increasing the police budget has not made riders of color feel safer and over-policing distinctly threatens the safety of riders of color. Three out of five community-based organizations we interviewed have stated from their research and organizing that police presence on Metro acts as a barrier to mobility while two out of five have stated that the amount of money going to policing is an equity issue and does not positively serve all populations. Abolitionist activist, educator, and organizer Mariame Kaba defines crime as, "a socially constructed set of norms that define what a society decides for itself they will criminalize." For Metro to be able to measure indicators of safety that are considerate of their most vulnerable transit riders, they must look beyond increased police presence in hopes of crime reduction, which has been proven to be untrue (ACT-LA, 2021). LA Metro has introduced a Public Safety Advisory Committee (PSAC) this year that intends to work with law enforcement and identify alternatives to armed law enforcement in response to nonviolent crimes (LA Metro, 2022). Tracking safety indicators alongside PSAC initiatives is an opportunity to understand how safety for all riders can be measured.

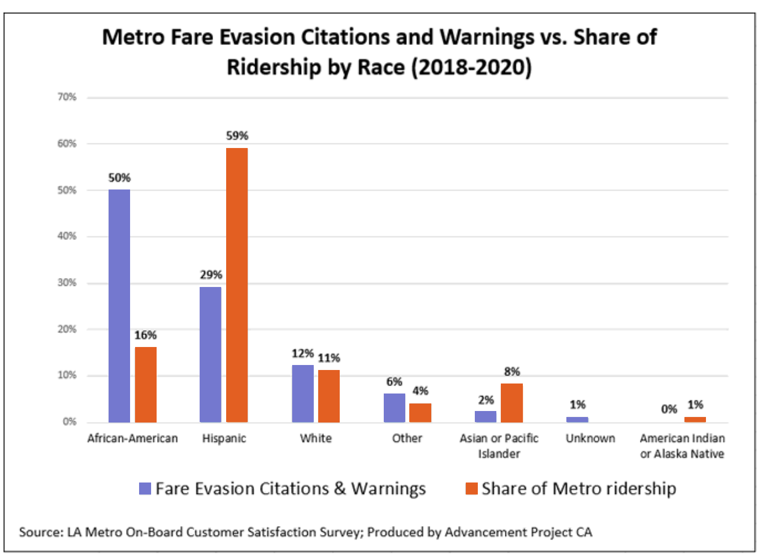


Figure 1. Metro Fare Evasion Citations and Warnings vs Share of Ridership by Race

> **THE STATUS QUO OF TRANSIT SAFETY MUST BE CHANGED.**

LA Metro already collects data on incidents of crime within their system and that information can be used to understand racial disparities in citations, and how interactions with police officers among different rider demographics impact rider safety. Black riders, who make up 18 percent of riders, have been issued 50 percent of citations and arrests by Metro's officers (ACT-LA, 2021). Figure 1 shows the racial distribution of Metro ridership and citations for fare evasion.

Reports of crime and other incidents on Metro, while important to track, do not provide the full narrative on safety for all riders. Using existing crime data to understand racial disparities in citations and arrests can be used to inform a more complex understanding of incidents where officers involved actually caused or escalated a violent incident on Metro. Armed personnel in particular have made riders of color feel unsafe (TransitCenter, 2021). Based on this analysis, a possible safety metric could look at the effectiveness of unarmed transit ambassadors proposed through a PSAC initiative. The Bay Area Rapid Transit (BART) system has piloted a transit ambassador program since 2020. Within the first year of the program, ambassadors had 10,000 rule check-in interactions and 12,000 interactions to notify riders of rule violations. Within these contacts, police were only requested in 132 of these incidents (BART, 2021). Ambassadors are trained to navigate incidents or interactions on the transit system that do not necessarily require the presence of armed police officers. Incidents or interactions can be loosely defined as situations that involve rule and code of conduct violations on transit and require intervention.

This indicator could be measured as a ratio comparing the number of ambassador interactions where police are requested by ambassadors over the total number of ambassador interactions. This ratio can be expressed as a percentage, with the idea that the number should go down over time, as ambassadors will be present to navigate situations that don't require police presence. Like BART's ambassador program, these ambassadors could be transit personnel specifically trained to navigate rule violations, health emergencies, and unhoused riders. These ambassadors are trained in de-escalation and anti-bias techniques (BART, 2021). Effectively, the number should go down over time as ambassadors are better able to de-escalate situations or connect people to resources without requiring police backup, proving the success of the ambassador program.

PERCEPTION INDICATORS

The perception of safety is holistic and varied depending on the user and what informs the user's environment. Table 3 shows how other transit agencies query riders to better understand their perceptions of safety. Many of these questions relate to the presence of armed officers, unarmed ambassadors, and people using the system who some riders may feel unsafe around. Designing survey questions about unarmed ambassadors would be a useful way to address how riders can find help on the Metro system without involving armed officers.

AGENCY	FORMAT	QUESTION/STATEMENT	OPTIONS
LA Metro	Rider survey (2019)	I feel safe waiting for this bus/train; I feel safe while riding this bus/train	Strongly Agree to Strongly Disagree
NYC MTA	Rider survey (2021)	How safe does the presence of each of the following make you feel?	Uniformed Police Officers MTA Staff$Uniformed Security Guards Customer Ambassadors/ Volunteers
CTA (Chicago)	Rider Survey (2021)	Respondents asked to prioritize/rank a number of safety-related investments, most of which are covid-related	General Security presence on vehicles or at stops/stations Other covid-related safety measures
SFMTA	Rider survey (2018)	No specific safety questions, but included among other choices in questions such as, what would you most like to see improved?	Better security/safety from crime Too many rude/ rowdy/ homeless/crazy/impaired people on vehicles Other non-safety related options such as frequency, cleanliness, overcrowding
Portland TriMet	Survey	Agency created a "Safety Advisory Committee to pilot new approaches to system safety", including rider surveys tracking the riders' perception of system safety	Not stated in TransitCenter report

Table 3. Existing survey questions relating to safety currently carried out by transit agencies across the country.

Additionally, many of the questions in these existing surveys fail to ask about the built environment and how it informs perceptions of safety. Metro could design surveys that could ask about environmental design and other physical features of rail stations and bus stops that inform riders' safety. Indicators for this purpose could include the presence of lighting and the level of isolation people feel at stations at different times of the day (Loukitou-Sideris, 2021). A 2021 ACT-LA report found that crime prevention design has resulted in built environments in transit systems that result in increased surveillance of riders and hostile and uncomfortable design in the name of safety (ACT-LA, 2021). Examples include removing rain or sun shelters around bus stops to prevent congregation near bus stops or reducing station exits and entrances when keeping these features would actually increase rider comfort while using Metro.

To better understand perceptions of safety, especially for vulnerable riders (people of color, women), Metro could design survey questions that focus specifically on indicators of perceived safety. It would be beneficial for Metro to design or weigh the surveys so their most vulnerable riders and most transit dependent riders' safety can be prioritized. These indicators could revolve around the presence of lighting, shelter, and unarmed ambassadors. Specifically, this indicator could be calculated based on the results of a single survey question that asks "Which of the following will make you feel safer on Metro?" with choices such as:

- Brighter lighting on stops and stations
- More seating on stops and stations
- More Metro personnel at stops and stations
- More Armed security personnel
- Less Armed security personnel
- Kiosks to communicate with remote security personnel
- Increase in security cameras

MULTI-MODAL NETWORK QUALITY

JUSTIFICATION + IMPORTANCE

Multi-Modal Network Quality refers to the ability to move from origin to destination with ease, comfort, and efficiency by way of active transportation modes. We included this as a focus area as Multi-Modal Network Quality was a recurring theme in our literature review and our engagement with community-based organizations. Organizations we spoke with described a desire to be less reliant on cars, and to be able to safely and reliably use non-auto modes to get to destinations. For this to happen, the proper infrastructure must be in place first, including the installation of bicyclist and pedestrian-oriented infrastructure such as bicycle facilities and sidewalks. Connectivity is also an important aspect of a multi-modal network. Connectivity influences the ease with which people can reach their destinations and is a large determinant of whether individuals decide that they can use active transportation modes, or public transit, in an area. Further, the type and quality of multi-modal connections has an influential role in whether individuals will use the connections available to them.

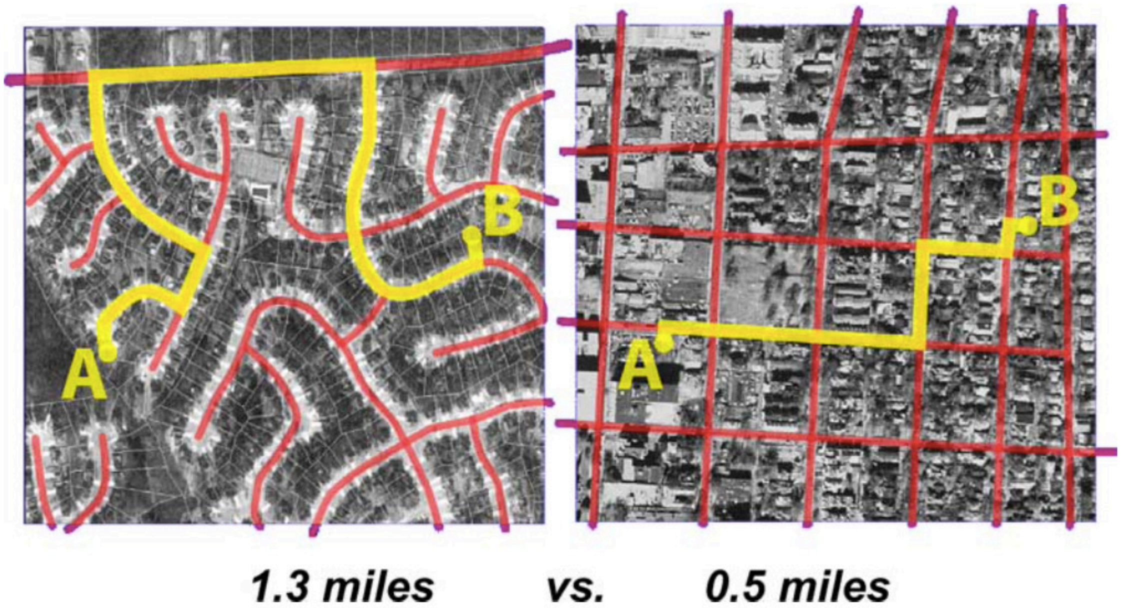


Figure 2. Comparison of travel distances with differing street connectivity networks (Frank et al., 2007). In the example on the right, although a shorter walking distance, the better connectivity resulted in more physical activity than the longer street network showcased on the left.

Street networks that have shorter and smaller blocks, more intersections, and fewer dead-ends increase walkability in an area (Berrigan et al., 2010). Additionally, bicycle networks that have physical separation between fast-moving vehicles and cyclists provide a safer and more comfortable environment, and the installation of these physical separation buffers was found to be more influential to mode choice than other objectively measurable characteristics (Blanc and Figliozzi, 2016; Riggs, 2019). This perception of safety, in turn, encourages increased use of active transportation modes. With a more connected and safe street network, individuals are more likely to walk, bike, and participate in other non-motorized activities. LA Metro's 2020 Transit Service Policy and NextGen Report recognizes this relationship and encourages a pedestrian and cyclist-oriented landscape in their planning. For example, the agency strives to have "streetscape and other design features [to] make it easier for pedestrians and bicyclists to access the stations", including "safe and well-lighted pathways, sidewalks and curb cuts, grid street network, and level topography" (Metro Transit Service Policies and Standards, 2020, p.8 and p. 13). Measuring and tracking connectivity improvements within the non-automobile network, particularly the active transportation network, will play a pivotal role in influencing modeshift away from private vehicles.

Networks of safe bicycle routes and infrastructure are similar in many ways to pedestrian infrastructure in terms of connectivity, completeness, visibility, and continuity. In a 2009 analysis of bicycle infrastructure, eight cities spanning three continents compared measurements of bicycle mode share changes that corresponded with increases in each city's bicycle infrastructure. In all cases, mode share jumped when the bicycle network was substantially improved (Pucher et al., 2009). While there is not enough consistency between each city's results to determine the threshold of connected streets required to yield increased mode share, a separate 2009 study looking at location-based data determined that bicycling was most likely to occur in areas with a "well-connected street grid and mix of land uses" (Dill, 2009 p.S106).

While a route may be physically connected and available, research shows that the user experience is equally, if not more, important. Both active transportation infrastructure and perceptions of safety influence travelers' decision to walk or bike to their destinations. The Oregon Department of Transportation collected and analyzed data that revealed how the presence of large commercial vehicles were the strongest factors affecting cyclists' comfort levels negatively, while separated facilities and traffic calming on residential streets would help increase comfort levels (Blanc and Figliozzi, 2016). A 2004 study in Los Angeles concluded that people who lived in areas with greater vehicular burden and who reported the most traffic stress had the lowest health status, including depressive symptoms (Gee and Takeuchi, 2004). Pedestrians and bicyclists alike have good reason to be concerned for their safety and health near roadways. The City of Los Angeles published a Vision Zero Safety Study in 2017 that found that from 2003 to 2013, "people walking and bicycling [were] involved in only 14 percent of all collisions but account[ed] for almost 50 percent of all traffic deaths" (Vision Zero Safety Study, 2017, p.5). These studies and statistics suggest that a general focus on metrics measuring users' experiences and levels of stress, and then implementing solutions to lower stress levels along clear active transportation routes, is an ideal approach to increasing active transportation usage. Furthermore, these findings remind policy makers that it's important to plan for an audience aged 8-to-80: planning for less confident or abled users will yield infrastructure that also protects more skilled or confident active transportation users, thus cascading benefits across the entire mode option.

Source: LA Metro

Corroborating our findings from our literature review, multiple community-based organizations that we interviewed believe that a multi-modal transportation system would improve the economic outcomes of individuals, particularly those belonging to underserved communities. One CBO stressed that walking and biking should not be scary and daunting choices to make, and that the traveler's perception of the level of effort to get to a transit station should be strongly considered.

In terms of LA Metro's influence, while the agency plans and implements transit service routes and schedules, it does not have direct jurisdiction over street layouts and the built environment. As such, LA Metro attempts to influence the built environment of street networks by assisting local jurisdictions to plan first/last mile connections to major transit stops, as well as by helping fund transportation projects. Given how influential the built environment is to potential active transportation users, LA Metro is well-positioned to do more to ensure a high-quality, mode-balanced transportation system through influence, direct funding of local road implementations, and the ability to collect data countywide.

Cities around the world have included active transportation indicators in their plans and dashboards. For example, the OneNYC plan includes the percentage of New Yorkers living within a quarter mile of the bicycle network as a key indicator for ensuring streets are safe and accessible, with a goal of 90 percent by 2022. The city also tracks the number of traffic fatalities and serious injuries with a target of zero, per their Vision Zero aspirations (OneNYC). The greater Paris region's Île-de-France Urban Mobility Plan also includes road safety indicators including the number of crashes, as well as a measure of the accessibility of sidewalk routes to understand gaps for persons with disabilities (2016). Additionally, the Orange County Transportation Authority's (OCTA) Active Transportation Plan includes measures of comfort and stress for pedestrians and cyclists based on a number of factors (2019). For example, the pedestrian level of comfort includes the average daily traffic, missing sidewalks, and the degree of separation between sidewalks and the road (OCTA, 2019). The bicycle level of stress also includes average daily traffic as well as the presence of existing bikeways and number of vehicle lanes on the road (OCTA, 2019).

> **"INFRASTRUCTURE THAT PROTECTS MORE VULNERABLE USERS AND PROVIDES LOW-STRESS MODE OPTIONS FOR CAR-DEFICIENT HOUSEHOLDS IMPROVES NON-AUTOMOBILE MODE SHARE."**

Source: LA Metro

Lastly, active transportation safety strategies are not limited to streets and sidewalks. On-site bicycle storage and lockers can also encourage the use of active modes. In particular, lockers and lockable/covered parking at transit stations have been proven to increase bicycle use, relative to lockable but uncovered parking at transit stations (Taylor and Mahmassani, 1996). These amenities provide protection from both theft and vandalism, resulting in 2.5 times more of an incentive to ride a bicycle (Taylor and Mahmassani, 1996).

Creating a built environment that makes it easy to travel using non-auto modes is key to a healthy, multi-modal society. Multiple studies have shown that active transportation use is correlated with sidewalk/street connectivity, and people are more likely to be heavier, overweight, or obese if they live in less walkable areas (Frank et al, 2007). Infrastructure that protects more vulnerable users and provides low-stress mode options for car-deficient households improves non-automobile mode share. Therefore, by increasing the opportunities for active transportation through better street/sidewalk connectivity, it encourages more physical activity, reduces risk for chronic diseases, and improves overall health (Frank et al., 2007) while supporting a more multi-modal, high-quality transportation system.

EMPIRICAL INDICATORS

As we explored potential metrics that would show progress towards an environment more conducive to active transportation, authors McCahill et al. remind us in their chapter within "Parking and the City" that it is land use regulations that most affect pedestrian activity in a commercial area (McCahill et al., 2018). Given Metro's limited direct control over land use regulations, which would provide for the best outcomes for a pedestrian friendly environment, the sprawled geographic nature of Los Angeles County, and that improved bicycle networks often include provisions for improved pedestrian environments including implementations that act to reduce vehicular speeds, we focus our attention on the county's bicycle network. Additionally, multiple CBOs stressed the need for a convenient and safe bicycle network during our community engagement. It is important to note that this focus does not diminish the role of a safe pedestrian network, but rather boosts focus on a mode that provides the largest geographic range and overall benefit within active transportation network improvements.

Improving Bicycle Facilities

Analysis by Pucher et al. in 2009 showcased that bicycle mode share increased as a result of bicycle lane infrastructure investments, suggesting that with a better user experience, individuals will be encouraged to bike more. A publication from the Portland Bureau of Transportation sought to further explain this finding: after surveying city residents, the agency found that there are generally four types of cyclists: the "strong and fearless;" the "enthused and confident;" the "interested but concerned;" and the "no way, no how." Of these four categories, the "interested but concerned" category made up roughly 60 percent of Portland's population (Geller, 2009). These results corroborate Pucher et al.'s findings that bicycle infrastructure yields mode share increases because bicycle infrastructure often rededicates roadway space to allow the separation of cyclists from moving vehicles. The State of Oregon's Department of Transportation went a step further by collecting and analyzing data that revealed how the presence of large commercial vehicles were the strongest factors affecting cyclists' comfort levels negatively while separated facilities and traffic calming on residential streets would help increase comfort levels (Blanc and Figliozzi, 2016). Findings such as these have brought about the concept of "8 to 80 Cities" where planners are encouraged to focus on the quality of life and mobility of residents who range from as young as eight years old to as old as 80 years old. Using Portland's findings for cyclists as an example, the great majority of those who might benefit from an infrastructure or policy implementation are generally cautious and must be sure of the usefulness and safety of an implementation before they reap the benefits. As such, by focusing on the needs of such a broad range of users, jurisdictions and agencies plan and build for a low bar of user entry, which encourages greater use of active modes while also providing facilities for more confident or enthusiastic users. All findings from this report point towards the utilization of the "8 to 80" concept for all recommendations and implementations.

Source: LA Metro

INDICATOR	AGENCY	WHAT IT MEASURES	INDICATOR TYPE
Bicycle Network Buildout: Percent of existing bikeways and their facility by class	OCTA	Addresses existing and available infrastructure.	Bicyclist-based
Completes the Network (Connectivity)	OCTA	Measured by the number of intersections with other existing and proposed bikeways.	Bicyclist-based
Total miles of protected bikeway installed	SFMTA	Addresses the availability of bikeway infrastructure.	Bicyclist-based
Percentage of safety treatment miles installed in Communities of Concern	SFMTA	Addresses the availability of bikeway infrastructure that promotes the user experience.	Bicyclist-based

Table 4. Selected methods for measuring multi-modal network quality (OCTA, 2019; SFMTA 2019; SFMTA 2017)

Traffic Speeds

Traffic safety is one prominent factor in active transportation that several studies have examined. If individuals perceive safety concerns in using active modes, they are less likely to participate in active transportation. In particular, high vehicle speeds near schools pose a significant safety concern as they are correlated with a higher risk of injury and/or fatality, and therefore deter parents from allowing their children to walk or bike to school (Ling et al., 2021). Additionally, for every 10 percent increase in the proportion of vehicles exceeding the posted speed limit, there was a corresponding 10 percent decrease in the prevalence of active school transportation. Other studies found similar findings: a 2019 study in Boston demonstrated that reducing the speed limit from 30 to 25 miles per hour significantly decreased mean speeds and excess speeding, and a 2020 study in Toronto found a 7 mile per hour reduction in speed to be associated with a 28 percent reduction in pedestrian-motor vehicle collisions (Ling et al., 2021). These studies both illustrate how controlling traffic speeds can result in less fatal collisions.

When vehicular traffic is prioritized over other modes of transport, active transportation users are less likely to feel safe and less likely to walk or bike or use existing active transportation infrastructure. Proximity to car-centric roadways, such as multi-lane or high speed arterials, make traveling more dangerous for pedestrians and cyclists who share that space with vehicles. Taken together, increased use of active transportation modes will be seen when a network of connected destinations is available, and can be bolstered with better bike infrastructure that provide a barrier or buffer between active modes and vehicular traffic.

Transit agencies across California have tracked different indicators in order to ensure a high multi-modal network quality. For example, OCTA created its bikeway prioritization criteria, which is used in the review of planned local bikeway improvements. Within their eight criteria, we decided to highlight two we found to be most relevant to our study of increasing non-automobility. *Bicycle Network Buildout* measures the existing and available infrastructure, and highlights areas where there is a need for bike facilities. It helps to prioritize corridors that are already built and improve the network (OCTA 2019). Furthermore, an analysis of the type of facility class of the bike facilities will provide more insight. Research shows a positive correlation between better infrastructure by facility class and increased ridership. Through the creation of safer, dedicated bicycle facilities, users will find that traveling via active transportation is possible and they will be more likely to use these routes. Additionally, OCTA's Completes the Network is a criteria that addresses the connectivity of the network. Regional corridors which connect to other regional and local bikeways help complete the bikeways network, and this connectivity encourages individuals to use active transportation modes more often (OCTA 2019). While OCTA defines this criteria as Completes the Network, we refer to this indicator as Connectivity in our report. Connectivity is a crucial component of active transportation and our engagement with multiple CBOs stressed a need for routes to easily and directly lead to their destinations. Research has also shown a strong correlation between street connectivity and the number of individuals using active modes.

In SFMTA's 2019 Bike Program Report, the agency developed four metrics that allow them to measure yearly progress toward their bike goals. The first metric is the most applicable to this project: "Improve Safety, Comfort, and Connectivity for All People Traveling by Bike" (SFMTA 2019). Within this metric, SFMTA includes the indicator of *Total Miles of Protected Bikeway Installed*. Research has shown that the better the bicycle infrastructure, the higher the ridership (Blanc and Figliozzi, 2016). As the total miles of protected bikeway installed increases, individuals are more likely to ride their bikes because they feel safe using this infrastructure. A component of this indicator is captured

> **...RESEARCH HAS SHOWN THAT THE TYPE AND QUALITY OF A ROUTE'S CONNECTIVITY IMPACTS WHETHER INDIVIDUALS DECIDE TO USE ACTIVE TRANSPORTATION**

within the *Bicycle Network Buildout* since *Bicycle Network Buildout* seeks to classify the different types of bike facilities. In SFMTA's 2017 Vision Zero report, an indicator the agency tracks is the *Percentage of Safety Treatment Miles Installed in Communities of Concern* (SFMTA 2017). This is particularly important to track as researchers have found that there is an equity concern with infrastructure quality, with communities of color more likely to have lower quality and/or less pedestrian-oriented infrastructure available. In line with the concept of planning for the most in need, a focus on communities of concern encourages networks to be built or improved in areas that will have the most impact on a community's lived experience.

Ultimately, based on our literature review and public outreach, individuals want to have the proper infrastructure in place before they consider using active transportation to arrive at their destination. While facilities protected by vertical barriers such as curbs, bollards, or flex posts yield increased safety, any dedicated space, such as a simple marked bike lane, where traffic speeds are appropriate enough that any user error is less likely to yield serious injury or death, is an improvement in areas where no bicycle network exists. Not only is the physical infrastructure availability important, but having infrastructure that allows individuals to reach their destination with ease and efficiency is equally, if not more, important. Therefore, the indicators we feel best capture this sentiment are *Bicycle Network Buildout* and *Connectivity*.

Measuring *Bicycle Network Buildout* plays a major role in determining whether current and potential users can consider active transportation as a viable mode to safely reach their destinations. As a mileage-based metric, it is ideal in determining the regional health of the bicycle network and easily modified to focus attention on areas of increased need. For our purposes here, we will detail in the recommendations section how to implement *Bicycle Network Buildout* (MAT Program Corridors), where we use Metro's identification of priority active transportation corridors in its countywide Measure M Active Transportation Program (MAT Program) to directly measure Metro's progress in improving these corridors with the inclusion of bicycle facilities. We again remind readers that active transportation incorporates more than bicycle facilities, however, extra focus must be shifted to bicycle facilities as their implementation often includes pedestrian improvements as part of a broader street redesign and can increase pedestrian safety through lower vehicle speeds, all while encouraging mobility within Los Angeles' sprawled landscape.

Measuring *Connectivity* is crucial because growing research has shown that the type and quality of a route's connectivity impacts whether individuals decide to use active transportation. As a more localized metric to a particular geographic area, *Connectivity* is easily modified to focus on Metro's First/Last Mile planning efforts to encourage connections to region-wide transit and active networks, while also providing a starting point metric for Metro to work on increasing cyclists' confidence that they can safely reach their destinations. For our purposes, we will detail in the recommendations section how to implement *First/Last Mile Bicycle Connectivity*, where we use OCTA's concept of measuring facilities at the intersection level to encourage infrastructure implementations that build networks rather than standalone facilities that come and go along a cyclists' route. To ensure that networks are built on routes where they are needed most, we add qualifiers to the indicator to detail what roads, bicycle facilities, and intersections count toward the indicator. Such qualifiers are based on widely accepted standards for safe active transportation facilities, as detailed by the National Association of City Transportation Officials (NACTO), and include both specified speed and vehicle volume standards to encourage the use of the most appropriate facility for a given roadway, and to limit the scope of this indicator to exclude slow residential streets that do not need bicycle infrastructure to improve community safety and mobility. To provide a geographic focus area relevant to Metro's interests and efforts, we use the agency's Measure M Active Transportation Program (MAT Program)'s Cycle 1 First/Last Mile Prioritized Locations list to help rank Metro's rail and BRT stations. The list's ranking scores are based on active transportation crash metrics as well as California Healthy Places Index scores and measures assessing whether communities qualify as being "disadvantaged." We find this scoring metric equitable for both safety and investment prioritizations and will recommend it be used as a baseline for measuring First/Last Mile Bicycle Connectivity.

By using both *Bicycle Network Buildout* (MAT Program Corridors) and *First/Last Mile Bicycle Connectivity*, Metro will be able to more directly track its progress towards infrastructure implementations necessary to meet non-automobility goals identified in the Vision 2028 Strategic Plan.

PERCEPTION INDICATORS

Researchers have found perceptions of safety to be a key factor in increasing bicycle mode share, particularly among potential riders who are not yet confident (Blanc and Figliozzi, 2016; Riggs, 2019). Blanc and Figliozzi find that "perceptions about the availability of comfortable bicycle infrastructure were a stronger determinant of cycling than objectively measurable characteristics about the availability of comfortable bicycle infrastructure" (2016, p.101).

Researchers have performed studies to understand perceptions of cycling and intermodal integration. Research done by Jamal et al. (2020) assessed individuals' perceptions of social and physical conditions in the neighborhood by trip and socio-demographic characteristics. The study found that individuals are more likely to take longer trips using active modes when individuals have more positive perceptions of the neighborhood conditions, such as reduced crime rates and improved traffic safety (Jamal et al., 2020).

Traffic Stress

Traffic stress arises from an interaction between an individual and their environment relating to transportation. Measuring the level of traffic stress endured by active transportation users directly reveals where and what type of changes need to occur to improve user experiences. It can also measure to what extent the network connections built by policymakers and planners resulted in facilities deemed by the general public as safe and usable. As a perception-based metric influenced by the built environment, level of traffic stress needs to be measured through direct user feedback to best understand the customer experience.

One of the pertinent environmental characteristics related to the perception of traffic stress is the presence of vehicles in the neighborhood (Gee and Takeuchi, 2004). Gee and Takeuchi suggest that the vehicular burden of the neighborhood interacts with individual perceptions to produce stress (Gee and

Takeuchi, 2004). When stress exceeds the ability to cope with stress, illness can occur within the individual. Alleviating traffic stress not only improves mode choice options but now becomes a mechanism for improving health outcomes.

Public agencies, including LADOT, as well as researchers studying other cities and transit systems, have identified methods for directly surveying cyclists about their levels of stress and perceived safety levels in their neighborhoods or on their commute. This approach could reveal bike trip segments, including in first/last mile connections, perceived to be stressful that may otherwise not show up in an empirical calculation of bicycle level of stress. LADOT, for example, has an online survey that asks respondents for their neighborhood and work location, followed by a series of questions about specific features that would facilitate more cycling and aspects of their trip they perceive to be stressful (see Table 5; LADOT, 2020).

Academic researchers studying Philadelphia and the San Francisco Bay Area took an approach similar to LADOT's open-ended question in an intercept survey to cyclists arriving or departing at transit stations. In addition to questions about the approximate locations where these cyclists began or ended their trip, the survey contained an open space for the respondent to

AGENCY/ SOURCE	QUESTION	RESPONSE FORMAT
LADOT	I would like to get around more often by walking and biking in my community if it was safe, pleasant, and convenient to do so.	Agree/Disagree
LADOT	What would make you more likely to walk or bicycle more often in your community?	Various check-boxes, including low speed, traffic volumes, separation, etc.
LADOT	What stresses you out when you think about walking and biking in your neighborhood more often?	Open response
Academic Research on Philadelphia and San Francisco	Please use the space below to sketch what the bicycle and transit trip you answered questions about on the 2nd page of this survey looks like. Feel free to be creative – add stick figures, notes on your favorite (or least favorite) parts of your trip, important landmarks, ideas about how the trip could be safer, better, and more enjoyable, and anything else that makes sense to you.	Open response/ sketch

Table 5. Examples of surveys studying perception of bicycle facility and network quality

roughly sketch their commute and include "ideas about how the trip could be safer, better, and more enjoyable" (Flamm and Rivasplata, 2014). Some respondents drew maps of their bike trip from home to the station, pointing out areas such as, "scariest part of my trip" (Flamm and Rivasplata, 2014). LA Metro could take a similar approach by augmenting traditional stop/station survey methods with questions to cyclists about their first/last mile journey including a space for qualitative descriptions of stressful parts of their trip. Such questions could also be adjusted to capture feedback from different types of active transportation modes as appropriate to the geographic location of the survey respondents.

We include more details on the calculation of these indicators in the next section, along with other recommendations on data collection and soliciting feedback from users.

Source: LA Metro

RECOMMENDATIONS

This section includes our final indicator recommendations for our three focus areas located in Table6, as well as explanations of how each indicator can be calculated and implemented. We have also included broader recommendations on data collection, user feedback, data management, and data sharing that will help the indicator program achieve its full potential, based on best practices from our literature review and engagement.

DEPENDABILITY INDICATOR RECOMMENDATIONS

Our community engagement and literature review revealed the importance of public transit dependability. To measure the dependability of the system, we recommend Metro use the indicators of *Additional Bus Stop Time* and *Perceived Wait Time*. While many factors influence transit dependability, we focused on wait time given our research finding that transit riders find wait times to be more onerous than other aspects of their trip as well as our narrow scope of distilling the broad concept of dependability into specific, actionable indicators.

Additional Bus Stop Time can be calculated as the average added time customers wait at a stop for a bus, compared with their scheduled wait time. The "scheduled wait time" could be based on headways for routes with frequent service, and based on scheduled departures for infrequent routes. For frequent routes, the calculation assumes uniform arrivals to the stop, so the average passenger's wait time is half of the headway. For example, if buses were scheduled to run every six minutes, the scheduled wait time would be three minutes on average. If one rider arrived every minute, and buses came evenly at the :06 and :12 minute marks, then 12 riders would wait an average of three minutes for a total of 36 minutes. If, instead of two buses coming evenly at the :06 and :12 minute marks, the buses bunched and came at the :02 and :12 minute marks (or at the :10 and :12 minute marks), then two lucky riders would wait an average of one minute, and ten riders would wait an average of 5 minutes, for a total of 52 minutes for the 12 riders, or an average wait time of 4 minutes and 20 seconds. In this example, the average "additional bus stop time" beyond the average "scheduled wait time" would be 1 minute and 20 seconds. For routes with frequent service, the more consistent the headways, the better the indicator performs. By merging existing per-stop boarding data with GTFS data, Metro can establish total person-minutes of wait time and then calculate the average additional bus stop time by stop, by route, or for the whole system.

For infrequent routes, for each passenger, the difference between scheduled and actual wait time could be the number of minutes behind the actual schedule a bus departs. It is the difference between GTFS (static) and GTFS-RT (actual). If a scheduled stop is skipped entirely, it could be assumed that half

CATEGORY	INDICATOR	MEASURED AS
DEPENDABILITY	**Empirical indicator**:	
	Additional Bus Stop Time	Average added time customers wait at a stop for a bus, compared with their scheduled wait time (weighted by boardings)
	Perception indicator:	
	Perceived Wait Time	Average minutes riders perceived their wait to be at a stop/station, relative to the actual headway
SAFETY	**Empirical indicator**:	
	Effectiveness of Transit Ambassadors	Number of ambassador interactions where police are requested by ambassadors / total number of ambassador interactions
	Perception indicator:	
	Perceived Comfort	Percent of riders who would feel safer or more comfortable from various safety interventions, based on results of a multiple choice survey question answer to "Which of the following will make you feel safer using Metro?"
MULTI-MODAL NETWORK QUALITY	**Empirical indicators**:	
	Bicycle Network Buildout (MAT Program Corridors)	Percent of total miles of Metro's MAT Program Cycle 1 Priority Active Transportation Corridors built out countywide with bicycle facilities
	First/Last Mile Bicycle Connectivity	Total bicycle network connections as a share of total road network connections at qualified intersections, within a 3 mile radius of rail and BRT stations, and weighted by station points from Metro's MAT Program First/Last Mile Ranked Locations List
	Perception indicator:	
	Rider-identified Levels of Stress	Number of times first/last mile corridors/streets are identified as stressful or uncomfortable through a qualitative survey of people at transit stops/stations

Table 6. Recommendations Matrix

of the passengers boarding the next bus had been waiting since the previous scheduled departure time. LA Metro has both Automatic Passenger Counting (APC) data and TAP card data that, when combined with General Transit Fleet Specification - Real Time (GTFS-RT) vehicle-tracking data, could enable the use of this passenger-based indicator.

The *Average Perceived Wait Time* can be calculated by aggregating survey results that ask riders how long they waited for a given bus or train. This could be accomplished through rider intercept surveys, as Metro currently performs in its customer experience survey, with the addition of a question that asks the rider for the stop/station where they waited. This could also be a question pushed to riders via electronic survey methods, such as in Metro's partner application, the Transit App. The inclusion of the stop/station where the rider waited for a bus or train allows for the aggregation of results to the stop/station and line levels by averaging the perceived wait time by time of day (peak/off-peak/night) and by stop/station and line. Finally, the actual average wait times, obtained via GTFS-RT data can be subtracted from the average perceived wait time over a certain time period (e.g., 3 months) at the stop/station or line level to identify stops/stations or lines where wait time is perceived to be relatively longer than actual wait times. For example, a lack of shade at a station may make riders feel as though they are waiting longer than the real time data would suggest.

TRANSIT SAFETY INDICATOR RECOMMENDATIONS

Our interviews with community based organizations and our literature and plan reviews have led us to recommend the number of ambassador interactions where police are requested by ambassadors over the total number of ambassador interactions and an index of a multiple choice survey question answer to "Which of the following will make you feel safer using Metro?" Both sources emphasized the important role officer presence and built environment features play in informing both empirical and perceived concepts of safety while using Metro.

The number of ambassador interactions where police are requested by ambassadors over the total number of ambassador interactions can be expressed as a percentage. Transit ambassador programs have been shown to be successful in both improving the safety of existing riders and addressing code of conduct violations, without requiring the presence of armed police officers. The emphasis on this indicator is more about how this information can be construed to improve the safety of existing vulnerable riders as opposed to how police presence is currently used to address safety.

The percent of riders who would feel safer from safety interventions can be calculated by surveying riders with the question, "Which of the following will make you feel safer using Metro?" with multiple potential responses. For each stop/station, as well as at the systemwide level, Metro could track the percent of riders who would feel safer or more comfortable based on each of the following factors or interventions:

- Brighter lighting on stops and stations
- More seating on stops and stations
- More Metro personnel at stops and stations

- More Armed security personnel
- Less Armed security personnel
- Kiosks to communicate with remote security personnel
- Increase in security cameras

When measured at both the systemwide and individual stop/station level, the results can capture a holistic understanding that adheres to the needs of the varied demographics using Metro, as well as identify specific interventions that are particularly lacking at certain stations, such as lighting.

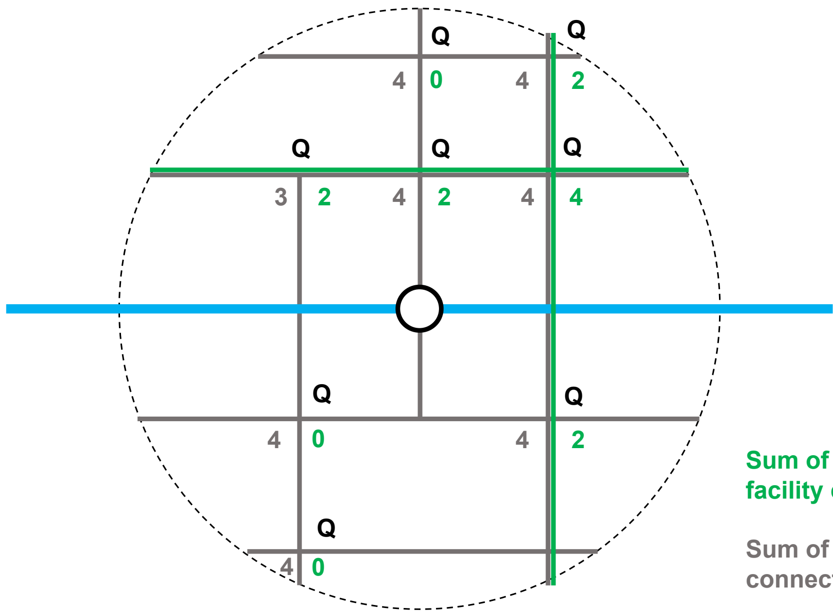
MULTI-MODAL NETWORK QUALITY INDICATOR RECOMMENDATIONS

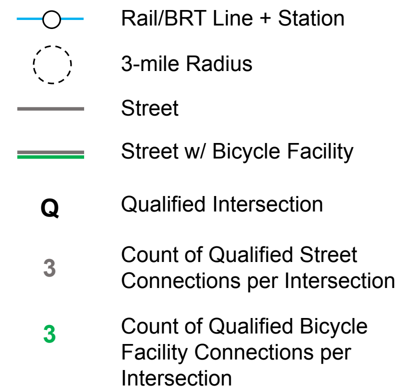
Our literature and plans review showed a strong correlation between mode-shift, particularly for cycling, and higher-quality infrastructure. Given Metro's limited direct control over land use regulations, which would provide for the best outcomes towards a pedestrian-friendly environment given the sprawled geographic nature of Los Angeles County, and given that improved bicycle networks often include pedestrian improvements as part of a broader street redesign and can increase pedestrian safety through lower vehicle speeds, we focus our recommendations on the county's bicycle network. Additionally, multiple CBOs stressed the need for a convenient and safe bicycle network during our community engagement. To measure Multi-Modal Network Quality, we recommend Metro use the empirical indicators of *Bicycle Network Buildout (MAT Program Corridors)* and *First/Last Mile Bicycle Connectivity*, and the perception indicator of *Rider-Identified Levels of Stress*.

Bicycle Network Buildout (MAT Program Corridors) is measured as the percent of total miles of Metro's MAT Program Cycle 1 Priority Active Transportation Corridors that have been built with bicycle facilities. As a regional priority list, the MAT Program Active Transportation Priority Corridors list provides a countywide assessment of the health of bicycle infrastructure. The priority list from Cycle 1 should be used to create a baseline to measure progress that incorporates multiple priority metrics identified by Metro. This baseline should be updated no earlier than every eight to ten years to provide continuity in the metrics. With a focus on regional connectivity, this indicator will help Metro provide system users with increased confidence that they can safely reach their destinations.

First/Last Mile Bicycle Connectivity is calculated as the total bicycle network connections as a share of total road network connections at qualified intersections, within a three mile radius of rail and BRT stations, and weighted by station points from Metro's MAT Program Cycle 1 First/Last Mile Ranked Locations List. Modeled after OCTA's Bikeway Prioritization Index "Completes the Network" criteria, First/Last Mile Bicycle Connectivity encourages LA Metro to provide safe bicycle facilities all the way to intersections' limit lines rather than giving up at the intersection where the most potential for conflict with vehicles exist. By focusing on safe network connectivity surrounding rail and BRT stations, Metro expands upon existing first/last mile planning efforts while encouraging the use of best practices for safety, all while providing an indicator to measure success in building out those plans. The *First/Last Mile Bicycle Connectivity* indicator also directs network investments to locations that would increase the real and perceived feasibility of regional transit lines and active modes as a competitive travel option for current and potential system users.

1 Station Area Score Calculation Example

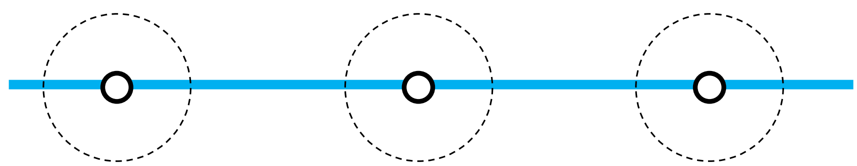




Connections Score:

$$\frac{\text{Sum of qualified bike facility connections}}{\text{Sum of qualified street connections}} = \frac{12}{31} = 0.39$$

2 Aggregate Connectivity Score Example



Score from station area connectivity calculation (Connections Score):	**0.39**	**0.21**	**0.65**	
Points given to station in prioritization process:	**20**	**15**	**25**	**Total:** **60**
Percent of all points given to station:	**20/60 =** **33%**	**15/60 =** **25%**	**25/60 =** **42%**	**100%**
Weighted Station Score:	**0.39 x 33% =** **0.13**	**0.21 x 25% =** **0.05**	**0.65 x 42% =** **0.27**	**Aggregate score:** **0.45 or 45%**

For our *First/Last Mile Bicycle Connectivity* indicator, an intersection qualifies to be included in the metric's calculation if it falls within a three mile radius of a rail or BRT station and features three or more streets feeding into it with vehicle volumes of at least 3000 vehicles per day (VPD). Each street featuring 3000 VPD feeding into the intersection qualifies as one "road network connection" to be used in calculating this indicator. The numerator for the indicator's calculation is "bicycle network connections." Based on the National Association of City Transportation Officials (NACTO)'s widely accepted standards for best practices, a qualified bicycle network connection should be any Class I, Class II on a road with a posted speed limit of no more than 35mph, Class III on a road with a posted speed limit of no more than 25mph, or a Class IV facility with pavement markings, which may include conflict zone markings, that extend to an intersection's limit line. Once the "connections score" of total bicycle network connections divided by total road network connections at qualified intersections is determined, this decimal score should be weighted by the points scored in Metro's MAT Program First/Last Mile Ranked Locations list. To do this, divide a station's ranking points by the total points given to all stations and then multiply the result by the "connections score." The resulting score is our First/Last Mile Bicycle Connectivity indicator, sometimes referred to as a "Station Score" in report graphics, which features a score between zero and one. Each station's weighted First/Last Mile Bicycle Connectivity score can be added together countywide to provide a single aggregate countywide metric showcasing Metro's progress towards first/last mile bicycle infrastructure improvements.

Calculating the *Perceived Level of Stress* for cyclists in first/last mile corridors (three miles around Metro Rail or BRT lines) can be performed through intercept surveys of cyclists arriving at rail/BRT stations, as San Jose State University researchers performed in their study of cyclist transit riders in the Bay Area and Philadelphia (described in more detail in the Analysis section).

Source: LA Metro

Like the surveys performed by these researchers, these cyclist intercept surveys could contain an open-ended sketch section and/or basemap of the three miles surrounding the station for cyclists to highlight or sketch the sections of their bike trip to the station that are most stressful. This could also be accomplished via electronic means, such as tablets held by the intercept surveyors for cyclists to highlight the most stressful or uncomfortable sections of their trip on a digital map. The agency could then count the number of times each road segment in the station area was highlighted by a cyclist over the course of the survey period to identify the corridors perceived to be most stressful. These results can be compared with the corridors identified by the empirical measures, described above, to either validate those results or highlight corridors that do not show up in the empirical analysis but are nevertheless a stressful experience for cyclists.

ADDITIONAL RECOMMENDATIONS

In order to ensure that the recommended indicators are as effective as possible, we have included additional recommendations that center on how the indicators should be implemented. These recommendations come from our research on indicator effectiveness as well as from our conversations with community organizations and activists.

LA Metro currently administers an annual customer experience survey which is useful in gaining community feedback. However, more frequent feedback would allow Metro to gain a more immediate understanding of system issues, maintain a sense of indicator progress, make riders feel heard, and learn from riders what their immediate needs are. For these reasons, we recommend that Metro consider administering the survey on a monthly or quarterly basis. Metro has more recently been implementing short, per-trip surveys through the Transit App. This is a great step toward receiving immediate feedback and more regular data from system users. We recommend Metro expand this type of daily and per-trip surveys beyond app users by advertising surveys at bus stops and rail stations that can be responded to over the phone, by text, or on a website. These surveys could capture user location and provide an understanding of exactly where on the system more resources are immediately needed. We also recommend Metro explore how to better capture the immediate feedback about the first/last mile experience, as well as how to obtain feedback from past riders who decided to stop taking Metro.

Lastly, we heard from community organizations that more readily available data would allow them to better serve Meto's ridership base without doubling up on Metro's existing efforts. We recommend that Metro make survey data and other empirical data available to the public in an accessible data dashboard. We also recommend that data collected by Metro be released in a timely manner for public use. Regardless of the method used to gather user feedback, making aggregated survey data available to the general public in an online dashboard provides community-based organizations and policymakers with a clear understanding of the challenges and concerns that the county's transportation system faces. Our recommendations can help LA Metro define, measure, and share progress toward their goals through a focus on data, experiences, and perceptions of the transportation system.

LA Metro and other cities and transit agencies can use the indicators we have recommended in this report to track progress in improvements towards three key areas: Transit Dependability, Transit Safety, and Multi-Modal Network Quality. Our review of academic literature, research on existing indicators and plans at other agencies, and engagement with community-based organizations all highlight the importance of these three focus areas in improving the quality of non-auto modes. Additionally, our analysis reveals the importance of an indicator framework that captures both empirical system performance as well as qualitative perceptions of the non-auto mode network. Tracking both empirical and perception indicators in the three focus areas we identified will help both improve service for existing non-auto mode users and identify factors that encourage mode shift away from the automobile, especially as policies to manage automobile demand are enacted.

APPENDICES

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APPENDIX A: INTERVIEW QUESTIONS

OVERARCHING GUIDING QUESTION:

- *What does your organization find to be a good indication of a well-functioning transportation system unreliant on private vehicles?*

INTERNAL GUIDING QUESTIONS:

- *What is the mission of the organization? What are the organizations' key objectives and goals for non-auto mobility?*
- *What possible metrics/indicators does the group see as important to measuring progress toward these key objectives and goals?*
- *How would mobility in Los Angeles be different if the region were less dependent on automobiles?*
- *How does the organization see the existing metrics/indicators that Metro is using to measure performance of planning objectives?*
- *How can Metro communicate possible metrics/indicators to promote understanding, clarity, and/or to empower the people the organization serves?*
- *How can Metro build trust in the process of communicating?*
- *Does the organization have access to data that could contribute to indicator development?*

INTERVIEW QUESTIONS:

- *Can you tell us about your organization, like the community members you serve and your organization's goals and priorities?*
- *Can you describe your role and work at the organization?*
- *Is there a population that your organization serves that is sometimes difficult to determine the needs of? What makes it difficult to assess their needs?*
- *What do you see as the biggest barriers for mobility other than having regular access to a personal vehicle, especially in regards to the people you serve?*
- *What factors do the people you serve consider when determining how they get around?*
- *What do you believe are important considerations for Los Angeles as it transitions to being less dependent on automobiles?*
- *How can Metro do a better job of considering the needs of the groups you represent through their outreach process?*
- *What difficulties/barriers are there for your organizations and members in the engagement process?*
- *What do you think of the existing metrics that Metro is using to measure the performance of planning objectives (existing metrics - travel time, job accessibility, roadway congestion, transit ridership, mode share, and household budget spent on transportation)?*
- *Are there any metrics that you see are missing or that could lead to inequitable outcomes?*
- *Are there qualitative metrics or metrics based on traveler experience you think Metro should track? For example, traveler perceptions of safety, travel time, and the accessibility of particular destinations.*
- *Is increased (bus, bike, etc) ridership an important thing to measure? Is increased mode share a good indication of a well-functioning system?*
- *Does your organization track metrics for non-auto mobility? If so, how and what data do you collect or want to collect?*
- *What quantifiable metrics do you look at when determining if your community is making progress toward your organization's goals?*
- *Are there other people we should talk to or resources we should check out to expand our research?*
- *For organizations concerned with both mobility and access outcomes, we coordinated engagement efforts with the research team looking at access to opportunities, as this team is researching access indicators in detail.*

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APPENDIX B: LITERATURE REVIEW

In this literature review, we identify academic articles, reports, and plans created by transit agencies and city planning departments to understand the factors that influence travel behavior, how indicators can assess these factors, and which specific quantitative and qualitative indicators planners can use to track progress against mode shift goals. We also review literature on the use of location-based services (smartphone movement) data in transportation planning, with an eye towards using this data to measure mode share. Finally, we have included examples of mode-shift results from relatively cost-effective non-auto mobility interventions in other cities to help illustrate the potential impacts of these interventions in Los Angeles.

BACKGROUND ON FACTORS THAT INFLUENCE TRAVEL BEHAVIOR

When making travel choices, people may consider their options in terms of a number of factors, including total cost, total travel time, comfort, enjoyment, and safety. When an intervention significantly alters one or more of these factors, the relative attractiveness of each option changes, and people may adjust their behavior accordingly. Understanding how various factors and interventions affect decision-making is critical to the process of strategically designing a system of performance indicators that includes intermediate outcomes with the greatest potential to help LA Metro achieve their vision to "double the percent usage of transportation modes other than solo driving, including taking transit, walking, biking, sharing rides, and carpooling" (Los Angeles County Metropolitan Agency, 2018). For this reason, we begin our literature review by examining the relationships between transportation system factors—including land use and parking, network connectivity, transit attributes, and active transportation infrastructure—and people's choices about whether or not to drive alone. The purpose of this section is not to provide a comprehensive overview of travel behavior literature, but rather to ground the eventual discussion of indicators in an evidence-based framework that centers real-world decision-making. Recommending best practices requires an understanding of how those practices might affect perceptions and change behaviors.

LAND USE AND PARKING

Free and convenient parking at home, at work, and throughout the city is a significant factor impacting auto- versus non-automobility choices. For example, a study found that households without bundled parking were found more likely to use transit (59 percent, relative to 16 percent). The study found that these households were also more likely to be frequent transit users, even after controlling for socioeconomic and built environment factors, such as proximity to transit and household income (Manville and Pinski, 2020). San Francisco's affordable housing lottery acts as a "natural experiment" showing such results are not simply a reflection of car-free households relocating to car-free buildings, but rather that the built environment has a causal impact on travel behavior. Among residents of these below-market-rate housing units, access to parking was found to have three times the effect on transit use as living in an area with good transit access, a good Walk Score, or a good Bike Score (Millard-Ball et al., 2021). Similarly, residential areas with scarce parking were correlated with a 37 percent reduction in solo vehicle commutes and a 25 percent reduction in solo vehicle grocery store trips (Chatman, 2013).

Parking also matters at work. Across seven case studies, including five from Los Angeles, employer-paid parking resulted in a 67 percent solo driver mode share, versus just 42 percent among employees required to pay for their own parking (Shoup, 2005). Finally, the cost of on-street parking can affect travel behavior. For example, when San Francisco tested the effect of charging for parking, transit ridership increased 11 percent on pilot blocks, lending some empirical support to stated preference survey results which found if parking were free, only 5 percent of commuters would take the bus and 75 percent would drive alone, while if it were not free, 43 percent would take the bus and 37 percent would drive alone (Krishnamurthy and Ngo, 2018).

Given the potential for parking to impact mode choice, some transportation agencies are incorporating regulations on parking provision into their planning documents. Transportation review guidance from the District of Columbia Department of Transportation includes a table of maximum parking ratios by land use and proximity to transit; for example, a new residential development within a half mile of a Metro station or a quarter mile of a priority bus stop are required to provide .35 spaces or fewer per residential unit or provide a plan to mitigate their impact (Zimmerman et al., 2021). Plan Bay Area 2050, a regional plan developed by the Metropolitan Transportation Commission (MTC) and the Association of Bay Area Governments (ABAG), also aims to decrease automobile mode share (Plan Bay Area, 2050). MTC and ABAG have limited authority over land use, but they plan to use their discretionary transportation funding as leverage. Their current TOC Policy draft conditions the receipt of regional discretionary funds for transit expansion, enhancement, and improvement projects on removing parking minimums and allowing shared and unbundled parking. Parking maximums are also required for residential and commercial properties near rail or bus rapid transit stops (Joint MTC Planning Committee with the ABAG Administrative Committee Agenda Item 5b, 2022). These research findings, plans, and policies are relevant to LA Metro for their potential to inform potential intermediate performance indicators that measure interagency collaboration and characteristics of transit-oriented development.

STREET / SIDEWALK NETWORK

There is growing evidence that the built environment can influence travel behavior. There are two fundamental concepts of the built environment that impact travel mode choice: proximity (relating to the density and mix of land uses) and connectivity (route directness) between activities. Connectivity, or street configuration, influences the ease with which people can walk to their destinations. Street networks that have shorter and smaller blocks, more intersections, and fewer dead-ends generally increase walkability (Berrigan et al., 2010). With a more connected street network, individuals are more likely to walk, bike, and participate in other non-motorized activities.

Researchers have found empirical evidence for an increase in walking behavior in areas with higher street connectivity and better sidewalk infrastructure. One Washington study found that people who live in neighborhoods with higher walkability reported walking 30 minutes more for transportation each week and overall had higher total physical activity, compared to those who live in neighborhoods with lower walkability (Frank et al., 2007) (see Figure 2). Another study demonstrated that "high walkable" neighborhood residents walked two times more per week than "low walkable" neighborhood residents (Sallis et al., 2003). There is also an equity aspect: findings from one research study revealed that predominantly African-American neighborhoods were significantly more likely to have uneven sidewalks and more sidewalk obstructions (Lee et al., 2017).

If the built environment increases opportunities for active transportation, this encourages more physical activity, reduces risk for chronic diseases, and improves overall health (Frank et al., 2007). More than 70 percent of adults do not meet the recommended physical activity levels, and physical inactivity costs more than $77 billion per year in the United States in direct medical expenses alone (Sallis et al., 2003). Multiple studies have shown that people are more likely to be heavier, overweight, or obese if they live in less walkable areas (Frank et al, 2007). Creating a built environment that makes it easy to travel with non-auto modes is key to a healthy society.

A connected street network encourages individuals to walk, bike, and use other forms of non-motorized activities. By incorporating more non-automobility mode shares into our daily routines, we will create a healthier and less car-dependent urban realm.

TRANSIT ATTRIBUTES

Researchers have found service frequency and cost to influence the choice to take transit. These factors were found to be responsible for 26 percent of the variance in per capita ridership, and improvements in service frequency and fares impacted ridership levels much more than improvements in route coverage or route density (Taylor et al., 2009). As such, policies addressing fares and service frequency could potentially double or halve ridership in a given area. Fare reductions may increase transit ridership, although the extent to which this will occur varies by user type, trip type, transit type and the time period of measurement (Litman, 2021). Fare-reduction programs can also be targeted to specific riders. For example, when UCLA provided students, faculty, and staff with fare-free public transit on Santa Monica's Big Blue Bus, transit ridership for commuting to campus increased 56 percent in a single year, and solo driving dropped by 20 percent (Brown et al., 2003).

Service frequency also significantly impacts transit ridership levels. One study by the Institute for Transportation Development and Policy (ITDP) developed twelve mobility indicators (such as share of population, jobs, or low-income households with proximity to transit, or the share of opportunities accessible within 30 or 60 minutes) and analyzed 25 North American cities to determine which indicators most strongly predicted sustainable mode share (2019). The most influential of these indicators was the share of population within close proximity to frequent transit (defined as stops with service an average of five times per hour from 7 a.m. to 9 p.m. on a weekday).

The cities with the highest transit mode shares also had strong corridors of frequent coverage, rather than disparate islands (ITDP, 2019). In Portland, Oregon, when bus service-hours were streamlined into twelve core routes to increase frequency, ridership on these routes increased 18.2 percent, while ridership on the routes that lost service-hours decreased only 0.7 percent (Litman, 2021). Similarly, in 2015, Houston METRO re-designed its bus network to create a gridded network of frequent lines (Binkovitz, 2016), as LA Metro has done with its NextGen Bus Plan. Houston METRO increased service on high-frequency routes and expanded weekend service (Binkovitz, 2016). As a result, bus ridership increased across the board by 1.2 percent, though there was a much greater increase in weekend trips, especially on Sundays where the increase was 34 percent (Binkovitz, 2016).

While many transit agencies focus primarily on vehicle speed, in Human Transit, Jarrett Walker argues that what matters most to riders is not speed, but delay (Walker, 2011). Walker defines three types of delay: traffic delay, signal delay, and passenger-stop delay. All of these delays undermine speed, but focusing on delay measurements may shift the planning focus and result in not only greater speeds, but also more reliable service for riders. In practice, both speed and delay are vehicle-based metrics that must be weighted by route ridership or per-stop boarding delay. The importance of transit attributes may guide the development of intermediate indicators for LA Metro related to transit service frequency, fares, and reliability. The City of Vancouver's Transportation 2040 Plan, for example, defines "great transit" as fast, frequent, reliable, accessible, comfortable, and complete (City of Vancouver, n.d.).

ACTIVE TRANSPORTATION INFRASTRUCTURE

Active transportation infrastructure and perceptions of safety can influence travelers' decision to walk or bike to their destinations. As discussed previously, research has shown that built environment factors such as street network connectivity can positively influence the decision to use active modes. This section will discuss other factors that can influence active transportation choices.

Traffic safety is one prominent factor in active transportation that several studies have examined. If individuals perceive safety concerns, they are less likely to participate in active transportation. In particular, high vehicle speeds near schools pose a significant safety concern as they are correlated with a higher risk of injury and/or fatality, and therefore deter parents from allowing their children to walk or bike to school (Ling et al., 2021). A study evaluating the relationship between motor vehicle speed and active transportation in Canadian schools demonstrated that students reduced active school transportation by 3 percent for every 1 kilometer per hour vehicle speed increase (Ling et al., 2021). Additionally, for every 10 percent increase in the proportion of vehicles exceeding the posted speed limit, there was a corresponding 10 percent decrease in the prevalence of active school transportation. Another recent study in Canada found that the majority of drivers surpassed the speed limit during school activity hours (7:30am-6:00pm) at nearly half of the schools in the study area (Ling et al., 2021). Other studies found similar findings: a 2019 study in Boston demonstrated that reducing the speed limit from 30 to 25 miles per hour significantly decreased mean speeds and excess speeding, and a 2020 study in Toronto found a 7 mile per hour reduction in speed to be associated with a 28 percent reduction in pedestrian-motor vehicle collisions (Ling et al., 2021).

Active transportation strategies are not limited to streets and sidewalks. On-site bicycle storage and lockers can also encourage the use of active modes. In particular, lockers and lockable/covered parking at transit stations have been proven to increase bicycle use, relative to lockable but uncovered parking at transit stations (Taylor and Mahmassani, 1996). These amenities provide protection from both theft and vandalism, resulting in 2.5 times more of an incentive to ride a bicycle (Taylor and Mahmassani, 1996). Physical activity spaces and convenient access to public transportation have also demonstrated a positive effect on physical activity behaviors (Alfonsin et al., 2019). In addition to physical design, operational design elements such as employee incentive programs can promote active transportation.

CONCEPTUAL BACKGROUND ON INDICATORS

If one of LA Metro's goals is to make walking, biking, public transit and other non-auto modes more attractive options than driving alone, travel behavior literature is necessary to help transportation planners and community members understand and evaluate the relative promise of various strategies to effect change and progress toward this goal. When goals and strategies are widely shared and clearly understood, a collection of indicators can be a valuable tool to organize attention, communicate with the public, and evaluate progress. This section will review literature discussing frameworks for thinking about indicators, the purposes indicators serve, how to identify leverage in a complex system, what makes indicators successful, types of indicators in practice, and potential dangers and considerations to be aware of when using indicators.

WHAT ARE INDICATORS? HOW CAN THEY BE CATEGORIZED?

Indicators are "representative data that highlight key characteristics of phenomena under surveillance" (Phillips, 2005, p. 8). Researchers have proposed several frameworks for categorizing indicators according to what they measure or how they are used. Different frameworks may be valuable for different organizational contexts and serve different purposes.

One framework proposed by Innes and Booher (2000) consists of system performance indicators, policy and program indicators, and rapid feedback indicators. System performance indicators look at the big picture and should measure the performance of the system as a whole. Consensus about what kind of system the community wants is important when developing system indicators; however, this does not mean it is best to avoid controversy and settle on lowest-common-denominator indicators with minor influence. These indicators provide a shared sense of direction, helping people see the whole system and anticipate changes. Since system indicators are the highest level of indicator, it is best to develop at most three to five of them. Each one should measure something valuable in and of itself that results from the functioning of the complex system. When considering non-automobility, examples of system indicators might be sustainable mode share or community satisfaction with multimodal options.

Policy and program indicators have a narrower focus and do not require the same level of consensus as system indicators. These indicators allow decision-makers to analyze subsystems, and it is often beneficial to create multiple policy or program indicators for a given topic or goal. Some may be outputs of ordinary activity and not require additional effort or expense to track. Policy and program indicators provide clues that may be helpful in analyzing the system as a whole. These indicators may also guide planners and policy makers in setting strategic priorities and making decisions; however, an indicator should never be the sole basis for judging the success of a program or policy, but rather should be one component of a more comprehensive evaluation. When considering non-automobility, policy or program indicators might measure factors such as transit service frequency, perceived safety, or the quality of active transportation infrastructure.

The third category of indicator in the framework developed by Innes and Booher (2000) is the rapid feedback indicator. Rapid feedback indicators are based on technology that can provide information in real time and help people manage their activities and make decisions. Examples of this type of indicator could include parking availability information or current traffic delays and travel time estimates.

Another framework for thinking about indicators separates indicators into state indicators and driving force indicators (Bell and Morse, 2001). Driving force indicators measure what are thought to be causal mechanisms; state indicators look at effects. Driving force indicators may also be called intermediate indicators or sub-indicators. They might be used to track community perceptions, transit attributes, or built environment factors thought to influence behavior. This framework of organization, however, may generate debate about what should be classified as a cause and what should be considered an effect. For example, an indicator like average bus speed could be either an effect (of creating more bus-only lanes or implementing congestion pricing) or a cause (of greater mode share for public transit or increased customer satisfaction). A related way of organizing indicators that may lend clarity to such discussions is a framework consisting of process measures, input measures, output measures, and outcome measures (Litman, 2007). Process indicators measure types of policies and planning activities. Inputs refer to resources invested (such as funds for bicycle parking), outputs refer to direct results (such as share of transit stops with secure bicycle parking), and outcome indicators measure progress toward ultimate goals like attitude or behavior change (such as sustainable mode share).

The above frameworks categorize indicators according to what they measure. Another way indicators could be categorized is according to their purpose. Kitchin et al. (2015) distinguish between descriptive indicators, diagnostic indicators, and predictive indicators. The purpose of descriptive indicators is simply to provide context or insight into how phenomena change over time. For example, they might measure changes in population for various geographic areas. Descriptive indicators may help planners assess needs or notice trends relevant to understanding the rest of the system, but they do not imply a theory of causality or a target direction of movement. On the other hand, the purpose of diagnostic indicators is to assess performance toward a goal. Feedback from these indicators may be used to identify unmet expectations and adjust policy or planning processes accordingly. Use of an indicator often applies assumptions that relate it to more complex phenomena (Phillips, 2005). One benefit of this classification framework is to promote critical thinking about why indicators are chosen and how they will be used. However, the indicators may serve more purposes than just these, and the purpose of any single indicator may be multifold or change and evolve over time.

PURPOSES OF INDICATORS

Indicators may serve a variety of potentially overlapping functions. These include "description, simplification, measurement, trend identification, clarification, communication, and catalyst for action" (Phillips, 2005 p. 4). As descriptors, they help users understand what things are like. As simplifiers, they give users a glimpse into the big picture of a complex system. As measuring tools, they use data to numerically answer questions of quality or quantity. As trend identifiers, they can establish baseline information and reveal changes over time. As clarification tools, they can highlight what is most important. As communication tools, they can make data accessible to a wide audience. Finally, as catalysts for action, indicators can raise awareness and spark the desire to work for change.

Beyond these roles, indicators are often valuable to the evaluation process as one component of a larger information chain or monitoring framework. Other features of a complete monitoring strategy may include a conceptual model (showing relationships between the networks of the system under surveillance), procedures and methods for data collection, management, analysis, and synthesis, a reporting strategy, and periodic critical reflection on the effectiveness of the strategy (Phillips, 2005). Indicators may be used to evaluate community, government, and other organizations and can help evaluate both internal and external phenomena (Phillips, 2005). A clear understanding of who will use the indicators and how—whether they will primarily be used as learning tools, planning tools, or communication tools—is important in developing the overall monitoring strategy.

Indicators may be used for implementation monitoring, impact monitoring, or strategic monitoring (Phillips, 2005). Process, input, output, and outcome measures may each be valuable for these different types of monitoring within organizations. Indicator programs are often designed with the hope that they will be a catalyst for action. Outcomes that result from indicators may be classified as intangible, concrete, or measurable (Gahin et al., 2003). Intangible outcomes include serving as a forum for discussion, increasing awareness, and shifting values. Concrete outcomes include the development of new agendas and programs, influence over decision making, incorporation into plans, and effects on resource allocation. Measurable outcomes mean change, as measured by the indicators. Actual change measured by the indicators is the rarest of these three outcomes and may take considerable time to manifest (Gahin et al., 2003). However, understanding the characteristics of successful indicators and how they fit into complex systems may increase the likelihood that their use leads to measurable changes.

INDICATORS IN COMPLEX SYSTEMS

When the goal of an indicator program is to effect change, it can be important to identify "leverage points" in a system. Leverage points are "places within a complex system (a corporation, an economy, a living body, a city, an ecosystem) where a small shift in one thing can produce big changes in everything" (Meadows, 1999 p. 1). Meadows (1999) develops a hierarchy of places to intervene in a system according to their power to effect change. At the bottom, she says, are parameters, which often receive 99 percent of the attention but simply result in slight adjustments to the speed of inflows or outflows without changing the underlying system. Parameters rarely change behavior. Near the middle of the hierarchy are interventions to allow negative feedback loops, drive positive feedback loops, and improve information flows. A negative feedback loop refers to the ability of a system to self-regulate. For example, in a congested transportation system, some drivers with flexible schedules may postpone their trips when they know there is heavy traffic. A positive feedback loop refers to a cycle through which the more something works, the more it gains power to work more. For example, when London implemented congestion pricing, bus speeds improved, more people rode public transit, and the increased ridership made service improvements more feasible, which further increased ridership (Small, 2005). Improving information flows by making transportation system users more aware of changes or opportunities to save time or money restores "missing feedback" and may be necessary to change habitual behaviors. Innes and Booher (2000) explain that parts of a system may improve if they get feedback and have the capacity to respond.

Even higher on the hierarchy of impactful places to intervene in a system are the rules of the system, the goals of the system, and the mindset, or paradigm out of which the system arises. Removing minimum parking requirements from city codes or the automobile "level of service" metric from environmental impact review could be considered examples of rule changes. Increasing mode share for sustainable modes of transportation is a goal change. If society stopped considering private vehicle ownership necessary or desirable, that would be a paradigm shift. Applying systems thinking to the development of non-automobility indicators means looking for potential interventions and measurement strategies for higher-level leverage points in the transportation system. However, the potential for systemic impact of the phenomena under surveillance is just one of many criteria to consider when selecting indicators.

CHARACTERISTICS OF SUCCESSFUL INDICATORS

For an indicator program to achieve its potential, ideas must be institutionalized throughout the organization and be part of the ordinary decision making of key players, users must be involved in the design, and indicators must be clearly associated with a policy or set of possible actions (Innes and Booher, 2000). Learning among key players and the creation of new shared meanings was found to be more important than the indicators themselves (Innes and Booher, 2000). This suggests an indicator program for LA Metro may benefit from outreach conducted not only among the wider community, but also among LA Metro employees.

Phillips (2005) develops a longer but similar list of criteria for selecting successful indicators, including the extent to which the indicators are: scientifically valid, representative of community values, responsive to changes in the environment and human activities, controllable, relevant to goals and user needs, understandable by potential users, comparable to thresholds or targets, comparable to other jurisdictions, collectable from available data, cost-effective, clear, attractive to media, comprehensive, sensitive to equity concerns, and able to deliver timely feedback. Other effectiveness factors include funding, community ownership, and cultural sensitivity (Gahin et al., 2003). When evaluating potential indicators, the relative importance of each of these factors will vary depending on the context, but considering the full list of criteria can help planners identify potential trade-offs between choices.

TYPES OF INDICATORS IN PRACTICE

Indicators reflect data, which must be collected, managed, analyzed, and synthesized. This data may be either quantitative or qualitative, and many indicator collections include both types of measures. Indicators with reference units (such as per capita, per trip, or per dollar) are called ratio indicators and may be helpful to facilitate comparisons across time or place (Litman, 2007).

A single indicator is a direct measure of a single phenomenon. Single indicators are usually clear and easy to understand, and a collection of multiple single indicators may be used to understand progress toward a larger goal. A composite indicator, or index, refers to multiple indicators, often assigned different weights according to their perceived importance, combined into one. Composite indicators are harder to understand and learn from but may have value for their sensitivity to the existence of contradictory goals within a system and ability to reflect overall progress across multiple goals in a single number. For example, Zheng et al. (2013) explain the process of creating an index through the development of a "Transportation Index for Sustainable Places" that incorporates sometimes-competing environmental, social, and economic transportation goals.

McKinsey and Company's "Elements of Success: Urban Transportation Systems of 24 Global Cities" reviews transportation systems of 24 major global cities and assesses them with five metrics: availability of transportation, affordability, efficiency, convenience, and sustainability (McKinsey & Company, 2018; City of Chicago plan).

POTENTIAL DANGERS OF INDICATORS USE

Several researchers warn of potential concerns to be aware of when using indicators in planning. For example, indicators seem to demand improvement in the present, while some policies may take decades to mature (Kitchin et al., 2015). Indicators may be laden with the assumption that indicator data are apolitical and can be taken at face value; however, a critical understanding of data means understanding that data don't exist independently of the ideas, instruments, practices, and knowledges that generate, process, and analyze them (Kitchin et al., 2015). Indicators reflect a "naïve instrumental rationality" based on science rather than experience, and they may be open to manipulation by vested interests (Kitchin et al., 2015). Summarizing complexity into simple numbers can be dangerous (Bell and Morse, 2001) and it is possible that indicators may mislead policy makers away from examining the complexity and subtlety of problems (Phillips, 2005). Along these lines, many indicators are based on a worldview of "world as machine," as if fixing individual parts will fix the system, while in reality the world is more like an organism – constantly growing, evolving, and adapting, with all parts interconnected with one another (Innes and Booher, 2000).

QUANTITATIVE INDICATORS IN PRACTICE

In the next two sections, we describe specific indicators that reflect best practices from other cities and transit agencies as well as indicators identified in the literature as relevant to non-auto modes. We have also included indicators proposed in academic literature that cities and agencies have yet to implement in practice. In this section, we describe quantitative indicators in particular, with an emphasis on indicators that rely on LBS data. These indicators also capture several sub-indicators that can be useful for agencies and cities to track in their own right.

TRANSIT COMPETITIVENESS

One such quantitative indicator concept is a transit competitiveness indicator created by Boston's transit agency, the Massachusetts Bay Transportation Authority (MBTA). The overarching indicator is the percentage of all trips in the region in which transit is competitive with driving (Gartsman et al., 2020). The agency also tracks the percentage of trips made by certain groups in which transit is competitive with driving to understand the extent to which their competitive transit network is (or is not) equitably distributed (Gartsman et al., 2020). For example, in addition to the percentage of all trips, the MBTA also tracks the percentage of trips made by low-income people, people of color, and people with disabilities that have a competitive transit option (Gartsman et al., 2020). The trip data itself comes from LBS data and the agency uses the local neighborhood around the smartphone home location to characterize the demographics of the device holder (Gartsman et al., 2020).

To determine which trips have transit options that are competitive with driving, the MBTA divides competitiveness into eight different measures, split between scheduled network quality elements and provided service quality elements (Gartsman et al., 2020). Scheduled network measures include the distance for a traveler to access service (i.e., first/last mile connections), scheduled frequency, the number of transfers, and scheduled trip times (Gartsman et al., 2020). The authors recognize that transit schedules do not always reflect reality, and therefore also include actual frequency, travel times, reliability and variability of travel times, and the conditions on board, including measures of comfort and crowding, in their provided service quality measures (Gartsman et al., 2020). Agencies can use these measures to create city-specific benchmarks to determine whether transit is competitive with driving. For example, an agency could consider transit trips competitive with driving only if first/last mile connections are less than a quarter mile, frequency is ten minutes or less, the trip requires a maximum of one transfer, and the total trip time is at most 1.25 times as long as driving (Gartsman et al., 2020).

The integration of scheduled network and provided service quality measures into one overarching indicator of transit competitiveness is a helpful way to understand the potential for non-auto mobility in a region. That said, each of the sub-measures themselves are still important indicators in their own right, with cities and agencies including these or similar indicators into their plans and dashboards. For example, in the "Efficient Mobility" section of New York City's OneNYC 2050 plan, the city includes "average citywide bus speeds" as an indicator they will use to track progress towards their initiative of modernizing the city's mass transit networks. The plan also references subway on-time performance (OneNYC). The San Francisco Municipal Transportation Agency includes three related measures on their performance indicators dashboard: percentage of scheduled service hours delivered, on-time performance, and the percentage of trips meeting headway adherence (SFMTA, 2022)

INTERMODAL CONNECTIVITY & ACTIVE MOBILITY OPPORTUNITY

While the transit competitiveness indicator used by the MBTA alludes to active transportation modes with the inclusion of the distance required to access transit, it can be helpful for cities and transit agencies to identify quantitative indicators specifically relevant to walking, biking, and rolling. One such indicator identified in recent academic literature is the concept of perceived walkability as it relates to objective walkability (Sevtsuk et al., 2021). The authors use LBS data from smartphone apps to identify thousands of walking trips throughout San Francisco, and then characterize the pedestrian routes based on a number of factors that either improve or worsen the pedestrian experience (Sevtsuk et al., 2021). These factors include the slope of hills, the number of turns, sidewalk width, protection from sun and weather, traffic speeds, among others (Sevtsuk et al., 2021). The authors then compare the routes taken by pedestrians with hypothetical alternate routes to come up with distance equivalent for each of the factors that influence pedestrian route choice (Sevtsuk et al., 2021). For example, each additional meter of elevation gain in a walking route is equivalent to an additional 3.8 meters of walking distance (Sevtsuk et al., 2021). The authors use these distance equivalents to create a "perceived" walking distance, in which all of these factors are taken into account, resulting in more realistic walksheds around transit stations.

Transit agencies could use an analysis such as this one to identify perceived barriers in first/last mile connections, such as narrow sidewalks or high-speed streets, and then recommend interventions to address these issues. The factors that comprise pedestrian route choice identified by Sevtsuk et al. can also be used to calculate citywide indicators such as the percentage of all streets (excluding freeways) that include high-quality pedestrian and bicycle infrastructure, as suggested by Gillis et al. (2016). Cities can include indicators such as sidewalk width and the presence of bike lanes with or without vertical separation to determine which streets they should consider to be part of their high-quality active transportation network.

Cities have included active transportation indicators in their plans and dashboards. For example, the OneNYC plan includes the percentage of New Yorkers living within a quarter mile of the bicycle network as a key indicator for ensuring streets are safe and accessible, with a goal of 90 percent by 2022. The city also tracks the number of traffic fatalities and serious injuries with a target of 0, per their Vision Zero aspirations (OneNYC). The greater Paris region's Île-de-France Urban Mobility Plan also includes road safety indicators including the number of crashes, as well as a measure of the accessibility of sidewalk routes to understand gaps for persons with disabilities (2016). Additionally, the Orange County Transportation Authority's (OCTA) Active Transportation Plan includes measures of comfort and stress for pedestrians and cyclists based on a number of factors (2019). For example, the pedestrian level of comfort includes the average daily traffic, missing sidewalks, and the degree of separation between sidewalks and the road (OCTA, 2019). The bicycle level of stress also includes average daily traffic as well as the presence of existing bikeways and number of vehicle lanes on the road (OCTA, 2019).

MEASURING EQUITY

Cities and transit agencies are increasingly interested in understanding the equity implications of non-auto mobility interventions as well as the ways in which the current transportation network has disparate impacts on historically marginalized groups. Measuring equity can take the form of its own set of indicators, or it can be included as a different way to segment an existing indicator. For example, the MBTA's transit competitiveness index is not exclusively an equity indicator but can be subset to understand the equity implications of transit competitiveness by calculating the percentage of trips in which transit is competitive with driving for certain groups, such as people of color or low-income people (Gartsman et al., 2020). Such an indicator can illuminate where low-income transit riders have acute transit challenges relative to the general population. Similarly, the perceived walkability indicator and methodology proposed by Sevtsuk et al. could include an analysis to characterize pedestrian trajectories based on the demographics of the device home neighborhood, as performed by Gartsman et al., and therefore identify whether people of color experience greater pedestrian barriers than the city's population as a whole.

In the Boston area, the Metropolitan Area Planning Council (MAPC) maintains a regional indicators website that includes measures along several dimensions, including "Improved Equity" and "Affordable Commutes" (MAPC, 2016). Under Improved Equity, the agency tracks the disparity in commuting mode share between people who are white and people of color, as "any disparity between mode use by a social group… reflects inequity in commute mode" (MAPC, 2016). MAPC also tracks households' annual transportation expenditures in order to understand the transportation burden of households in the region (MAPC, 2016). Additionally, the agency tracks the change in transit fares over time relative to the change in gas prices (MAPC, 2016).

In addition to equity indicators themselves, there are equity considerations in collecting and analyzing data to track non-auto mobility indicators. For example, some groups may be underrepresented in LBS data, such as older adults who may be less likely to use smartphones (Gartsman et al., 2020). Additionally, U.S. Census data can be unreliable for people with limited mobility and Limited English Proficiency populations, requiring agencies to consider ways to better understand the transportation challenges of these groups (Gartsman et al., 2020). We discuss these implications in more detail in Section 5.

PREVALENCE OF PRIVATE VEHICLES

While a number of factors influence the decision to purchase a vehicle, many of which are outside the control of individual cities or transit agencies, tracking the prevalence of private vehicles and drivers can be an indication of the quality of non-auto mobility options. For example, the OneNYC plan tracks the number of vehicle registrations in New York City, with a goal of decreasing this number. MAPC includes the percentage of eligible adults that are licensed to drive as one of its regional indicators as a lagging indicator of perceptions of the non-auto modes in the region.

QUALITATIVE INDICATORS IN PRACTICE

While quantitative indicators may be easier to calculate numerically, qualitative indicators attempt to measure more nuanced ideas, such as the experience or perception of different modes and feelings of comfort and safety. In this section, we discuss several studies that examine what users of non-auto modes prioritize and feel during their journeys.

TRANSIT CUSTOMER EXPERIENCE / PERCEPTION

LA Metro published its first Customer Experience (CX) Plan in 2020, which provided an honest and comprehensive look at riders' experiences using LA Metro. LA Metro sought the responses of thousands of riders through surveys, social media, complaints, and community meetings. In addition to riders, LA Metro also interviewed Board members and bus operators. In the plan, LA Metro identified ten priority areas for improvement: bus reliability, accuracy of real-time information, bus frequency, bus stops, ease of payment, speed, crowding, personal security, homelessness, and cleanliness. Prior to the COVID-19 pandemic, the overall satisfaction for LA Metro riders was very high, with 90 percent of riders stating they were satisfied with LA Metro. Ridership dropped by 50 percent during the COVID-19 pandemic, and riders during this time period wanted to see enhanced cleaning, reduced crowding, and more work done by LA Metro to address homelessness. The CX Plan discusses each of the ten priority areas and concludes with section-specific recommendations, as well as overall recommendations to the LA Metro service. The CX Plan conducted by LA Metro provides a great perspective on the user experience and can shed valuable insight on what indicators agencies and researchers can prioritize when trying to improve the transit experience.

Similar to the CX Plan, other studies have examined what transit riders prioritize. In a 2010 study, researchers asked transit users to rate the importance of various features related to access, reliability, information, amenities, and safety on a scale from "not important" to "very important" and their level of satisfaction with the feature, from "strongly disagree" to "strongly agree" (Iseki and Taylor, 2010). The three most important things to riders were safety at night, safety during the day, and schedule adherence. The benefit of creating a satisfaction index weighted by the importance of various aspects to users allows planners to better estimate which particular efforts hold the most promise to increase overall satisfaction. While it is already common to focus on user satisfaction for indicators, using a weighted range allows researchers to also consider importance. This article was written with the research purpose of better understanding the values and needs of transit users; it was not directly about indicators. However, their methodology could inspire a creative approach to the development of a qualitative index, a system performance indicator capable of reflecting the big picture of user satisfaction while also providing valuable individual insights.

Other transit agencies have taken steps recently to incorporate qualitative measures of perceptions of transit network quality. For example, SFMTA incorporates customer satisfaction information, broken down by time of day, into a larger set of objective performance metrics they track at the neighborhood level and by individual transit lines, such as on-time performance and service gaps (TransitCenter, 2021). This approach helps the agency identify geographically and temporally specific interventions, such as addressing service gaps that lead to crowding on a specific bus line through Chinatown during peak hours (TransitCenter, 2021). Some agencies also go beyond traditional surveys in their approach to soliciting feedback of perceptions and experiences of transit. For example, Metro Transit in Minneapolis-St. Paul provides funding to CBOs to conduct outreach (TransitCenter, 2021), who may hold more trust within the local community than the agency itself.

Beyond community perceptions of transit, researchers have performed students to understand perceptions of cycling and intermodal integration. Research done by Jamal et al. (2020) assessed individuals' perceptions of social and physical conditions in the neighborhood with trip and socio-demographic characteristics. The study found that individuals are more likely to take longer trips using active modes when individuals have more positive perceptions of the neighborhood conditions (Jamal et al., 2020). Students were especially likely to use active modes, compared to non-students, with the improved environmental conditions (Jamal et al 2020).

Public perceptions of transit and transportation projects can not only inform the use of transportation infrastructure but also how projects are funded and how they meet the wider goals of transportation agencies. A working paper from the Tinbergen Institute in the Netherlands proposes Participatory Value Evaluation (PVE) as an alternative to the more traditional planning tool of Cost Benefit Analysis (CBE) (Mouter et. al, 2019). The drawbacks of CBE include an oversimplified value analysis of the nuances between different local transportation projects and a lack of broader social equity goals related to transportation planning. The paper conducts a case study by distributing PVE experiments among citizens in the Netherlands to rank transportation project priorities on fictional budget constraints. Planners will always have to make tradeoffs on project priorities when budget constraints exist, but using PVE can more widely capture the public's preferences for safety, mobility and other broader social goals when prioritizing transportation projects. PVE allows individuals' personal experiences using transportation infrastructure to inform the future of planning.

MEASURING THE PERCEPTION OF NON-AUTO MODES

Qualitative data can also describe perceptions of modes, including transit service and bicycle and pedestrian networks. Researchers have found perceptions of safety to be a key factor in increasing bicycle mode share, particularly among potential riders who are not yet confident (Blanc and Figliozzi, 2016; Riggs, 2019). Blanc and Figliozzi find that "perceptions about the availability of comfortable bicycle infrastructure were a stronger determinant of cycling than objectively measurable characteristics about the availability of comfortable bicycle infrastructure" (2016, p.101).

In terms of measuring perceptions of quality or safety of different modes, Misra et al. reference 'crowdsourcing' as a potential method for involving a "large group of stakeholders in transportation planning and operations" (2014, p.1). In one example, researchers at Carnegie Mellon University created an app called Tiramisu Transit, which allows users to submit information about their experience riding the bus such as bus crowding, which can help people with disabilities choose which bus to board (Misra et al., 2014). Additionally, researchers at George Mason created an accessibility mapping system for crowdsourced identification of barriers or obstacles in pedestrian networks that need repair (Lee and Sener, 2020). Such an approach could help incorporate ADA accessibility into measures of sidewalk quality, as recommended by TransitCenter (2021).

In Minneapolis-St. Paul, a website called "cyclopath", created by researchers at the University of Minnesota, allows users to rate bike routes/paths and report path conditions (Misra et al., 2014). While the primary purpose is to help other cyclists, the data could also be used by transit agencies or cities when identifying issues with existing routes or first/last mile connections. Similarly, Oregon DOT developed a smartphone app to collect data on cyclists' bicycle infrastructure preferences and safety issues (Blanc and Figliozzi, 2016). Cyclists were asked questions about their trip purpose, comfort on their route, and concerns about conflicts with motor vehicles (Blanc and Figliozzi, 2016). The agency found that the presence of large commercial vehicles was the strongest factor to affect users' comfort negatively, and that separated facilities and traffic calming on residential streets would help increase comfort levels (Blanc and Figliozzi, 2016).

TRACKING INDICATORS WITH DATA – LOCATION-BASED SERVICES

In recent years, transportation planners have turned to location-based services (LBS) data, as these data can provide "more accurate, detailed data on travel patterns" than traditional Census data sources (TransitCenter, 2021). LA Metro's own work with LBS data in the NextGen bus project found they could generate insights from these sources not present in traditional Census or National Household Travel Survey (NHTS) data, such as the fact that "travel intensity doesn't align completely with employment or residential density" (TransitCenter, 2021).

Investing in LBS data sources has "a high return, as officials will be better informed about which operational changes and capital investments serve riders equitably and effectively" (TransitCenter, 2021 p.39). There are several examples of cities, transit agencies, DOTs, and researchers using LBS or similar GPS data to understand trip patterns and mode share behavior. For example, a 2009 study using GPS data from cyclists in Portland, Oregon revealed that half of all miles traveled were on roads with bicycle infrastructure, such as bicycle lanes, paths, or bicycle boulevards, even though these facilities were present on only 8% of the street network (Dill, 2009). As a result, Dill concluded that cycling in Portland was most likely to occur in areas with a "well-connected street grid and mix of land uses" (2009, p.S106). The cities of Glasgow and Ottawa both use bicycle route data at the segment level to understand the impact of bicycle infrastructure before and after implementation (Lee and Sener, 2020). Additionally, an internal study at Virginia Department of Transportation (VDOT) on the use of LBS-derived trip data found several examples of its use for transportation planner purposes (Yang et al., 2020). In one example, Georgia DOT used LBS data to create origin-destination matrices for a new Downtown Connector project, while another example involved planning consultants using LBS data to understand station-level travel behavior in Sacramento (Yang et al., 2020). The VDOT report concluded that, based on these cases, "the performance of using the LBS data was satisfactory for analysis, except that the quality required further validation" (Yang et al., 2020 p. 12).

Further validation efforts of LBS data should include efforts to better understand biases inherent in smartphone-derived movement data and steps planners can take to address these biases. Researchers have found that smartphone users tend to be "economically active, tech savvy, and younger" (Lee and Sener, 2020). Similarly, the Oregon DOT app used to collect cyclists data, described in the previous section, found their sample set was more likely to be young and male than the general population (Blanc and Figliozzi, 2016). TransitCenter found that LBS data tends to underrepresent older adults and non-English speakers, who are less likely to have smartphones (2021). The VDOT report on LBS data for transportation planning states that "simply relying on LBS data will not produce robust and accurate results – and therefore researchers and planners have integrated other data sources such as surveys, camera systems, vehicle plate systems" (Yang et al., 2020 p.13).

As such, agencies and cities often do not solely rely on a single LBS and/or GPS data source to understand trip patterns. For example, consultants hired to study origin-destination patterns on U.S. 101 along California's central coast integrated LBS data with vehicle classification count data, license plate analysis data, and survey data (Yang et al., 2020). Yang et al. note that these supplemental strategies are particularly crucial for modes with lower volumes, such as cycling (2020). At Oregon DOT, planners supplement bicycle travel demand models with data from other sources, such as data from fitness apps like Strava, bike-share data, and manual and automated bike counts (Lee and Sener, 2020). Additionally, researchers have complemented LBS-derived bicycle flow data with field counts and intercept surveys (Lee and Sener, 2020). Finally, given the relative novelty of LBS data in transportation planning, LBS data brokers may change their algorithms or partnerships with mobile applications and cell service providers over time, making it difficult to perform year-over-year trip volume comparisons (Yang et al., 2020), requiring supplemental data to create trustworthy time series comparisons.

INDICATORS IN PRACTICE – RESULTS FROM OTHER CITIES

By tracking overall mode share over time, cities and transit agencies have been able to track how policy and planning changes have increased (or decreased) the proportion of people walking, biking, or taking transit. While these policies are not necessarily the result of using specific mobility indicators, they may be valuable case studies for nudging an overarching mode share indicator in a desired direction. They also may reveal additional indicators transit agencies could track on the path towards achieving mode share goals.

Several studies have documented changes in bicycle travel mode share that occurred over the same time period as infrastructure implementation. Despite this documentation, ultimately "little is known about the specific effectiveness of any one policy in increasing walking or cycling, or what the ideal mix of policies would be" (Winters et al., 2017 p. 283), given the vastly different contexts across cities. Pucher et al. also caution that the same policies can have very different effects in cities with different baseline levels of cycling (2009). That said, cities can learn lessons from these case studies and identify a potential range of outcomes based on different infrastructure investments. For example, a 2003 study of 40 US cities found that "each additional mile of bike lane per square mile was associated with an increase of approximately one percentage point in the share of workers commuting by bicycle" (Pucher et al., 2009 p. S107). Another study in Seattle found that people within one half mile of a bike path were 20 percent more likely to bike at least once per week (Pucher et al., 2009).

The authors advise readers that these changes in mode share may not be solely a result of bike lanes. Rather, a "complete system of cycling infrastructure (lanes, paths, cycle tracks, signals, parking) may have a far greater impact than the sum of its parts" (Pucher et al., 2009 p. S122). Additionally, many of these cities are European. Adapting similar policies to the American context may struggle to find similar increases in cycling levels given the lack of regional land use coordination and lack of restrictions on car use (Pucher et al., 2009). As such, Davis, California, one of the first cities to implement bicycle lanes, saw a decrease in bicycle commuting mode share from 28% in 1980 to 14% in 2000, which Pucher et al. attribute to the growth in long-distance commuting from Davis to Sacramento and San Francisco (2009).

CONCLUSION

While indicators themselves may not drive mode share changes, selecting the right set of indicators can help cities and transit agencies better identify factors leading to mode choice decisions. Our literature review has identified multiple indicators that can assess travel behavior, including quantitative and qualitative indicators that can be used to track progress against a mode shift towards non-auto mobility. We have also identified best practices and potential challenges associated with using location-based services (LBS) data for tracking mode share and other indicators that inform mobility planning decisions. Given this research, LA Metro and other transit agencies using LBS data should connect these data with other sources to verify the data and incorporate more qualitative factors associated with mode choice, such as the perception of network quality and performance. Finally, we have identified mode share changes, particularly bicycle mode share increases, as a result of specific infrastructure changes cities have implemented in the last several years to highlight the potential mode share return on infrastructure investments. Together, this review of travel behavior, indicators, and location-based services data will offer guidance to inform LA Metro's efforts in finding ways to measure their progress towards their goal of increasing non-auto mode share in LA County.

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