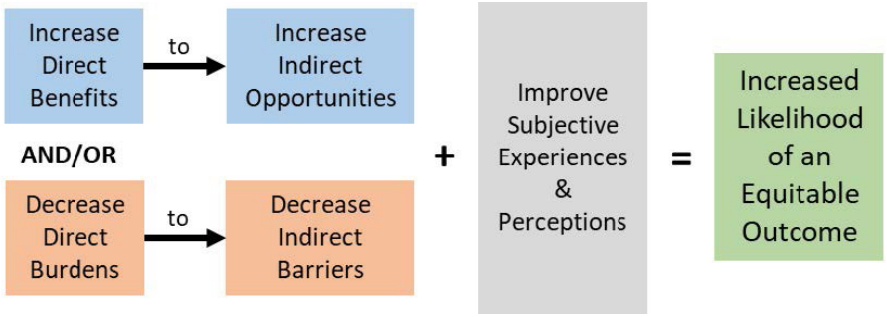
Leading Indicators of Transportation Equity: Equity in Planning

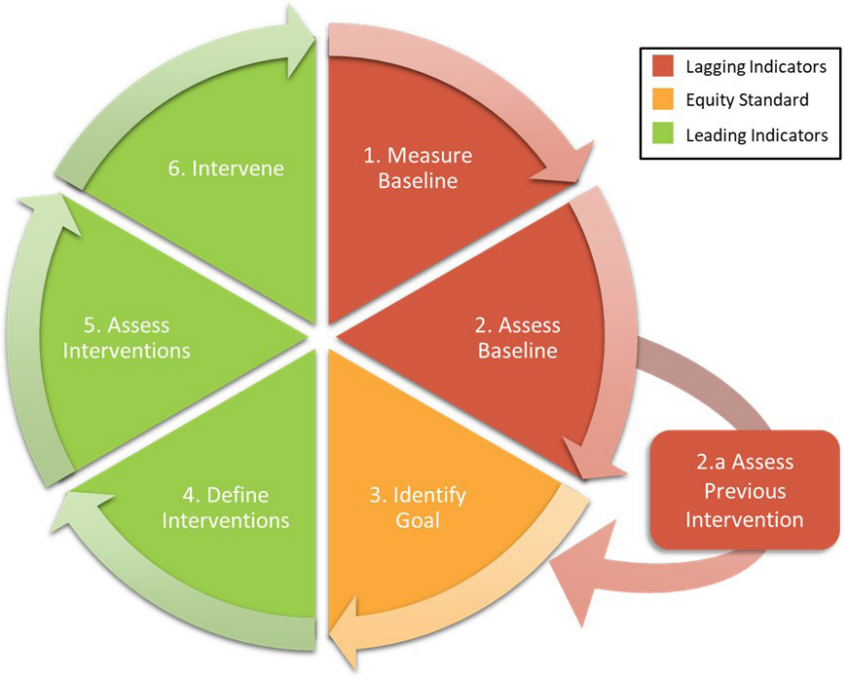
WA-RD 938.1

Elyse O. Lewis
Bethany M. Gordon

December 2023



Different types of transportation indicators and how they combine to create leading indicators of transportation equity.



Relationship between leading and lagging indicators in the Transportation Equity Planning Cycle.

Washington State Department of Transportation
Office of Research & Library Services

WSDOT Research Report

Research Report
Agreement T1461, Task 99
Equity in Planning
WA-RD 938.1

Leading Indicators of Transportation Equity:

Equity in Planning

by

Elyse O. Lewis, Ph.D.
Research Assistant
University of Washington

Bethany M. Gordon, Ph.D.
Assistant Professor
University of Washington

Washington State Transportation Center (TRAC)
University of Washington, Box 359446
University Tower
4333 Brooklyn Ave NE
Seattle, Washington 98195-9446

Washington State Department of Transportation
Technical Monitor
Faris Al-Memar

Prepared for
The State of Washington
Department of Transportation
Roger Millar, Secretary

December 2023

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
WA-RD 938.1		

4. TITLE AND SUBTITLE	5. REPORT DATE
LEADING INDICATORS OF TRANSPORTATOIN EQUITY: EQUITY IN PLANNING	DECEMBER 2023
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Elyse O. Lewis, Ph.D., Bethany M. Gordon, Ph.D.	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. WORK UNIT NO.
Washington State Transportation Center (TRAC) University of Washington, Box 359446 University Tower; 4333 Brooklyn Ave NE Seattle, Washington 98195-9446	11. CONTRACT OR GRANT NO. Agreement T1461, Task 99
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Research Office Washington State Department of Transportation Transportation Building, MS 47372 Olympia, Washington 98504-7372 Project Manager: Jon Peterson, 360.705.7499	Research Report 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT:

This report was commissioned as part of the Washington Department of Transportation's (WSDOT) Equity in Planning (EiP) project. It presents knowledge drawn from the transportation equity academic literature, practice-oriented literature, community engagement, geospatial (GIS) analysis, and a survey of planning professionals. The project aims to comply with Washington state's Environmental Justice (EJ) legislation, SB 5141, known as the HEAL Act. The HEAL Act sets the goal that 40 percent of major state expenditures be directed toward overburdened communities and vulnerable populations. It mandates that EJ analyses be performed by seven state agencies, including WSDOT.

This report identifies leading indicators of transportation equity that WSDOT can incorporate in its planning processes for long-range, regional, and corridor planning initiatives.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Equity, Leading indicators, planning, community engagement, geospatial analysis	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
None	None	175	

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Washington State Department of Transportation or Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Contents

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

This report details the foundational work of the Equity in Planning project over the course of one year. This involved synthesizing the extant literature, engaging planners and communities about using the concept of leading indicators to guide equitable work, and implementing findings into graphics by using geospatial analysis (geospatial information system, GIS).

Literature Review: This review provides a framework for operationalizing equity in transportation planning efforts by using the concept of *leading indicators*. The concept of leading indicators, however, is found predominantly in the occupational safety literature, with no existing overlap between transportation equity planning and leading indicator concepts. Therefore, this document provides a detailed summary of the metrics used to measure transportation equity in relation to the concept of leading indicators.

> Leading indicators of transportation equity can be characterized as follows: *proactive and preventative measures that may indicate the potential equity impacts of transportation plans. This includes revealing potential inequities so that they may be addressed early and at every level possible in the transportation system planning process*.

In contrast, lagging indicators measure outcomes or existing realities. Because transportation equity efforts seek to avoid, minimize, or mitigate burdensome transportation externalities and to intentionally allocate benefits, different metrics associated with transportation equity can serve as either leading or lagging indicators, depending on the point in time when they are utilized. Moreover, incorporating transportation equity in planning is an iterative and on-oing process that requires consistent, meaningful community engagement throughout.

For community engagement to be meaningful, transportation professionals must understand their role in relation to community members. This requires a transportation professional to understand how to leverage relevant data, methods, and tools in combination with the context-specific, lived-experience knowledge that only affected communities have the expertise to provide. Additionally, efforts to form ongoing relationships between Washington

State Department of Transportation (WSDOT) representatives and community organizations are strongly encouraged to foster relational rather and transactional engagement.

Engaging Planners and Communities: The community consultation, which engaged 207 participants, yielded many insights into community needs and perceptions, as well as into the community engagement process as a whole. The engagement process highlighted the importance of engaging at locations and times that are convenient for community members and the ways that support from local service providers can increase reach. Communities expressed strong buy-in into project aims and implementation of Washington state's Healthy Environment for All (HEAL) Act in general. They specifically requested more regular interaction with WSDOT.

The WSDOT planner survey, which engaged 36 participants, collected feedback on the Equity Strategies tables (Section 7.4) and the communication of leading indicators information contained in a previous draft of this report. Additionally, participants identified data, methods, tools, and policies related to equity in their work. This knowledge was combined with information obtained during a review of the practice-oriented literature related to leading indicators of transportation equity.

A synthesis of the findings from both surveys suggested that to fully integrate equity in planning, community engagement efforts should do the following:

- separate community engagement from individual projects
- ensure engagement is cyclical – report back to communitie.
- focus on building community relationships in-house (rather than contracting work out)
- hold events at times and places familiar to communities and with necessary materials
- compensate community members and local organizations.

Implementing the Findings by Using GIS: The geospatial component of the analysis focused on an assessment of cumulative impact indices, including Washington state's Environmental Health Disparities (EHD) Map. The researchers conducted a review of all US federal agency indices currently in use (see Section 4.3.c and Appendix C) and completed a detailed analysis of the EHD and the USDOT's Equitable Transportation Community (ETC) Explorer. The analysis asked the following questions:

- Are existing cumulative impact indices more likely to designate urban tracts as disadvantaged in comparison to rural tracts?
- How should practitioners approach existing indices?

Both the EHD and ETC were found to be more likely to assign disadvantage status to urban census tracts than to rural tracts under 13 different, equally valid calculation scenarios. Indices did, however, tend to offer stable estimates at either end of their distribution. This suggests that areas classified as very disadvantaged or not at all disadvantaged tend to be the most accurate. This precision increases when multiple indices or versions of indices are considered. Analysts are therefore encouraged to cross-reference between multiple indices, with guidance provided to aid in this process in Figure 4.3 in Section 4.3. Ultimately, analysts are encouraged to err on the side of inclusion at the low levels of spatial resolution afforded by the census tract and block group-level analyses that these indices provide and to seek more localized data when possible.

Because the concept of disadvantage is so broad, open to many valid interpretations and therefore lacking a singular ground truth measure, tools should be utilized with an appreciation of their limitations.

HOW TO USE THIS DOCUMENT

This document is intended as a reference guide for practitioners seeking to incorporate equity in their work. Content can be classified in two categories: foundational and directly applicable. The concept of equity encompasses a wide range of theories with an even wider range of potential applications.

SOLIDIFY UNDERSTANDING OF CONCEPTS

The conceptual, knowledge-oriented sections of this report offer broad framings and definitions that help orient the reader. They are primarily written for individuals new to equity in transportation planning. Practitioners well-versed in this field will hopefully still find them to be a useful review.

Generally, Section 3 and Section 4.1 provide conceptual overviews of leading and lagging indicators, the cyclical process of transportation equity, and transportation-relevant theories of equity. Sections 4.2 and 4.3 cover socio-demographic and unit-based considerations, respectively. Concerning socio-demographic considerations, Washington state's Environmental Justice (EJ) legislation, the HEAL Act, is highlighted throughout the document but especially in Section 4.2.

Key terms are bolded throughout to catch the reader's eye – most are concepts that highlight potential pitfalls in the planning process and deserve careful attention. Many of these potential pitfalls can be found in Section 4.3, which focuses on the interplay and tension between measures that center people vs. those that measure geolocations. Because transportation equity is fundamentally concerned with both the traveling public and the physical facilities they use to move between places, both forms of measurement must be considered.

Accessibility – both physical accessibility regulated by the Americans with Disabilities Act (ADA) and measures of geospatial accessibility – are central considerations in transportation equity planning. While physical, ADA accessibility considerations are incorporated throughout the Indicator tables (see Section 4.4), a comprehensive coverage of geospatial accessibility exceeds the scope of this report. Still, a conceptual overview is provided in the Accessibility indicator Section 4.4.a. This section, as well as a Recommendations subsection (Section 7.6), highlights multiple practice-oriented reports that focus exclusively on geospatial accessibility concepts and applications.

The Indicators tables (Section 4.4) and the Methods and Data tables (Section 4.5) offer a broad, synthetic review of measures, methods, and data that can be used to perform a transportation equity analysis. They are as expansive and varied as the concept of equity itself; therefore, the Recommendations found in Section 7 provide more concise summaries and suggestions. Recommendations are directed at WSDOT but offer insights for transportation practitioners broadly.

INCORPORATE EQUITY IN PRACTICE

Below are a few ways that a practitioner could step through and apply the information contained in this report:

Place-based: Assess areas for disadvantage funding priority in accordance with HEAL Act mandates and current guidance.

1. Use the flow chart (Figure 4.3 and Table 4.4) to step through location assessment using cumulative impact indices such as the Environmental Health Disparities (EHD) Map. Further details and guidance provided in Section 4.3.c and Appendix C.
2. Review additional sources of data, example data sets, and their geospatial utility with Table 4.17 in Section 4.5

Person-based: Identify and plan engagement with communities.

1. Review the Communities of Concern Table 4.3 in Section 4.2.b to understand which communities tend to be vulnerable and disproportionately affected by transportation.
2. Consult the Equity Strategies tables 7.1 and 7.2 to review engagement strategies and interventions that tend to meet the needs of the communities identified.
3. Review community engagement Lessons Learned in Section 6.1.b.

Person-based: Engage with communities.

1. Use the Equity Strategies tables 7.1 and 7.2 as a common language for dialogue with communities.
2. Reference the Indicators tables (Section 4.4) for detailed options to expand on strategies.

Once the scope has been narrowed and a direction has been established, Indicators (Section 4.4) and Methods and Data (Section 4.5) are detailed to actualize analyses. The bulk of the report content can be found in Section 4.4. The beginning of the section describes the framework used to organize the detailed summary tables of transportation equity metrics by

category, type, components, variations, mode relevance, and leading vs. lagging indicator use cases. Metric summaries present a synthesis of findings from peer-reviewed journal articles, as well as a practice-oriented literature review (Nawrocki et al., 2023). Additional guidance programs and materials are listed in tables 6.1 and 6.2 in Section 6.2 (general policy and programs) and in Section 7.6 (geospatial accessibility analyses).

The breadth of this project invites readers to take initiative and dive deeper into this work, using this report as a guide.

1 INTRODUCTION

This report was commissioned as part of the Washington Department of Transportation's (WSDOT) Equity in Planning (EiP) project. It presents knowledge drawn from the transportation equity academic literature, practice-oriented literature, community engagement, geospatial (GIS) analysis, and a survey of planning professionals. The project aims to comply with Washington state's Environmental Justice (EJ) legislation, SB 5141, known as the Healthy Environment for All (HEAL) Act. The HEAL Act sets the goal that 40 percent of major state expenditures be directed toward overburdened communities and vulnerable populations. It mandates that EJ analyses be performed by seven state agencies, including WSDOT. The goal of the project was to identify leading indicators of transportation equity that WSDOT can incorporate into its planning processes for long-range, regional, and corridor planning initiatives.

The concept of leading indicators comes from the discipline of construction safety. The Occupational Safety and Health Administration (OSHA) defines leading indicators as "proactive and preventive measures that can shed light about the effectiveness of safety and health activities and reveal potential problems in a safety and health program" (US Department of Labor, n.d.). Within academic literature, the concept of leading indicators remains focused on occupational hazards such as construction safety (Alhammadi, 2022). To apply the concept to a transportation equity context, this base definition can be restated as follows:

> *proactive and preventative measures that may indicate the potential equity impacts of transportation plans. This includes revealing potential inequities so that they may be addressed early and at every level possible in the transportation system planning process*.

This report is broken into five main sections, numbers three through seven: (3) Components of Transportation Equity, (4) Identification of Components, (5) Limitations, (6) Survey Results, and (7) Recommendations.

Section 3 provides a working definition for leading and lagging indicators of transportation equity within the context of a transportation equity process.

Section 4 contains most of the content presented in this report because it breaks down and presents detailed examples of each component of transportation equity defined in Section 3. The first subsection of Section 4 presents the equity standards found in the transportation literature

that the authors deem most relevant to the EiP project. This is followed by subsection 4.2, which presents the concept of communities of concern as defined by the Washington state HEAL Act, as well as definitions found in the transportation equity literature. Subsection 4.3 presents the main categories of units of analysis used in transportation equity assessments and explains the benefits and potential pitfalls associated with each type.

Subsection 4.4 summarizes the various types of measures (indicators) of transportation equity collected from a review of over 100 scholarly articles drawn from a search for transportation planning equity indicators. The beginning of this subsection provides a detailed explanation of how the indicators were organized by type, with the detailed lists of indicators categorized as Accessibility, Mobility and Economy, Land Use, Environment Health and Safety, and Qualitative and Engagement. Subsection 4.4.a is the most extensive because it presents the concept of transportation accessibility in addition to related indicators. Each table of indicators includes columns detailing those indicators' potential utility as leading indicators of transportation equity. The final subsection (4.5) details methods of analysis that can be used to operationalize and assess the indicators presented in subsection 4.4.

Section 5 identifies and details limitations in the current transportation equity literature. Based on the information presented in Sections 3 through 6, Section 7 presents recommendations, including Equity Strategies tables. Taken together, the report provides a comprehensive overview of transportation equity, with the framework and component details necessary to incorporate equity into WSDOT's planning efforts.

2 METHODOLOGY

This project brought together knowledge from four distinct sources to inform WSDOT's efforts to incorporate equity in its planning efforts: literature (practice-oriented and academic), community insights, geospatial analysis, and WSDOT agency planners. This section details the methodologies used to elicit knowledge from each source.

2.1. LITERATURE REVIEW

The initial phase of the project involved a review of both the practice-oriented and academic literature regarding equity in transportation planning. The practice-oriented review was completed by members of the WSDOT project team (Nawrocki et al., 2023). The academic literature review was completed by the University of Washington (UW) team and served as the primary source of structure and content for this report.

The academic literature review methodology followed the snowballing technique (Wohlin, 2014). Google scholar searches for "transportation planning equity," "leading indicators of transportation equity," and "transportation equity planning guidance material" were used to identify an initial subset of texts. On the basis of a review of abstracts, key texts were identified and used to identify additional, more recent texts that cited them. A total of n=110 articles were reviewed, with a focus on work from academic literature and largely excluded secondary sources. The practice-oriented review findings from Nawrocki et al. (2023) were integrated into the relevant indicator tables in Section 4.4. Agency and design guidance insights were also added into this report document in Section 6.2.

2.2. COMMUNITY ENGAGEMENT

Community engagement for this project took the form of a community consult survey. The survey was targeted to overburdened and vulnerable populations based on HEAL Act definitions and additional findings from the academic literature detailed in Section 4.2 Communities of Concern. The questionnaire was developed by the UW team with questions related to each of the five indicator categories (see Section 4.4). A third-party contractor was hired by WSDOT to translate the questionnaire into seven additional languages: Chinese, Spanish, Russian, Arabic, Somali, Vietnamese, and Korean. All versions were coded into SurveyMonkey by WSDOT team members, resulting in a survey tool offered in eight languages. The full survey text (in English) can be found in Appendix B.

Survey distribution was facilitated by WSDOT team members through community organizations and local service providers throughout the state of Washington. Four hundred local service providers from all six WSDOT regions were contacted via email to request a time and place to meet to discuss the project and potential collaboration for survey distribution. Twenty-five responded with availability, interest, and a willingness to engage without compensation. Most of the initial engagement meetings occurred in-person at locations convenient to the local service providers, and some meetings occurred via Zoom. A full list of service providers engaged in this initial stage can be found in Appendix B.

Survey distribution occurred in two phases: an initial in-person push during August 2023 followed by a purely electronic effort through September and October. In-person events were held at locations frequented by community members with banks of computers. Events were promoted by local service providers and were co-facilitated by these providers along with WSDOT team members. These events were limited by funds and team availability, which necessitated the switch to remote distribution via local service providers. Because funds were not available to compensate local service providers, additional distribution efforts were limited to email listservs.

According to the Washington State Office of Equity guidelines for community compensation, funds were made available for survey respondent compensation. Survey respondents who provided a valid email received a $45 electronic cash gift card. Alternative compensation options were discussed, such as cash and local grocery store vouchers, but the final decision to use Tango e-cards was based on distribution logistics and an effort to avoid store-based favoritism. Tango card purchase and distribution was managed by the UW team. A total of n=207 responses were collected.

2.3. GEOSPATIAL ANALYSIS

The third source of knowledge considered in this project was geospatial analyses. Specifically, transportation equity applications that complied with the Washington state HEAL Act were identified. Per the HEAL Act, the Washington State Department of Health (DoH) is required to maintain the state's Environmental Health Disparities (EHD) Map. The EHD is a cumulative impact index – an analysis tool that converts a set of variables deemed relevant measures of interest into a single, composite value that can be used to measure relative disadvantage over a region or between groups. The EHD is the primary tool used to quantify

relative disadvantage in Washington state and is used to determine funding priority to meet the HEAL Act's goal of 40 percent funding allocation to disadvantaged areas.

In addition to geolocating viable community consult survey responses by county and WSDOT planning region, the bulk of the geospatial analysis for this report focused on analyzing the EHD and a comparable tool, the United States Department of Transportation's (USDOT) Equitable Transportation Community (ETC) Explorer. The analysis for this project focused on two questions:

- Are existing cumulative impact indices more likely to designate urban tracts as disadvantaged than rural tracts?
- How should practitioners approach existing indices?

Results are summarized in Section 4.3.c, with analysis detail provided in Appendix C.

2.4. AGENCY PLANNER FEEDBACK

The final source of knowledge considered for this report was WSDOT agency planner feedback. To collect this information, the UW team developed and distributed another SurveyMonkey survey tool. The survey consisted of a general, short version and an extended version. The latter included a guided review of content from the academic literature review draft of this report. The full survey text can be found in Appendix D.

The survey was promoted by WSDOT team members at planning managers' meetings and by WSDOT and UW team members at a WSDOT Planning and Data Academy session focused on incorporating geospatial information systems (GIS) into equity analyses. A total of 36 responses were collected, with ten participants providing in-depth feedback. Results are summarized in Section 6.2, and detailed feedback responses were used to make final report edits and recommendations.

3 COMPONENTS OF TRANSPORTATION EQUITY

Transportation equity is a recursive process – no single step or indicator (or even set of indicators) alone can guarantee transportation equity. This section presents a working definition for leading and lagging indicators of transportation equity within this context of a transportation equity process.

3.1 LEADING AND LAGGING INDICATORS

Leading indicators of transportation equity can take a few forms: benefits and opportunities, burdens and barriers, and subjective experiences and perceptions. Benefits and burdens are things that can be directly measured, such as the number of buses in operation or emissions generated by a bus. Opportunities and barriers can also be measured, but they typically require analyses of direct measures. For example, access (or lack thereof) to regional jobs is measured on the basis of an analysis of values such as travel times, residential locations, and employment centers.

These components of the transportation system can be quantified with observed values and are therefore classified as **objective measures**. In contrast, **subjective measures** are based on individual experience and perceptions; they cannot be objectively observed, they can only be self-reported. For example, many attributes of transit service can be objectively measured, but whether riders are satisfied with the service can be collected only through rider survey responses. Figure 3.1 presents the types of indicators (measures), how they relate to each other, and how they combine to inform the development of leading indicators of transportation equity.

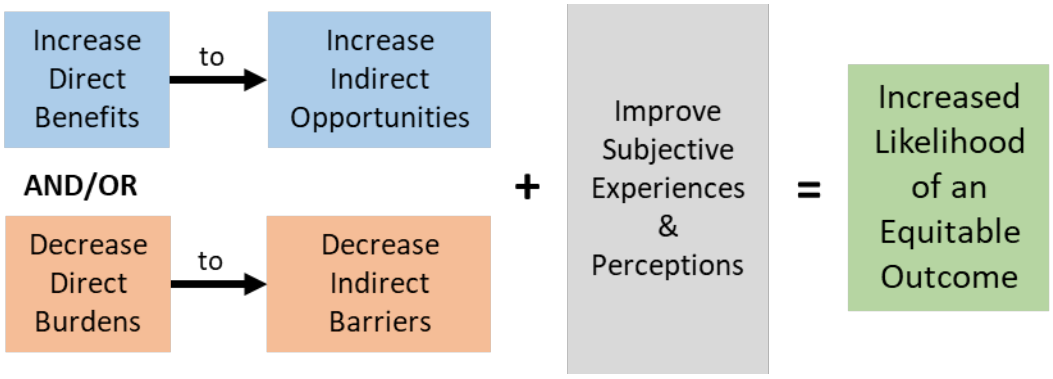


Figure 3.1. The different types of transportation indicators and how they combine to create leading indicators of transportation equity.

Outcomes that are projected to provide some increase in direct benefit must also provide an appreciable, meaningful increase in associated indirect opportunities. For example, adding bicycles and stations to a bike sharing service can be viewed as a direct benefit; the exact number of vehicles (bicycles) and facilities (stations) can be measured. However, if these direct benefits are not added with the broader cycling network in mind (ex: protected bike lanes) or the origins and destinations most useful to users (ex: housing, employment centers, recreation areas, etc.), then the added, direct benefits may not have any appreciable, meaningful increase in the indirect opportunity of accessibility. And if an increase in direct opportunities is not achieved, then an improvement in subjective experiences and perceptions (ex: people believing that the bike sharing service meets their needs or enjoying using the service) will likely not occur, either.

To be a leading indicator of transportation equity, projected outcomes should not onlyyield positive results based on objective measures but should also yield positive, subjective results. While it is possible for some people to perceive and feel bad or upset about a change that objectively improves their lives, most often people's perceived frustrations provide insight into elements that are not well measured or are potentially overlooked entirely by objective measures (Curl, 2018). For example, objective measures such as satisfaction have proved to be stable indicators of subjective experience, particularly when aggregated over a population (Di Ciommo et al., 2019). It is therefore critical to account not only for objectively observed measures of the transportation system and associated outcomes but also for the subjective experiences and perceptions of those who use and are affected by the system.

As a result, a measure of a direct benefit alone does not meet the criteria for a leading indicator of transportation equity – direct measures must always consider the broader context of their indirect impacts and associated subjective experiences and perceptions.

Leading indicators can also be understood by their counterpart, lagging indicators. Whereas leading indicators aim to address equity issues before they arise, lagging indicators simply measure the situation as-is. For example, a leading indicator of equitable transportation safety is the coverage of streetlights and general lighting at transit stops. This is a leading indicator because well-lit areas are known to reduce the experience of crime, both perceived and actual (Uteng et al., 2019).

In other words, this measure of an object is known to decrease direct burdens (crimes) and associated indirect barriers (perceived danger preventing a trip), as well as improve

subjective experiences (less fear and stress in transit) and perceptions (belief that transit is dangerous). A lagging indicator may be reported crimes and survey responses of perceived safety. While the lagging indicators can help highlight and quantify a problem, the leading indicator can be used during the planning stage to help alleviate the burden altogether.

3.2. THE TRANSPORTATION EQUITY PLANNING CYCLE

Most metrics have the potential to be both leading and lagging – the difference depends on the point at which it is applied in an equitable planning process. Berg and Newmark's (2020) work on exploring equity in pedestrian master plans broke down the equity process into phases of acknowledgement, accountability, and application. The HEAL Act has already created the policy environment of acknowledgement, and their accountability and application components have been integrated with the processes defined by Guo et al. (2020), Martens et al. (2019), and Davis and Pilkington (2019) to create Figure 3.2.

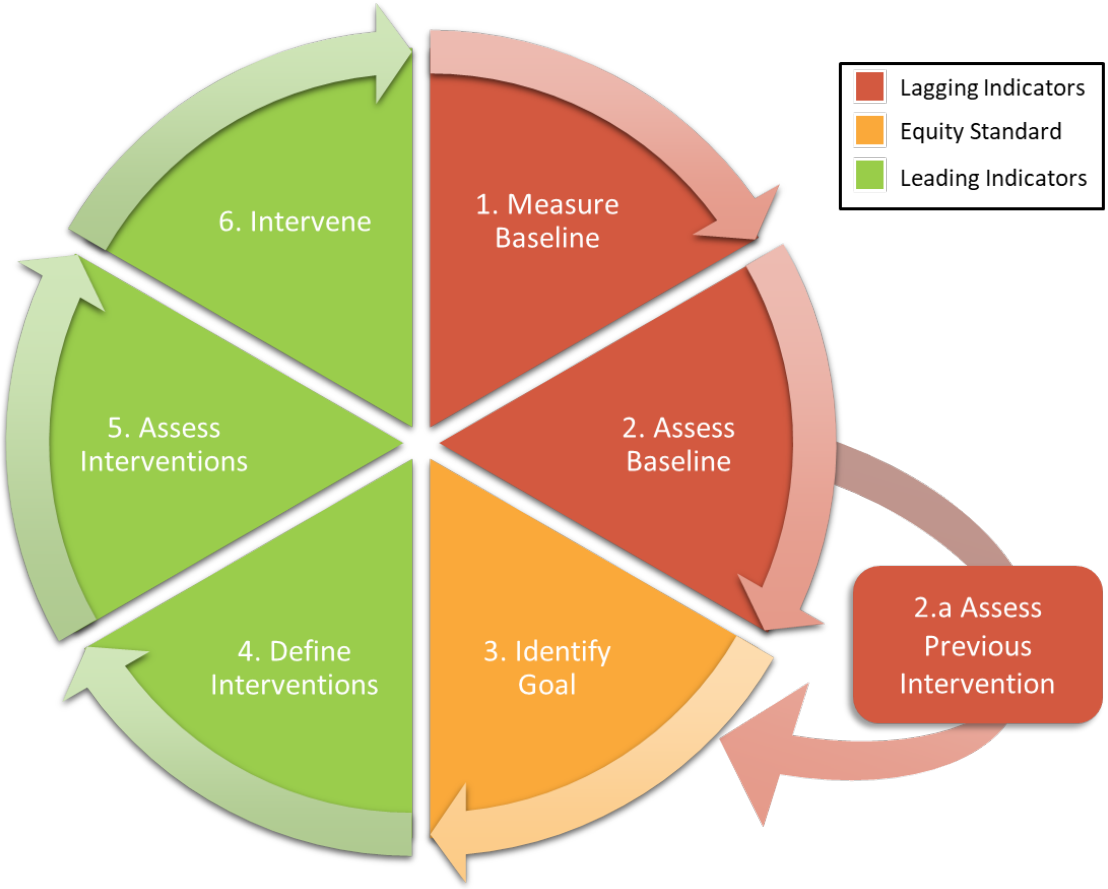


Figure 3.2. The relationship between leading and lagging indicators in the Transportation Equity Planning Cycle

The cyclical format is used to highlight the recursive nature of transportation equity efforts, and the different phases are highlighted to clarify at what point an indicator may be leading vs. lagging.

Table 3.1 provides further details related to each step in the transportation equity planning cycle. It is a synthetic product of the literature and planner feedback. Each process step has a set of associated questions to guide planners at that stage, as well as a rough estimate of an ideal split of knowledge between community and transportation professionals. This is intended to highlight and differentiate the roles of the community and professional within a transportation equity process. To achieve transportation equity, affected communities must be centered (Boisjoly and Yengoh, 2017; Griffin and Jiao, 2019; Stewart and Zegras, 2022). When community-identified concerns and professional interventions are closely aligned, an equitable outcome is more likely to occur (Sanchez and Brenman, 2008).

Table 3.1. Transportation equity cycle guiding questions and ideal knowledge split.

Process Step		Associated Questions	Ideal Knowledge Split	
			Community Identified	Professional Analyses
1	Measure Baseline	What should be considered?	Half	Half
		How should it be measured? (data & methods)	-	Full
		Where? For Whom?	Half	Half
2	Assess Baseline	How equitable is the status quo?	Majority	Partial
2.a	Assess Previous Intervention	Has the status quo changed?	Half	Half
		In what way? By what amount?		
		Was the change meaningful?	Majority	Partial
3	Identify Goal	What reality would be more equitable?	Half	Half
		What would constitute a meaningful change towards this equitable reality?		
		By what amount? By when?		
4	Define Interventions	What changes might help move towards equity?	Partial	Majority
5	Assess Interventions	What is the potential equity impact?	Feedback	Majority
		What resources are necessary to achieve results?	-	Full
		How long will it take to see results?	-	Full

Process Step		Associated Questions	Ideal Knowledge Split	
			Community Identified	Professional Analyses
6	Intervene	Actualize intervention(s) that have the highest equity potential	-	Full

After any given intervention, a new baseline is established. It is important to compare the new, post-intervention baseline to the original baseline to assess the impact of the intervention. Rather than assessing the potential of an intervention, this assessment uses lagging indicators to determine the effectiveness of a previous intervention. Specifically, the degree and meaningfulness of the change is key. While transportation professionals can objectively measure the amount of change that occurred using observational, objective measures, meaningfulness is an inherently subjective measure. The affected communities are therefore the best judge of the degree to which a change was meaningful. This assessment can then inform a renewed resolve toward the existing equity goal or can help reshape it.

It is critical that interventions address disparities identified in the early stages of the process, and involving communities in the process early and often not only promotes accountability but ensures that community members will be key players in identifying where and for whom interventions are necessary (Berg and Newmark, 2020). It is then the responsibility of transportation professionals to execute this vision, balancing competing interests and constraints. Karner and Marcantonio (2018) emphasized the importance of fund allocation, not only to support the engagement process but also to ensure that the engagement process will be made meaningful through intervention. They discussed how to identify and "tailor" metrics to address the identified problem and recommended using metrics on an annual basis to measure progress as it unfolds over time (p. 119).

4. ELEMENTS NEEDED TO IDENTIFY LEADING INDICATORS OF TRANSPORTATION EQUITY

The concept of leading and lagging indicators and the transportation equity planning cycle defined in the previous section provide a framework for the necessary components of transportation equity and how they relate to each other. This section details the component parts of the process, including detailed lists of transportation equity indicators. These indicators are organized along multiple dimensions and are presented in terms of their utility as leading and lagging indicators.

4.1. EQUITY STANDARDS

As the Transportation Equity Planning Cycle demonstrates, a key component of transportation equity work is setting a goal (Step 3). To inform this goal-setting effort, theories of equity have been established that can guide transportation professionals. Tables of equity theory definitions and transportation-specific examples can be found in Appendix A.

Equity standards refer to the different theories of equity that might be applied to a given situation. Theories of equity are a product of philosophical ideas related to how resources should be distributed within society; they are inherently concerned with justice and are therefore inherently normative (Lewis et al., 2021). In contrast to **positive knowledge**, which is concerned with observing and measuring the world *as it is*, **normative knowledge** is concerned with how the world *should be*. Because of the subjective nature of normative ideals, it is critical that affected communities be consulted early and often to ensure that interventions reflect their needs and expectations.

Leading indicators hold normative import whereas lagging indicators simply offer positive measures of existing or past phenomena. For example, lagging indicators related to safety simply measure the state of (un)safe conditions – they offer information about what is without passing any normative judgement. In contrast, leading indicators operationalize a normative goal. Leading indicators related to individual efficiency operate on the normative ideal that transportation *should* prioritize the use of personal vehicles.

Several equity standards have been applied in transportation literature either implicitly or explicitly (Lewis et al., 2021). When equity standards and associated goals are not defined explicitly, planner and researcher biases are instead applied as implicit equity standards and goals. This implicit, unintentional application of the concept of equity has led to confusion

within the transportation literature and can lead to incoherent and contradictory assumptions, methods, and results (Lewis et al., 2021). Martens and Golub (2021) provided an explicit connection between equity standards and US policy in what they refered to as a Ladder of Justice Standards.

The top rung of their five-level ladder identifies the restorative equalization standard, defined as follows:

> "Traditionally marginalized communities receive substantially more benefits than the majority population with the aim to correct past wrongs over time." (p. 432).

And related to planning guidance, they noted:

> "[The] Civil Rights Act was meant to address past discrimination. DOT Title VI regulation (49 CFR Part 21) explicitly condones affirmative action where past discrimination left inequalities in the present." (p. 432).

Broadly, the history of government sanctioned and (in many cases) mandated policies of racial segregation that continued late into the 20th century continue to be reinforced by modern day tax and resource distribution structures (Rothstein, 2017). Specific to transportation, the Interstate highway system was routed through these segregated communities in the 1950s and '60s, leaving marginalized communities to bear a disproportionate share of the burdens. The body of EJ knowledge has established that these historically minoritized communities in the US face disproportionately high environmental burdens (i.e., are overburdened).

In the State of Washington, the Healthy Environment for All (HEAL) Act provides an example of policy guidance that establishes a restorative equalization standard to address these harms. The **HEAL Act** was written to advance environmental justice (EJ) in the state through the restorative equalization policy goal of 40 percent of major agency expenditures going toward disadvantaged communities. Defining and identifying these communities is the ongoing effort of the HEAL Act implementation team and is a central consideration in the following sections 4.2 and 4.3.

4.2. COMMUNITIES OF CONCERN

"Communities of concern" is a concept that consistently arises in the transportation equity literature because identifying these communities allows analysts to measure and compare transportation outcomes between groups. For example, Bills and Walker (2017) presented their

equity analysis methodology in terms of a target group vs. a comparison group, the target group being a group facing some form of transportation equity burden. To identify which communities should be prioritized for transportation planning initiatives, first the relevant socio-economic attributes must be identified. The HEAL Act provides guidance for agencies in the State of Washington by defining communities of concern that must be considered by agency. It does not, however, claim this to be the full and complete list of communities that should be considered. The following sections present the HEAL Act definitions. These are followed by communities of concern identified in the transportation equity literature, why, they relate to the HEAL Act, and how. Of the 110 articles reviewed, 64 provided community of concern classifications.

4.2.a. As defined by the HEAL Act

The HEAL Act provides the following definitions for overburdened and vulnerable groups:

(11) "**Overburdened community**" means a geographic area where vulnerable populations face combined, multiple environmental harms and health impacts, and includes, but is not limited to, highly impacted communities as defined in RCW 19.405.020.

(14)(a) "**Vulnerable populations**" means population groups that are more likely to be at higher risk for poor health outcomes in response to environmental harms, due to:

(i) Adverse socioeconomic factors, such as unemployment, high housing and transportation costs relative to income, limited access to nutritious food and adequate health care, linguistic isolation, and other factors that negatively affect health outcomes and increase vulnerability to the effects of environmental harms; and

(ii) sensitivity factors, such as low birth weight and higher rates of hospitalization.

(b) "Vulnerable populations" includes, but is not limited to:

(i) Racial or ethnic minorities;

(ii) Low-income populations;

(iii) Populations disproportionately impacted by environmental harms; and

(iv) Populations of workers experiencing environmental harms.

(RCW 70A.02.010)

"**Highly impacted community**" means a community designated by the Department of Health based on cumulative impact analyses in RCW 19.405.140 or a community located in census tracts that are fully or partially on "Indian[1] country" as defined in 18 U.S.C. Sec. 1151 (RCW 19.405.020 (23)).

The legal definitions of over-burdened, highly impacted, and vulnerable communities explicitly reference tribal communities and provide the minimum guidelines for communities that must be considered under the HEAL Act. However, these definitions also recognize that the given list is not exhaustive and leave space for agencies to expand on these attributes as necessary. Sixty-four of the transportation equity articles reviewed included lists of relevant socio-economic variables, some simply as lists (ex: review and community engagement articles) and others as quantified components of analysis. Table 4.1 presents socio-economic variables found in the transportation equity literature and how they relate to HEAL Act definitions.

Table 4.1. Communities of concern identified in the transportation equity literature, rationale, and their relationship to the HEAL Act.

Variable	Communities of Concern	Measures	Transportation concern	Reason for concern	Frequency of use in Lit.	Defined in HEAL Act
Age	children, young people	<5yo, <19yo	exposure to high levels of ambient noise	significant deficits in cognition, memory, and executive functions	39%	"other factors"
	children, the elderly	<5yo, >= 60, 64, 65, 70yo (varies)	exposure to high levels of air pollutants	at higher risk for morbidities		
			experiences of traffic collisions	disproportionately high		

[1] While the word "Indian" is used extensively in US legal documents, individuals who are not First Nations tribal members should not use the word "Indian." The one exception may occur when the word "Indian" is included in the full name of a First Nations tribe, such as the Quinault Indian Nation. Even then, Quinault Indian Nation is typically referenced by its acronym (QIN) in tribal and other official documents (Quinault Indian Nation, n.d.). While "First Nations," "indigenous," and "tribal" are appropriate terms, whenever more focused analysis occurs (ex: corridor planning), it is most appropriate to refer to relevant tribes by name. There are 29 federally recognized tribes throughout the State of Washington, as well as three non-federally recognized tribes (American Library Association, n.d.). Each tribe is a sovereign nation with varied cultural heritage, native lands, and treaty rights at the federal level. To navigate intergovernmental relationships with appropriate respect and in alignment with federal law, WSDOT has Tribal Liaisons on staff.

Variable	Communities of Concern	Measures	Transportation concern	Reason for concern	Frequency of use in Lit.	Defined in HEAL Act
			limited access to private vehicle, spatially diverse activities, reliance on transit	increased experience of social isolation		
			difficulties navigating hostile traffic environments	restricted ability to travel		
	the elderly	>= 60, 64, 65, 70yo (varies)	concerns & feelings regarding traffic safety			
Ability	people who are physically or mentally impaired (disabled)	census or other survey responses % for permanent disabilities	experiences of traffic collisions	at increased risk of traffic injuries and fatalities	22%	"other factors"
			inaccessible design of street environment and public transport vehicles	severely restricted ability to travel		
			lack of information necessary to identify traversable routes			
			negative attitudes of drivers and passengers alighting transit vehicles			
			limited access to private vehicle, spatially diverse activities, reliance on transit	increased experience of social isolation		
			tend to be dependent on	transportation costs tend to		

Variable	Communities of Concern	Measures	Transportation concern	Reason for concern	Frequency of use in Lit.	Defined in HEAL Act
			more-expensive modes	make up a disproportionately high cost of living		
			more likely to travel during off-peak periods	disproportionately large amounts of time spent in transit		
Gender & Sexuality	women	census or other survey responses %	more likely to serve as caregivers and travel during off-peak periods	disproportionately large amounts of time spent in transit	19%	"other factors"
	women & LGBTQ+		experiences of sexual harassment while traveling	disproportionately high		
			concerns & feelings regarding traffic safety	restricted ability to travel		
Race & Ethnicity	people of color (Black, Hispanic non-white, American Indian or Alaskan native, Asian or Pacific Islander, multiracial)	>= 50% or >70% PoC (by area or elementary school enrollments)	higher exposure to heavily trafficked roadways	increased risk of negative health and safety externalities	31%	yes
			exposure to high levels of air pollutants	disproportionately high		
			experiences of traffic collisions	disproportionately high		
			limited access to private vehicle, spatially diverse activities, reliance on transit	increased experience of social isolation		
Language	% of people who speak another language at home and who	census or school recorded %	tend to have more difficulty navigating transportation system	increased experience of social isolation	5%	yes

Variable	Communities of Concern	Measures	Transportation concern	Reason for concern	Frequency of use in Lit.	Defined in HEAL Act
	speak English "less than very well"		see Race & Ethnicity concerns			
Income	people who are lower-income	<= poverty line or a regional-specific value related to median and/or quantiles	higher exposure to heavily trafficked roadways	increased risk of negative health and safety externalities	66%	yes
			limited access to private vehicle, spatially diverse activities, reliance on transit	increased experience of social isolation		
			affordability of available modes	transportation costs tend to make up a disproportionately high cost of living		
			experiences of benefits of shared mobility	disproportionately low		
Credit	people who are unbanked	census or other survey responses %	access to payment methods for trips	likely to experience lower levels of access	2%	no
Employment Status	people who are students or unemployed		reliance on transit services in remote locations and during off-peak operating hours	disproportionately large amounts of time spent in transit that can affect ability to earn or retain employment	16%	yes
Job Type	people who work low-paying/deemed "low-skill" jobs	census by industry sector (LODEs data) %			9%	"workers experiencing environmental harms"
Educational Attainment	people with high school as highest level	census or other survey responses %	experiences of traffic collisions	at increased risk of traffic injuries and fatalities	6%	no
			experiences of benefits of shared mobility	disproportionately low		

Variable	Communities of Concern	Measures	Transportation concern	Reason for concern	Frequency of use in Lit.	Defined in HEAL Act
Cost of Living	people facing high housing and transportation costs relative to income	census or other survey responses % OR % rent-burdened households (>= 30% income spent on rent)	affordability of transportation & housing	potential for displacement due to rising housing costs in high-growth areas	11%	yes
Household Composition & Marital Status	varies (single parent, divorced households)	varies	varies	varies	14%	no

4.2.b. As Defined by the Transportation Equity Literature

The longest list of transportation concerns is associated with the variable of ability and the community of concern: people who are physically or mentally disabled. It is important to note that experiences of disability can be permanent or temporary; while much of the literature is concerned with identifying individuals with permanent disabilities, this undervalues the breadth of experience captured by this variable. Immigration status was mentioned in one paper reviewed, but the relevant concern (linguistic isolation) is more precisely covered by a measure of language use in the household. Variables related to household composition and marital status were included in 14 percent of the 64 articles, but the details and specifications varied widely. Like immigration status, this suggests that the variation found in these social attributes may simply duplicate elements more precisely measured and more directly associated with transportation outcomes. For example, a single parent household is more likely to have only one earner supporting one or more children. This earner may be classified as low-income, or they may not; the variable for income is more directly related to transportation outcomes and is directly measured. However, in studies of transportation behavior, a single parent may combine trips and broadly exhibit different travel patterns relative to other types of households.

Social exclusion is defined as a "constraints-based process which causes individuals or groups not to participate in the normal activities of the society in which they are residents and has important spatial manifestations." (Preston and Raje, 2007). Although employment is an important component of social inclusion, the concept of social exclusion encompasses a wider set of attributes, such as participation in cultural and leisure activities, political engagement, and social networks. (Currie and Delbosc, 2010) (Boisjoly and El-Geneidy, 2021, p. 226)

It is also important to recognize that the lived experience of individuals within any given socio-economic category can vary tremendously. For example, while elderly individuals tend to experience lower rates of accessibility, this varies dramatically depending on the ability (physical and mental), race, ethnicity, English proficiency, income, transportation resources, and residential location of any given elderly individual. If the goal is to capture the diverse breadth of transportation experience and associated equity, then focusing on any one socio-economic variable or category will not provide the depth of information necessary to accomplish this.

Kimberle Crenshaw introduced the concept of intersectionality to identify the ways that the intersection of marginalized identities leads to a compounding experience of marginalization (Carbado et al., 2013). Her work used case law to demonstrate that Black women, when considered by just their racial identity (Black), or by just their gender identity (woman), were not perceived as facing statistically significant burdens; companies hired racially proportionate numbers of Black workers or offered equal pay to women. However, when considering the intersection of their racial and gender identities, Black women did, indeed, face both disproportionately lower job offers and wages.

Sider et al. (2015) recommended and developed a context-specific composite variable of socio-demographic need they refered to as a Social Deprivation Index (SDI). The SDI considers unemployment rate, immigration rate, percentage of income spent on rent, and median income for all traffic analysis zones in the Montreal Metropolitan Area. A full list of composite indicators is included in Section 4.4.1, the Accessibility indicators subsection.

4.3. UNITS OF ANALYSIS: BENEFITS AND POTENTIAL PITFALLS

One of the primary debates in current transportation equity discourse is the question of units: do you perform an equity analysis at the individual level or at the communal/spatial level? The two analysis types vary tremendously in data requirements, computational complexity, and accuracy and precision of results. Each type has its benefits and pitfalls that must be understood

and either compared against available resources or used to guide necessary funding allocation to acquire or develop the resources necessary. This section outlines the differences between the two types of measures and presents common spatial units of analysis.

4.3.a. Person vs. Place

Place-based measures account for an attribute or phenomenon relative to its location in space. For example, air pollutants can be measured by their concentration in a census block group. In contrast, person-based measures account for attributes specific to individuals. For example, satisfaction with a transportation facility would have to be measured on a person-by-person basis.

An associated concept within the transportation equity literature is the distinction between horizontal and vertical equity. These terms, however, are imprecise and have led to conceptual confusion (Lewis et al., 2021). Most commonly, these terms are used to differentiate between analyses that consider distributions of benefits and burdens by spatial units (horizontal) or by socio-economic attributes (vertical). For example, an analysis that measured the distribution of a bike share fleet by neighborhood (or census block or tract or any spatial unit of analysis) would be classified as horizontal equity, whereas an analysis that considered bike share user registrations and trip characteristics by race (or gender or income or any socio-economic variable of interest) would be classified as vertical equity. Additionally, socio-economic variables can be expressed in terms of spatial units (ex: percentage race by category by census tract). In this report, these concepts are broken out and named precisely; units measure spatial (place) or individual (person) characteristics, and equity analyses can pertain to spatial and/or socio-economic equity considerations.

Siddiq and Taylor (2021) found that, of 54 accessibility tools analyzed, the vast majority (36) were place-based, nine were person-based, and nine offered a combination of place- and person-based approaches. Only five tools were packaged and readily available for use in planning applications; of those five, all were useful for planning (rather than project) efforts, and all were place-based only. This corresponds to the tendency toward more simplistic, lower data and analytical efforts.

Such simplified measures, however, are subject to a few issues. First, overly simple methods risk fake precision. **Fake precision** (or over-precision or spurious precision) occurs when detailed values are used to represent calculations and data that are not very precise to begin

with. These detailed values can give the appearance of precision and cause overconfidence in results that may misrepresent the reality and ultimately lead to skewed equity analyses (Fransen and Farber, 2019). Another source of concern is the potential of ecological fallacy. **Ecological fallacy** occurs when all individuals living in the same area are assumed to have the same attributes and experiences. For example, a rural census tract could include a high percentage of older individuals. As Table 4.1 shows, older individuals face an array of transportation risks such as limited access to private vehicles. It would be an ecological fallacy, however, to assume that every person aged 60 years and older does not have access to a private vehicle.

Fransen and Farber (2019) recognized that person-based measures require "a collection of elaborate" data sets of individual travel behaviors, detailed data related to the transport network, and computationally complex models. Nevertheless, they still argued that the "benefits outweigh the costs" and that person-based measures are "vital in counteracting the phenomenon of transport poverty and social exclusion" (p 68). Miller (2018) also argued in favor of person-based utility measures while acknowledging that current tools will need significant refinement before becoming widely operational. Fransen and Farber (2019) also noted, however, that person-based measures present a composite score of place- and person-based contributions that are difficult to disentangle and isolate. Levine et al. (2019) argued that person-based measures will never be viable for longer-range planning efforts because they require too many assumptions about the attributes of future residents, which can also risk fake precision.

A recent NCHRP report presented a comprehensive list of accessibility measure types as those detailed in Table 4.7. (Karner et al., 2022) Another practice-focused report focused on the accessibility measures they deemed most applicable in a planning context: place-based (or spatial) measures (Sundquist et al., 2021). They argued that spatial measures offer the most readily available application of accessibility for planning purposes, and they provide a solid foundation on which additional accessibility concepts such as considerations of time, cost, and competition can build. Regardless of the method chosen, it is critical to remember that objective measures such as these always risk misrepresenting the lived experiences of the traveling public, and especially those that fall into the category of communities of concern. It is therefore imperative for agencies to always assume community engagement as a given, required analysis cost and to select additional units of analysis and analytical methods accordingly.

4.3.b. Spatial Units

The two main types of geospatial information system (GIS) analysis are vector and raster analysis. Raster analysis is based on values assigned to pixels of areal or satellite photographs. Vector analysis relies on shapefiles that can contain either points, lines, or polygons. While rasters, points, and lines all have potential applications in transportation GIS analyses, this section focuses on polygons, or areal spatial units of analysis (shortened to spatial units in this document). These vector, polygonal, spatial units of analysis are used to measure and describe attributes distributed over an area.

Figure 4.1 presents the hierarchy of spatial units of analysis by number of people represented and associated levels of detail and aggregation. Arrows denote how each unit relates to others, as does color; green is used for spatial units generated by or that align with US Census Bureau (USCB) units. For example, contiguous census block groups create a census tract, contiguous census tracts create counties. PUMAs are Public Use Microdata Areas and correspond to Public Use Microdata Sample (PUMS) data sets generated by the USCB for each calendar year. The PUMS data set provides a representative sample of long-form American Community Survey (ACS) responses over areas that encompass multiple census tracts to provide detailed data while maintaining the privacy of respondents. Similar to counties, they comprise tracts, but they do not necessarily align with county boundaries. The red lines highlight person-based units and how PUMAs can be used to disaggregate aggregated spatial data using a method called population synthesis (Bills, 2022).

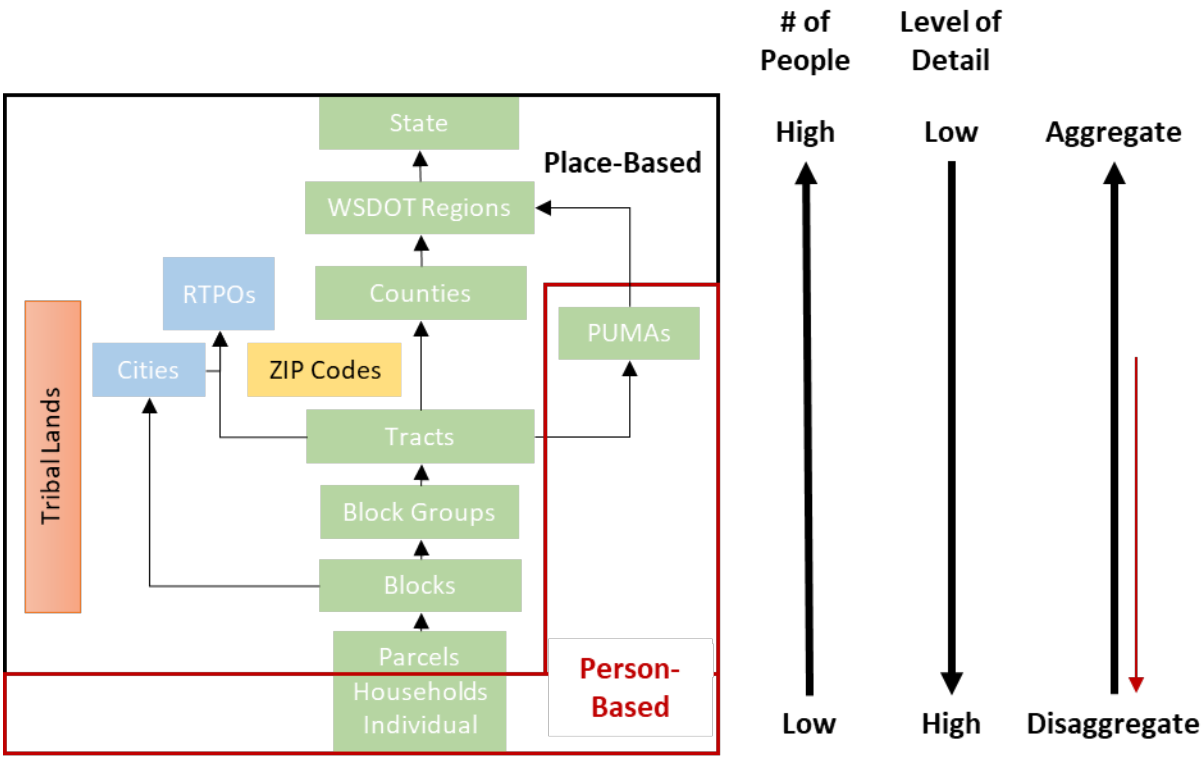


Figure 4.1. Levels of data aggregation and associated spatial units of analysis.

Non-USCB spatial unit types include Tribal lands, cities, regional transportation planning organizations (RTPOs), and postal Zone Improvement Plan (ZIP) codes. Tribal lands and ZIP codes are the product of federal negotiations and postal service operations (respectively) and do not relate to USCB boundaries. Cities comprise census blocks, but their boundaries may overlap with rather than contain larger-scale USCB boundaries. RTPOs contain city boundaries, but (at least in the State of Washington) they correspond to broader USCB tracts for the areas surrounding city limits.

The selection of the appropriate spatial unit(s) of analysis often depends on the data available. Still, appropriate spatial scale is important to consider. The **modifiable areal unit problem (MAUP)** is a phenomenon similar to the ecological fallacy; findings at more aggregate levels (i.e., large areas with less detail) may not reflect the reality at a more disaggregate level (i.e., small areas with more detail). In the case of environmental justice analyses, smaller spatial scales tend to reveal greater environmental disparities and burdens than analyses at higher scales (ex: areas surrounding roadways vs. aggregated over census tracts) (Mohai et al., 2009). However, transportation equity researchers have found that, depending on the spatial unit of

analysis, the outcome of an equity analysis could flip from a positive to a negative outcome (van Wee and de Jong, 2023).

Generally, analyses that begin with more disaggregate data (i.e., values presented relative to a smaller spatial scale) tend to yield better results because they allow for more precise measurements that do not risk ecological fallacy. As long as samples are representative of larger areas of interest, the risk of MAUP is also low. However, with rural areas, a new issue arises. Because rural areas are so sparsely populated, using smaller spatial scales can skew results because there are not enough observations of all variables of interest in a given area (Karner, 2016). For example, cases of asthma in low-income children in a rural area may be difficult to measure at a small spatial scale because some areas may not contain enough or even any children who are low-income to complete the analysis. This can lead to extreme values suggesting either no air quality issue for low-income children or an extreme issue because there is one child with comorbidities that skews results to the higher extreme. It is therefore important to carefully assess not only what data are available but their quantity and quality; while some data may exist, they may not be sufficient to answer a detailed question.

The Environmental Health Disparities (EHD) tool presents data at the census tract level for this reason. However, while the use of tract-level data protects against fake precision, extreme misrepresentation, or missing data, it provides data only at a highly aggregate, limited detail scale. The creators of the tool recognize this limitation and emphasize the importance of using the EHD as a first step in identifying areas and communities of concern. To avoid ecological fallacies, they encourage agency staff to remain critical and utilize other methods such as community engagement to inform action.

4.3.c. Recommended Application of Environmental Health Disparities (EHD) Map and Similar Tools: Cumulative Impact Indices

One way that spatial data are used to perform equity analyses is in **cumulative impact indices**. This subsection provides a summary of the geospatial analyses associated with the broader EiP research project. Specifically, this section summarizes the findings associated with the following two questions:

- Are existing cumulative impact indices more likely to designate urban tracts as disadvantaged than rural tracts?
- How should practitioners approach existing indices?

More details about the analysis can be found in Appendix C, and the full analysis can be found in Chapter 3 of Lewis (2024).

Cumulative impact indicators (or **indices**) convert any set of variables deemed relevant measures of interest into a single, composite value that can be used to measure relative disadvantage over a region or between groups. Variable selection depends on the goal of a given index, but for publicly maintained indices, data must be readily available and regularly maintained (Lee, 2021). Indices follow a common set of methodological components that determine their structure: data re-scaling, weights, hierarchy, and aggregation (Nardo, 2005).

For each methodological component, a decision must be made regarding which mathematical method will be applied. For example, data re-scaling could involve z-score normalization, min-max scaling, decile ranking, or any number of other methods. Once all analytical decisions had been made and a single, composite score has been calculated, scores can either provide a range of (dis)advantage from least to most, or a threshold value can be applied to the distribution to yield disadvantaged/not disadvantaged assignments.

The Environmental Health Disparities (EHD) Map is a Washington State Department of Health (DoH) data product that was developed as part of the HEAL Act implementation process (WSIPP, 2022). The Equitable Transportation Community (ETC) Explorer tool was developed by the U.S. Department of Transportation (USDOT) as part of Executive Order 14008 and the associated Justice40 initiative to curb climate change and address EJ issues at the federal level (OST, 2023). Both indices offer a single, composite value based on readily accessible and regularly updated spatial data used as a proxy for disadvantage. Once scores and rank-based values have been calculated, both apply threshold values (60th and 80th percentile for the EHD and 65th percentile for the ETC) to ultimately designate a tract as disadvantaged or not. These designations are then used to inform prioritization decisions related to funding and programs.

The EHD and ETC were selected from a broader list of cumulative impact indices developed and maintained by public entities in the US, which are detailed in Table 4.2. The EHD and ETC were selected for further analysis on the basis of their relevance to transportation equity. More details about the analysis can be found in Appendix C, and the full analysis can be found in Chapter 3 of Lewis (2024).

Table 4.2. Summary of cumulative impact indices developed and maintained by public entities in the US.

Developed and Maintained by	Name(s)	Purpose	Citation
Center for Disease Control, Agency for Toxic Substances and Disease Registry (CDC/ATSDR)	Social Vulnerability Index (SVI)	EJ Disaster risk assessment and management	(Flanagan et al., 2011; GRASP, 2022)
CDC/ATSDR	Environmental Justice Index (EJI)	EJ disadvantage screening	(McKenzie et al., 2022)
White House Council of Environmental Equity (CEQ)	Climate & Economic Justice Screening Tool (CEJST)	Climate & Economic disadvantage screening	(White House CEQ, 2022)
Environmental Protection Agency (EPA)	Environmental Justice Screening Tool (EJScreen)	EJ disadvantage screening	(OEJECR, 2023)
Federal Emergency Management Agency (FEMA)	National Risk Index (NRI)	EJ Disaster risk assessment and management	(Zuzak et al., 2023)
United States Department of Transportation (USDOT)	Equitable Transportation Community (ETC) Explorer	Transportation, Climate & Economic disadvantage screening	(OST, 2023)
Washington Department of Health (WA-DOH)	Environmental Health Disparities (EHD) Map	EJ disadvantage screening	(Min et al., 2019; UW-DEOHS, 2019)
University of Wisconsin Center for Health Disparities Research (CHDR)	Singh's Area Deprivation Index (ADI)	Community disadvantage indicator for regression analyses	(Singh, 2003; Kind et al., 2014)

The analysis of the EHD and the ETC found that both indices are more likely to classify urban tracts as disadvantaged than rural tracts. This remained true over 13 different calculation iterations for each index, although the magnitude of urban disadvantage assignment varied from only two times more likely to nearly 50 times more likely. Iterations were based on variations in choice in the mathematical methods used to calculate indices. All iterations relied on the same basic component structure and simply varied the analytical choice at each stage. For example, different iterations used the data rescaling techniques of z-score normalization, min-max scaling, and decile ranking. Each iteration was based on a variation in analytical choices that were all valid and that had all been used in cumulative index specification.

Figure 4.2 presents the 2020 census tracts in terms of whether they were classified as disadvantaged by either of the indices, both indices, or neither under any iteration of mathematical choices. Additional figures are included in Appendix C, which show the number of times a tract was classified as disadvantaged (ranging from 0 to 13) and the range of values

calculated for each tract (i.e., the difference between the maximum iteration value and the minimum). Taken together, they demonstrate that the tracts that were most consistently classified as disadvantaged with the least variation in scores were the urban tracts. Figure 4.2 shows most urban tracts classified as disadvantaged at least once by both indices, while more variation exists in the rural tracts.

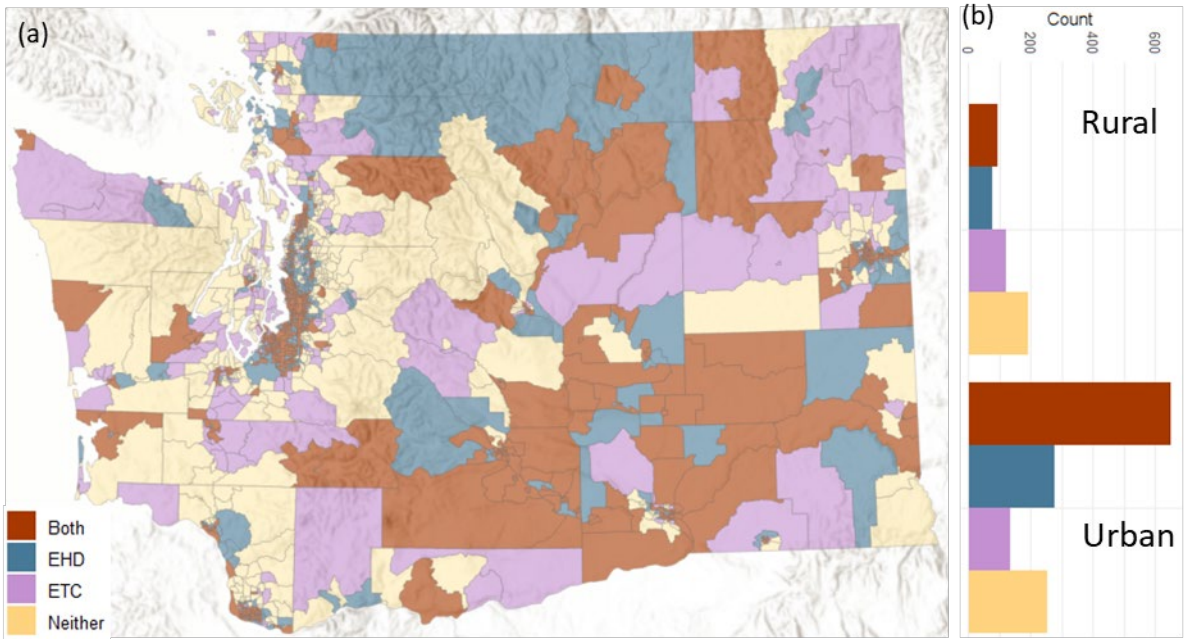


Figure 4.2. Tracts classified as disadvantaged given any of the 13 iterations at the top 40% threshold for EHD and 65th percentile threshold for ETC by inclusion type (a) mapped (b) by tract type.

Cumulative impact indices offer a useful first step in the process of assessing disadvantage and associated resource allocation. For the areas that are consistently classified as not disadvantaged, it is likely fair to assume that there are areas in greater need. For areas that are consistently classified as disadvantaged, it is likely fair to assume that these areas should be treated as top priority locations. It is the areas in-between the far ends of the distribution where cumulative impact indices become most sensitive and deserve the highest scrutiny. Or, more specifically, decisions regarding an area's status of relative disadvantage deserve more careful consideration in the form of additional analytical steps.

Presumably the more consistently a tract is classified as disadvantaged, the more likely the disadvantage classification reflects a disadvantaged reality. However, at this level of data aggregation, it is not possible to definitively determine whether the more variable tracts (i.e.,

those that are sometimes classified as disadvantaged but sometimes not) are indeed more or less disadvantaged than other variable tracts. Classifying these tracts as definitively not disadvantaged based on a single index or even a single version of the possible ways an index could be calculated runs a distinct risk of screening out disadvantaged areas with a just claim to fund allocation. Screening such areas on the basis of a single method would be disingenuous to the broader effort of equitable consideration when many assignments could be based more on methodological artefacts than an accurate representation of disadvantage.

This limitation is recognized in the materials used to document and present every index identified in this article. The EPA's EJScreen documentation clearly states that the tool should not be used as the sole arbiter of EJ status for areas or communities (OEJECR, 2023). The WA EHD is similarly presented as a first step in an EJ screening process and not a definitive end-all-be-all scoring system (UW-DEOHS, 2019; WSIPP, 2022). This can be difficult to reconcile with the reality that tools such as Washington's EHD have been developed with considerable public engagement and have received buy-in across state actors, boards, and citizen groups (UW-DEOHS, 2019). However, the use of multiple tools to screen areas based on cumulative impacts has precedent. The USDOT's ETC is explicitly intended for use in conjunction with the White House's Council on Environmental Equity's (CEQ) Climate and Economic Justice Screening Tool (CEJST) (OST, 2023), and Lee's (2021) found that EJ assessments tend to be completed with a combination of the Environmental Protection Agency's (EPA) EJScreen and a state's version of CalEnviroScreen. In the State of Washinton, this is the EHD (WSIPP, 2022).

Figure 4.3 presents a decision tree to guide practitioners on how to utilize the existing indices identified in Table 4.3. Because different indices include and present different types, sources, and aggregations of data all relevant to the overarching concept of cumulative disadvantage, different situations may call for different processes and considerations. The designations of federal and state maintenance are not intended to dissuade a practitioner from using a tool but simply to note jurisdiction. An exception to this is Tribal lands.

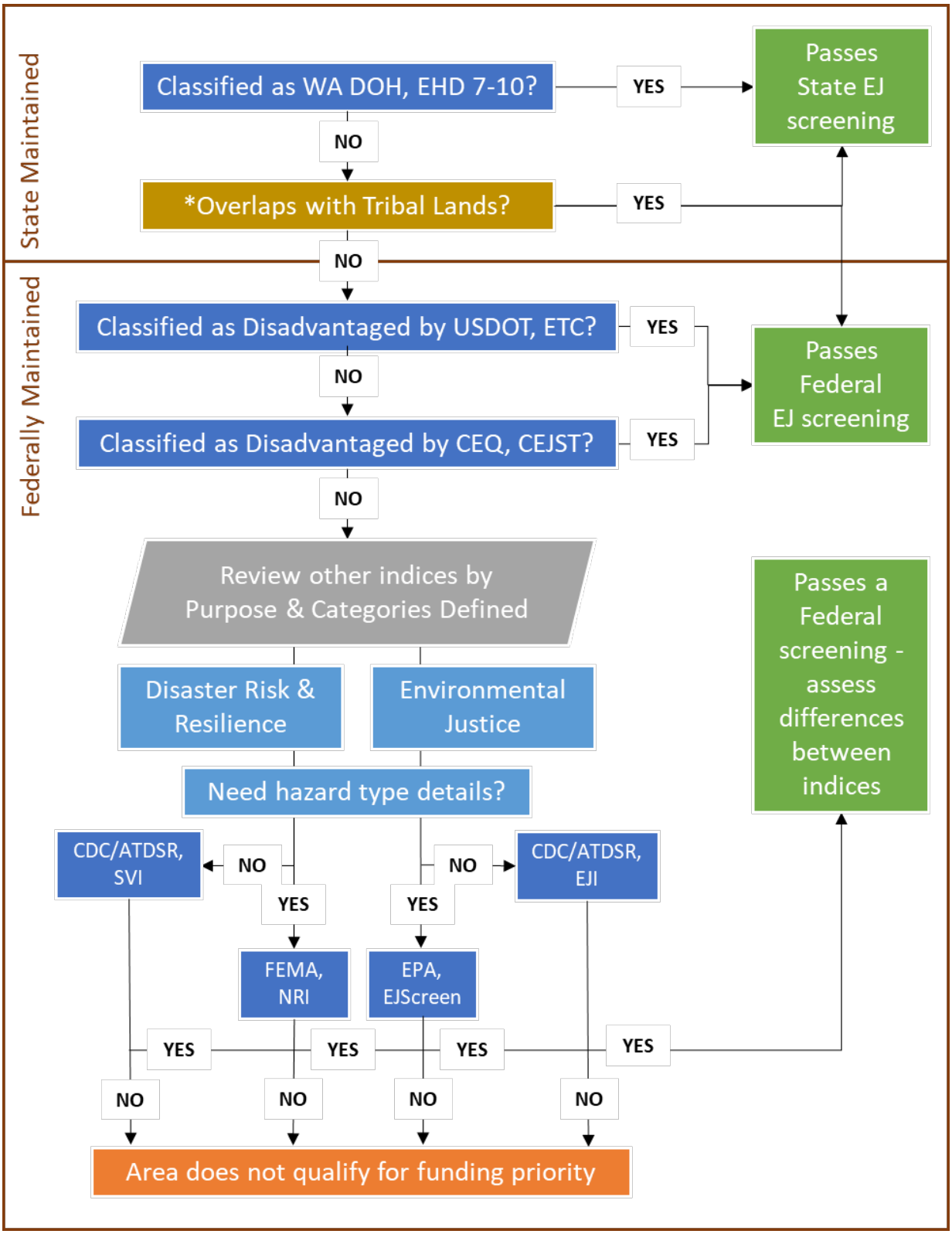


Figure 4.3. Recommended process of cumulative impact index application to determine whether an area qualifies for equity-oriented funding priority. *Seek local guidance regarding Tribal land designations and appropriate applications relative to census TIGER/Lines.

Federally recognized Tribal Nations have treaties with the US federal government and are recognized as sovereign, domestic dependent nations. Because Tribal lands exist within state jurisdictions managed by state entities, agencies such as WSDOT engage with Tribal Liaisons to ensure proper governmental compliance when working with Tribal Nations. According to both the Washington state HEAL Act and federal definitions of overburdened communities, Tribal lands are automatically assigned a disadvantage status.

However, since Tribal lands are not contiguous with census area TIGER/Lines, there is ongoing discussion regarding how to associate Tribal land and census tract disadvantage assignment. The central consideration is the difference between where people's homes are located and where they travel on a daily basis. Tribal members who live on Tribal lands may move about their daily lives exclusively on the reservation or beyond it; this represents a quintessential person vs. place units of analysis conflict.

The National Risk Index (NRI) of the Federal Emergency Management Agency (FEMA) attempts to account for this by assigning Tribal land status (and associated top risk rating) for tracts that overlap with or are adjacent to tracts that overlap with reservations (Zuzak et al., 2023). This can expand the disadvantaged area associated with Tribal lands from a relatively small reservation to multiple, typically large surrounding rural tracts. Whether this tract-based expansion of Tribal land is best to determine disadvantage or other methods are better (such as accessibility-based buffer zone alternatives – see Section 4.4.a) is open to consideration. It is therefore best to seek local guidance regarding Tribal lands. In the State of Washington, authoritative geospatial data files concerning Tribal lands are maintained by the Department of Ecology and accessible via the Washington State Geospatial Open Data Portal.

Ultimately, the Figure 4.3 decision tree provides a process to guide WSDOT planners in working through a series of readily available and governmentally recognized tools to screen areas for disadvantage priority. Specifically, the process recommended aligns with current HEAL Act working group recommendations.

4.4. INDICATORS

Over 100 scholarly articles pertaining to transportation equity planning indicators were reviewed to inform the summary tables presented in this section. These included several literature review articles and a community engagement article in which the authors identified

organizational structures to summarize different types of transportation equity metrics as presented in Table 4.3. These categorizations informed the structure of this report.

Table 4.3. Metric classifications by review article.

Citation	Dimensions	Description
van Wee and Mouter (2021)	Accessibility Safety the Environment	Review of transportation equity evaluation methods in academic literature
Heyer et al. (2020)	Accessibility/Mobility Health (traffic-related air pollution exposure) Distribution of transit funds Potential for Displacement (housing and transportation affordability)	Review of transportation equity metrics used by MPOs in Regional Transportation Plans
Guo et al. (2020)	Accessibility Traffic emissions Safety outcomes	Review of transportation equity metrics in academic literature
Lucas and Martens (Eds.) (2019)	Benefits: Accessibility Burdens: Pollution, Safety, Health Social Outcomes	Section organization of book on Measuring Transport Equity
Martens et al. (2019)	Resources Opportunities/Risks Outcomes Well-being	Focal Variable of transportation equity measures given a review of transportation equity evaluation methods
Boisjoly and Yengoh (2017)	Transportation infrastructure and services Impacts (burdens of transportation) Places Groups	Community engagement to identify transportation issues important to community members:
Bajada et al. (2016)	Meso (physical & online infrastructure) Micro (ability to move easily in system)	Public transport infrastructure equity analysis

For this report, indicators were recorded and classified by characteristics such as what is measured, transportation components considered, and inferred analysis type. These classifications, their categories, andtheir definitions are provided in Table 4.4.

Table 4.4. Metric type classifications used to structure indicator organization.

Classification	Category	Accounts for..
What is measured	Access	how people access destinations and services
	Mobility	how people and goods move through the transport system

Classification	Category	Accounts for..
	Environment	how transport externalities interact with environmental considerations
	Health	how transport externalities interact with human health
	Safety	how transport externalities interact with human safety (collisions)
	Economy	how transportation interacts with economic considerations
Transport Components	Fleet	vehicles in the transport system
	Facility	transportation facilities used by individuals and vehicles
	Service	transportation services
	Land Use	various land uses that interact with transportation components
	Finance	funding of transportation components
	Policy	guiding requirements and expectations, legal or otherwise
	Engagement	community and stakeholder interactions
Inferred Analysis	Summary	values that provide an overview, aggregate data point
	Place-based	values derived from geospatial analysis (GIS)
	Person-based	values derived from individual-level, highly disaggregate data

The tables further summarizing the indicators by sub-category are broken out by categories of what is measured. Over 40 percent of the indicators were classified as accessibility, and just under 40 percent were classified as mobility. Because measures of mobility are needed to specify the spatial component of accessibility, many articles included both types of indicators. From there, nearly 10 percent considered the environment, 15 percent considered health, 10 percent considered safety, and nearly 35 percent considered economy. Economic indicators were often combined with mobility and/or accessibility indicators, whereas indicators related to the environment, health, and safety tended to arise in separate articles. The exception were articles that based their findings on stakeholder interviews (Lowe, 2014; Boisjoly and Yengoh, 2017; Karner and Marcantonio, 2018; Boisjoly and El-Geneidy, 2021) or that provided a review of other research articles (see Table 4.3).

Although accessibility as a concept has existed in the transportation lexicon since the mid-20th century (Hansen, 1959), accessibility measures are still in their infancy and diverse in nature. They are therefore given their own Accessibility subsection. Because accessibility indicators are specified with some combination of mobility, economy, and land-use indicators, these sub-subsections follow the Accessibility subsection. While economic indicators can be found in most of the indicator subsections, the majority of the overlap occurs with mobility indicators; thus the combined subsection of Mobility and Economy.

These are followed by a subsection for Environment, Health and Safety as well as a subsection summarizing indicators of Qualitative and Engagement measurement. Environment measures in the transportation equity literature are almost exclusively concerned with human health impacts, making these two categories a natural combination. Safety is another indicator that can be found interspersed throughout the other subsections, but collision-specific measures are included in the Environment, Health and Safety subsection. Finally, qualitative measures cover all other categories and are often associated with measures of engagement efforts; thus the combination of these categories from separate classifications.

The transport component categories are used as subcategories within relevant tables. For example, the Mobility and Economy table (Table 4.9) comprises predominantly fleet-based and facility-based subcategories used to organize the indicators summarized. The other transport component categories are similarly utilized throughout the other tables. The inferred analysis categories are not broken out in the tables, but it is interesting to note that of the 380 indicators 28 percent are summary, 55 percent are place-based, and 18 percent are person-based. This aligns with the place vs. person units of analysis findings.

4.4.a. Accessibility

Accessibility measures make up nearly half of the transportation equity literature. This is because accessibility is a critical indicator type with many applications as a leading indicator of transportation equity. Section 4.4.a.i defines the concept of accessibility, the metric types and organizational frameworks developed to help structure the concept, and data requirements to specify the different types of measures. This is followed by a detailed list of accessibility indicators by type and their utility as leading and lagging indicators of transportation equity. The final three sub-subsections provide details concerning types of thresholds commonly used in accessibility metric specifications: spatial, temporal, and speed.

4.4.a.i. Defining the Concept of Accessibility, Metric Types, and Data Requirements

Hansen's (1959) seminal article on the relationship between transportation and land use defined accessibility as "the spatial distribution of activities about a point, adjusted for the ability and the desire of people … to overcome spatial separation" (p. 73).

While simply stated, the concept of accessibility has proved difficult to operationalize because of its multi-faceted nature. Until recently, the computational power required to analyze the relationship between users, time, the transportation system, and land uses at scale did not

exist. While the necessary computing power does exist now, readily applicable tools are still a work in progress. To meet a reasonable level of conceptual completeness, an accessibility analysis tool "should account for many of the most important factors thought to affect accessibility, be able to depict accessibility at both the individual and spatially aggregated levels, draw on widely available data, and be relatively easy to use and intuitive to understand" (Siddiq and Taylor, 2021, p. 505). Currently no such tool exists.

As a result, many different types of accessibility measures have been proposed, and even fewer are in-use by agencies and practitioners. Table 4.5 presents review articles dealing with transportation equity and the categories they have used to organize the concept and associated measures of accessibility. In addition to the academic literature review, practice-oriented reports were also consulted for this section. The dimensions identified in the recent NCHRP report by Karner et al. (2022) were used as the primary organizational structure for the accessibility indicators presented in this report. While the focus of this report is summary and place-based measures, Karner et al.'s (2022) category of "Trip Characteristics" provides a section for temporal constraints and beyond.

Table 4.5. Accessibility measure classifications by review article.

Citation	Categories	Description
Karner et al. (2022)	• Proximity; • Access to opportunities; • Competitive; • Trip Characteristics; • Potential Path Areas; • Logsums; • Conceptual; • Qualitative; • Other	NCHRP Report on accessibility measures in practice
Siddiq and Taylor (2021).	Place-based: • Cumulative Opportunities • Gravity Based Person-based: • Utility-based • Constraints-based	Critical review of accessibility measures
Guo et al. (2020)	• Coverage-based (service zone); • Reachability-based (ex: cumulative opportunities, negative exponential)	Review of transportation equity metrics in academic literature
Fransen and Farber (2019)	Place-based: • Spatial restrictions Person-based:	Argument and case demonstration for use on

Citation	Categories	Description
	• Temporal restrictions • Individual restrictions	person rather than place-based accessibility measures
Curl (2018)	• Time • Cost • Frequency • Quality • Comfort	Study of perceptions of accessibility and the disconnect between objective and subjective assessments
Caspi et al. (2012)	• Spatial • Availability • Affordability • Acceptability • Accommodation	Conceptual components of accessibility from a disabilities perspective
Lucas (2012)	• Individual • Land-use • Transportation • Temporal • Cognitive	Five conceptual components of Accessibility (building off of Geurs and van Wee (2004))
Lotfi and Koohsari (2009)	• infrastructure-based (mobility); • activity-based (macro: potential-accessibility, micro: time-space); • utility-based (economic)	Comparative analysis of objective vs. subjective assessments of accessibility

4.4.a.ii. Detailed List of Accessibility Measures and Their Relationship to Leading and Lagging Indicators

Table 4.6 summarizes the accessibility indicators identified in this literature review. The "Type" classifications draw primarily from Karner et al. (2022), with "Components" for each type drawing from structures from other review articles presented in Table 4.5, and specifically from Siddiq and Taylor (2021). The "Variations" column lists the indicators relevant to that type and component – different variations are all listed here. The "Mode Relevance" column identifies which modes, if any, are specifically covered by that subset of indicators. Finally, the "Leading when…" and "Lagging when…" columns identify the leading and lagging use cases for the given indicators.

The leading and lagging use case columns align with the definition of leading and lagging indicators presented at the beginning of this report. The use of the word "meaningful" follows the expectations set in Section 3.2; essentially, leading indicators of equity must prove that a proposed intervention has the potential to move the needle toward an established equity goal by

an appreciable amount in a timely manner. The projected outcomes of an intervention must meet these conditions to be considered meaningful.

NOTE: Physical accessibility considerations (i.e., ensuring ADA compliance) are covered in Section 4.4.b. Mobility and Economy.

Table 4.6. Accessibility measures and their potential as leading and lagging indicators of transportation equity.

Type	Components	Variations	Mode Relevance	Leading when..	Lagging when...
Proximity (coverage, service area, buffer)	distance threshold	Euclidean	any	projected increase in benefit areas and/or decrease in burden areas	measured
		network (by mode)			
		network (by type)			
	temporal threshold	based on assumed modal speed by mode type along a network			
	spatial statistics	clusters			
		kernel density			
		standard deviational ellipse			
Access to opportunities (points of interest, key destinations, peripheral destinations)	fixed temporal threshold	# of available destinations by type (cumulative access)	any	projected, meaningful increase	measured
		isochrone of accessible area			
	variable threshold	# of available destinations by type (gravity function, decay function)	any		
Trip Characteristics	safety	see other tables where safety is presented			
	temporal	in-vehicle/out-of-vehicle components[1]	any	projected, meaningful decrease	measured
		average trip time for required trips			
		congestion			
		trip time variation by time of day, week, and season			

Type	Components	Variations	Mode Relevance	Leading when..	Lagging when...
		experienced			
	cost	road-pricing schemes (ex: tolls)	private motorized	considered as components of affordability	
		parking			
		purchase price			
		insurance			
		maintenance			
		cost of fuel/energy			
		fare structure	service-based		
	affordability	transport costs as % of national median income	all	projected to be meaningfully more affordable	
		cost relative to household income			
		% household income spent on transport			
		payment plans			
		discounts or subsidies[2]			
	service	hours of operation	service-based	projected meaningful improvement	
		peak/off-peak[3] frequency			
		reliability			
		transfers			
		counts of available vehicles/access points			
		accessibility accommodations[4]			
		perceived			
	booking & payment	level of digitalization	service-based	projected to be meaningful accessible & accurate	
		off-line options			
		banking requirements			

Type	Components	Variations	Mode Relevance	Leading when..	Lagging when...
		pre-paid options			
		perceived ease (user experience)			
	reliable[5] traveler information	distance	any		
		routing alternatives			
		expected travel time			
		grade differential	private modes		
		facility type (ex: separations & restrictions)			
		pavement type			
		allowable speeds			
		parking locations			
		costs (ex: tolls, parking)			
		presence of stairs or steps	non-motorized		
		service locations	service-based (fixed-route[6])		
		wayfinding			
		service routes			
		service type	service-based (general)		
		service area			
		service timing			
		vehicle types			
		real-time vehicle locations			
		crowding			
		service cost			
		terms of agreement	service-based (on-demand/ shared[7])		
		derived activity area	any		measured

Type	Components	Variations	Mode Relevance	Leading when..	Lagging when...
Models & Microsimulations[8]	spatial components	tour-based accessibility		projected, meaningful increase	
		tour-level trip classifications			
		tour frequency			
	outcome measures	consumer benefits	any		
		consumer surplus			
		(dis)utility			
		logsum measures			
		value of time			
Composite (other)	Facility	walkability index	walk	used to inform meaningful, accessibility-focused interventions	measured
		bikeability index	cycling		
		index of network vulnerability and resilience	motorized		
		index of transportation connectivity	varies		
		multi-criteria index for mobility hub site selection	service-based		
	Service	new service viability index	service-based		
		public transport access			
		public transport need index			
		connecting power of a transit station			
		mode provision and vulnerability			
	Land use	index of land use intensity	N/A	used to inform meaningful, resilience-	
		index of resiliency			

Type	Components	Variations	Mode Relevance	Leading when..	Lagging when...
		comparative environmental risk index (CERI)		focused interventions	
		index of future growth potential			
		economic potential accessibility index			
	Justice	subgroup index of inequality	N/A	used to inform meaningful, accessibility-focused interventions	
		index of disadvantaged populations			
		socially relevant accessibility impacts	varies		
		bike equity index	cycling		
		transportation justice threshold index framework (TJTIF)	varies		
		Equitably Designed Network optimization			
		public transport need indicator (PTNI)	transit		
	Behavior	low automobility index	motorized		
		activity-weighted accessibility	any		
		social demand index			
	Engagement	enthusiasm index	any	used to inform engagement methods	
		dialogue quality index			

[1] in/out of vehicle time varies by mode: walk [access, egress], wait, transfer, park. Wait time can also be used as a proxy measure for supply of demand-responsive ridehail services when actual supply data are not available, as is often the case with major service providers such as Uber and Lyft (Guo et al., 2020)

[2] discounts and subsidies could be based on frequency of transit use or socio-dem characteristics. Ghasemlou et al. (2021) presented transit pass categories of normal, student, elderly, person w/ disabilities, and limited use

[3] recognizing that off-peak may look different for midday, nights, Saturdays, and Sundays and that service quality characteristics impact access potential

[4] see facilities and fleets for more details on accommodations

[5] reliable refers to accuracy, precision, and consistency of data coverage and access

[6] fixed-route: traditional transit
[7] on-demand/shared: bikeshare, carshare, ridehail, CAV
[8] because they often are concerned with modeling potential scenarios, they often report in changes - average change in

Both proximity and access to opportunities measures are place-based indicators and are the most common form of accessibility measures found in the literature. A wide range of trip characteristics can be measured and used to improve on these core place-based measures, as recommended in the SSTI report (Sundquist et al., 2021). The concept of affordability is particularly important as a measure of access; it comprises trip cost characteristics, but affordability measures account for more contextual information such as income and subsidies. Some affordability measures specified in the literature focus on transportation costs needed to reach basic, mandatory activities such as school and work. Some refer to this as commute burden or required trip burden. These analyses operate from a sufficiency lens and focus on the economic component of social life.

It is important to remember, however, that many more types of trips (ex: grocery, healthcare, recreation) are necessary to live a fulfilling life and that analyses that focus exclusively on accessibility from an economic lens tend to overlook the experience of broad social groups such as the young, the elderly, individuals with disabilities, and caretakers. This is where not only type of destination (discussed further in Section 4.4.c) but also time of day become critical accessibility considerations. Periera (2019) refered to the potential to lose important insights and reach non-generalizable conclusions based on time of day variation as the **Modifiable Temporal Unit Problem (MTUP)** and compared it to the Modifiable Areal Unit Problem (MAUP) discussed in Section 4.3.b.

The affordability of private modes can be difficult to quantify because private modes come with purchase cost, insurance, and maintenance in addition to cost of fuel. Cost of fuel, however, is the most obvious cost. While it's possible to combine all costs to calculate a cost-per-trip for private vehicle use, it is not an intuitive way to present this information, as users rarely think in these terms. An exception to this, of course, is lower-income individuals. Those with tighter budgets are more sensitive to all aspects of transportation costs, and as a result, private vehicle ownership can be a greater source of economic stress and burden than benefit (Martens et al., 2019).

4.4.a.iii. Spatial Thresholds (Proximity/Coverage)

Spatial thresholds are integral to proximity measures, which are concerned with spatial coverage of transportation opportunities and barriers. Example distances and thresholds by type are presented in Table 4.7. Threshold distances are most often measured as Euclidean, or as-the-crow-flies, distances, and they are always measured this way when exposure is considered. For example, to estimate the area most likely to experience air pollution from a highway capacity expansion project, a spatial threshold of 1,000 ft might be used to create a halo (or buffer) area around the centerline of the proposed project corridor.

Table 4.7. Common distance thresholds used to calculate transport service areas.

Type	Components	Variations	Use-case
Facilities	Non-motorized Access	400-m (0.25-mi)	general access, transit stop
		0.5-mi	metro, Amtrak, ferry, intercity bus
	Investment	2-km, 3-mi	motorized transport facility proximity
	Exposure	150-m, 1000-ft	more/less conservative estimates of exposure to motorized facility externalities
Land Use	Required	1-mi, 2-km	access to jobs and schools
	Necessary	1-km, 2-km, 4-km, 5-km	access to healthcare, food, social services, recreation

Alternatively, spatial thresholds can define an area based on network distance. For example, to estimate the service area around a transit stop, a buffer can be generated either by using a Euclidean distance of 400 m to generate a circular area with a radius of 400- m, or by using a network distance to generate a buffer that better reflects the user experience. Network-based thresholds can be further specified by considering only pedestrian or bicycle-friendly infrastructure. Bolten and Caspi's (2021) work detailed additional network components that must be considered to accommodate individuals with varying levels of ability. The tool, AccessMap, operationalizes this with a data structure and routing algorithm.

Once a buffer area has been established, GIS analysis tools can be used to measure access or exposure in terms of percentage of population, percentage of homes, percentage of area, or ratio of area. Essentially the thresholds can be used to calculate areas, which can then calculate values for comparison. While they offer a relatively quick and simple estimate of proximity or coverage, it is important to remember that these estimates do not account for many factors. For

example, thresholds of 0.25- mi for bus stops and 0.5 mi for longer-distance transit services estimate the reality that most individuals will accept a longer first mile/last mile access distance for longer-distance transit trips, but these values do not hold true for every potential user.

Concerning exposure to negative externalities, the relationship between pollutants emitted along a corridor and actual exposure concentrations vary tremendously by weather patterns, as well as by patterns in human behavior. As a result, there is no universal, causal proximity distance for estimating exposures (Guo et al., 2020). As with any threshold, they have the benefit and drawback of drawing a definitive break within the data. While this is conceptually and analytically simpler than other methods, this break can eliminate important complexity in the data and effectively obscure and/or misrepresent complex realities.

4.4.a.v. Temporal Thresholds

Temporal thresholds are most used in access to opportunity accessibility measures but have broad application potential. Table 4.8 presents thresholds commonly found in the literature and why. In some cases, multiple thresholds are considered and compared, such as by Karner and London (2014), who analyzed access to jobs by type (blue-collar, healthcare, education, and retail) at temporal thresholds of 15, 30, and 45 minutes. They then compared accessibility by car to accessibility by transit at each threshold to highlight the disparity in accessibility between those with access to a private vehicle and those who were transit-captive.

Table 4.8. Common travel time thresholds used to calculate accessibility.

Thresholds	Associated consideration
10 min	Very short trip, preferred trip time range for non-motorized trips
15 min, 20 min	Short trip for motorized modes, longer trip for non-motorized but still viable
30 min, 45 min	Medium trip for motorized modes, too long for non-motorized – typical time thresholds considered for commute trip accessibility
60 min, 90 min, 120 min	Considered for transit trips and depending on context (ex: large metro areas)

A common policy application of temporal thresholds involves the 15- or 20-minute city initiatives (Cappasso Da Silva et al., 2019; Mackness et al., 2021; Moreno et al., 2021; Millonig et al., 2022; Khavarian-Garmsir et al., 2023). These initiatives try to operationalize a sufficiency equity standard that all urban residents should be able to meet all of their needs within a 20-minute travel time. Cities from Paris to Portland have made this a development goal.

4.4.a. vi. Speed Thresholds

Unlike spatial and temporal thresholds, discussions of speed thresholds tend to focus on safety and mode mix rather than possible accessible destinations. Rather than focusing on spatial allocation of facilities by mode, Nello-Deakin (2019) suggested that a more appropriate measure of transportation equity would be reached by offering an equitable mix of speed zones for multimodal travel. For example, agencies would offer an adequate network of low-speed zones focused on pedestrian and cyclist mobility, as well as higher-speed facilities focused on motorized vehicle movement. The goal of safety would be achieved by keeping the modes as separated as possible.

While appropriate speed thresholds may vary by mode or mode mix, 20-mph zones enforced with traffic calming measures have been found to reduce collisions, deaths, and injuries. A more recent study even found no evidence of casualty migration to nearby roads without interventions; however, this study was not able to account for potential confounders such as other road safety initiatives such as traffic cameras (Davis and Pilkington, 2019). They also noted that sign-only enforced low-speed zones have a smaller effect on collision reduction. In other words, low-speed zones are safer and more effective when enforced with traffic calming measures and potentially with other measures such as speed cameras.

4.4.b. Mobility and Economy

While economic indicators can be found in most of the subsections, most of the overlap occurs with mobility indicators; thus the combination of the two indicators in this section. Mobility indicators are important measures of direct transportation system benefits and burdens, and they are common within current transportation analysis practice. They are useful measures of observable, objective aspects of the transportation system and are necessary first steps to calculating higher-order measures such as accessibility. As a result, most mobility and economic metrics do not serve as leading indicators of transportation equity by themselves, but they offer important insights within the broader equity analysis process.

Currently, the academic literature regarding longitudinal measures of large-scale economic impacts comes from China (Li et al., 2018; Yang et al., 2018; Zhou et al., 2018; Sun and Zacharias, 2020; Zhang and Zhao, 2021). On the other hand, US-based literature focuses on economic impacts from the perspective of agencies' investment cost (Karner and Golub, 2019; Heyer et al., 2020), the perspective of workers in relation to spatial access to jobs (Golub and

Martens, 2014; Karner and London, 2014; Anderson et al., 2017; Martens et al., 2019; Dixit and Sivakumar, 2020; Chen and Li, 2021), or the perspective of individuals in relation to utility-based measures (Bills and Walker, 2017; Nahmias-Biran and Shiftan, 2020). Utility-based measures have originated in economic literature and can serve multiple purposes. For example, in the Accessibility table of indicators (Table 4.6), they fall under the "Models and Microsimulations" indicator type.

Table 4.9 summarizes the indicators of transportation equity that measure components of mobility and economy. They are divided into types of supply (facility-based and fleet-based), demand (behavior), and measures that are a function of both supply and demand.

Table 4.9. Mobility and economy measures and their potential as leading and lagging indicators of transportation equity.

Type	Components	Variations	Mode Relevance	Leading when..	Lagging when...
Facility-based	capital investments	total funds allocated by program	any	allocation aligned with equity goals	measured
		projects by type/mode[1]			
		capacity per facility			
		road density by type	motorized		
		intersection density			
	safety	ADA compliance	varies	meaningfully integrated in life cycle expectations	
		Designation, ADT, & design speed appropriate to adjacent land use & sight distances			
		number of lanes, lane width, shoulder width			
		intersection controls, roundabouts			
		protected/separated ROW			
		zebra crossings, curb extensions			
		traffic calming speed bumps, chicanes			
		highly reflective signage, flashing LED signage, solar crosswalk flashing beacons			
		well-lit			
		left- and right-turn restrictions, pedestrian priority signal timing			
		well-maintained pavement quality			

Type	Components	Variations	Mode Relevance	Leading when..	Lagging when...
		well-maintained landscaping appropriate to adjacent land use			
		well-maintained stormwater utilities			
		materials resilience			
	operations	funds for O&M by facility type	any		
		regularity of maintenance by facility type			
	connectivity	% with two or more types of connecting modes	any		
		# of possible paths/routes			
		efficiency of intermodal interchanges			
	regulations	ADA guidelines	non-motorized	end users integral players in regulation choice	measured by associated lagging indicators (outcomes)
		pedestrian priority			
		private vehicle use restrictions	motorized		
		speed limits[2]			
		HOV/HOT lanes			
		bus priority lanes			
		parking restrictions			
		parking pricing			
		requirements for developers to fund necessary remedial roadworks at time of development	varies		
Fleet-based	safety	vehicle ratings by vehicle or average for all vehicles per household	motorized	projected, meaningful increase	measured
		level of automation[3]			
	vehicles	total private vehicle ownership	motorized	projected outcomes align with equity goals	
		average # of vehicles per household			
		% households with 0 vehicles			
		% households with fewer vehicles than adults			
		market penetration by sales, by type, by emissions, by efficiency, by operational needs, by relation to roadway types			

Type	Components	Variations	Mode Relevance	Leading when..	Lagging when...
	operations	bikes rebalanced[4] by time period	Service-based		
		# transit lines in operation by time of day and week			
		frequency of service by time of day and week			
		reliability of service by time of day and week			
	regulations	safety rating requirements	motorized*	established with end user safety held paramount	measured by associated lagging indicators (outcomes)
		automation-related			
		emissions-related			
		ADA compliance	varies		
		capacity requirements			
		roadway-type requirements			
Demand (behavior)	mode share	miles by type per time period	any	projected outcomes align with equity goals	measured
		% split			
		vehicle occupancy rates			
		primary mode of transport			
	miles traveled	person miles[5]	any		
		vehicle miles	motorized		
		congested vehicle miles			
	trips	by type by time period	any		
		total distance by time period			
		vehicle drop-offs	service-based		
		boardings			
		alightings			
		riders by type[6] by timeframe			
	activities	by type by time period[7]	any		
		use of local & small businesses			
	temporal	value of time	any		
		idle time[8]			
	regulations	laws	any	established with end user safety held paramount*	measured by associated lagging indicators (outcomes)
		licensing	motorized		
		posted restrictions			

Type	Components	Variations	Mode Relevance	Leading when..	Lagging when...
		average daily distance BUDGET by [mode] based on equivalent CO2 and emission reduction goals			
Combined	travel[9] cost[10]	distance and/or time/duration	any	projected outcomes align with equity goals	measured
		value-weighted travel times			
	facility use[10]	user volume	any		
		utilization of capacity			
		level of service			
		marginal cost			
		travel impedance parameter	motorized		
		vehicle volume			
		flow of traffic			
		traffic levels by type[11]			
		traffic density per area			

1 measured as lane miles, % lane miles, % area, cost, % cost, average cost – note that the funding source as well as allocation of funds are of interest from an equity perspective

2 see discussion about speed thresholds in Section 4.4.a.v

3 safety considerations vary by automation levels of different types of vehicles and their integration in the overall fleet (fleet mix)

4 mean # bikes rebalanced can be used as a proxy measure for demand when actual data are not available, as is often the case with private service providers (Guo et al., 2020)

5 weekly walking for transport vs. leisure purposes hold different equity implications, particularly between income groups with different access to transport services and safe facilities (Iroz-Elardo et al., 2020)

6 type of card/account holder

7 could be referred to as frequency of going to a given destination of interest/activity

8 mean inverse idle time in spatial unit per day to estimate demand for shared use vehicles when actual demand data are not available

9 journey is a synonym for travel or trip

10 by segment, network link, O/D pair, between spatial units, generalized over a spatial unit

11 ex: % of truck traffic per current annual average daily traffic rate (Beiler & Mohammed, 2016)

Connectivity is a key mobility concept that has a strong influence on accessibility. It involves assessing transportation facility investments not only as individual projects but as components of an interconnected network. Connectivity can be achieved through intentionally locating things such as bus hubs, pedestrian bridges, or any type of transportation facility that improves the flow of people through the broader system. The more connected a system, the higher the regional accessibility. It is also important to ensure that facility design decisions are

appropriate to surrounding land use. This is important not only for connectivity reasons but especially for safety considerations (Nawrocki et al., 2023).

Fleet regulations could theoretically include non-motorized fleets (bicycles, skateboards, etc.), but most frequently they refer to what powers a motorized vehicle (gasoline, diesel, electric, etc.) and who controls it (non- vs. autonomous vehicles and by level of automation). Relevant non-motorized regulations can include weight capacity, while motorized can included person capacity (and associated weight assumptions) or regulations by roadway type such as narrower and/or winding streets that require smaller vehicles to navigate them safely.

Laws and restrictions related to mobility behavior range from speed limits to stop signs, lights, turn restrictions, etc., and they can also include restrictions related to walking (ex: no jaywalking) or where bicycles or e-vehicles (bikes, scooters, etc.) may or may not operate. Many of these restrictions are long-standing, but wider-reaching enforcement of new restrictions would require significant end-user engagement and buy-in to function equitably. An example is restricting private vehicle access to promote healthier, safer non-motorized environments (Bajada et al., 2016) or an even more ambitious mobility budget regulation scheme; Millonig et al. (2022) proposed a mobility budget that would restrict individual mobility based on emissions goals.

While measures of mobility and associated economic indicators do not address transportation equity considerations directly, they are necessary components of the transportation equity analysis process. They can be used to specify place-based accessibility measures or in statistical models to estimate person-based accessibility in the form of marginal costs by facility, mode, or activity location, among others.

4.4.c. Land Use and Displacement

Land use and transportation components are inextricably linked – land use affects transportation behaviors and experiences and vice versa. Because measures of accessibility are concerned with the transportation externality of opportunity, land-use measures are key elements of accessibility measures, which, in turn, are key indicators of transportation equity. Land-use measures detail origin and destination types and densities, and they offer means of measuring economic development and displacement precarity. Table 4.10 details the indicators related to land use found in the transportation equity planning literature.

Table 4.10. Land-use measures and their potential as leading and lagging indicators of transportation equity.

Type	Components	Variations	Leading when..	Lagging when...
Land Use	origins: residential	population density	used to inform meaningful, accessibility-focused interventions	measured
		residential density (# of dwellings per area by type)		
		adverse housing structure (lead likelihood, reinforcement)		
		peripheral location		
		segregation		
	destinations: economic	destination density		
		employment density		
		total jobs by type[1]		
		employment by sector		
		multi-type employment mix[2]		
		employment mixture entropy		
		proportion of population accounting for secondary and tertiary industries		
	destinations: other	education: schools by level		
		health: hospitals, clinics, pediatricians, general practice doctors, dentists, pharmacies		
		healthy food: greengrocers, butchers, bakers, supermarket, farmer's markets		
		social needs: bookshops, general shopping, social service offices, banks, post offices, libraries, voting locations		
		recreation: parks, beaches, greenways, open space, recreation facilities		
	transportation-specific	parking ratios & utilization		
		high-speed roads dividing community		

Type	Components	Variations	Leading when..	Lagging when...
		impermeable barriers		
		well-maintained landscaping, street furniture & art appropriate to adjacent land use		
	categories	urban, suburban/peri-urban, rural[3]		
		neighborhood		
		car-oriented, active transport-oriented[4]		
		mixed land use		
		urban sprawl		
		priority development areas		
		high-growth areas		
	environmental factors	FEMA 100yr floodplain	used to inform meaningful, resilience-focused interventions	
		annual flood risk zone		
		sea level rise risk		
		tsunami inundation zone		
		% impervious surface area		
		wildfire risk		
		earthquake risk		
		liquefaction susceptibility		
Economic Development	jobs	employment growth (new jobs by sector)	projected outcomes align with equity goals	measured
		unemployment rate		
		% difference in people employed between census years		
	broader	GDP per capita by area		
		% GDP comprised of secondary and tertiary industries in area		
		retail activity		
		proportion of local fiscal expenditure on education and science		

Type	Components	Variations	Leading when..	Lagging when...
		total sales of consumer goods per capita		
		investment in fixed assets per total GDP		
Displacement	factors[5]	households	projected outcomes align with equity goals	measured
		multifamily housing options		
		new homes		
		real estate activity (empty stores, foreclosures)		
		jobs by type		
		population characteristics		
	precarity	% people with a median monthly housing costs for occupied housing units below the regional average	projected, meaningful decrease	
		% income spent on transportation and housing		
		% discretionary income spent on transportation		
	regulations	zoning	end users' integral players in regulation choice	measured by associated lagging indicators (outcomes)
		affordable housing: public housing projects, rent stabilization		
		anti-displacement policies		

1 job types by sector [service, retail, manufacturing, healthcare, education, finance, etc.] or by wage
2 Iroz-Elardo et al. (2020) utilized a five-tier employment mix to capture multiple categories in a single, composite value
3 types of rural = Declining rural (population, enviro hazard, economic losses), chronic poverty rura,l Eisenberg (2020)
4 well-designed, safe, and clean
5 amount measured in #, % difference, % change - change in location of, amount of, cost of all measured relative to proportion of regional population density

Beyond categorical differences between urban and rural settings, Eisenberg (2020) further differentiated between four different types of rural Americas and focused their analysis on two main categories: chronically poor rural America and declining resource-dependent rural America. They noted that the former category tends to comprise racial minorities, whereas the latter comprises predominantly white Americans. Both groups tend to face environmental harm; however, residents of the latter category have historically enjoyed economic benefits in exchange

for environmental and health degradation. They specifically discussed the experience of rural communities in the Pacific Northwest, which had formerly been sustained by the timber industry but were currently in decline because of reductions in harvesting on public lands.

In urban contexts, neighborhood divisions and gentrification require equity attention. The US Interstate system has a history of being used to destroy and divide marginalized communities (Rothstein, 2017). Recent research has found, however, that physical infrastructure such as bridges and freeway caps not only help reconnect communities but can lead to significant increases in economic prosperity (Dutta et al., 2022). Nawrocki et al.'s (2023) practice-oriented literature review "identified gentrification as having a strong influence on many vulnerable populations. Gentrification is a powerful force for economic change but is often accompanied by extreme and unnecessary cultural displacement (Richardson et al., 2019). Gentrification presents a challenge to communities that are trying to achieve economic revitalization without the disruption that comes with displacement" (p. 16).

4.4.d. Environment, Health and Safety

Within the transportation equity literature, indicators concerning the environment are almost exclusively tied to impacts on humans, making these two categories a natural combination. Safety is another indicator that can be found interspersed throughout the other subsections, but collision-specific measures are included here. While these three categories combined make up only a third (or less, given the overlap in content) of the transportation equity literature reviewed, the definitions of communities of concern within the HEAL Act (overburdened, vulnerable, and Tribes) focus heavily on the externalities covered in this section. As a result, these indicators are important factors when leading indicators of transportation equity are considered.

Table 4.11 details the various types of indicators related to the environment, health, and safety. While many measures relate to environmental impacts, only metrics that directly measure environmental conditions are included in this section. For example, number of bicycles owned or number of SOV trips have associated potential (bicycles) or direct (SOV trips) emission values that in turn have lower or higher environmental impacts. These are not considered in this section but instead can be found in the Mobility and Economy indicators Section 4.4.b.

Table 4.11. Environment, health and safety measures and their potential as leading and lagging indicators of transportation equity.

Type	Components	Variations	Mode Relevance	Leading when...	Lagging when...
Air & Noise	emissions[1]	by mode, by facility, by congestion levels	motorized	projected, meaningful[2] decrease	measured
		area-based emission inventories modelled concentration			
		dispersion modelling			
	exposure	proximity to facility by type	motorized		
		congestion, Level of Service			
		% heavy vehicles			
		measured pollutant concentration			
		land use regression (LUR)			
		by individual travel behavior (travel demand modeled - TDM)			
	efficiency	by mode	motorized	projected, meaningful increase	
	regulations	low-emission zones[3]	motorized	established with knowledge and buy-in from impacted communities	measured by associated lagging indicators (outcomes)
		zero-emission vehicle projects[3]			
		proximity of busy traffic corridors to sensitive facilities[4]			
Temperature	land use	spatial coverage of well-maintained greenery[5]	N/A: facilities and land use	meaningfully integrated in life cycle expectations	measured
		% impervious surface area			
		land cover near facility			
	individual	experience of thermal comfort	any + facilities and land use	projected	
Outcomes	life	expectancy	any		measured

Type	Components	Variations	Mode Relevance	Leading when...	Lagging when...
		# years lost		associated interventions utilized to reduce projected risk exposure	
		deaths, morbidity, mortality			
	injuries[6]	by severity, by collision type, by mode, by facility, by actual travel behavior	any		
	broader health outcomes	incidence by area by type compared to average	any		
		% increase in likelihood			
		by type and prevalence of prescriptions			
	costs	treating injuries	any		
		lost days of work			
		prescription costs			
	satisfaction	health	any		
		environmental quality			
		safety			

1 equivalent CO_2 (thousands of tons) or other pollutants such as NOx/SOx/COx/PMx, dB(A) for noise

2 Highly used and presently high-emitting modes

3 measured in # and location, selected by highly polluted areas/locations of overburdened populations and/or high diesel air pollution areas (given a prioritarian, restorative equality equity lens)

4 Locations where vulnerable populations are more likely to be, such as hospitals, schools, elder care facilities - also pertains to noise

5 well-maintained greenery affects aesthetic and safety experience, as well as thermal outcomes. This includes landscaping and tree canopy

6 measured in # and location, % (ex: % collisions that are fatal per year), crashes per 100,000 per area

Equivalent CO_2 is the most common measure of pollutants for climate purposes. The full list of regulated air pollutants found in traffic emissions includes CO, NOx, benzene, and PM including fine particles (PM2.5) and elemental carbon (EC), all of which have been linked to adverse health effects. CO, NO_2, and PM2.5 are routinely monitored throughout the US, BUT "monitoring networks are very sparse and generally inadequate for intra-urban equity analyses" (Guo et al., 2020, p. 5). NO_2 has been found to be influenced by traffic counts and is less

commonly found in the atmosphere than other air pollutants (Guo et al., 2020). Therefore, where reliable measures of NO_2 do exist, these provide the best proxy estimate of the presence and severity of transportation-specific emissions. For more details, Guo et. al (2020) provided an excellent discussion of trade-offs between types of pollutant measures and estimates.

Concerning human health, impacts include exacerbated asthma, potential childhood asthma development, impaired lung function, other respiratory ailments, and cardiovascular disorders associated with mortality and morbidity (Guo et al., 2020). Additionally, exposure to high levels of ambient noise pollution has been linked to significant deficits in cognition, memory, and executive functions for children and young people (Martens et al., 2019). A notable exception to this can be found in Millonig et al.'s (2022) article that explored the concept of fair mobility budgets. Budgets would be set based on accessibility level considerations and emissions, with the goal of reducing total emissions.

Studies concerning broader health outcomes can consider positive, negative, or both, but the literature mostly focuses on negative health outcomes (burdens) related to transportation. However, studies of active transport modes have found tremendous health benefits for individuals and for society, accounting for positive impacts on mortality, morbidity, and quality-of-life indices, as well as controlling for negative externalities of increased exposure to pollutants and traffic risks (Martens et al., 2019).

4.4.e. Qualitative and Engagement

Qualitative measures of transportation equity cover the full spectrum of indicator types. While some measures of engagement found in the literature are objective measures (ex: number of community meetings), many are subjective in nature. As a result, both qualitative and engagement indicators are included in this section. Because these measures focus on the self-reported, lived experience of community members, they are indispensable tools of transportation equity. However, because qualitative measures tend to focus on past experiences, they are most often expressed as lagging indicators. These are critical to understanding how meaningful an intervention was (or wasn't) and therefore play a crucial role in the cycle of transportation equity. In contrast, indicators of engagement are almost exclusively leading indicators of equity, as long as these indicators demonstrate meaningful engagement and lead to associated interventions. When community identified concerns and professional interventions are closely

aligned, an equitable outcome is more likely to occur (Sanchez and Brenman, 2008; Karner and Marcantonio, 2018).

Transportation experiences that are self-reported or perceived are synonymous with qualitative measures. Karner et al. (2022) included qualitative as a category of accessibility measures. Because this report considers transportation equity indicators more broadly, qualitative accessibility indicators are instead placed in this section as shown in Table 4.12.

Table 4.12. Qualitative and engagement measures and their potential as leading and lagging indicators of transportation equity.

Type	Components	Variations	Mode Relevance	Leading when..	Lagging when...
Qualitative (self-reported, perceived)	accessibility	of trip by characteristics	varies	associated interventions utilized to increase likelihood of positive outcome	measured
		to a private vehicle			
		available opportunities			
		capabilities, functionings			
		barriers, opportunity inaccessibility			
		difficult routes by mode and user type			
		perceive driving alone as only modal option			
	satisfaction	with transport experience	varies		
		accessibility in the local area			
		experiences with trip characteristics			
		with participation in out-of-home activities			
		with ownership of a vehicle by type			
	impact of[1]	facilities by type	any		
		vehicles by type			
		interactive planning tools			
	impact on	self, skills, ability to work, comfort, stress, safety, vulnerability, convenience	any		
		region, mode users by type, norms, efficacy,			

Type	Components	Variations	Mode Relevance	Leading when..	Lagging when...
		control, aesthetic experience			
	attitude toward	project, agency, engagement process	any		
	guidance	# and clarity of equity goals	any		
		materials and trainings			
		performance measures for accountability			
Engagement	representation	vote share of each MPO member from a given jurisdiction relative to total number of votes for all jurisdictions	any	representation reflects constituency	measured
		socio-dem summary statistics within geographical area of participation by public engagement method			
		population share of a member jurisdiction relative to total population of MPO			
		representation ratio - vote share/population share			
	events	# of citizen forums	any	meaningful amount and type provided to engage communities	
		# and type of public engagement events			
		# of focus groups w/ combination of experts & citizens			
		# transportation equity planning-specific meetings w/ diverse community representatives			
		# of consultation meetings open to citizens and community groups by location			

Type	Components	Variations	Mode Relevance	Leading when..	Lagging when...
	resources	# of community orgs working specifically on transportation issues	any		
		presence of skilled facilitator to engage stakeholders with transportation-related social issues			
		resources provided to community groups to meaningfully participate			
		representative survey responses			
		actively maintained informational website			
	interaction	use of information website	any		
		use of platform for citizen comment on transportation issues[2]			
		# of persons involved in engagement method			
		# of survey respondents by identity and location			
		average # of planning tool device interactions per user by [touching, pointing at] screen			

[1] can be the impact of any type of intervention - most commonly refers to projects, but can apply to programs, services, etc. concept of traffic-related stress applicable to fleets and facilities includes AVs and potential ability (or inability) to work while in-vehicle

[2] separate considerations for interactions during vs. outside of an event setting

In contrast to the other indicators presented in the tables in the above sections, qualitative indicators cannot be readily observed. Qualitative indicators are most often collected in the form of survey responses to questions that use a Likert scale to record an individual's experience. For example, a survey could include a question about transit service satisfaction on a (Likert) scale from 1 to 5, satisfied to unsatisfied. Use of a Likert scale provides respondents an opportunity to rate the intensity of feeling.

The qualitative experience of accessibility is of particular interest within the transportation equity literature. Curl (2018) noted that "where perceived accessibility differs from objective measures the reasons need to be understood, otherwise basing policy decisions on objective measures are likely to perpetuate inequalities and exclusion from activities by ignoring the reasons why some people do not or cannot access destinations, despite having an 'acceptable' level of access according to objective measures" (p. 1150).

Lotfi and Koohsari (2009) found that subjective (qualitative) assessments of accessibility often do not correspond to objective (quantitative) assessments, even when multiple objective, quantitative measures are considered. Notably, trip characteristics are experienced differently depending on the experience of choice in selecting a mode (Reardon et al., 2019; Nahmias-Biran and Shiftan, 2020). For example, the experience of walking or riding a bus will typically be more enjoyable for individuals who choose to walk or ride, whereas those who have no choice (i.e., are transit-captive) typically experience less satisfaction and more negative affect related to their travel. One's ability to participate in the decisions that ultimately affect their daily lives also tends to lead to greater overall satisfaction (Banister, 2008)

Uteng et al. (2019) presented multiple methods for engaging with urban women to identify and address experienced and perceived safety issues in their daily trips. To measure the complex relationship between objective and qualitative transportation experiences, Reardon et al. (2019) presented the daily reconstruction method (DRM), which involves a daily activity diary and survey to gain an understanding of how and to what degree an individual's subjective well-being is affected by their daily activities. Additionally, semi-structured interviews were conducted with respondents to place their survey responses in the broader context of their lives. Table 4.13 presents the dimensions of subjective well-being included in their survey.

Table 4.13 Affective dimensions by category, measured on a Likert scale from 0 ("not at all") to 6 ("very much"). Copied from Reardon et al. (2019, p. 210).

Categories	Affective Dimensions Considered
Experiences	Happy, Relaxed, Frustrated, Sad, Anxious, Impatient, Engaged, Focused, Competent
Eudemonia	Worthwhile and meaningful, Benefitted someone else, Helped achieve goals
Evaluation	Day satisfaction, Life satisfaction

Di Ciommo et. al (2019) used a similar yet simplified approach. Rather than collecting detailed diaries and multiple affective states, they focused on travel time and satisfaction to classify trips as shown in Table 4.14.

Table 4.14. Categories of comparative travel time and level of satisfaction. Copied from Di Ciommo et. al (2019, p. 267).

Travel time threshold	Level of satisfaction	
	Satisfied	Unsatisfied
Below threshold (faster trip)	1	2
Above threshold (slower trip)	3	4

In a review of transportation equity literature, van Wee and Mouter (2021) found that the vast majority of studies employed a metric of accessibility. They noted, however, that "it is not clear whether this is caused by a researcher's preference to study this topic (supply driven research) or because potential users of (in)equality studies value this information (demand driven research)" (p. 121). Stewart and Zegras (2022) provided some insight into this question by studying how citizens respond to different framings of transport project benefits. Using an interactive tool representing the effect of a hypothetical transit improvement project, they tested stakeholders' response to benefits presented in terms of accessibility vs. travel time. They found that use of an accessibility framing "encouraged discussing the wider land-use system" and "seemed to mitigate skepticism and car users' predispositions against upgrading bus service" (p. 646). Broadly, they found that use of an accessibility framing led to improved attitudes about the project and engagement process. Essentially the use of accessibility as a means of presenting potential intervention outcomes will likely lead to an improved engagement experience.

4.5. METHODS AND DATA

Once relevant indicators have been identified for a given planning process, one or more methods of analysis must be employed to inform action (leading) or measure results (lagging). For example, if an assessment of environmental externalities and health concerns is being performed and a combination of values of NO_2 emissions and proximity to high-capacity facilities has been selected as indicators, then these values must be analyzed by using an equity-relevant method.

Similar to the Indicators Section 4.4, this section details the categories of analytical methods identified in review articles that helped inform the structure of analytical methods

presented. Table 4.15 presents the categories identified in review articles of transportation equity analyses.

Table 4.15. Analysis method classifications by review article.

Citation	Categories	Description
Boisjoly and El-Geneidy (2021)	Measure of inequality (Gini) Gap Analysis (composite indices of provision and vulnerability) Difference Between groups (descriptive stats, correlation tests)	Critical review of public transport equity outcomes
Guo et al. (2020)	mismatch analysis statistical approaches inequality indicator-based approaches.	Critical review of transportation equity measures

Guo et. al (2020) defined a mismatch analysis as essentially bivariate mapping, noting that it serves to present macro information in an intuitive manner. Indeed, mismatch analyses can offer a presentation of how (dis)proportionate transportation system externalities are. Guo et. al (2020) noted, however, that the products of mismatch analyses are cumbersome to analyze and do not readily offer quantitative information on equity performance. They recommended that they instead be presented in tandem with a provision and need index. All the types identified by both articles aim to measure whether or not transportation conditions are proportionally distributed, either spatially or between socio-demographic groups. Table 4.16 accounts for the structures presented in Table 4.12 and expands on them.

Specifically, Table 4.16 presents methods of analysis by type, focus, and variations, similar to the tables in previous sections. This table, however, focuses on use-cases as well as the software available—proprietary and open-source—that can be used to actualize the analyses detailed.

Table 4.16. Methods of analysis, use-cases, and software to realize analyses

Type	Focus	Variations	Use-case	Software	
				Proprietary	Open-Source
Measures	Cross-sectional Comparison	absolute value by comparison group, % of total, ratio, share, ratio of 95th/5th quantile, Cost Benefit Analysis (CBA), Aggregate Density curve comparison	Comparing between groups, modes, alternatives, or outcomes	Excel, Matlab, Minitab, SAS, SPSS, Stata	Python, R/RStudio
	Longitudinal Change	absolute change, % change, change in %	Measuring impact of intervention or general change over time		
Statistical Methods	Distributional Descriptors	quantiles [5th, median, 95th], mean, min, max, standard deviation (std), mean log deviation, relative mean deviation, coefficient of variation, density curves	Describing potential values and variation	Excel, Matlab, Minitab, SAS, SPSS, Stata	Python, R/RStudio
	Significance Tests	analysis of variance (ANOVA), bivariate correlation analysis, odds ratio, Fisher exact test, Kendall's tau, Wilcoxon signed-rank test, Mann-Whitney U test	Determining the statistical significance between comparison group values	Matlab, Minitab, SAS, SPSS, Stata	
	Models	OLS regression, spatial autoregression, Poisson, negative binomial, latent variable, structural equation modeling (SEM), activity-based model, travel demand model, Land use regression (LUR), dispersion modelling	Identifying complex relationships between relevant variables to better understand phenomena and/or to estimate potential outcomes		
Indices	Established Inequality Indices	Gini coefficient (also: Gini index, Lorenz curve), Atkinson Index, Theil Index	Comparing relative range of differences within distributions and between groups[1]	Excel, Matlab, Minitab, SAS, SPSS, Stata	Python, R/RStudio

Type	Focus	Variations	Use-case	Software	
				Proprietary	Open-Source
	Composite Indices	See Accessibility table			
Geospatial	Areal Analysis (Euclidean)	points of interest, census area assessments (blocks, block groups, tracts, counties, etc.), service/catchment area (buffer analysis), clusters, kernel density, standard deviational ellipse	Assessment of phenomena over a geospatial area	ArcGIS Pro, ArcGIS Online	QGIS, Python, R/RStudio[3]
	Raster Analysis	% paved area, vegetation/pavement mix, heat island effect	Land cover assessments for environmental considerations[2]		
	Network Analysis	# of available destinations by type, isochrone of accessible area from a point	Accessibility assessments	ArcGIS Pro - Network Analyst[4], ArcGIS Online - World Traffic Service[4], CUBE Access, Conveyal	

1 limitation of Gini is that it cannot compare between groups - that is utility of Atkinson and Theil indices

2 heat island effect, vegetation/ pavement mix, etc.

3 all three software programs have open-source add-ons and packages for analysis; R packages include *sf* for basic geospatial analysis and *r5R* for network analysis - *r5R* utilizes the Conveyal JavaScript-based network algorithm and includes options for GTFS-based transit networks and bicycle level of stress network attributes - network data are typically pulled from Open Street Map (OSM) using API scraping scripts/packages for open-source analyses

4 network analyst extension costs extra, World Traffic Service requires an organizational subscription

Percentages are often used to make cross-sectional (i.e., point-in-time) comparisons between groups. Comparisons of percentages relative to average or median values are also common. Examples include percentage of truck traffic per current annual average daily traffic rate (Beiler and Mohammed, 2016), or household transportation costs as a percentage of national median income (Anderson et al., 2017).

Fransen and Farber (2019) averaged accessibility across all socio-economic groups, considered as the regional benchmark against which each group was compared. Bills and Walker (2017) argued that analyses should look beyond comparisons of average values because average values "may mask important individual level outcomes" (p. 63). They instead encouraged analysts to plot and compare the distributions of outcomes for the socio-economic "target" and "comparison" groups defined within a study (p. 66). Many researchers have accounted for this by employing other descriptive statistics of population outcome distributions.

Concerning composite indices, van Wee and Mouter (2021) found that the Gini Index is the most frequently employed. Again, they noted that it is unclear whether policy makers prefer this means of analysis or whether it is simply a researcher preference. In this review of over 100 transportation equity articles, nearly a third of the articles included a composite index of the authors' creation.

Table 4.17 details some sources of data that can be used to perform transportation equity analyses. The goal is to provide examples of some of the primary, regularly maintained data sources rather than to offer a comprehensive list. Non-public agency data sources are included for comparison, but many additional open-source and proprietary data sources exist. For each source presented, example data sets available via that source are described.

Again, this is not meant to be a comprehensive list of data sets available from each source. Rather, it is a starting point to provide understanding of where data can be accessed and a sample of what data exist to operationalize the methods and indicators listed above. The annotation used in the Geospatial and Network columns are detailed below the table. These columns are used to denote how the given data sets can be utilized in geospatial analysis, with special additional categorization for data sets that can be used for network analysis, respectively. All the data presented can be analyzed in tabular form using software such as Excel, R, or Python.

Table 4.17. Some sources of transportation equity analysis data and example data sets by type.

Source		Data			
Name	Type	Example Sets	Description	Geospatial	Network
USCB	Public - Federal	TIGER/Lines	census-derived areal units of civic organization & analysis	v	
		Decennial	aggregated, complete US national census collected every 10 years	a	
		ACS	aggregated, sampled surveys based on decennial census, collected annually	a	
		PUMs	detailed ACS responses anonymized and sampled over census areas (PUMAs) of 100K people	a	
		LODEs/LEHD	jobs, work trips, and work-related population data	a	
USDOT/ BTS-NTAD	Public - Federal	HPMS	Highway Performance Monitoring System maintained by FHWA	v	
		FAF5	Freight Analysis Framework maintained by FHWA	a	
		FARS	traffic fatality data set maintained by NHTSA	v	
		all federal facilities	all data re: transportation facilities collected by federal agencies (FHWA, FAA, FRA, etc.)	v	*
		National Transit Map Routes & Stops	geospatial data product composite of all GTFS feeds nationally	v	X
		ACS-based data products	transportation-specific geospatial data products derived from ACS data such as household size by vehicles available, travel time to work, etc.	v	
		National Transportation Noise Map	Volpe data product	r	
		Alternative Fueling Stations	NREL-maintained data set updated daily	v	
WTN	Public - Washington State DoH	Climate & Health, Community, Environment, Exposure, Health	Single source of data sets aggregated to WA and relevant to cumulative impact analyses	v	

Source		Data			
Name	Type	Example Sets	Description	Geospatial	Network
WA Geospatial Open Data	Public - Washington State	Natural Hazards, Boundaries, Economy, Geology, Environment, Agriculture, Education, Imagery, Health, Water, Transportation, EHD	single source of data sets collected and maintained by WA agencies + ACS and other geospatial data products	X	*
MPOs, RTPOs	Public - within state	HHTS	Household Travel Surveys and other localized data are collected, maintained, and made available by these entities	a	
Counties, Cities, DOTs	Public - within state	varies	various localized data are collected, maintained, and made available by these entities	a	
Transit authorities	Public - within region	GTFS	Generalized Transit Feed Specification is the standardized data format for transit schedule data - many software packages and applications have been developed to analyze and operationalize GTFS data	a	X
		rider card data	data generated by rider card taps while using transit system	a	
		AVL	Automated Vehicle Location data collected from vehicles with GPS	a	
		APC	Automated Passenger Counter data collected from vehicles with counters set up for vehicle boardings and alightings	a	
		other operations	various other data collected and maintained by transit authorities	a	
Open Street Map (OSM)	Open-source	points, lines, and areas of interest	wide range of tags available to search and scrape features of the natural and built environment (29 primary categories and over 70 sub-categories)	v	X
AccessMap	Open-source, public university maintained	accessmap	detailed non-motorized network attributes with a standardized data framework and collection methodology to power network routing that can be queried by	v	X

Source		Data			
Name	Type	Example Sets	Description	Geospatial	Network
			mobility (dis)ability - only available in cities/localities where data has been collected		
Google API	Proprietary	points, lines, and areas of interest	extensive geospatial and metadata Big Data repository and API engine - expensive	X	X
Esri	Proprietary	points, lines, and areas of interest	extensive geospatial and metadata repository specifically designed for the Esri product suite (ArcMap, ArcGIS Pro, ArcGIS Online)	X	X

a Data are available in tabular (CSV, TXT) formats with identifiers necessary to visualize in a geospatial format (ex: lat/lon coordinates, TIGER/Line identifiers)

r Data are available in raster format only – rasters are pixelated geospatial data typically conveyed in JPEG, PNG, or GIF file formats.

v Data are available in vector format only – vectors are either points, lines, or polygons (areas) typically conveyed in SHP file format.

X In the Geospatial column, this means all possible geospatial formats are available, in the Network column, this means the data is built to routable network specifications

* This means data could potentially be used for networking purposes, but may not have been developed with network routing in mind and so may require additional cleaning and management to meet network functionality

NOTE: GDB (geodatabase) file structures can contain vector, raster, and tabular data.
Acronyms not specified in the table can be found in Appendix E.

5. LIMITATIONS OF THE ACADEMIC LITERATURE

This section highlights the limitations of the academic transportation equity literature.

5.1 LOCALIZED STUDIES AND KNOWLEDGE

Many examples of transportation equity case studies focus on locations outside of the US (Murray and Davis, 2001; Solomon and Titheridge, 2007; Arsenio et al., 2016; Bajada et al., 2016; Lucas et al., 2016; Boisjoly and Yengoh, 2017; Aparicio, 2018; Aivinhenyo and Zuidgeest, 2019; Carrasco and Lucas, 2019; Curl, 2019; Jaramillo et al., 2019; Kim and Wang, 2019; Lira, 2019; Antipova et al., 2020; Vecchio et al., 2020; Qi et al., 2020). A significant portion present Chinese case studies (Zhou et al., 2018; Xiongbin, 2019; Zhao and Zhang, 2019; Sun and Zacharias, 2020; Wang et al., 2022), some of which focus on high-speed rail project analyses (Yang et al., 2018; Li et al., 2018; Fan et al., 2019). Zhang and Zhao (2021) provided an excellent review, comparing and contrasting the literature on transportation equity in China with western-based methods and framings. While the end-user (citizen) insights derived from these non-US works are not directly applicable to a US case, they do provide useful frameworks and fresh ideas. For example, the UK's social exclusion report (Solomon and Titheridge, 2007) led to the creation of extensive data collection and analysis methods, driving the robust application of accessibility concepts through the UK (Dixit and Sivakumar, 2020). In the US, many studies have focused on the Bay Area of California (Castiglione et al., 2006; Bills et al., 2012; Karner and Niemeier, 2013; Golub and Martens, 2014; Bills and Walker, 2017; Karner & Marcantonio, 2018; Heyer et al., 2020; Bills, 2022).

US state-level planning studies tend to exist only in the form of non-academic reports (Creger et al., 2018; Fan et al., 2019; Williams et al., 2021) that develop useful frameworks, but they are not subjected to the same level of academic rigor as a journal article. An exception to this comes from Wang et al. (2022). They analyzed perceived accessibility in South Carolina using structural equation modeling (SEM), which is rigorous but difficult to achieve in a state agency planning context.

5.2 URBAN, MOTORIZED FOCUS

The majority of US-focused studies are reviews of metropolitan planning organization plans and funded projects (Grengs et al., 2013; Lowe, 2014; Luna, 2015; Manaugh et al., 2015; Lubitow et al., 2019; Karner and Golub, 2019; Heyer et al., 2020; Lempert et al., 2020; Boisjoly

and El-Geneidy, 2021; Krapp et al., 2021; Martens and Golub, 2021). Comparatively few studies have focused on rural, US contexts (Karner and London, 2014; Beiler and Mohammed, 2016; Karner, 2016). Fransen and Farber's (2019) analysis of the Wasatch Front region of Utah provided an interesting comparison not only of place- vs. person-based measures but also accounted for urban and rural areas. Their solution to rural analysis was extensive, individual-level data collection.

While some articles focus on non-motorized modes in US contexts, such as analyses of micromobility such as escooters and bikeshare fleets (Johnston et al., 2020; Chen and Li, 2021) or on active modes in general (Lee et al., 2017; Wu et al., 2019; Griffin and Jiao, 2019; Berg and Newmark, 2020; Iroz-Elardo, 2020), the vast majority of analyses focus on motorized modes.

5.3 INFANCY OF TOOLS

Siddiq and Taylor (2021) found that, of 54 accessibility tools analyzed, only five tools were packaged and readily available for use in planning applications. Of those five, all are useful for planning (rather than project) efforts. Planners interviewed for the article noted that, while there is significant desire to incorporate accessibility into planning efforts, the lack of tools poses a significant deterrent. The concern related to more complex measures was also presented, namely that complex tools tend to operate as "black boxes," are difficult to operationalize, and produce results that are more difficult to interpret and explain. This leaves them more uncertain and easier to contest.

5.4 DATA

Because transportation equity is such a wide-ranging topic that is most accurately and precisely assessed at the individual-level of data (dis)aggregation, data are a major limitation. Fransen and Farber (2019) provided a compelling argument in favor of data investments to power person-based analyses, and the UK's data investments have proved fruitful (Dixit and Sivakumar, 2020). Quality data collection, maintenance, and analysis would require a concerted staff and financial effort.

6. SURVEY RESULTS

This section details the results of the community consult and WSDOT planner feedback surveys. Information about survey development and distribution processes is detailed in the introductory Sections 2.2 and 2.4. Neither survey generated enough responses to be considered a representative sample of the study population, but both surveys offer some useful insights nonetheless.

6.1. COMMUNITY CONSULTATION

The community consultation process yielded many insights into community needs and perceptions, as well as into the community engagement process as a whole. This section first provides summary statistics based on the survey responses themselves, followed by key lessons learned.

6.1.a. Summary of Survey Responses

Following a set of figures that provide an overview of survey respondent identifiers, survey responses are presented relative to the five main indicator categories detailed in Section 4.4: Accessibility; Mobility and Economy; Land Use and Development; Environment, Health and Safety; and Qualitative and Engagement. The final subsection on Qualitative and Engagement findings details the engagement lessons learned reported by the WSDOT team who translated this survey tool, coded it into SurveyMonkey, and distributed it.

The project team worked to collect responses from overburdened and vulnerable populations as defined in the HEAL Act and according to the academic literature detailed in the Communities of Concern Table 4.1 in Section 4.2.a. While 400 local service providers in all six planning regions were contacted in the WSDOT team's initial outreach efforts, engagement moved forward with 25, and in-person data collection was viable at only two locations: the Moses Lake Library and the Rainbow Center in downtown Tacoma.

A total of n=207 responses were collected; however n=32 responses were submitted by minors and had to be discarded because of Institutional Review Board (IRB) protocol. A total of n=205 responded to at least the first two questions. Up to n=177 answered the full set of transportation equity questions and some of the optional socio-economic identification questions. The least answered questions were those that asked for date of birth (n=125) and income (n=121). For date of birth, a few responses were not useable because respondents provided

location of birth rather than date. Of the n=121 income responses, n=27 monthly incomes were salvaged. Incomes were either explicitly reported as monthly values or were assumed to be monthly if the reported value was <= $10,000.

As Figure 6.1 shows, roughly a third (1/3) of total responses and two thirds (2/3) of geolocatable responses came from the Tacoma area. Geolocations were based on mailing addresses collected from respondents, and the most successful in-person events were held at the downtown Tacoma community center, the Rainbow Center. It is therefore possible that individuals who were able to respond in-person with WSDOT representatives and local service provider staff present had greater trust and associated willingness to provide this information. This also demonstrates the potential of in-person events to improve engagement results when those events are held at places that people already visit, with necessary resources (in this case, computers).

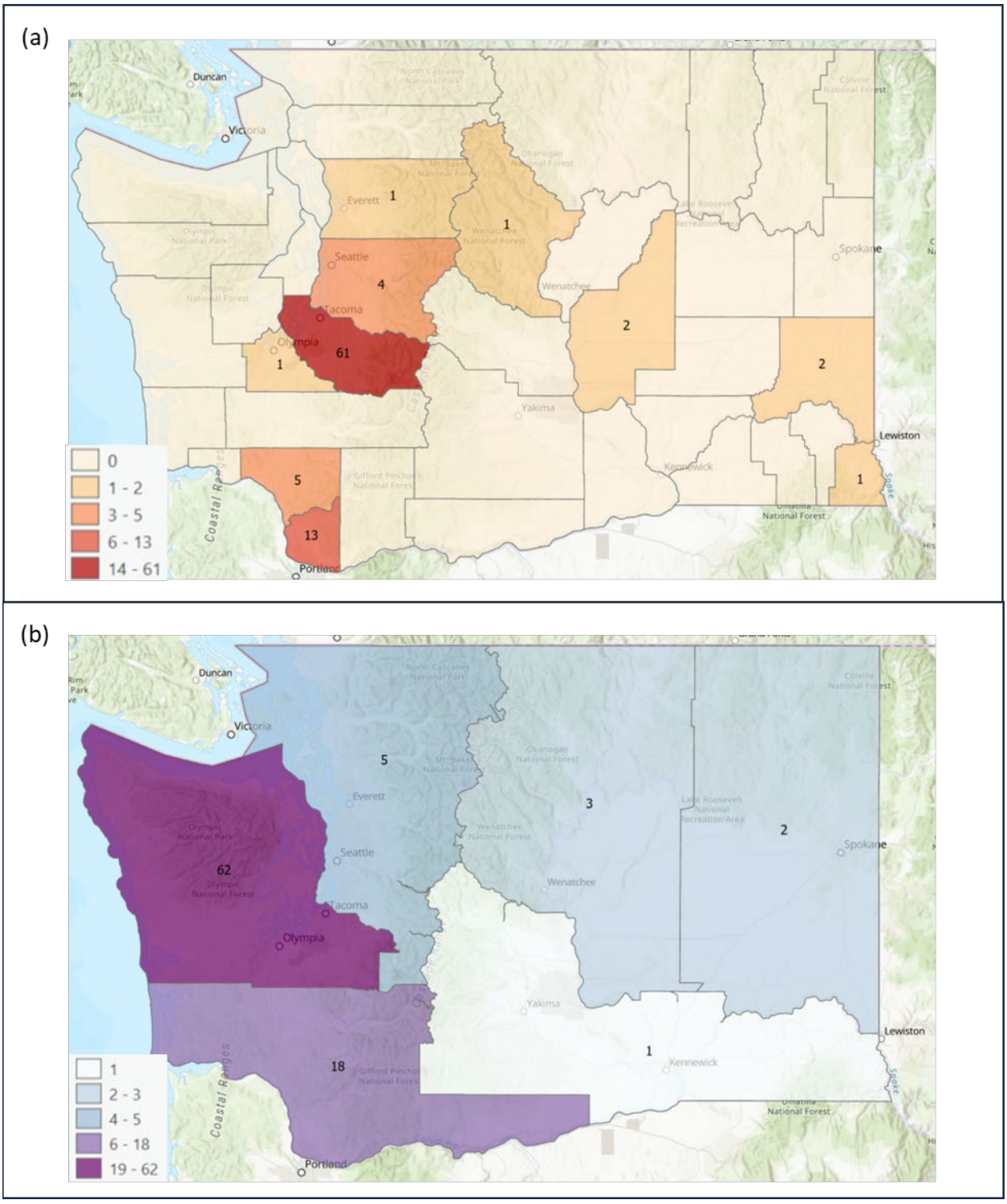


Figure 6.1. Map view of survey responses with viable geolocation information (n=91) out of 125 total responses plotted by (a) county and (b) WSDOT Region.

Figures of summary statistics can be found in Appendix B. They demonstrate that 83 percent of the n=120 viable income respondents were classified as low-income earners. This analysis used the Washington State Legislature RCW 84.14.010 (8) definition of low-income of 80 percent median by family size, with values calculated based on state median. State median income values were sourced from the Census Bureau Median Family Income By Family Size, cases filed between April 1, 2022, and May 14, 2022, inclusive[2]. The largest intersectional group of respondents (43 percdnt) identified as a person of color and were low-income earners, and 5 percent of respondents identified as Tribal members. Most respondents (55 percent) were renters.

While eight language versions of the survey were available, all responses were collected using the English language version of the survey. The majority of responses came from native English speakers. Responses included six languages other than English listed as first languages, with Spanish speakers being the largest group. Specifically, there was a large contingent of young adult native Spanish speakers who responded, although the largest group of respondents were Millennials (27 to 42 yos).

The survey succeeded in engaging certain marginalized groups (low-income, persons of color, and persons with disabilities). The results do not, however, provide a representative sample of marginalized communities across the state, and engagement with non-native English speaking and older populations could be improved. Additionally, the survey effort resulted in many (n=31) responses from high school aged individuals. These could not be used because of the IRB protocols established for this study, but the potential to reach younger travelers is encouraging.

Figure 6.2 presents respondent sentiments regarding the goals of the HEAL Act. The vast majority (85 percent) found it important, of which 46 percent found it extremely important. Rural residents did not find it as extremely important as suburban or urban residents, but the majority still found it important.

[2] https://www.justice.gov/ust/eo/bapcpa/20220401/bci_data/median_income_table.htm

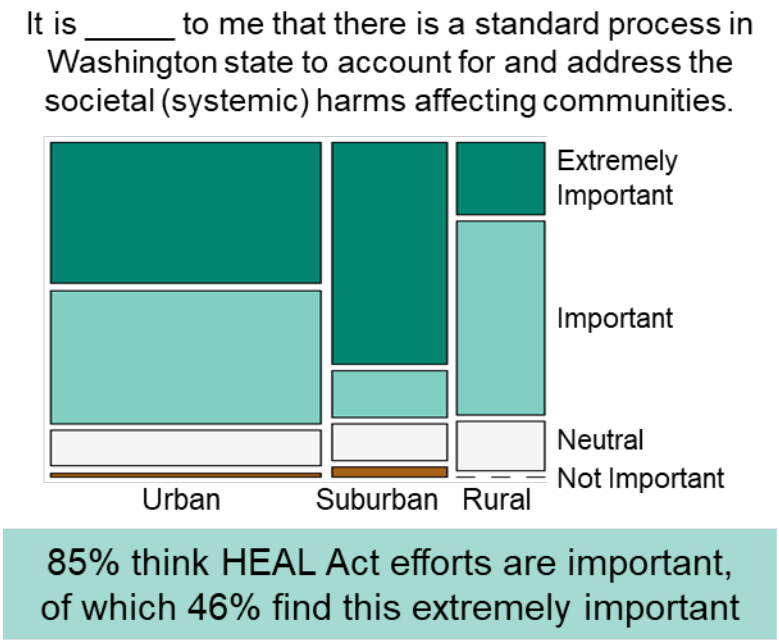


Figure 6.2. Responses to the question "It is _____ to me that there is a standard process in Washington state to account for and address the societal (systemic) harms affecting communities." presented by respondent-identified home location type (n=152).

Figures presenting the summary statistic results for responses to questions related to each of the indicator categories – Accessibility, Mobility and Economy, Land Use and Displacement, Environment, Health and Safety, and Qualitative and Engagement – can all be found in Appendix B.

Figure B.2(a) shows that people experienced about a 50/50 good/bad experience of accessibility on average, with people with disabilities consistently experiencing worse access. This aligns with the literature findings detailed in the Communities of Concern Table 4.1 in Section 4.2.a, which identifies individuals with disabilities as experiencing disproportionately worse access. Over a third (1/3) reported difficulties such as limited funds, options, and disability or accompanying someone with a disability. Those who reported difficulties struggled finding options that met needs, their but many still had most or all needs met (Figure B.3(b)).

Respondents relied on a variety of modes, although ~2/3 said they relied predominantly on personal vehicles (Figure B.3(a)). Nearly a fifth (21 percent) of respondents reported many roadways dividing their community, with the majority (71 percent) identifying some to many. Regarding displacement, two thirds (2/3) of renters were concerned that they would not be able to afford living in their current location in the next few years, with roughly a third (1/3)

expressing extreme concern (Figure B.4(b)). Even for homeowners, over half expressed some concern.

Responses regarding air and noise were mostly the same, with slightly more concern/awareness of noise pollution relative to air pollution (Figure B.5(a,b)). This could suggest an underlying group of individuals who are aware of and concerned about pollution in general. The presence of safe/dangerous crossings for pedestrians, cyclists, and motorists yielded similar results (Figure B.5(c)), as did questions related to how enjoyable a respondent believed it was to walk or cycle where they lived (Figure B.6). Further analysis would be necessary to determine whether differences were a function of location, race/ethnicity, or some other underlying factor such as health and safety consciousness. Additionally, nearly 50 percent were happy and had options that met their needs (Figure B.7).

6.1.b. Lessons Learned

Local service provider and organization representatives and the broader communities they served were very receptive to the Equity in Planning project. From interactions with these organizations and with community members themselves at in-person events, the following lessons were learned:

1. **Be intentional with meeting time, place, and resources.**
    a. Hold meetings at locations and times that are convenient for community members.
    b. Hold meetings where tech is available or bring portable options.
2. **Budget for compensation and other resources.**
    a. For local service provider engagement facilitation support.
    b. Have alternative distribution methods for community members who engage.
    c. For physical resources to aid in engagement (such as tech, materials, etc.).
3. **Build up foreign language offerings.**
    a. Build up agency wide-capacities.
    b. Build trust with organizations that serve English as a second language (ESL) communities.
4. **Strive for engagement that is relational.**
    a. Community organizations and members were eager to engage, but they voiced desire to be engaged more than just when WSDOT needs something from them.

Lesson 1: Intentionality of time, place, and resources corresponds with best practices from the literature, and it was the starting point for project engagement. The WSDOT project team understood the importance of engaging community members at locations and times that were convenient for them. The partnership with the Rainbow Center in downtown Tacoma highlighted the efficacy of time and place as well as resources. The Rainbow Center was not only a place where community members had already spent time, it also had a bank of computers that respondents could use to complete the survey. The Moses Lake Library was also chosen for the presence of computers, but because it was not already a common location for the community members that the local organization supported, the event was not as successful.

Rather than relying exclusively on locations with necessary tech resources on-site, ideally banks of laptops and AV equipment could be rented and brought along to preferred community locations. The WSDOT project team attempted this once the project was already in-progress and were not able to incorporate this additional component.

Lesson 2: The team was, however, able to secure late-stage funds for respondent compensation but did not consider local service provider and organization compensation. For a nominal amount, local service providers and organizations would have been able to provide on-the-ground support that could have improved reach. As the survey distribution statistics and Figure 6.1 show, reach was significantly improved when this support was provided. Tango card e-vouchers contracted through the University of Washington were the final choice for respondent compensation. Alternatives such as cash or vouchers to local grocery stores were considered, but they were not selected for logistical reasons and, in the case of the grocery store vouchers, concerns regarding business favoritism.

Ideally WSDOT would have a set of compensation options established to avoid project-by-project efforts such as this one and to ensure alignment with Washington State Office of Equity guidelines for community compensation. While business-specific vouchers may not be viable, routing money through established welfare services may be a viable option. Examples could include WIC vouchers, transit fare vouchers, or vouchers through local programs such as the City of Seattle Fresh Bucks program, which provides vouchers useable at farmers' markets throughout the city.

Lesson 3: The WSDOT project team learned many lessons regarding the logistics and mechanics of distributing surveys in multiple languages. They learned to seek contractors with

transportation area expertise to ensure that concepts were interpreted correctly, and how to navigate the templates used by SurveyMonkey to upload foreign language copies. Rather than focusing on each component detail, this lesson reiterates the need for agency-wide capacity rather than relying on individual project team efforts.

The team also noted that, while many logistical obstacles were overcome to offer surveys in eight different languages, the fact that only the English version of the survey was used suggests that other barriers exist. Specifically, the historical lack of non-English engagement alternatives has likely left ESL communities isolated and potentially mistrustful of the agency. A single survey from a one-year project was not going to overcome these broader, relational obstacles. These will take time and trust to fully address.

Lesson 4: To effectively address not only the logistical considerations detailed above but also the broader consideration of trust, the agency needs to strive for engagement that is relational rather than transactional. To accomplish this at scale and equitably distributed across state geographies and programs will require an agency-wide, in-house effort.

Leaving engagement as a project-by-project or program-by-program activity relegates it to a check-box activity that is subject to highly variable budgets and often too-short timelines. Where budgets allow, teams ill-equipped to complete engagement efforts are more inclined to hire consultants to do the work. While this may result in excellent engagement for that project, once the project ends, so does that connection to the community. Without in-house capacity for engagement efforts, consistent community relationships with WSDOT will not be possible.

Beyond logistics, tying engagement to individual agency activities results in siloed, transactional efforts. A move away from transactional engagement was an explicit request of community organizations and that members reiterated throughout this project.

6.2. WSDOT PLANNER SURVEY

The full set of summary statistic figures can be found in Appendix D.

The majority of the 36 respondents who completed the optional identity questions were male (58 percent) and reported no disability (83 percent). The majority of respondents reported a racial identity of white (63 percent) followed by Asian (13 percent). The survey reached members of fourteen WSDOT divisions, including five of the six planning regions (Olympic, Northwest, Southwest, South Central, and Eastern). The primary type of work done by respondents was technical analysis, followed closely by project or program management.

Table 6.1 was adapted from the practice-oriented literature review (Nawrocki et al., 2023) and edited to include planner free responses. The discrepancy in guidance adopted by transportation agencies (Table 6.1) and those reported by WSDOT planners (tables 6.1 and 6.2) has a few explanations. Because planners reported in a free-response manner, it is possible that planners use the guidance listed in Table 6.1 and simply did not remember to report it. It is also possible that the difference in reporting reflects the reality, and WSDOT planners rely on different guidance materials than those identified in the practice-oriented literature review.

The answer most likely lies somewhere in-between. Additionally, the planner survey does not offer a representative sample of all planners at WSDOT. Rather than offering a clear answer regarding WSDOT planners' use of guidance materials to inform equity analyses, the findings highlighted in figures 6.1 and 6.2 invite further inquiry. They raise a few questions:

- How useful are existing guidance materials for informing transportation equity efforts in practice?
- If they are not in use, what is limiting their application? Do they lack applicable content or are there other barriers to content application?

Answering these questions would require a more systematic approach than the single open-response method used here. A key takeaway at this stage is that equity analyses are not a new topic to WSDOT planners, who already rely on a variety of data, methods, tools, and guidance.

Table 6.1. Design and planning guidance by agency adoption.

	Complete streets	Context sensitive design	Livable communities	Smart growth	Safe systems	Performance management
Agency or organization						
FHWA	X	X	X	X	X	X
FTA	X	X	X	X	X	
TRB	X	X	X	X	X	X
AASHTO	X			X	X	X
APTA	X	X	X	X	X	
NACTO	X	X	X	X	X	X
Other						

	Complete streets	Context sensitive design	Livable communities	Smart growth	Safe systems	Performance management
ITE	X	X	X	X	X	X
APA	X	X	X	X	X	X
WSDOT	X	X	X	X	X	X
Planner-reported	X					

Table 6.2. Data, methods, tools, and guidance currently used by WSDOT planners to perform equity analyses.

Data Source	Data Type	Methods	Tools	Guidance & Requirements
state-wide	GIS data (state & federal), EHD, ETC, EJScreen, environmental data, health data, Census data	defining target populations, Investment ranking w/ equity prioritization, evaluate grant programs based on equity, LEP assessment, EJ assessment, TDM	ArcGIS Pro & ArcGIS Online, Excel, WSDOT tools, Adobe, Canva	Title VI, Justice40, HEAL Act, HUD LEP guidance, Target Zero, Complete Streets, WSDOT policy manuals, trainings on equity
local	household transportation survey (HHTS), ridership data (including demographics), voluntary demographic data collection @ engagements, on-the-ground observations			
engagement	discussions w/ communities, relationship building w/ community groups & orgs, Tribal consultation	Community Engagement Plans, diversity of outreach efforts, avoid jargon in community discussions, assessing reach w/ demographic data		

6.2.a. Barriers and Needs Identified

Planners offered a number of insights into the barriers they have faced in efforts to incorporate equity in their work. When asked which single (a) resource and (b) skill set were most in need of improvement, respondents focused on non-technical considerations, as shown in Figure 6.3. Options focused on non-technical and technical skills and work, considering

allocations of time, funds, and staff and skills for self or other staff. Responses covered the full range of options provided, as well as write-in recommendations that highlighted the need for improved guidance and contextual knowledge of communities.

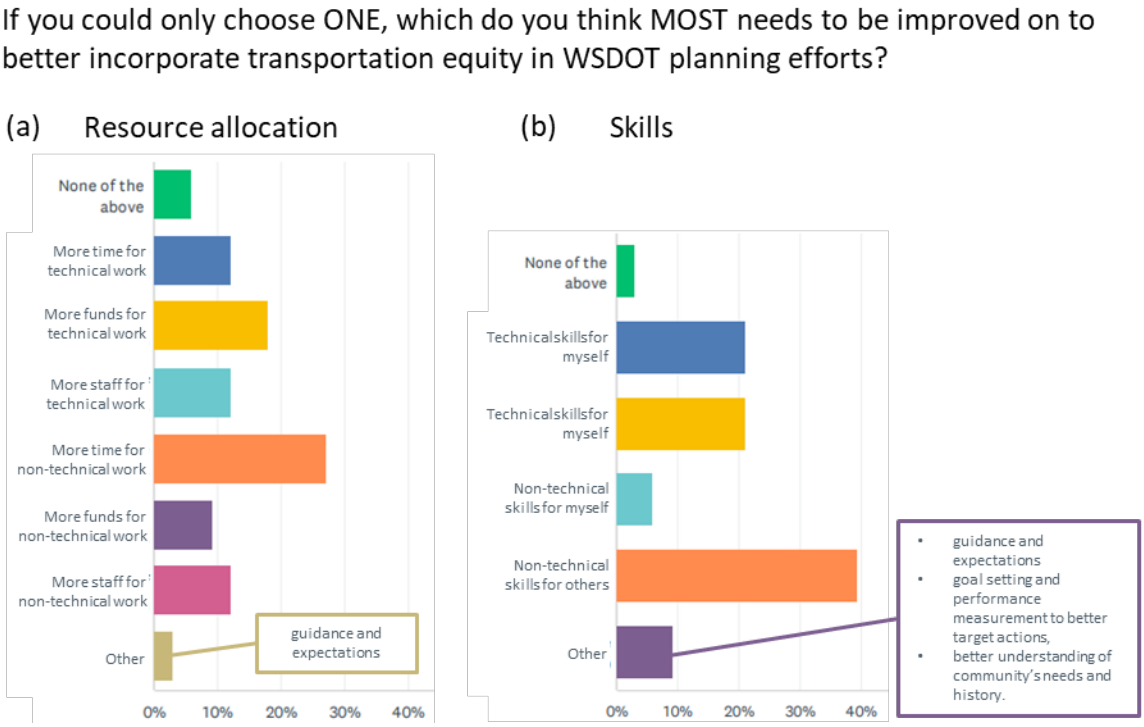


Figure 6.3. WSDOT planner survey responses for most important consideration that needs to be improved to better incorporate equity in WSDOT planning efforts by (a) skills and (b) resource allocation (n=33). Examples provided for technical—data management, statistical knowledge, coding, GIS, etc. – and for non-technical—communication, community engagement, assessments of justice, identification of historical, political, and legal context, etc.

Free responses provided additional insights, with respondents noting that timelines often moved too fast to engage with communities. One noted the "limited WSDOT staffing to implement meaningful community engagement. We have been supplementing gaps with using consultants." Another noted that the agency needed "to build relationships of trust with our most under-invested and historically under heard communities" – something that cannot be achieved when all engagement efforts are consigned to contracted consultants on individual, disparate projects.

Others highlighted the importance of effective interagency collaboration and how wide-spread equity adoption integrated into workflows would be necessary to avoid reliance on a few groups for an effort that needed to be wide-spread to be effective. They noted the importance of

localized analyses and that on-the-ground insights made great resources, since details were often lost in census-level data. They recognized, however, that this was difficult for smaller communities with less capacity for data collection and maintenance.

The barrier of limited guidance was also reiterated, with some noting a lack of clear guidance on how to use data that did exist. One respondent stated that, while integration of equity analysis was happening, there was a need for "more comprehensive tools to make increasingly informed decisions." Others identified broader issues, such as a "lack of consistency in how equity is defined and applied across communities where we work," with one highlighting that this lack of a cohesive vision for transportation equity left groups "often pitted against each other for 'who has it worse'," which "makes it challenging to develop a cohesive vision and prioritize solutions."

7. RECOMMENDATIONS

Transportation equity is a multifaceted concept and therefore requires a multi-faceted and multi-disciplinary approach. Incorporating equity into the WSDOT planning process will require a shift in analysis tools and methods, both for technical analyses as well as subjective engagement and analysis methods. Many of these tools and skill sets exist outside the traditional realm of the planning and engineering professions. It is therefore imperative that the agency invest in people to ensure that the necessary skills are available at scale, likely through some combination of continued education initiatives and new staff.

7.1. CONTEXT AND ACCOUNTABILITY ARE KEY TO EQUITABLE OUTCOMES

Transportation plans and interventions do not exist in a vacuum; they exist within the context of communities, land, and history. Community engagement is a critical component to establish accountability and to develop a rich sense of context. It is also important, however, for planners to develop some contextual knowledge of their own. This self-education is not meant to supplant community voices but to ensure that communities do not bear the sole responsibility for educating planners. Developing a sense of context for an area can range from scrolling through Google maps to familiarize oneself with an area to exploring cumulative impact indices (see Chapter 4), to a full Environmental Impact Statement (EIS). Taking any amount of time to learn about an area and the people who live there will allow planners to approach their work from the perspective of the end user and will increase their likelihood of proposing equitable solutions.

Efforts to self-educate and familiarize themselves with an area and the people who live there also sets up planners for more successful community engagement efforts. An example is reading course materials before attending a lecture; is it possible to learn from the lecture regardless? Probably. Would the planner take in more information and perhaps even be ready to apply more of the lecture material if they prepare before attending? Almost certainly. But unlike a single course, this work involves higher stakes and greater responsibilities.

Transportation planners are civil servants whose clients are the traveling public. Engaging with the public should therefore be treated more as a performance review than a passive lecture. A performance review requires preparation and collaboration for a successful outcome. It is also a sign of respect and accountability to arrive prepared. While WSDOT has some staff (such as Tribal Liaisons, Title VI experts, Multimodal Planning and Data team

members) and Planning and Data Academy seminars to provide knowledge and support to aid in this process of context development, a more wide-spread effort is necessary to make community engagement ongoing and relational rather than task-specific and transactional.

7.1.1 Relational Community Engagement

Community engagement is not just a source of knowledge to inform the planning process, community engagement is a collaborative, iterative process. As Section 4.2 discussed, community engagement in the early stages of a planning process is critical for knowledge and context building, but it must also continue into later stages to allow agencies to revise and maintain alignment with overarching needs and goals. It is this regular and ongoing conversation that holds planners accountable and provides citizens with full participation in the decisions that affect their lives. To accomplish this, consider the following recommendations:

- Separate community engagement from individual projects.
- Ensure engagement is cyclical – report back to communities.
- Focus on building community relationships in-house (rather than contracting work out).
- Hold events at times and places familiar to communities and with necessary materials.
- Compensate community members and local organizations.

Planners expressed concerns regarding timelines for any given project and how there is rarely time for engagement. Disentangling engagement from individual projects will not only allow for more time but will also allow a more equitable allocation of resources across communities. Furthermore, a change from one-off, isolated efforts will shift engagement from a transactional, check-box activity to one focused on relationship and trust building.

Logistically, in-person events will improve engagement results when they are held at places that people already visit, with necessary resources. The Washington State Office of Equity provides guidelines for community compensation that can serve as a starting point to ensure that community members are adequately compensated for their time. Additionally, local community organizations offer a unique connection to on-the-ground experiences and needs. Ideally, relationships will include resources for organizations in the form of funds and materials and regular interactions with WSDOT to foster trust and accountability. Using a diversity of

engagement methods is also recommended, and especially leveraging the wide range of new opportunities that technology offers.

Ultimately, communities want a relationship with WSDOT, not just a transactional exchange of needs. Investing in ongoing relationship building will require investment in dedicated WSDOT staff, as well as nominal monetary investments in local community providers and organizations to tap into existing community networks. The goal is to build open channels of communication and trust; this will require an agency-wide commitment of time, effort, and resources.

7.2. SCREENING AREAS BY DISADVANTAGE SHOULD CROSS-REFERENCE RESULTS BETWEEN TOOLS – ERR ON THE SIDE OF INCLUSION AT LOW LEVELS OF SPATIAL RESOLUTION

Cumulative impact indices such as Washington state's Environmental Health Disparities (EHD) Map and the USDOT's Equitable Transportation Community (ETC) Explorer are scientifically and statistically valid tools for disadvantage screening. They, along with a range of other publicly maintained indices (see Table 4.2 in Section 4.3.c) have been rigorously developed and have strong stakeholder buy-in.

However, because the concept of disadvantage is so broad, open to many valid interpretations and therefore lacking a singular ground truth measure, tools should be utilized with an appreciation of their limitations. Variations in data selection and the analytical methods applied can lead to substantial variation in rank values and, subsequently, classifications of disadvantage assigned to areas. Specifically, existing indices (the EHD and ETC) are more likely to classify urban tracts as disadvantaged than rural tracts.

Indices do, however, tend to offer stable estimates at either end of their distribution. This suggests that classifications of areas as very disadvantaged or not at all disadvantaged tend to be the most accurate. This precision increases when multiple indices or versions of indices are considered. Analysts are therefore encouraged to cross-reference among multiple indices; guidance is provided to aid in this process in Figure 4.3 in Section 4.3.c. Ultimately, analysts are encouraged to err on the side of inclusion at the low levels of spatial resolution afforded by census tract and block group-level analysis that these indices provide and to seek more localized data when possible.

7.3. MEANINGFUL INTERVENTIONS MUST CONSIDER ALIGNMENT, TIMELINESS, AND MAGNITUDE

The concept of meaningfulness is reiterated throughout the previous sections because it is a critical element of equitable work. For an intervention to be equitable, it must be meaningful. Meaningfulness can account for many things, but relative to equity, key elements can be summarized by the concepts of alignment, timeliness, magnitude.

Alignment considers how well a given intervention aligns with established equity standards and goals. Such standards are defined by civic engagement and become the responsibility of transportation planners to enact. In the State of Washington, the HEAL Act provides a mandate toward restorative equalization in alignment with the broader environmental justice (EJ) movement. This means that meaningful transportation equity interventions in the State of Washington must align with the restorative equalization equity standard. A restorative equalization equity standard operates on the assumption that the existing distribution is unjust and that efforts must be made to reduce disparities. Functionally, this means focusing efforts on (i.e., prioritizing) overburdened and vulnerable communities (i.e., communities of concern). Alignment suggests not only prioritizing interventions toward communities of concern but also ensuring that interventions align with community identified concerns and goals.

Timeliness and magnitude were highlighted by Martens et al (2019) when they noted that equity-oriented interventions that do little to appreciably reduce disparities and/or that will not or cannot be delivered in a reasonable timeframe may offer "no more than tokenism, while largely maintaining the status quo" (p. 33). Transportation planners are tasked with defining actionable visions over varying timeframes. Timeliness and magnitude urge long-range planners to be bold and shorter-range planners to be exacting, pushing forward interventions that appreciably reduce disparities and improve health and well-being as soon as possible.

The inherently subjective nature of meaningfulness makes affected communities the best judge of whether or not, and to what degree, a transportation intervention is meaningful. Transportation professionals can, however, use the concepts of alignment, timeliness, and magnitude to guide their efforts.

7.4. EQUITY STRATEGIES TABLES

Tables 7.1 and 7.2 offer example interventions by equity indicator category and communities of concern. Table 7.1 presents examples of interventions that, when applied with

appropriate context, will most likely lead to an equitable outcome. These interventions are divided into eight groups, detailed below the table, and are related to the broad categories of indicators presented in Section 4.4. The interventions presented cover a range of detail and complexity; for example, improving access (as defined in category #1) can occur in many forms and requires an accessibility analysis to estimate project outcomes. In contrast, category #3 lays out more defined interventions, such as safe intersections and traffic calming measures.

Table 7.2 provides detail regarding context by relating interventions to communities of concern. While interventions such as any of the access improvements presented in example intervention set #1 would benefit any community, assignments in Table 7.2 focus on interventions explicitly related to known burdens faced by each community. These assignments are based on findings presented in Section 4.2. Because community engagement is a critical component of any leading indicator of transportation equity, locations, organizations, and groups are presented to highlight engagement opportunities. Taken together, tables 7.1 and 7.2 offer an example set of leading indicators of transportation equity; when the interventions in Table 7.1 are with and for associated communities of concern, equitable outcomes will most likely occur.

Table 7.1. Examples of leading indicators of transportation equity interventions by equity concept.

Example Interventions			Concepts Addressed			
			Accessibility	Mobility & Economy	Land Use & Displacement	Environment, Health & Safety
1	a	improved access to required activities (school, work)	X	X	X	
	b	improved access to care destinations (health, day, elder, disability)	X		X	X
	c	improved access to healthy, affordable food	X		X	
	d	improved access to other basic needs (recreation, banking, postal, voting)	X		X	
2	a	a variety of transportation options	X	X		
	b	low-stress transportation options	X	X		X
	c	time-efficient, off-peak transportation options	X	X		
	d	affordable transportation options	X	X		
	e	facility wayfinding designed to meet a wide range of user needs	X			
	f	facilities, fleets, and services designed for varying physical & cognitive limitations	X	X		
3	a	good-quality, well-maintained, well-connected non-motorized facilities	X	X		X
	b	separated non-motorized facilities	X	X		X
	c	safe intersection crossing measures				X
	d	traffic calming measures (physical & monitor-based)				X
	e	multimodal elements appropriate for adjacent land use	X	X	X	X
4	a	community re-connection projects (bridges & interstate caps)	X	X	X	X
	b	noise wall construction near sensitive facilities				X
5	a	a variety of forms of information about transportation options	X			
	b	access & communication support services	X			

Example Interventions			Concepts Addressed			
			Accessibility	Mobility & Economy	Land Use & Displacement	Environment, Health & Safety
6	a	well-lit and monitored facilities	X			X
	b	well-kept greenery in/around facilities				X
	c	safe reporting processes	X			X
7	a	various payment plans & methods offered	X	X		
	b	discounts & subsidies	X	X		
8	a	policies to encourage diffuse, wide distribution of goods & services (20-min city)	X			
	b	affordable housing & anti-displacement policies in conjunction with transport projects		X	X	
	c	policies to prevent siting of hazardous facilities near sensitive populations				X
	d	emission reduction policies & programs				X
	e	considering operator labor needs (living wage, affordability, dignified working conditions) within program funding and administration efforts		X		X

Intervention types are grouped numerically by the following categories:

1. key components of accessibility
2. key transportation system components
3. safety & flow considerations – SEE ALSO the Fleet-based, Safety indicators in Table 3.11, Section 3.4.b.
4. community-oriented
5. information access
6. sexual assault mitigation
7. affordability
8. policy & programmatic

Table 7.2. Example transportation equity leading indicator interventions and engagement by communities of concern.

Community of Concern	Relevant Interventions	Engagement Opportunities
the Young	1[a,b], 2[b,f], 3, 4[b], 7[b], 8[c,d]	schools, after-school programs, youth groups
students	1, 2[a,c,d], 3, 5[b], 7[a,b], 8[a,b,d]	higher education institutions
the Elderly	1, 2, 3, 4[b], 5, 7, 8[a,b,c,d]	senior centers, community centers, elder care facilities
people who are disabled		disability advocacy groups, disability community groups, disability support & education centers, care facilities
caregivers		care facilities (health, day, elder), schools, support groups
women	6	women's advocacy groups, community centers
LGBTQ+		LGBTQ+ advocacy groups
limited English proficiency	1, 2[e], 5	ESL schools & support services
people of color	1, 2[a,c,d], 3, 4[a], 8	racial & ethnicity-based/oriented advocacy groups, community centers
people with low-income	1, 2[a,c,d], 3, 4[a], 7, 8	advocacy groups, social workers, support organizations, posted fliers (at libraries, community centers, rental properties, public housing, transit stops, food banks)
renters	8[b]	
people facing high housing costs relative to income		
people facing high transportation costs relative to income	2[d], 7, 8[a]	
people w/o access to a private vehicle	2[a,c], 3[a,e], 8[a]	
people who are unbanked	7[a]	
people who are unemployed	1[a], 2[c,d], 7	
people w/o access to the internet	5[a], 7[a]	
people who are unhoused	5[a], 7, 8[b]	

While identifying relevant communities of concern must align with HEAL Act definitions, the communities identified in the HEAL Act should serve as the baseline. Additional, transportation-specific attributes should also be considered. The vulnerable communities highlighted in the transportation equity literature but not mentioned explicitly in the HEAL Act are children, young people, the elderly, women, queer individuals, and individuals with disabilities. It is also important to understand that Tribal Nations require unique consideration because they are sovereign nations. Tribal relations must first and foremost recognize Tribal councils as governing bodies of sovereign nations rather than as community boards or organizations. Consulting with and working through Tribal liaisons (such as WSDOT's Tribal Liaison Office) is critical to ensuring respectful and meaningful engagement with Tribes.

Designs that improve accessibility for individuals who are disabled improve travel conditions not only for individuals who are permanently disabled, but also for those who are temporarily disabled or hae in some way experienced limiting events. For example, an individual who is otherwise able-bodied could break their leg and experience limited mobility because of crutches. Or, even more commonly, individuals traveling with babies, small children, or bulky objects such as groceries also need accommodations similar to those needed by individuals with disabilities.

Broadly, ensuring that people have reasonable, reliable transportation choices is critical to delivering an equitable transportation system. This means investing in modes beyond private vehicles in ways that provide meaningful improvement to accessibility. To accomplish this, investments of time and resources will need to be allocated to establish analysis and associated data collection and management structures. An immediate jump to person-based analysis methods may not be viable, but as data collection and accessibility analysis tools continue to advance, the cost barrier will ideally decrease. While some of the more elaborate qualitative methods may not be viable for large-scale planning efforts, incorporating questions related to satisfaction, such as those by Di Ciommo et. al (2019), may provide key, subjective accessibility insights.

Beyond regional accessibility analyses, Guo et al. (2020) emphasized good quality, well-maintained, well-connected, non-motorized infrastructure as critical to transportation equity. This would require the separation of modal facilities—if not entirely, then at least by speed (Nello-Deakin, 2019). Where modes mix or when low-speed enforcement is critical (such as near

sensitive facilities), physical traffic calming methods, as well as regulatory measures such as cameras and speed level readouts, are known to improve safety outcomes. Incorporating streetlights and greenery in corridor designs will not only help improve safety but will also reduce environmental heat island.

It is especially important to prioritize non-motorized infrastructure improvements in areas with low-income communities of color because they tend to have worse existing infrastructure and therefore face the worst safety outcomes. Analysis of crash data in addition to socio-economic data can be used to focus these interventions. Efforts to reconnect communities divided by the Interstate system are especially important, either in the form of bridges or full highway caps. It is also critical to account for housing policies and housing security when transportation system improvements are considered in communities of concern. If these interventions do not go hand-in-hand, then these investments may prove more harmful than helpful by driving up housing costs and displacing the communities they were intended to serve.

While policy interventions such as affordable housing considerations may fall outside of the historical scope of transportation planning activities, the displacement of marginalized communities is inextricably linked to the many ways that transportation systems have been used to reinforce and exacerbate a history of government-enforced segregation that pervades to this day (Rothstein, 2017). Transportation professionals have always played a role in this process, whether they realized it or not. If we are to achieve the restorative equalization goals laid out in the HEAL Act and Title VI, then a broader awareness and professional consideration for the relationships among transportation, housing, and opportunity must be incorporated into transportation planning practice.

7.5. FUTURE PROJECTS

The goal of this project was to establish a baseline of knowledge and guidance to incorporate equity in WSDOT planning efforts. As a result, the project focused on breadth rather than diving deep into specific issues that fall under the umbrella of equity considerations. Based on findings from this years' worth of work, here is a list of potential projects moving forward:

1. Assess transportation-created community divisions.
2. Identify relationships between transportation and gentrification and assess impacts.
3. Assess guidance materials for quality.
4. Establish compensation alternatives and shareable resources for engagement.

5. Establish metrics for tracking accountability to communities.

Idea 1: Transportation facilities have the power to destroy and divide or create and connect. Historically, the US Interstate system has led to the destruction and division of marginalized communities, but physical infrastructure such as bridges and caps can support reconnection and revitalization (Rothstein, 2017; Dutta et al., 2022).

The Active Transportation division at WSDOT has developed multiple geospatial layers that could be used to assess a range of (dis)connectedness throughout the state (Active Transportation Route Directness Index) as well as the quality of facilities for non-motorized users (Active Transportation Level of Traffic Stress). **These are readily available data sets maintained by WSDOT that could yield many useful insights.** Further analysis of historical WSDOT project records could build on this to link past projects to present realities. This additional, explicit historical component would prove a time intensive exercise and may be best suited to a graduate student thesis or dissertation project.

Idea 2: Nawrocki et al.'s (2023) practice-oriented literature review found that gentrification had limited representation. They recommended pursuing a project to "identify leading indicators to anticipate gentrification based on transportation planning and engineering activities …[which] could also identify areas affected by gentrification and in need of strategies for mitigating its effects on vulnerable populations in Washington state" (p. 16).

Idea 3: A discrepancy was identified between the planner survey free-response results and the guidance materials identified in the practice-oriented literature review (Section 6.2, tables 6.1 and 6.2). While these are not conclusive results regarding whether WSDOT planners do or do not use the guidance materials listed in Table 6.1, it does raise the following questions:

- How useful are existing guidance materials for informing transportation equity efforts in practice?
- If guidance materials are not in use, what is limiting their application? Do they lack applicable content or are there other barriers to content application?

Notably, one planner suggested "an assessment of recent reporting documents [with] guidance re: what was done well and what opportunities were missed/what could be done better moving forward to incorporate equity in decision making."

Idea 4: As explained in the Lessons Learned from the community consultation survey process (Section 6.1.b), logistical barriers to improved engagement include compensation

budgeting and engagement resources. Section 6.1.b outlines a number of lessons related to these points. Specifically, it recommends a feasibility study to establish guidelines and alternatives to compensate local service providers to support engagement efforts and for community members to be compensated for engaging. Additionally, it recommends identifying or establishing an engagement technology and other tools and a resource library of sorts to support WSDOT engagement efforts.

Idea 5: While Section 4.4.e outlines some indicators for tracking engagement, further work is required to define metrics of accountability. Included in the planner feedback was the suggestion to identify "metrics that track how community engagement has been incorporated in planning efforts and down into tangible results citizens can appreciate."

7.6. ACCESSIBILITY ANALYSIS GUIDANCE

As Section 4.4.a discussed, the concept of accessibility, while over a half century old, is still in its infancy from an application standpoint. While accessibility is a simple concept in theory, its multi-dimensional nature, paired with computational limitations, have made it difficult to operationalize. Computational power now exists; however, complete, readily useable tools are still in development (Siddiq and Taylor, 2021). As a result, while many agencies have implemented some form of accessibility analysis in their workflows, the exact form and function remain highly variable (Karner et al., 2022).

Section 4.4.a of this report presents yet another overview of accessibility by offering summary information from the current state of transportation equity literature. It builds on the structure of previous work but presents a summary of measures relative to the concept of leading indicators. For further guidance relative to practical, agency-focused accessibility methods, we strongly recommend a close read of both the practice-oriented reports cited in this report: the SSTI report (Sundquist et al. 2021) and the NCHRP report (Karner et al., 2022).

The SSTI report offers an easy-to-read walk through of accessibility calculation and reporting basics, necessary data, existing methods and tools, and example analyses (Sundquist et al., 2021). The NCHRP report is organized in three concise chapters, followed by seven appendices. These present example metrics organized by agency, as well as accessibility practices by state DOT, case studies of existing practices and a use-case for the report, a comprehensive summary of software and data resources, and worksheets to step a planner

through the processes laid out in the report. Both reports serve as excellent resources for planners seeking guidance in accessibility implementation.

8 CONCLUSION

This report develops a working definition of leading indicators of transportation equity and presents a process framework to incorporate equity into WSDOT planning efforts. Within this framework, component parts have been detailed using knowledge derived from academic literature, practice-oriented literature, the community, and practitioners. All of this is supported by geospatial analysis and recommendations for the application of GIS tools in equity analyses. Transportation practitioners are left with the recommendation to err on the side of inclusion at the course resolution that most equity screening tools offer and to always seek more localized data and analyses when possible.

Communities expressed strong buy-in into project aims and HEAL Act implementation in general, specifically requesting more regular interaction with WSDOT. Planners noted limitations in time, funds, and staff allocation as barriers to equity work at WSDOT. When asked to identify the primary hinderance, planners chose time and development for non-technical tasks and skills and funds for technical analyses as top priorities, highlighting the breadth of skills and tools needed to complete these analyses. Additionally, planners reported a need for guidance.

This report provides a step in that direction. Additional work remains, but the breadth of this project invites readers to take initiative and dive deeper into this work, using this report as a guide.

ACKNOWLEDGMENTS

Thank you to the WSDOT project team who brought this project to life and contributed in a wide variety of critical ways, at various stages throughout the project process: Faris Al-Memar, Bill Bennion, Ryan Warner, Candice Tobin, Corwin Scott, Sasha James, Julie Jackson, Elizabeth Lanzer, Kyle Miller, Leilani Fitzgerald, Jon Peterson, Justin Nawrocki, Carol Thompson.

Additionally, thank you to the service providers who met with and helped facilitate community consult survey distribution and to the community members who completed the survey.

Finally, thank you to the planners who completed the planner feedback survey.

REFERENCES

Aivinhenyo, I., and Zuidgeest, M. (2019). Transport equity in low-income societies: Affordability impact on destination accessibility measures. In *Measuring transport equity* (pp. 111-128). Elsevier.

Alhammadi, S. A. (2022). Identification and Categorisation of Safety Improvement Practices in the Construction Industry: Review Study. International Review of Civil Engineering, 13(1), 53-66.

American Library Association. (n.d.). *Indigenous Tribes of Seattle and Washington*. Retrieved July 2023, from American Library Association: https://www.ala.org/aboutala/indigenous-tribes-seattle-and-washington

Anderson, K., Blanchard, S. D., Cheah, D., and Levitt, D. (2017). Incorporating equity and resiliency in municipal transportation planning: Case study of mobility hubs in Oakland, California. *Transportation Research Record*, 2653(1), 65-74.

Antipova, A. (2020). Analysis of Commuting Distances of Low-Income Workers in Memphis Metropolitan Area, TN. *Sustainability,* 12(3), Article 3.

Aparicio, Á. (2018). Equity challenges in major transport plans. *Transportation Research Procedia*, *31*, 121-135.

Arsenio, E., Martens, K., and Di Ciommo, F. (2016). Sustainable urban mobility plans: Bridging climate change and equity targets?. *Research in Transportation Economics*, *55*, 30-39.

Bajada, T., Mifsud, D., and Ciommo, F. D. (2016). *Accessibility as an indicator of transport equity: the case of public transport infrastructure in Malta, and its impact on the elderly*. Malta Chamber of Scientists.

Banister, D. (2008). The sustainable mobility paradigm. *Transport policy*, 15(2), 73-80.

Beiler, M. O., and Mohammed, M. (2016). Exploring transportation equity: Development and application of a transportation justice framework. *Transportation research part D: transport and environment*, *47*, 285-298.

Berg, A., and Newmark, G. L. (2020). Incorporating equity into pedestrian master plans. *Transportation research record*, 2674(10), 764-780.

Bills, T. S. (2022). Advancing the practice of regional transportation equity analysis: a San Francisco bay area case study. *Transportation*, 1-26.

Bills, T. S., Sall, E. A., and Walker, J. L. (2012). Activity-based travel models and transportation equity analysis: Research directions and exploration of model performance. *Transportation research record*, *2320*(1), 18-27.

Bills, T. S., and Walker, J. L. (2017). Looking beyond the mean for equity analysis: Examining distributional impacts of transportation improvements. *Transport Policy*, *54*, 61-69.

Bolten, N., and Caspi, A. (2021). Towards routine, city-scale accessibility metrics: Graph theoretic interpretations of pedestrian access using personalized pedestrian network analysis. *PLoS one*, *16*(3), e0248399.

Boisjoly, G., and El-Geneidy, A. (2021). Public transport equity outcomes through the lens of urban form. In *Urban Form and Accessibility* (pp. 223-241). Elsevier.

Boisjoly, G., and Yengoh, G. T. (2017). Opening the door to social equity: local and participatory approaches to transportation planning in Montreal. *European transport research review*, *9*(3), 1-21.

Capasso Da Silva, D., King, D. A., and Lemar, S. (2019). Accessibility in practice: 20-minute city as a sustainability planning goal. *Sustainability*, *12*(1), 129.

Carbado, D. W., Crenshaw, K. W., Mays, V. M., and Tomlinson, B. (2013). INTERSECTIONALITY: Mapping the Movements of a Theory1. *Du Bois review: social science research on race*, *10*(2), 303-312.

Carrasco, J. A., and Lucas, K. (2019). Measuring the influence of social capital and personal networks on transport disadvantage. In *Measuring transport equity* (pp. 231-246). Elsevier.

Castiglione, J., Hiatt, R., Chang, T., and Charlton, B. (2006). Application of travel demand microsimulation model for equity analysis. *Transportation Research Record*, *1977*(1), 35-42.

Chen, Z., and Li, X. (2021). Unobserved heterogeneity in transportation equity analysis: Evidence from a bike-sharing system in southern Tampa. *Journal of transport geography*, *91*, 102956.

Creger, H., Espino, J., and Sanchez, A. S. (2018). *Mobility Equity Framework: How to Make Transportation Work for People*. Transportation Research Information Database.

Curl, A. (2018). The importance of understanding perceptions of accessibility when addressing transport equity. *Journal of Transport and Land Use, 11*(1), 1147-1162.

Currie, G., and Delbosc, A. (2010). Modelling the social and psychological impacts of transport disadvantage. *Transportation*, *37*, 953-966.

Caspi, C. E., Sorensen, G., Subramanian, S. V., and Kawachi, I. (2012). The local food environment and diet: a systematic review. *Health & place*, *18*(5), 1172-1187.

Davis, A., and Pilkington, P. (2019). A public health approach to assessing road safety equity—the RoSE cycle. In *Measuring Transport Equity* (pp. 159-170). Elsevier.

Di Ciommo, F., Magrinya, F., Rondinella, G., and Shiftan, Y. (2019). A behavioral framework for needs-based transport assessment. In *Measuring Transport Equity* (pp. 265-275). Elsevier.

Dixit, M., and Sivakumar, A. (2020). Capturing the impact of individual characteristics on transport accessibility and equity analysis. *Transportation research part D: transport and environment, 87*, 102473.

Dutta, S., Armanios, D. E., and Desai, J. D. (2022). Beyond spatial proximity: The impact of enhanced spatial connectedness from new bridges on entrepreneurship. *Organization Science, 33*(4), 1620-1644.

Eisenberg, A. M. (2020). Distributive justice and rural America. *BCL Rev., 61*, 189.

Fan, Y., Guthrie, A., Van Dort, L., and Baas, G. (2019). *Advancing Transportation Equity: Research and Practice*. Center for Transportation Studies, University of Minnesota.

Fan, J., Li, Y., Zhang, Y., Luo, X., and Ma, C. (2019). Connectivity and accessibility of the railway network in China: Guidance for spatial balanced development. *Sustainability, 11*(24), 7099.

Fransen, K., and Farber, S. (2019). Using person-based accessibility measures to assess the equity of transport systems. In *Measuring transport equity* (pp. 57-72). Elsevier.

Ghasemlou, K., Ergun, M., and Dadashzadeh, N. (2021). Exploring equity in public transportation planning using smart card data. *Sensors, 21*(9), 3039.

Grengs, J., Levine, J., and Shen, Q. (2013). *Evaluating transportation equity: An intermetropolitan comparison of regional accessibility and urban form* (No. FTA Report No. 0066). United States. Federal Transit Administration. Office of Civil Rights.

Griffin, G. P., and Jiao, J. (2019). The geography and equity of crowdsourced public participation for active transportation planning. *Transportation Research Record, 2673*(1), 460-468.

Golub, A., and Martens, K. (2014). Using principles of justice to assess the modal equity of regional transportation plans. *Journal of Transport Geography, 41*, 10-20.

Guo, Y., Chen, Z., Stuart, A., Li, X., and Zhang, Y. (2020). A systematic overview of transportation equity in terms of accessibility, traffic emissions, and safety outcomes: From conventional to emerging technologies. *Transportation research interdisciplinary perspectives, 4*, 100091.

Hansen, W. G. (1959). How accessibility shapes land use. *Journal of the American Institute of planners*, *25*(2), 73-76.

Heyer, J., Palm, M., and Niemeier, D. (2020). Are we keeping up? Accessibility, equity and air quality in regional planning. *Journal of Transport Geography, 89*, 102891.

Iroz-Elardo, N., Schoner, J., Fox, E. H., Brookes, A., and Frank, L. D. (2020). Active travel and social justice: Addressing disparities and promoting health equity through a novel approach to Regional Transportation Planning. *Social Science & Medicine, 261*, 113211.

Jaramillo, A. G., Philips, I., and Lucas, K. (2019). Social impact assessment: The case of bus rapid transit in the City of Quito, Ecuador. In *Measuring Transport Equity* (pp. 217-229). Elsevier.

Johnston, K., Oakley, D., Durham, A. V., Bass, C., and Kershner, S. (2020). Regulating Micromobility: Examining Transportation Equity and Access. *JCULP, 4*, 682.

Karner, A. (2016). Planning for transportation equity in small regions: Towards meaningful performance assessment. *Transport policy, 52*, 46-54.

Karner, A., and Golub, A. (2019). Assessing the equity impacts of a transportation investment program. In *Measuring Transport Equity* (pp. 277-290). Elsevier.

Karner, A., Levine, K., Alcorn, L., Situ, M., Rowangould, D., Kim, K., and Kocatepe, A. (2022). *Accessibility measures in practice: A guide for transportation agencies* (No. NCHRP Project 08-121).

Karner, A., and London, J. (2014). Rural communities and transportation equity in California's San Joaquin Valley. *Transportation Research Record, 2452*(1), 90-97.

Karner, A., and Marcantonio, R. A. (2018). Achieving transportation equity: Meaningful public involvement to meet the needs of underserved communities. *Public Works Management & Policy, 23*(2), 105-126.

Khavarian-Garmsir, A. R., Sharifi, A., and Sadeghi, A. (2023). The 15-minute city: Urban planning and design efforts toward creating sustainable neighborhoods. *Cities*, *132*, 104101.

Kim, H., and Wang, F. (2019). Disparity in spatial access to public daycare and kindergarten across GIS-constructed regions in Seoul, South Korea. *Sustainability, 11*(19), 5503.

Krapp, A., Barajas, J. M., and Wennink, A. (2021). Equity-oriented criteria for project prioritization in regional transportation planning. *Transportation Research Record, 2675*(9), 182-195.

Lee, C. (2021). Another Game Changer in the Making? Lessons From States Advancing Environmental Justice Through Mapping and Cumulative Impact Strategies. *Envtl. L. Rep., 51*, 10676.

Lee, R. J., Sener, I. N., and Jones, S. N. (2017). Understanding the role of equity in active transportation planning in the United States. *Transport reviews, 37*(2), 211-226.

Lempert, R., Syme, J., Mazur, G., Knopman, D., Ballard-Rosa, G., Lizon, K., and Edochie, I. (2020). Meeting Climate, Mobility, and Equity Goals in Transportation Planning Under

Wide-Ranging Scenarios: A Demonstration of Robust Decision Making. *Journal of the American Planning Association, 86*(3), 311-323.

Lewis, E. O. C., MacKenzie, D., and Kaminsky, J. (2021). Exploring equity: How equity norms have been applied implicitly and explicitly in transportation research and practice. *Transportation research interdisciplinary perspectives*, *9*, 100332.

Lewis, E. O. (2024). Exploring Equity in Transportation: a critical review and assessment of concepts, indices, and methods. [Doctoral dissertation, University of Washington, Seattle, WA]. ProQuest Dissertations & Theses Global.

Levine, J., Grengs, J., and Merlin, L. A. (2019). *From mobility to accessibility: Transforming urban transportation and land-use planning*. Cornell University Press.

Li, T., Zhang, S., Cao, X., and Witlox, F. (2018). Does a circular high-speed rail network promote efficiency and spatial equity in transport accessibility? Evidence from Hainan Island, China. *Transportation Planning and Technology, 41*(7), 779-795.

Lira, B. M. (2019). Using a capability approach-based survey for reducing equity gaps in transport appraisal: Application in Santiago de Chile. In *Measuring transport equity* (pp. 247-264). Elsevier.

Lotfi, S., and Koohsari, M. (2009). Analyzing accessibility dimension of urban quality of life: Where urban designers face duality between subjective and objective reading of place. *Social Indicators Research, 94*(3), 417–435.

Lowe, K. (2014). Bypassing equity? Transit investment and regional transportation planning. *Journal of Planning Education and Research, 34*(1), 30-44.

Lubitow, A., Liévanos, R., McGee, J., and Carpenter, E. (2019). *Developing Data, Models, and Tools to Enhance Transportation Equity*. Institute for Sustainable Solutions - Portland State University, and University of Oregon.

Lucas, K. (2012). Transport and social exclusion: Where are we now?. *Transport policy*, *20*, 105-113.

Lucas, K., Martens, K., Di Ciommo, F., and Dupont-Kieffer, A. (Eds.). (2019). *Measuring transport equity*. Elsevier.

Lucas, K., Van Wee, B., and Maat, K. (2016). A method to evaluate equitable accessibility: combining ethical theories and accessibility-based approaches. *Transportation, 43,* 473-490.

Luna, M. (2015). Equity in transportation planning: An analysis of the Boston region metropolitan planning organization. *The Professional Geographer, 67*(2), 282-294.

Mackness, K., White, I., and Barrett, P. (2021). *Towards the 20 minute city.* Build Magazine.

Manaugh, K., Badami, M. G., and El-Geneidy, A. M. (2015). Integrating social equity into urban transportation planning: A critical evaluation of equity objectives and measures in transportation plans in North America. *Transport policy, 37*, 167-176.

Martens, K., Bastiaanssen, J., and Lucas, K. (2019). Measuring transport equity: Key components, framings and metrics. In *Measuring transport equity* (pp. 13-36). Elsevier.

Martens, K., Di Ciommo, F., and Papanikolaou, A. (2014). *Incorporating equity into transport planning: Utility, priority and sufficiency approaches*. In: "XVIII Congreso Panamericano de Ingeniería de Tránsito, Transporte y Logística. PANAM 2014", 11/06/2014 – 13/06/2014, Santander, España. pp. 1-16.

Martens, K., and Golub, A. (2021). A fair distribution of accessibility: Interpreting civil rights regulations for regional transportation plans. *Journal of Planning Education and Research, 41*(4), 425-444.

Miller, E. J. (2018). Accessibility: measurement and application in transportation planning. *Transport Reviews, 38*(5), 551-555.

Millonig, A., Rudloff, C., Richter, G., Lorenz, F., and Peer, S. (2022). Fair mobility budgets: A concept for achieving climate neutrality and transport equity. *Transportation Research Part D: Transport and Environment, 103*, 103165.

Mohai, P., Pellow, D., and Roberts, J. T. (2009). Environmental justice. *Annual review of environment and resources*, *34*, 405-430.

Moreno, C., Allam, Z., Chabaud, D., Gall, C., and Pratlong, F. (2021). Introducing the "15-Minute City": Sustainability, resilience and place identity in future post-pandemic cities. *Smart Cities*, *4*(1), 93-111.

Murray, A. T., and Davis, R. (2001). Equity in regional service provision. *Journal of Regional Science, 41*(4), 557-600.

Nahmias-Biran, B. H., and Shiftan, Y. (2020). Using activity-based models and the capability approach to evaluate equity considerations in transportation projects. *Transportation, 47*, 2287-2305.

Nardo, M. (2005). *Handbook on constructing composite indicators*. Organization for Economic Cooperation and Development (OECD) Statistics Working Papers.(03).

Nawrocki, J., Thompson, C., and James, S. (2023). *Equity in Planning (EiP) Research Project Phase 1: Literature Review and Best Practices.* Washington State Department of Transportation Report sponsored by the Public Transportation Division.

Nello-Deakin, S. (2019). Is there such a thing as a 'fair' distribution of road space?. *Journal of urban design*, *24*(5), 698-714.

Office of Environmental Justice and External Civil Rights (OEJECR). (2023). *Environmental Justice Mapping and Screening Tool: EJScreen Technical Documentation for Version 2.2.* U.S. Environmental Protection Agency (EPA), Washington, DC.

Office of the Secretary of Transportation (OST). (2023). *Equitable Transportation Community (ETC) Explorer: ETC Explorer Technical Documentation*. United States Department of Transportation, Washington, DC.

Pereira, R. H., Schwanen, T., and Banister, D. (2017). Distributive justice and equity in transportation. *Transport reviews, 37*(2), 170-191.

Preston, J., and Rajé, F. (2007). Accessibility, mobility and transport-related social exclusion. *Journal of transport geography*, *15*(3), 151-160.

Qi, Z., Lim, S., and Hossein Rashidi, T. (2020). Assessment of transport equity to central business district (CBD) in Sydney, Australia. *Transportation Letters, 12*(4), 246-256.

Quinault Indian Nation. (n.d.). *Quinault Indian Nation*. Retrieved March 2023, from Quinault Indian Nation: https://www.quinaultindiannation.com/

Reardon, L., Mahoney, L., and Guo, W. (2019). Applying a subjective well-being lens to transport equity. In *Measuring transport equity* (pp. 205-215). Elsevier.

Richardson, J., Mitchell, B., and Franco, J. (2019). *Shifting neighborhoods: Gentrification and cultural displacement in American cities*. National Community Reinvestment Coalition,

Rothstein, R. (2017). The color of law: A forgotten history of how our government segregated America. Liveright Publishing.

Sanchez, T. W., Brenman, M., Ma, J. S., and Stolz, R. H. (2018). *The right to transportation: Moving to equity*. Routledge.

Siddiq, F., and D. Taylor, B. (2021). Tools of the trade? Assessing the progress of accessibility measures for planning practice. *Journal of the American Planning Association, 87*(4), 497-511.

Sider, T., Hatzopoulou, M., Eluru, N., Goulet-Langlois, G., and Manaugh, K. (2015). Smog and socioeconomics: an evaluation of equity in traffic-related air pollution generation and exposure. *Environment and Planning B: Planning and Design*, *42*(5), 870-887.

Solomon, J., and Titheridge, H. (2007). *Transport equity and the elderly*. In 9th NECTAR conference, Porto, Portugal.

Stewart, A., and Zegras, P. C. (2022). Interactive mapping for public transit planning: Comparing accessibility and travel-time framings. *Journal of Transport and Land Use, 15*(1), 635-650.

Sun, Z., and Zacharias, J. (2020). Transport equity as relative accessibility in a megacity: Beijing. *Transport Policy, 92,* 8-19.

Sundquist, E., McCahill, C., and Brenneis, M. (2021). *Measuring accessibility: A guide for transportation and land use practitioners*. State Smart Transportation Initiative

University of Washington Department of Environmental and Occupational Health Sciences (UW-DEOHS). (2019). *Washington Environmental Health Disparities Map: technical report.* for Washington State Department of Health (DOH), Seattle, WA.

US Department of Labor. (n.d.). *Using Leading Indicators to Improve Safety and Health Outcomes.* Retrieved February 2023, from Occupational Safety and Health Administration: https://www.osha.gov/leading-indicators

Uteng, T. P., Singh, Y. J., and Lam, T. (2019). Safety and daily mobilities of urban women—Methodolgies to confront the policy of "invisibility". In *Measuring transport equity* (pp. 187-202). Elsevier.

Wang, Y., Cao, M., Liu, Y., Ye, R., Gao, X., and Ma, L. (2022). Public transport equity in Shenyang: Using structural equation modelling. *Research in Transportation Business & Management, 42*, 100555.

Washington State Institute for Public Policy (WSIPP). (2022). *Technical Review of the Washington State Environmental Health Disparities Map. for The 2021 Washington State Legislature*, Olympia, WA.

Williams, K., Boyd, T., Keita, Y., and Kramer, J. (2021). *Transportation Equity Needs Assessment Toolkit* (No. CTEDD 020-01). Center for Transportation, Equity, Decisions and Dollars (CTEDD)(UTC).

Wohlin, C. (2014, May). Guidelines for snowballing in systematic literature studies and a replication in software engineering. In *Proceedings of the 18th international conference on evaluation and assessment in software engineering* (pp. 1-10).

Wu, Y., Rowangould, D., London, J. K., and Karner, A. (2019). Modeling health equity in active transportation planning. *Transportation research part D: transport and environment, 67*, 528-540.

van Wee, B., and de Jong, T. (2023). Differences in levels of accessibility: The importance of spatial scale when measuring distributions of the accessibility of health and emergency services. *Journal of Transport Geography*, *106*, 103511.

van Wee, B., and Mouter, N. (2021). Evaluating transport equity. *Advances in Transport Policy and Planning, 7*, 103-126.

Vecchio, G., Tiznado-Aitken, I., and Hurtubia, R. (2020). Transport and equity in Latin America: a critical review of socially oriented accessibility assessments. *Transport Reviews, 40*(3), 354-381.

Xiongbin, L. (2019). Incorporating Equity Concerns into Transportation Planning and Policies in Urban China: The Status Quo of Practice and Implications. *China City Planning Review, 28*(1), 56-64.

Yang, J., Guo, A., Li, X., and Huang, T. (2018). Study of the impact of a high-speed railway opening on China's accessibility pattern and spatial equality. *Sustainability, 10*(8), 2943.

Zhang, M., and Zhao, P. (2021). Literature review on urban transport equity in transitional China: From empirical studies to universal knowledge. *Journal of Transport Geography, 96*, 103177.

Zhao, P., & Zhang, Y. (2019). The effects of metro fare increase on transport equity: New evidence from Beijing. *Transport Policy*, 74, 73-83.

Zhou, Q., Dai, D., Wang, Y., and Fan, J. (2018). Decade-long changes in disparity and distribution of transit opportunity in Shenzhen China: A transportation equity perspective. *Journal of Advanced Transportation,* 2018.

Zuzak, C., E. Goodenough, C. Stanton, M. Mowrer, A.Sheehan, B. Roberts, P. McGuire, and J. Rozelle. (2023). *National Risk Index Technical Documentation. Federal* Emergency Management Agency (FEMA), Washington, DC.

APPENDIX A ADDITIONAL EQUITY THEORY CONTENT

A.1. EQUITY THEORY AND TRANSPORTATION BIKE EXAMPLE TABLES

Tables copied from Lewis et al. (2021)

Table A.1. A summary of theories and associated categories of underlying assumptions

Theory	Fundamental Argument	What is ideal?	Resource	Focus	Base Case
Simple Equality	Everyone has equal humanity so deserves equal resources	Equal distribution	Physical Capital	Ends	a-historical
Formal Equality	Some reasonable distinctions between individuals exist within society (i.e. people can be categorized), but those within a given category deserve equal	Equal distribution within groups, differences justifiable between groups	Physical Capital	Ends	a-historical
Proportional Equality	Different people earn different resources – balance the equation of what is deserved and what is received	Circumstance-informed unequal distribution	Physical Capital	Ends	a-historical
Utilitarian	Resources should be distributed in whatever way maximizes aggregate welfare	Maximized aggregate benefit	Welfare	Ends	a-historical
Libertarian	Protect individual liberty and contracts – non-coerced, self-possessed individuals trading freely is fair	Individual liberty	Physical Capital	Process	a-historical[3]
Marx	Distributions "from each according to their ability to each according to their need" is just	Needs-based unequal distribution	Physical & Human Capital	Ends	Contextual
Smith (user-fee)	Individuals paying for what they use is fair	Individuals pay for their impact (cost-focused)	Physical Capital	Process	a-historical
Pareto	Distributions optimized to the point at which welfare is improved for as many individuals as possible without decreasing the welfare of any others is fair	Optimized welfare	Welfare	Ends	Contextual

Table A.2. A theoretical transportation example: what is a fair distribution of bicycles within a bicycle-centric society?

[3] Left-leaning libertarianism proposes a contextualizing mechanism relative to natural resource distribution

Theory	Bike example
Simple Equality	Give everyone a bicycle
Formal Equality	Distribute bicycles equally among relevant subsets of individuals. Ex: Give every adult an adult bicycle and every child a child bicycle/ Give every person with special needs a special needs bicycle and every able-bodied person the same standard bicycle
Proportional Equality	Give those who have trained harder or who can pay more nicer bicycles
Utilitarian	Distribute bicycles in whatever way maximizes the aggregate welfare – if measured in units of bicycles/person, in the case of three people and three bicycles, any distribution (one bike each, three bikes to one person and none to the others, etc.) yields the same result so any are ideal. Measuring in other units such as bicycle utilization in hours/day/person or Likert-scored satisfaction/person would likely yield different results.
Libertarian	Whoever can justly acquire a bicycle can have a bicycle – what constitutes just acquisition will be determined by whoever produced the bicycles and those interested in acquiring them
Marx	Those with the ability to give should give to those in need. Ex: Those who have more bicycles should give to those with less (elders who can no longer cycle should give their bike to younger adults, children growing out of their child bikes should give them to younger children, etc.)/ Those who are skilled mechanics should innovate to provide bicycles to those who are differently abled Those who are able-bodied should help the elderly (by offering rides on rickshaws) and those incapable of riding (young children in child seats)
Smith (user-fee)	Individuals pay for their use – if they wish to purchase a bicycle and have the funds to do so, they can. If there is a bicycle fleet offering rentals, individuals should pay for the incremental wear and tear their riding causes – those who ride further and on bumpier terrain should pay more, those who ride shorter distances on smooth terrain should pay less
Pareto	A similar assessment to the utilitarian distribution would be used, however a Pareto assessment is longitudinal and would account for the base case of bicycle distribution. If a base case involved no one with bicycles, the bicycles/person unit example would be constrained such that distributions in which some individuals receive multiple bicycles and some receive none would not be permissible. Similar constraints would apply to distributions measured in other units as well. However, if the base case was some individuals owned multiple bicycles and some owned none, alternate distributions would be possible only if the welfare of no one was decreased – if someone who owned multiple bicycles believed their welfare would decrease if one or more of their bicycles was redistributed, then those bicycles could not justly be redistributed
Rawls	Those who hold positions of importance within society may earn more (either in the form of more resources to buy more bicycles, buy a nicer bicycle, or in the form of more/nicer/custom bicycles given directly), and/or if unequal bicycle resources could benefit the least advantaged. Ex: provide a rickshaw service or custom bikes to those incapable of riding a standard bike (the elderly and the differently abled)
al-Sadr	Bicycles should be distributed using public and private means in whatever way improves the condition of the poor, ideally moving society towards poverty eradication. Ex: create a public sector program where wealthier households with extra bicycles can donate bicycles for redistribution to poorer households lacking in bicycles, requiring contributions as necessary if needs are not met by voluntary measures alone

Theory	Bike example
Capabilities Approach	Distribute types of bicycles and bicycle services such that all individuals have equal cycling capabilities – this means children's bikes for children, alternative designs for those who are differently abled, and rickshaw services for those who cannot ride a bike
Sufficientarian	Distribute bikes in a way that at least meets a sufficiency threshold – perhaps that has been set at a minimum of one bicycle per household (rather than one per person), or rickshaw service for all at a level of frequency and coverage that meets the basic needs of all for basic cycle transport. So long as basic needs are met, people can own as many and as nice bicycles as they want
Prioritarian	Distribute bicycles (and/or bicycle services as welfare needs dictate) beginning with the least well-off
Intuitionism	A morally minded person should assess the situation, consider alternatives (such as those laid out above), and take whatever course of action seems just within the context of a given situation

A.2. ADDITIONAL TRANSPORTATION EQUITY STANDARD DISCUSSION

If it is accepted that formal equality cannot be reasonably achieved, the equity standards of basic need, sufficiency, prioritarian, and maximum gap can provide useful guidance and operationalizations in pursuit of a restorative equity goal. Table defines and provides examples of these equity standards from the literature and policy.

Table A.3. Equity standards and associated transportation examples that align with restorative equity.

Standard	Description	Examples
Basic Need	different individuals and groups have different needs – resources should be allocated according to needs	Martens et al. (2019) highlighted how vulnerable populations for disease receive additional protections from pollutants, or provisions of transport for those with inability to have private transport (cannot afford, disability, no license)
Sufficiency	sets a minimum necessary benefit threshold to judge the distribution of benefits and to prioritize those below the threshold	researchers tend to agree that a minimum level of accessibility to some key destinations should be ensured, and that this threshold should be defined to allow individuals to meet their basic needs and participate in society (Lucas et al., 2016)
		Golub and Martens (2014) proposed thresholds of "access poverty" - percentage of the population who experiences an accessibility ratio (transit access/car access) of 0.25 and 0.34
	sets a maximum allowable burden threshold to judge the distribution of benefits and to prioritize those above the threshold	legal thresholds regarding maximum allowable exposure to pollutants
Prioritarian	benefits (or burdens) matter more the worse off a person is (i.e. marginal value is higher) and therefore those worse off should be prioritized	"individuals inevitably have unequal opportunities in a society, given internal and external constraints; therefore individuals more likely to have limited opportunities due to financial, cultural, physical, situational (e.g., lack of access to information), or cognitive constraints should be provided with higher levels of accessibility" (Boisjoly & El-Geneidy, 2021, p. 228)
		Murray and Davis (2001) focused on expanding public transit provisions to socio-economic groups most likely to need public transit
		Anderson et al. (2017) identified and focused analysis where disadvantaged groups are located in placement of multimodal facility recommendation analysis
Maximum Gap	defines a maximum range of fair outcomes – accepts inequality so long as they remain within range	Martens et al. (2019) noted that disparities may be the result of choices (ex: purchasing a house in suburbs with lower access for lower cost and more sq ft) – this theory allows for choice but aims to limit potential harm for those without the resources to make such a choice by assigning allowable range values

A.2.1. Basic Need and the Capabilities Approach (CA)

While basic need offers a straightforward concept that has been applied in various sectors, Martens et al. (2019) cautioned that, to execute a basic needs assessment properly, detailed information about individuals/groups is required. Similarly, the Capabilities Approach (CA) is presented in many transportation equity articles and is the equity standard that informed the United Nation's Sustainable Development Goals (SDGs) (Pereira et al., 2017; Nahmias-Biran and Shiftan, 2020; Lewis et al., 2021). The CA distinguishes between opportunities and functionings; opportunities are all the things a person reasonably *could* do, and functionings are what someone *does* do. Functionings are a product of opportunities and personal preference (choice), but one can only do what one has the legitimate opportunity to do. This opportunity set is based on many constraints, from the built environment to personal ability, and is concerned with all aspects necessary for a person to lead a fulfilling life.

Lira (2019) presented a methodological approach to quantify and compare capabilities and functionings and argued that the nuance provided by CA offers key insights into how users experience the transportation system. It requires, however, a 60+ question representative survey. Nahmias-Biran and Shiftan (2020) presented a method that utilizes activity-based models to evaluate the equity of transportation project alternatives. Again, this requires significant data collection efforts to power this person-based method (for more information on person-based measures, see Section 4.3.a). As a result, data and privacy constraints may limit the widescale operationalization of both CA and basic needs standards.

A.2.2. Sufficiency and Prioritarianism

The equity standard of sufficiency provides a method that relies on widely available data and generalized goals. Maximum allowable thresholds of pollutants are common in environmental regulations, but minimum allowable thresholds are less common as a framework for discussing transportation benefits. Golub and Martens (2014) operationalized this standard with their concept of an access poverty line (see Table 4.6). While setting a specific threshold could prove to be a difficult, political exercise, analysts can present possible threshold measures to provide useful, data-driven talking points.

The use of thresholds, however, has a significant drawback: they divide individuals and groups in black-and-white terms of haves and have-nots. Consider the example thresholds of Golub and Martens (2014); if the threshold of 0.25 were selected, someone with an accessibility

ratio of 0.26 would be classified as access rich and given the same consideration as someone with a ratio of 0.8. Martens et al. (2014) presented prioritarianism as a remedy to the rigid nature of sufficiency thresholds—instead of a fixed threshold, those lower in the distribution are prioritized.

While the other three equity standards focus analytical attention on those who are worse off (ex: lower on the distribution of benefits), the maximum gap standard is concerned not only with the worse-off but also with how disparate the worse-off's experience is from the best-off. Many authors have discussed methods to minimize this gap. Bajada et al. (2016) suggested adding bus-only lanes "where the time and cost savings to the bus operators and passengers exceed the equivalent delays to other road traffic" (p. 78). Guo et al. (2020) recommended interventions that offer a balance of minimizing the gap within and between groups while maximizing average benefits, particularly when agencies work to balance conflicting goals and constraints.

Guo et al. (2020) provided an excellent example of how to combine equity standards. Left as the only goal, maximizing average benefits is susceptible to the same pitfalls as the Pareto optimization. Additionally, focusing on average benefits alone can negate serious and concerning effects at the extremes. This is why additional, gap-focused constraints are important to consider when equity goals are set. It is important to remember, however, that minimizing the gap and setting clear bounds on a maximum gap are distinct exercises; the latter requires more political will and is more robust.

Prioritarianism aligns most closely with the current iteration and recommended use of the Washington State Department of Health's Environmental Health Disparities (EHD) map. The scoring system of the map highlights areas where burdens are highest so that those regions and individuals can be prioritized in planning efforts. However, without clear goals that hold agencies accountable to meaningful change for those prioritized, prioritarianism can fail to deliver equitable outcomes. Because all the equity standards presented in Table A.3 align with restorative equalization, any of them can fall prey to the same pitfalls. Specifically, if targets related to basic need, sufficiency, or maximum gap are too small and/or limited, then they will also fall short.

Each equity standard does not necessarily need to be applied independently. Conceptual overlap exists and can be harnessed to improve outcomes. Because the reality of planning

includes constraints and competing interests, creative problem solving is necessary to find balance. Where conflicts occur between groups (ex: interventions that might improve outcomes for some but cause a reduction for others), clearly defined equity standards can serve as a solid guide. However, where conflicts occur between categories (ex: accessibility vs. economy vs. environment), professional judgment informed by policy and community engagement must be used to weight and choose the best course of action.

APPENDIX B. COMMUNITY CONSULT SURVEY

B.1. COMMUNITY CONSULT SURVEY SUMMARY STATISTICS

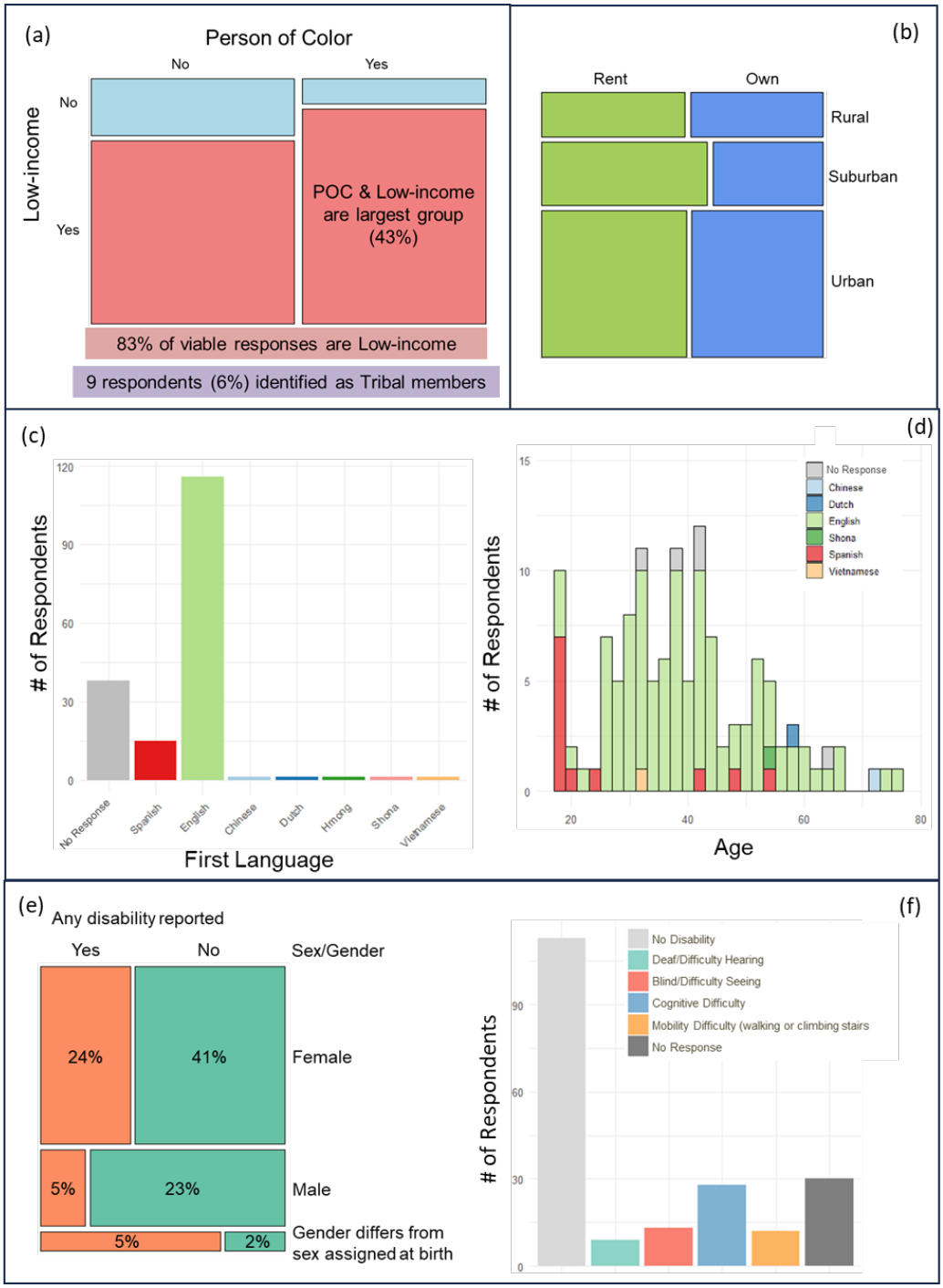


Figure B.1. Community consult summary statistics for responses for individuals who identified (a) as low-income (n=122) and a person of color (n=144), (b) as renting/owning their home and by level of education completed (n=143), (c) by their first language and (d) by age (n=125), (e) by disability and sex/gender identity with (f) disabilities detailed by type (n=142).

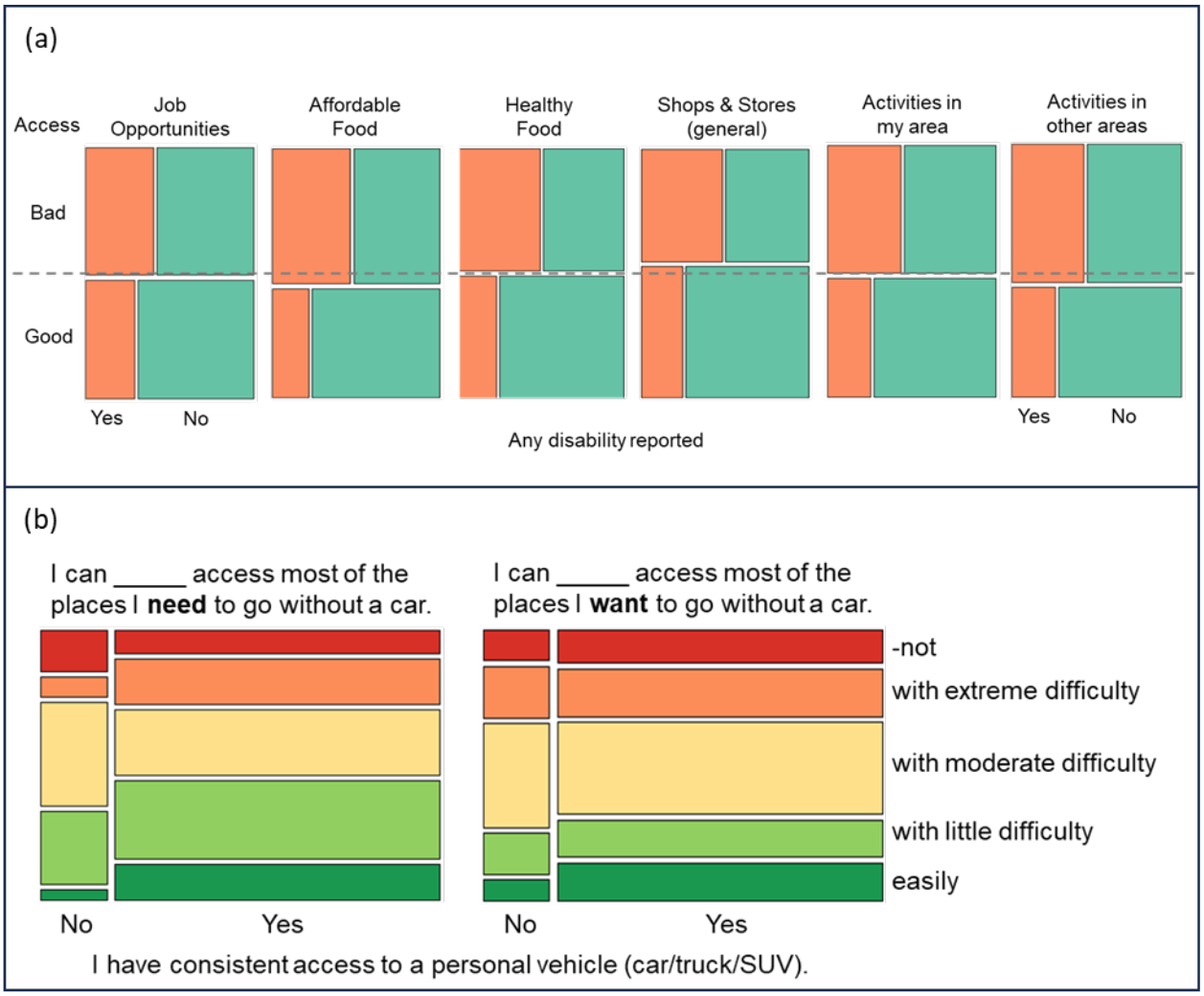


Figure B.2. Community consult survey responses related to accessibility indicators with (a) quality of access by destination type broken out by disability (n=156), and (b) level of difficulty reported for access to destinations of need and want broken out by reported access to a private vehicle (n=156).

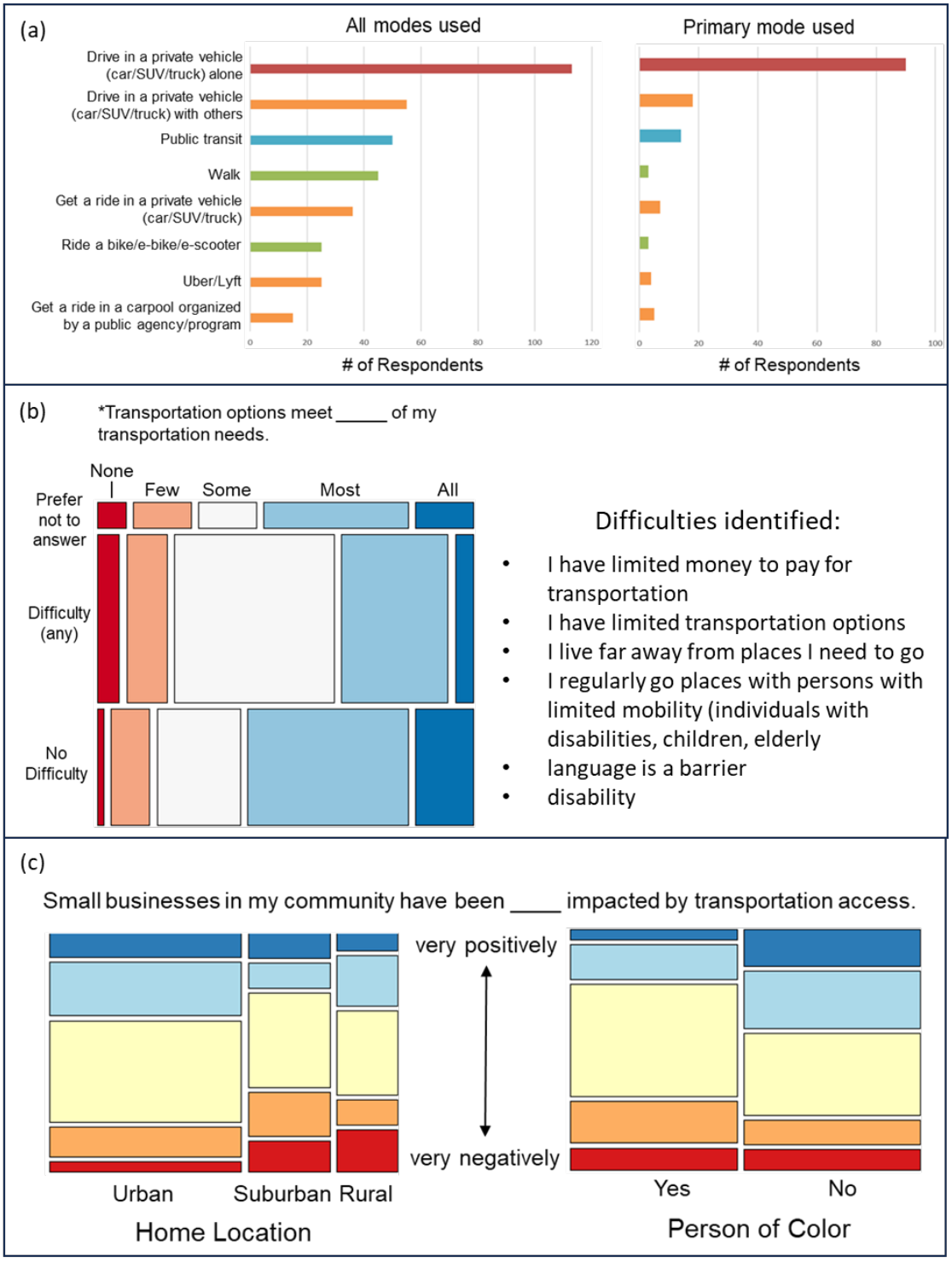


Figure B.3. Community consult survey responses related to mobility and economy indicators with (a) respondent mode share by all modes used and by primary mode (n=144), (b) assessment of quantity of transportation needs met by experience of difficulties related to transportation (n=144), and (c) perception of how small businesses in their community have been affected by transportation access broken out by home location and race/ethnicity (n=155).

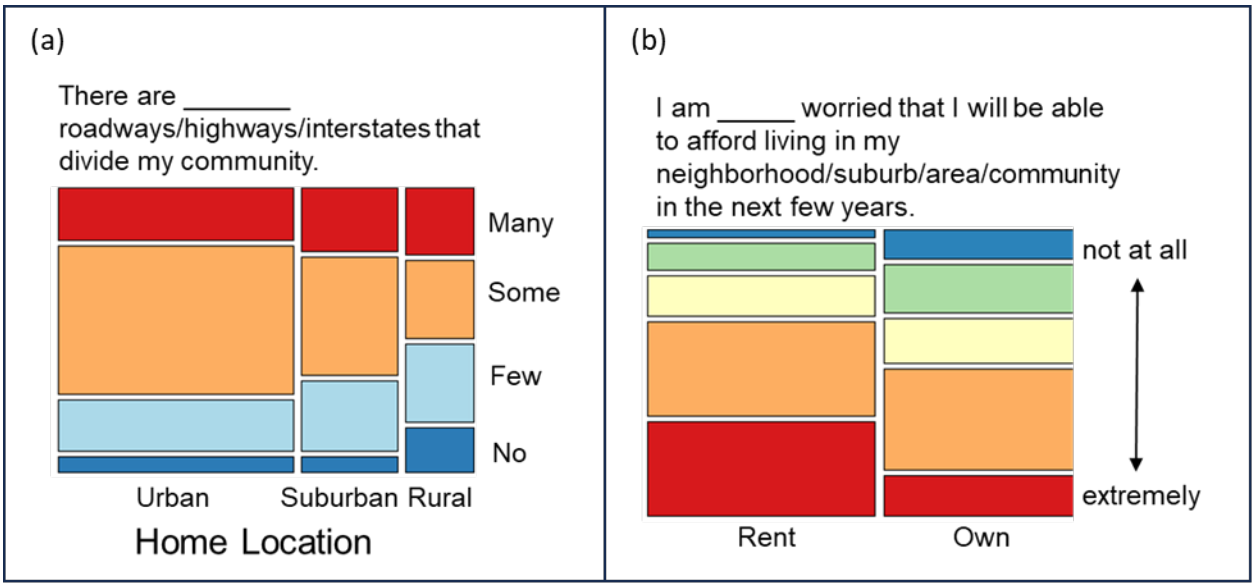


Figure B.4. Community consult survey responses related to land use and displacement indicators with (a) number of roadway facilities that divide the respondent's community broken out by home location (n=153) and (b) level of concern related to housing affordability broken out by whether a respondent rents or owns their home (n=155).

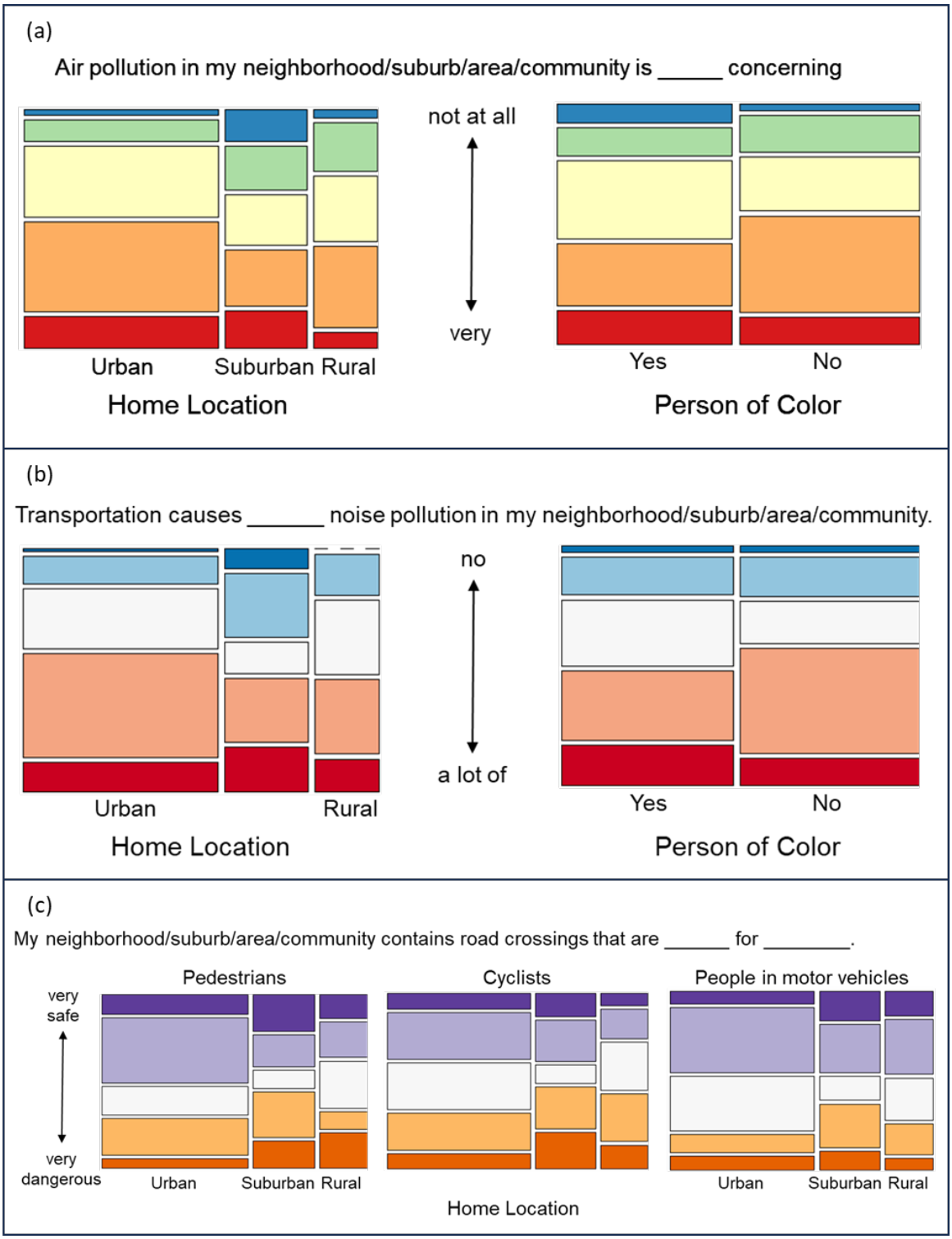


Figure B.5. Community consult survey responses related to environment, health and safety indicators with (a) concern regarding air pollution (n=157) and (b) experiences of transportation-related noise pollution broken out by home location and race/ethnicity (n=156), and (c) perceived safety of intersections by user type and broken out by home location (n=154).

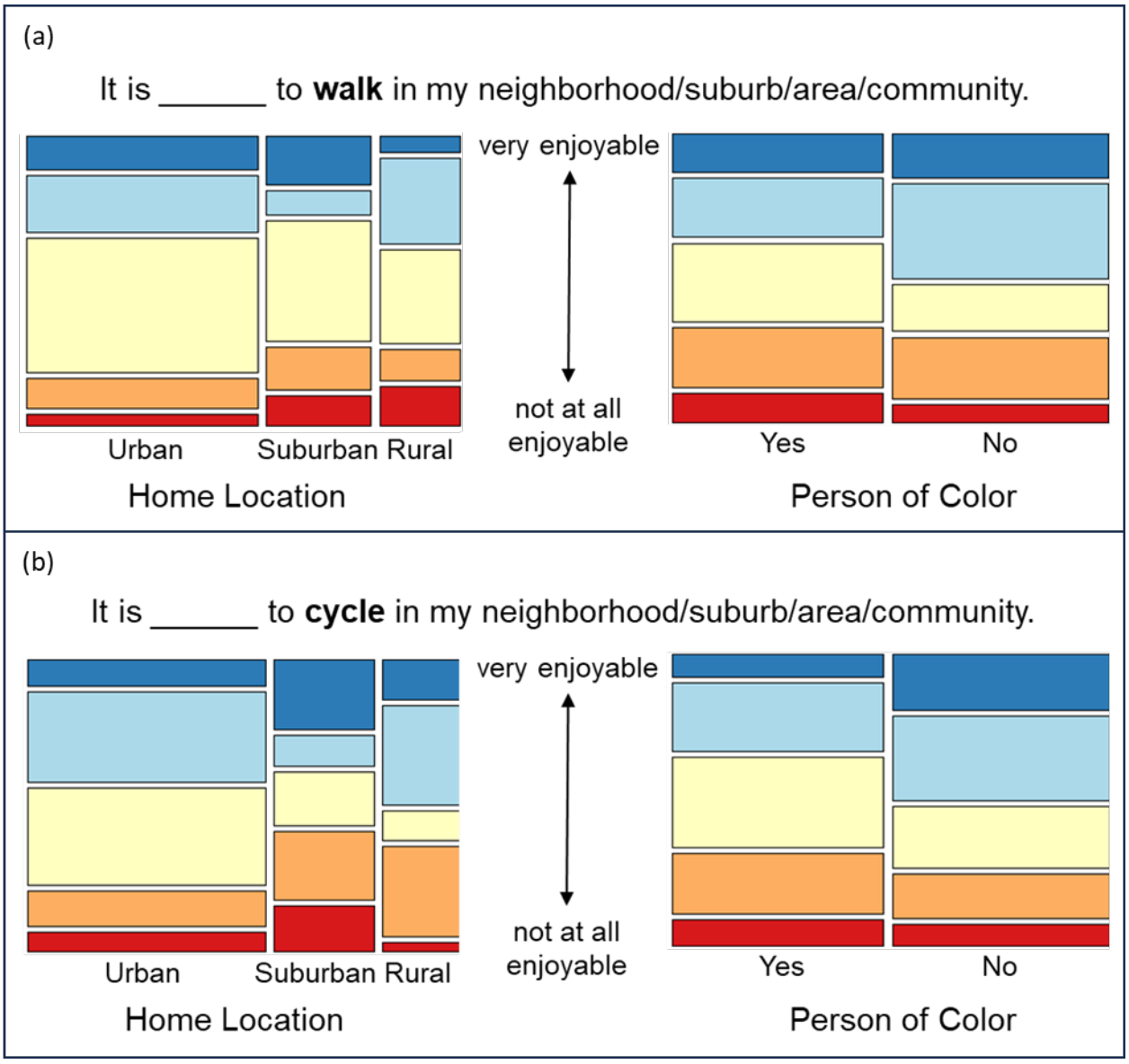


Figure B.6. Community consult survey responses related to qualitative indicators with how enjoyable the respondent perceives (a) walking and (b) cycling in their community broken out by home location and race/ethnicity (n=157).

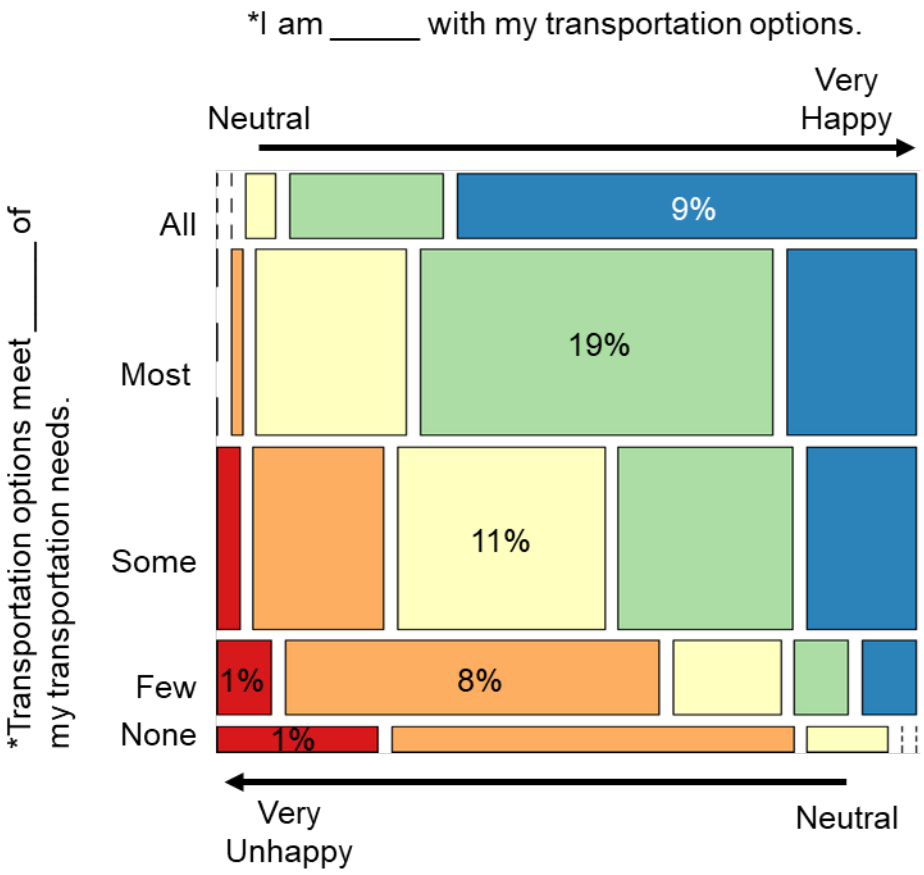


Figure B.7. Community consult survey responses related to qualitative assessments of the transportation system as a whole (n=272).

B.2. FULL COMMUNITY CONSULT SURVEY TEXT

UW IRB Exempt Status certified STUDY00018355: Equity in Planning Community Consult

Text provided to communities to explain the project:

The goal of this project is to understand how the Washington State Department of Transportation can better work with communities to address and prevent inequities across the state. Through this survey, we hope to better understand the experiences, needs, and desires of a diverse set of Washington state residents. Your responses will be considered a key source of knowledge in developing tools that state planners will use to inform:

- broad, state-wide transportation system visions;
- agency policy related to the planning of all different types of transportation facilities and services (such as pedestrian, cycling, car, rail, public transportation, and ferries);
- localized long-range transportation plans (e.g. corridor sketch plans [linked here])

Thank you for your time.

Dependent Variables

Transportation-specific

1. I am _____ satisfied with transportation options in my {neighborhood/suburb/area} [very - not at all]
2. Transportation options available to me in my {neighborhood/suburb/area} meet _____ my transportation needs. [all of - none of]
3. Area/Housing-oriented
4. I am _____ satisfied living in my {neighborhood/suburb/area} [very - not at all]
5. I _____ move out of the {neighborhood/suburb/area} I live [really want to - really don't want to]
6. I am _____ worried that I will be able to afford living in my {neighborhood/suburb/area} in the next few years [very - not at all]

Community-oriented

1. I believe that members of the following types of communities have experienced societal (systemic) harm. (select all that apply OR Likert of none - severe + unsure for each)
   a. People of color
   b. Tribal members
   c. Members of minority ethnic communities (in the US)
   d. People with lower income
   e. People who rent (housing)
   f. People who speak a non-standard variety of English
   g. People without a high school diploma or GED
   h. People who work in the service industry
   i. People who do manual labor for work
   j. People who have been incarcerated
   k. People with one or more disability
   l. People who are elderly
   m. Children
   n. People who are caretakers of elders and/or children
   o. People who do not have access to a personal vehicle
   p. People who live near busy roads
   q. People who live near a highway or interstate
   r. People who live near industrial sites
   s. Other _____
   t. None of the above
2. I believe that members of the following types of communities have experienced harm caused by transportation infrastructure (e.g. highways). (select all that apply OR Likert of none - severe + unsure for each)
   Ibid above list

3. It is _____ to me that there is a standard process in Washington State to account for and address the societal (systemic) harms affecting these communities. [Not at all important - very important (likert) CONDITIONAL on selecting any communities above]

Independent Variables

Access & Economic

1. I have access to _____ job opportunities within a reasonable commute time [a wide variety of - no (Likert)]
2. I have _____ access to places where I can get affordable food [easy - poor (Likert)]
3. I have _____ access to places where I can get healthy food [easy - poor (Likert)]
4. I have _____ access to shops and stores in general [easy - poor (Likert)]
5. I have _____ access to various activities within the city/town/area where I live [easy - poor (Likert)]
6. I have _____ access to various activities outside of the city/town/area where I live [easy - poor (Likert)]
7. Small businesses in my community have been _____ impacted by transportation access [negatively - positively (Likert) PLUS an "unsure" response]
8. There are _____ roadways/highways/interstates that divide my community [many - no]
9. I _____ access most of the places I **need** to go without a car [can very easily - could not possibly (Likert)]
10. I _____ access most of the places I **want** to go without a car [can very easily - could not possibly (Likert)]

Health & Safety

1. My {neighborhood/suburb/area} contains road crossings that are _____ for **pedestrians** [very dangerous - very safe]
2. My {neighborhood/suburb/area} contains road crossings that are _____ dangerous for **cyclists** [very dangerous - very safe]
3. My {neighborhood/suburb/area} contains road crossings that are _____ for **people in motor vehicles** [very dangerous - very safe]
4. It is _____ to walk in my {neighborhood/suburb/area} [very pleasant - very unpleasant]
5. It is _____ to cycle in my {neighborhood/suburb/area} [very pleasant - very unpleasant]
6. Air pollution in my {neighborhood/suburb/area} is… [not at all concerning - very concerning]
7. Transportation causes _____ noise pollution in my {neighborhood/suburb/area} [a lot of - no]
8. There are _____ nice public places to be outdoors in my {neighborhood/suburb/area} [many - no]
9. Public spaces in my {neighborhood/suburb/area} are _____ well-lit. [very - not at all]

General Demographics

Location-oriented

1. I live in a _____ location. [multiple choice: rural/urban/suburban]

2. Possible location-identifying questions:
    a. What are the nearest major cross streets where you live?
    b. What is the name of the {city/town/area} where you live?
    c. What is the name of the neighborhood where you live? [CONDITIONAL]

History

3. How long have you lived in your {neighborhood/suburb/area} ?

Person-oriented

4. All forms of transportation I rely on are [choose all that apply]
    a. I drive alone in a private vehicle (car/SUV/truck)
    b. I drive with others in a private vehicle (car/SUV/truck)
    c. I get a ride in a private vehicle (car/SUV/truck)
    d. I get a ride in a carpool organized by a public agency/program
    e. I take an Uber/Lyft
    f. I take public transit
    g. I ride a bike/e-bike/e-scooter
    h. I walk
5. What is your primary form of transportation [choose one - LIMITED by prev. response]
    a. I drive alone in a private vehicle (car/SUV/truck)
    b. I drive with others in a private vehicle (car/SUV/truck)
    c. I get a ride in a private vehicle (car/SUV/truck)
    d. I get a ride in a carpool organized by a public agency/program
    e. I take an Uber/Lyft
    f. I take public transit
    g. I ride a bike/e-bike/e-scooter
    h. I walk
6. I have consistent access to a personal vehicle (car/truck/SUV) [true/false - LIMITED by prev. response]
7. Transportation is difficult for me… [select all that apply]
    a. because of disability
    b. Because I regularly go places with persons with limited mobility (individuals with disabilities, children, elderly)
    c. Because I have limited transportation options
    d. Because I have limited money to pay for transportation
    e. Because language is a barrier
    f. Because I live far away from places I need to go
    g. I do not find transportation difficult
    h. Prefer not to answer

Standard identity/demographic census questions

8. Year of Birth
9. What is your race?
    a. Asian
    b. Black or African American

c. Middle Eastern or North African
d. Multiracial (Two or more races)
e. Native American or Alaska Native
f. Native Hawaiian or other Pacific Islander
g. White
h. Another race or ethnicity, please describe: [write here]
i. Prefer not to answer

10. Are you of Hispanic, Latino, or Spanish origin?
    a. No, not of Hispanic, Latino, or Spanish origin
    b. Yes, Mexican, Mexican Am., Chicano
    c. Yes, Puerto Rican
    d. Yes, Cuban
    e. Yes, another Hispanic, Latino or Spanish origin: [write here]
11. What is your first language?
12. How well can you speak English?
    a. Very well
    b. Well
    c. Not well
    d. Not at all
13. Which of the following best describes your gender identity?
    a. Female
    b. Male
    c. Transgender
    d. Non-binary
    e. Prefer not to answer
    f. Other

Disability

i. Are you deaf, or do you have serious difficulty hearing?
    a. Yes
    b. No
ii. Are you blind, or do you have serious difficulty seeing, even when wearing glasses?
    a. Yes
    b. No
iii. Because of a physical, mental, or emotional condition, do you have serious difficulty concentrating, remembering, or making decisions?
    a. Yes
    b. No
iv. Do you have serious difficulty walking or climbing stairs?
    a. Yes
    b. No
v. Because of a physical, mental, or emotional condition, do you have difficulty doing errands alone such as visiting a doctor's office or shopping?

a. Yes
b. No

Income (household)

vi. What is your approximate average household income?

Household size

vii. How many people live in your household?

Housing type [rent/own]

viii. Do you rent or own your home?

Education

ix. What is the highest level of education you have completed?

a. Did not attend school
b. 1st grade
c. 2nd grade
d. 3rd grade
e. 4th grade
f. 5th grade
g. 6th grade
h. 7th grade
i. 8th grade
j. 9th grade
k. 10th grade
l. 11th grade
m. Graduated from high school
n. 1 year of college
o. 2 years of college
p. 3 years of college
q. Graduated from college
r. Some graduate school
s. Completed graduate school

B.3. LIST OF COMMUNITY ORGANIZATIONS ENGAGED IN COMMUNITY CONSULT PROCESS.

Local service providers engaged in-person

- Okanogan County Community Action Council
- United Way Wenatchee/Chelan
- Sustainable Wenatchee
- Yakima Valley Community Foundation
- Cowiche Canyon Conservatory
- Northwest Fair Housing Alliance
- Spokane Human Rights Commission
- Hilyard Neighborhood Council
- NAACP
- East Central Neighborhood Council
- Community Coalition for Environmental Justice/GOT Green Seattle
- Washington Community Action Network
- Opportunity Council
- Whidbey Camano Land Trust
- National Organization for Women
- Arab Alliance Chamber of Commerce of Washington State
- Community in Motion

Local service providers engaged via Zoom

- Washington Policy Center Seattle
- NAACP Vancouver, Political Affairs Committee
- Asian Pacific Islanders Coalition SPS

APPENDIC C. GIS ASSESSMENT DETAILS: REVIEW AND ANALYSIS OF CUMULATIVE IMPACT INDICES

The full analysis can be found in Chapter 3 of Lewis (2024).

C.1. TABLES OF PUBLICLY MAINTAINED CUMULATIVE IMPACT INDICES.

Table C.1. Summary of existing indices related to environmental justice (EJ) initiatives.

Developed and Maintained by	Name(s)	Purpose	Citation
Center for Disease Control, Agency for Toxic Substances and Disease Registry (CDC/ATSDR)	Social Vulnerability Index (SVI)	EJ Disaster risk assessment and management	(Flanagan et al., 2011; GRASP, 2022)
CDC/ATSDR	Environmental Justice Index (EJI)	EJ disadvantage screening	(McKenzie et al., 2022)
White House Council of Environmental Equity (CEQ)	Climate & Economic Justice Screening Tool (CEJST)	Climate & Economic disadvantage screening	(White House CEQ, 2022)
Environmental Protection Agency (EPA)	Environmental Justice Screening Tool (EJScreen)	EJ disadvantage screening	(OEJECR, 2023)
Federal Emergency Management Agency (FEMA)	National Risk Index (NRI)	EJ Disaster risk assessment and management	(Zuzak et al., 2023)
United States Department of Transportation (USDOT)	Equitable Transportation Community (ETC) Explorer	Transportation, Climate & Economic disadvantage screening	(OST, 2023)
Washington Department of Health (WA-DOH)	Environmental Health Disparities (EHD) Map	EJ disadvantage screening	(Min et al., 2019; UW-DEOHS, 2019)
University of Wisconsin Center for Health Disparities Research (CHDR)	Singh's Area Deprivation Index (ADI)	Community disadvantage indicator for regression analyses	(Singh, 2003; Kind et al., 2014)

Table C.2. Overarching agency index details.

Agency, Index	Total Variables	Transportation Included?	Race/Ethnicity Included?	First Release	Current Release	Current TIGER Lines	Current Data Source Dates
CDC/ATSDR, SVI	16	1	Yes	2014	6th	2020	2016 - 2020
CDC/ATSDR, EJI	36	4	**Yes**	2022	1st	2010	2014 - 2021
CEQ, CEJST	31	2[a]	No	2022	v.1.0	2010	2014 - 2022
EPA, EJScreen	2 (DI[1]) or 5 (SDI[1]) + 12	1	DI[1] - Yes, SDI[1] - No	2015	v.2.2	2020	2017 - 2021
FEMA, NRI	85	2	Yes	2023	v.1.19.0	2020	2015 - 2021
USDOT, ETC	48	8	No	2023	1st	2020	2016 – 2022
WA DoH, EHD	19	1	Yes	2019	v.2.0	2010	2014 – 2021
UWisc, Singh's ADI	17	1	No	2014	3rd	2020	2016 - 2020

[a] The CEQ's CEJST includes Diesel particulate matter (µg/m3) a third measure of transportation burden, but this is not consistent with other indices which treat Diesel PM2.5 as the broad measure of industrial emissions that it functionally measures.

[1] (DI) and (SDI) refer to the Demographic Index and Supplemental Demographic Index, respectively. The DI is the default composite sociodemographic indicator multiplied against each Environmental Indicator presented in the EJScreen with the SDI offered as an addition/alternative composite sociodemographic indicator for the same purpose.

Table C.3. Methodological details for the agency indices considered.

Agency, Index	Data Re-scaling[1]	Hierarchy	Aggregation	Spatial Scale	Outcomes reported in online application			
					Binary Disadvantage	Single Composite	Component Composites	Variable
CDC/ATSDR, SVI	percentile rank, percentile rank	Yes	Additive	Tract	-	X	X	X
CDC/ATSDR, EJI	percentile rank, average	Yes	Additive	Tract	-	X	X	X
CEQ, CEJST	percentile rank	N/A	Thresholds + Logic[2]	BG & Tract	X	-	X	X
EPA, EJScreen	percentile rank, percentile rank	Yes	Multiplicative	BG & Tract	x[3]	-	X	X
FEMA, NRI	percentile rank, percentile rank	Yes	Multiplicative	Tract	-	X	X	partial
USDOT, ETC	min-max scaling, percentile rank	Yes	Additive	Tract	X	X	X	X
WA DoH, EHD	deciles, average	Yes	Multiplicative	Tract	-	X	X	X
UWisc, Singh's ADI	unclear	No	Additive	BG	-	X	-	-

[1] For Hierarchical indices, the data re-scaling method for base variables is listed first, followed by categorical data re-scaling.

[2] The CEQ's CEJST offers a unique methodology that applies thresholds (ex: 90th percentile) to each variable considered within a category and identifies an area as disadvantaged if ANY individual variable is classified as disadvantaged AND if the associated socio-economic variable also meets the disadvantage classification. While no singular, composite indicator is developed, this disaggregate, logic-based methodology allows for more focused, variable-specific analysis of disadvantage.

[3] The EPA's EJScreen doesn't provide a visual disadvantage/not layer, but they do provide a recommended threshold of disadvantage of 80% (i.e. 80th percentile or top 20% of the distribution).

Table C.4. Comparative breakdown of agency indices by categories, thresholds, variable counts and weights applied and implicit.

Agency, Index	Categories Defined	Threshold(s)	# Variables	Weighting	% of score from each variable existing[1]	% of score from each variable simple sum
CDC/ATSDR, SVI	Housing and Transportation	none specified	5	-	~5%	6.3%
	Household Composition and Disability		5		~5%	
	Socioeconomic Status		5		~5%	
	Racial & Ethnic Minority Status		1		~25%	
CDC/ATSDR, EJI	Environmental Burden	none specified	17	-	2%	2.8%
	Health Vulnerability		5		6.7%	
	Social Vulnerability		14		2.4%	
CEQ, CEJST	Climate change	90th	5	-	N/A	
	Energy	90th	2			
	Legacy pollution	90th	5			
	Water and wastewater	90th	2			
	Housing	90th	5			
	Transportation	90th	3			
	Health	90th	4			
	Workforce development	90th	4			
	Socioeconomic burden	65th OR <10%	1 OR 1			
EPA, EJScreen	Environmental Indicators	80th but variable	12	-	~50%	N/A
	Demographic Index (DI) OR Supplemental Demographic Index (SDI)		2 (DI) OR 5 (SDI)		~25% (DI) OR ~10% (SDI)	
FEMA, NRI	Expected Annual Loss	Centiles: 5 very high, 4 high	18	-	1.9%	1.2%
	Social Vulnerability		16		Varies[2]	

Agency, Index	Categories Defined	Threshold(s)	# Variables	Weighting	% of score from each variable	
					existing[1]	simple sum
	Community Resilience		51			
USDOT, ETC	Environmental Burden	65th	16	-	~1%	1.8%
	Hazard Vulnerability		(4) + 2[a]	-	~(1.4%), 6%	
	Transportation Insecurity		(6) + 2[a]	2	~(2.8%), 12%	3.6%
	Health Vulnerability		5	-	~3.3%	1.8%
	Social Vulnerability		13	-	~1.3%	
WA DoH, EHD	Fossil Fuel Pollution Exposure	Deciles: 9-10 highest need, 7-10 expanded consideration	5	-	5.7%	6.1%
	Other Toxic Exposures		5	0.5	2.9%	3.0%
	Sensitive Populations		2	-	14.3%	6.1%
	Socioeconomic Factors		7	-	4.1%	
UWisc, Singh's ADI	N/A	N/A	17	Varies[3]		5.9%

1 For the indices that use percentile ranking (rather than averaging) to establish category-based hierarchies, the estimated existing percent of score derived from each variable represents the average value with the ~ symbol used to denote variation.

2 The Expected Annual Loss is the only sub-index developed by FEMA for use in the NRI, therefore a simple breakdown of hierarchical/non-hierarchical is not possible. The Social Vulnerability component of the NRI is simply the CDC/ATSDR, SVI. The Community Resilience component was developed by (Cutter et al, 2014) and is comprised of six "resilience categories": social, housing/infrastructural, community capital, economic, institutional, and environmental (p. 70).

3 The 17 variables were identified using factor analysis (FA) and uses the rotated factor scores to weight variables (Singh, 2003).

a The USDOT's ETC includes sub-categorized variables that are the min-maxed sum of 4 future climate risk and 6 transportation access variables, respectively, added to the other min-maxed variables (2 each) of the Hazard and Transportation categories.

The percentage of the overall score derived from each variable included in the index under the existing index calculation structure, $P_{existing}$, can be calculate using Equations C.1 through C.3, where n_v is the number of variables per category, w_i is the weight applied to the category, and n_c is the number of categories.

$$P_{existing} = 1/f(n_v)/f(n_c) \quad \text{(C.1)}$$

$$where$$

$$f(n_v) = \sum_{i=1}^{n_c} n_{vi} * w_i \quad \text{(C.2)}$$

$$f(n_c) = \sum_{i=1}^{n_c} w_i \quad \text{(C.3)}$$

In contrast, the simple sum formulation assumes no categorical hierarchy. Under this assumption, the functional number of categories, $f(n_c)$, goes to one; therefore the percent of the overall score derived from each variable included in the index, $P_{simple\ sum}$, can be simplified as Equation C.4.

$$P_{simple\ sum} = 1/f(n_v) \quad \text{(C.4)}$$

For indices that apply a hierarchy by taking the average of the variables in each category (CDC/ATSDR's EJI and Washington's EHD), the values for existing percentage presented in Table C.4 are exact. However, for indices that apply a hierarchy by taking the percentile rank of the sum of the variables in each category (CDC/ATSDR's SVI, EPA's EJScreen, and USDOT's ETC), the values for existing percentages will vary with the magnitude of each variable's value. The values presented in Table C.4 do, however, provide an estimate of the contribution of each variable on average to the overall index score under hierarchical percentile ranking conditions.

C.2. GIS ANALYSIS: EXPLANATORY FIGURES, DATA AND METHODS

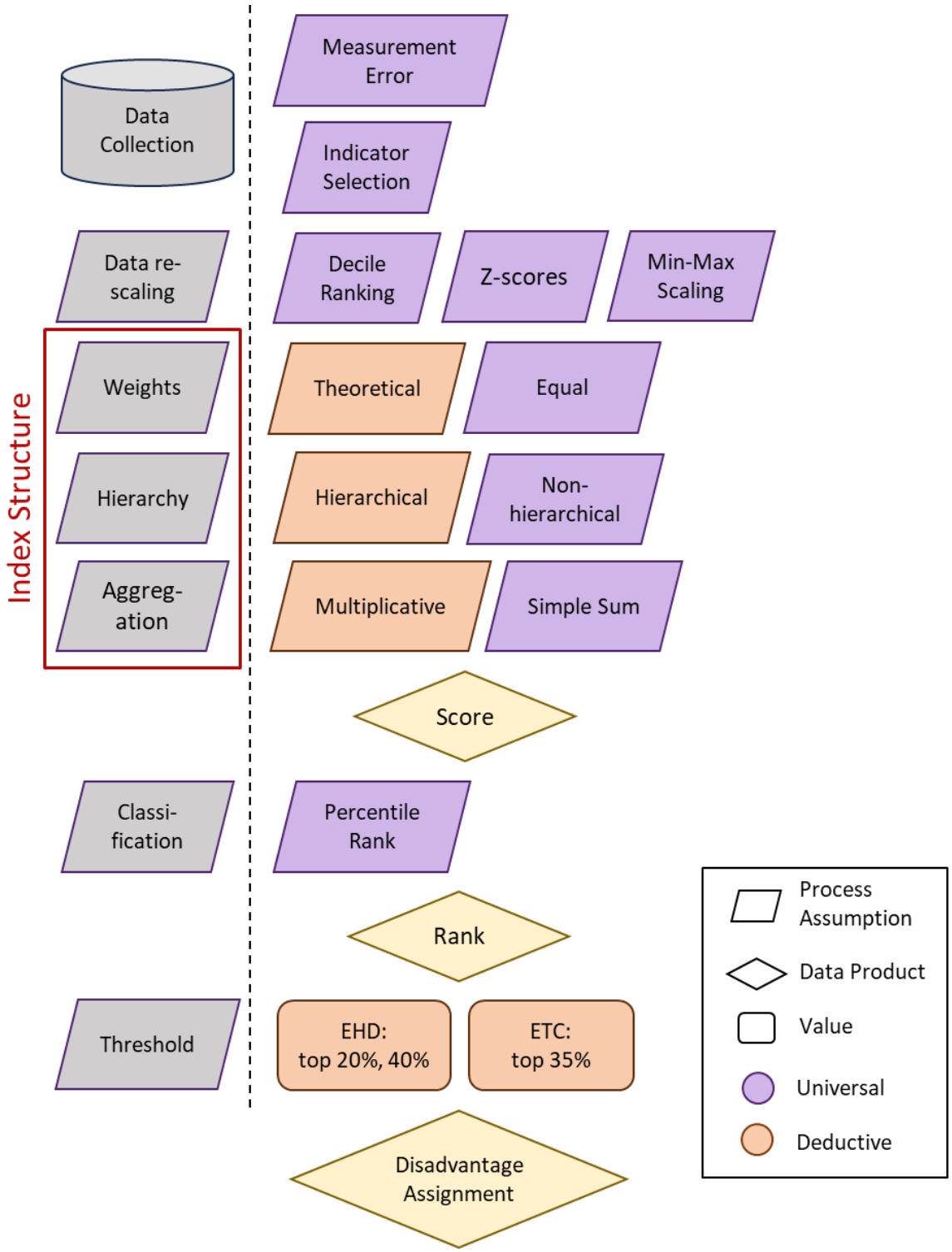


Figure C.1. The series of methodological decisions involved in the calculation of a composite indicator.

Data

For the EHD, a compilation of underlying variable data was accessed via the github repository[4] developed by Frostad (2023) as well as the current version 2.0 EHD tract scores accessed via the Washington State Geospatial Open Data Portal (WGODP)[5]. The state-level (rather than nationwide) version of the ETC data was accessed via the USDOT's Justice40 ETC Explorer information page[6]. Notably, the current version of the EHD is calculated with data aggregated to 2010 decennial census tract TIGER/Lines (n=1458 tracts), while the ETC is calculated with data aggregated to 2020 decennial census tract TIGER/Lines (n=1773 tracts). The R package *sf* was used to access 2010 and 2020 census tract TIGER/Lines, and the WGODP was used to access WSDOT's 2023 version of the Highway Urban and Urbanized Areas shapefile[7]. The ETC data download included a variable of total population for each census tract based on ACS 2016-2020 estimates. Population data for the EHD's 2010 census tract TIGER/Lines were accessed via the Washington Tracking Network (WTN) database[8]. The WTN is maintained by the Washington DoH and provides a centralized source of population-level health data. The 2019 population estimates used in this analysis were developed by the Washington State Office of Financial Management (OFM).

All variables included in the EHD have a positive association with the concept of disadvantage. In other words, as the value of any given variable increases, the level of disadvantage increases. While this is also true for the majority of variables included in the ETC, it is not true for all of them. The ETC includes the variables of "Frequency of Transit Services per Sq Mi" and "Jobs within a 45-min Drive" For those two variables, a higher value means greater advantage and therefore lower relative magnitude of disadvantage. In the original calculation of the ETC, they take the inverse of each variable in an effort to make these variables representative of relative disadvantage (OST, 2023). However, while taking the inverse of the values calculates the mathematical opposite of each value, it does not change the overall distribution of the values. Therefore, in our re-calculation of the index, instead of taking the

[4] https://github.com/jfrostad/ehd_mapsense/tree/main/code
[5] https://geo.wa.gov/datasets/WADOH::environmental-health-disparities-overall-ranking-current-version/about
[6] https://www.transportation.gov/priorities/equity/justice40/etc-explorer
[7] https://geo.wa.gov/datasets/WSDOT::wsdot-highway-urban-and-urbanized-areas/explore?location=47.131866%2C-120.274655%2C7.83
[8] https://fortress.wa.gov/doh/wtn/WTNPortal/#!q0=660

inverse of each value, we reversed the distribution of these variables using equation C3.5. Where v_{rev} is the reversed distribution value, v_{max} is the maximum value of the original distribution, v_{min} the minimum value, and v is the value in the original distribution.

$$v_{rev} = v_{max} - v + v_{min} \quad \text{(C.5)}$$

Index score iterations were calculated from these base variable values as detailed in the subsequent section. All data developed in this process, along with the code used, can be found at the lead author's github page[9].

Methods: Testing Urban/Rural Correlations in the EHD and ETC Indices

Two methods were used to test for urban/rural correlations in the EHD and ETC indices. Each variable used in both indices was tested for correlation to tract population density, and odds ratios of disadvantage classification by urban/rural tract status were tested for multiple iterations of each index. Population density was calculated for the respective TIGER/Line tract areas (2010 for EHD and 2020 for ETC) and respective population estimates (see Section 4.4). A binary urban/rural indicator was coded for the respective TIGER/Line tract areas based on the percentage of each area that overlapped with WSDOT's Highway Urban and Urbanized Areas. If 50 percent or more of a tract's area was classified as a Highway Urban and Urbanized Area, it was classified as Urban, or else Rural.

Testing Variables for Population Density Correlations

Each variable's correlation to population density was tested with both Pearson and Spearman tests to ensure the robustness of conclusions. Both tests are used to assess the correlation between two continuous variables, with the Pearson test assuming and measuring the linear relationship between variables. In contrast, the Spearman test does not assume a linear relationship and instead measures the monotonic relationship, i.e., whether the variables tend to increase or decrease together. Three conditions had to be met for a variable's Pearson correlation coefficient to be reported as likely correlated to population density:

1. the Pearson correlation 95 percent confidence interval did not cross zero (0), AND
2. the sign (+ or -) of the Pearson correlation coefficient (r) and the Spearman Rank correlation coefficient (ρ) had to be the same, AND

[9] https://github.com/elyseoc/transpoequity_indices

3. the p-value calculated for r and ρ had to be of the same magnitude (<0.001 ~ ***, <0.01 ~ **, <0.05 ~ *, <0. 1 ~ -).

Variables that did not meet these conditions were treated as non-correlated and assigned values of zero (0) for r and upper and lower confidence intervals to clearly distinguish them from likely correlated variables in results reporting.

Testing Variable Re-scaling and Index Structures for Existing Indices (EHD and ETC)

Figures C.2 and C.3 lay out the alternative mathematical choices used to specify alternative versions of the EHD and ETC. These alternatives were then compared against the current versions of each. Details about the current version of each index can be found in tables C.2 through C.4. Weighting for each index is discussed in Section 4.3.2 and was held constant within iterations. Categorical hierarchies were established by using percentile ranking for all iterations, and non-hierarchical multiplicative structures meant that categorical scores were multiplied together without the intermediary, hierarchical step of percentile ranking. For the EHD, two thresholds were considered: a more strict 9's and 10's or top 20 percent of tracts and a more lenient 7's-10's or top 40 percent of tracts. The latter was more comparable to the sensitivity-tested ETC 65th percentile threshold.

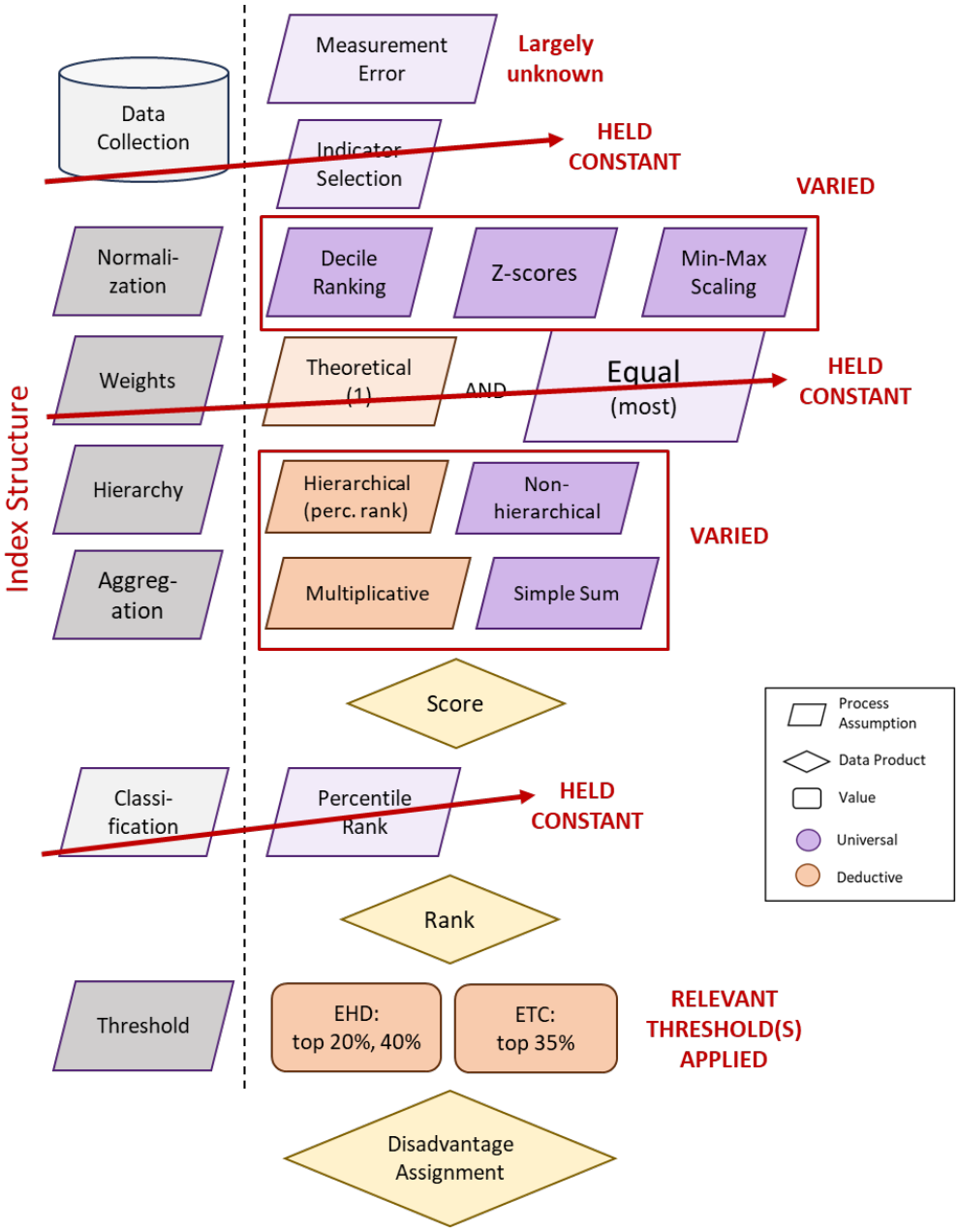


Figure C.2. Representation of the mathematical choices held constant and varied in index alternative iterations.

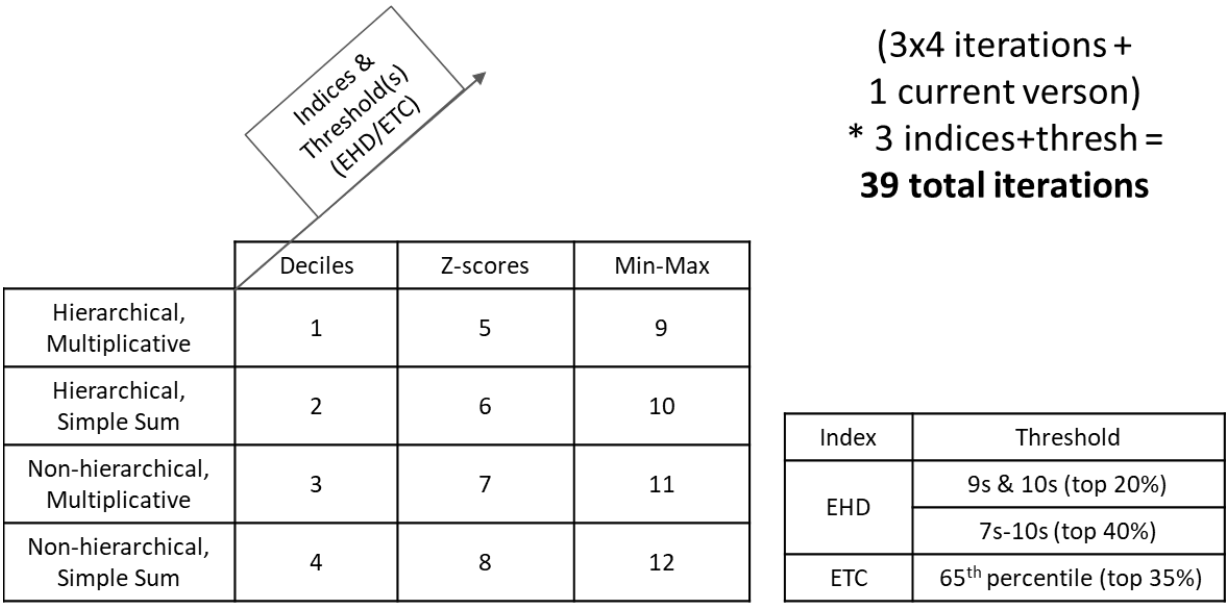


Figure C.3. Iterative breakdown of alternative index versions estimated and tested for urban/rural correlations.

C.3. EHD AND ETC FULL ANALYSIS RESULTS

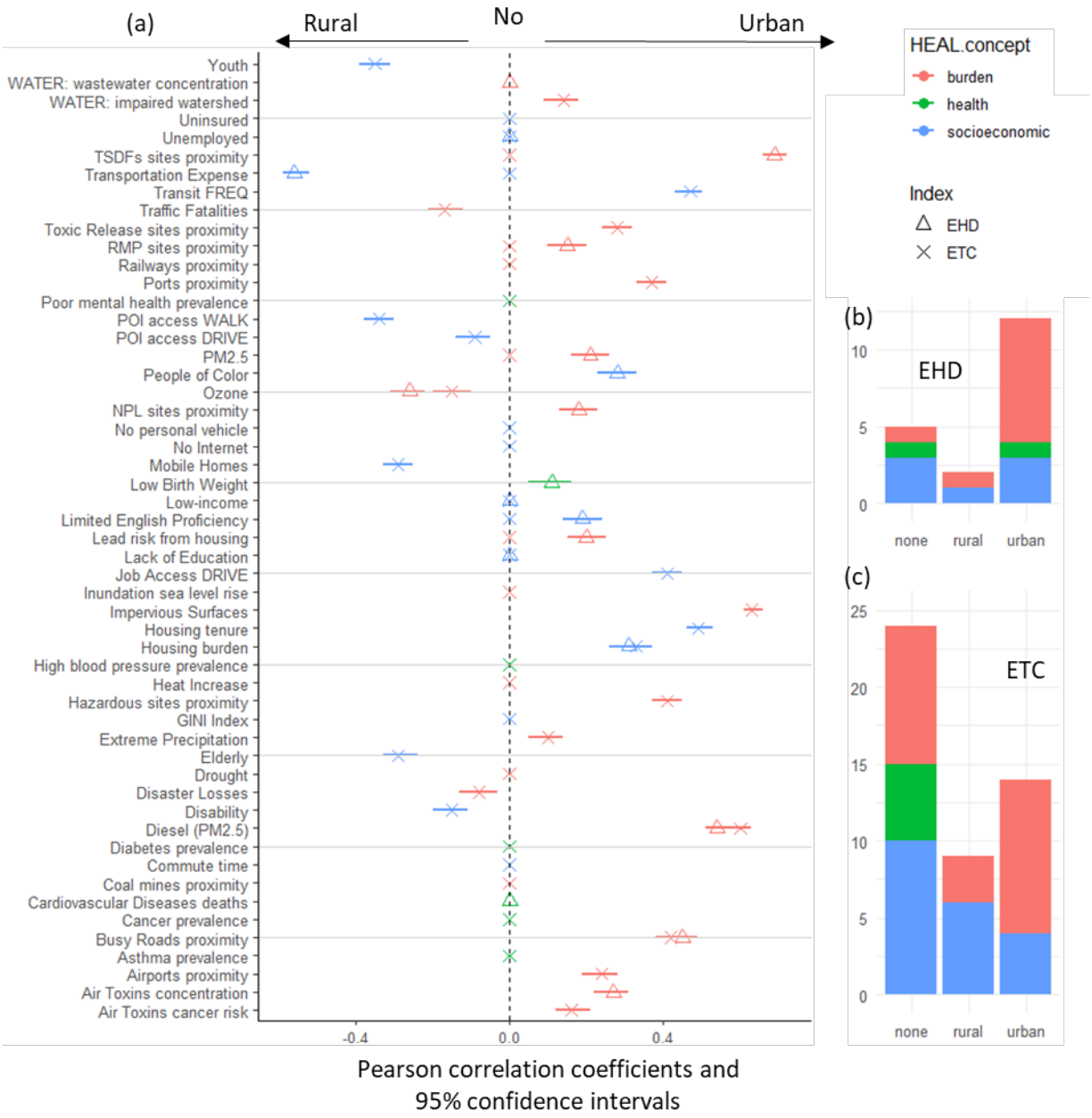


Figure C.4. Each variable's estimated correlation to census tract population density by HEAL Act concept type (a) reported by Pearson correlation coefficient and 95 percent confidence interval by index (b) counts of variables in the EHD (n=19) by correlation type (c) counts of variables in the ETC (n=48) by correlation.

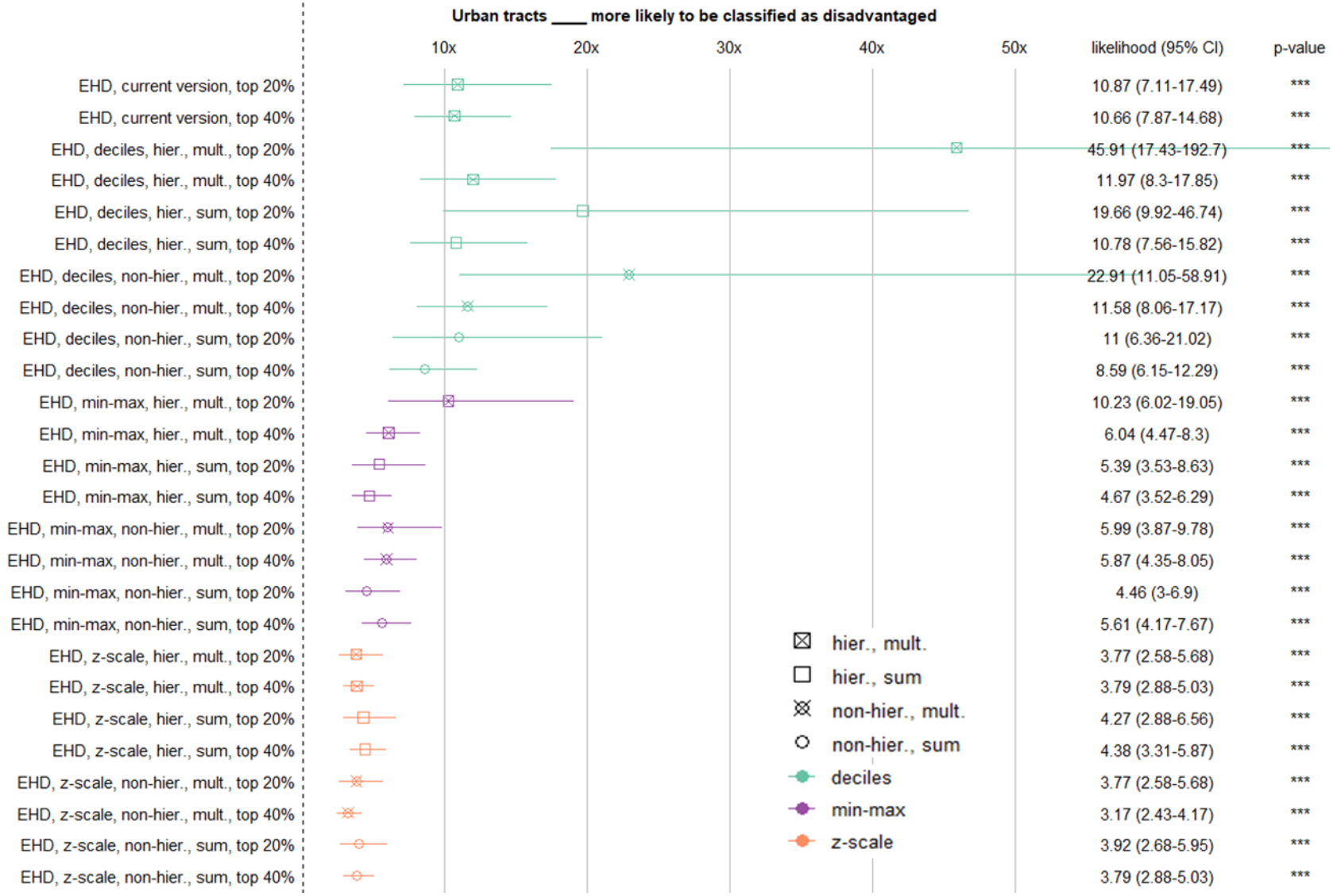


Figure C.5. Likelihood of urban tracts to be classified as disadvantaged relative to a rural tract baseline (0) by iteration of EHD calculation and threshold values (top 20 percent or deciles 9 and 10; top 40 percent or deciles 7-10).

Figure C.6. Likelihood of urban tracts to be classified as disadvantaged relative to a rural tract baseline (0) by iteration of ETC calculation and threshold value (65th percentile).

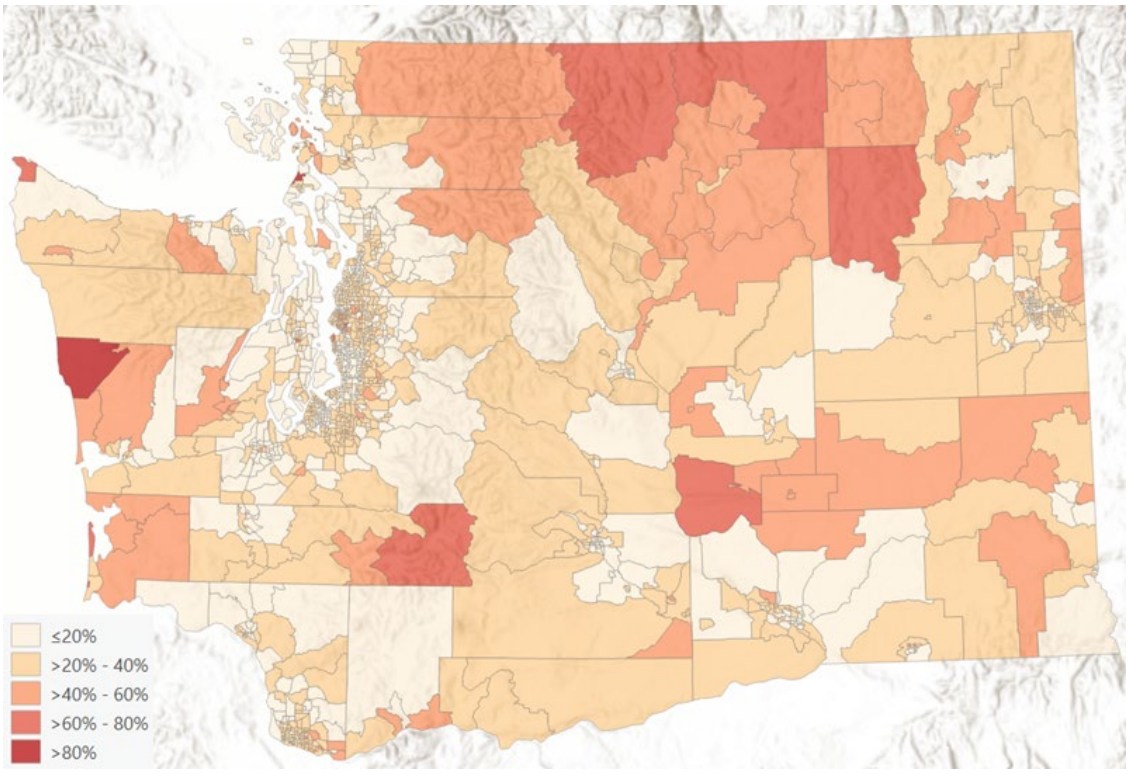


Figure C.7. Range of EHD index values by tract calculated over the 13 iterations.

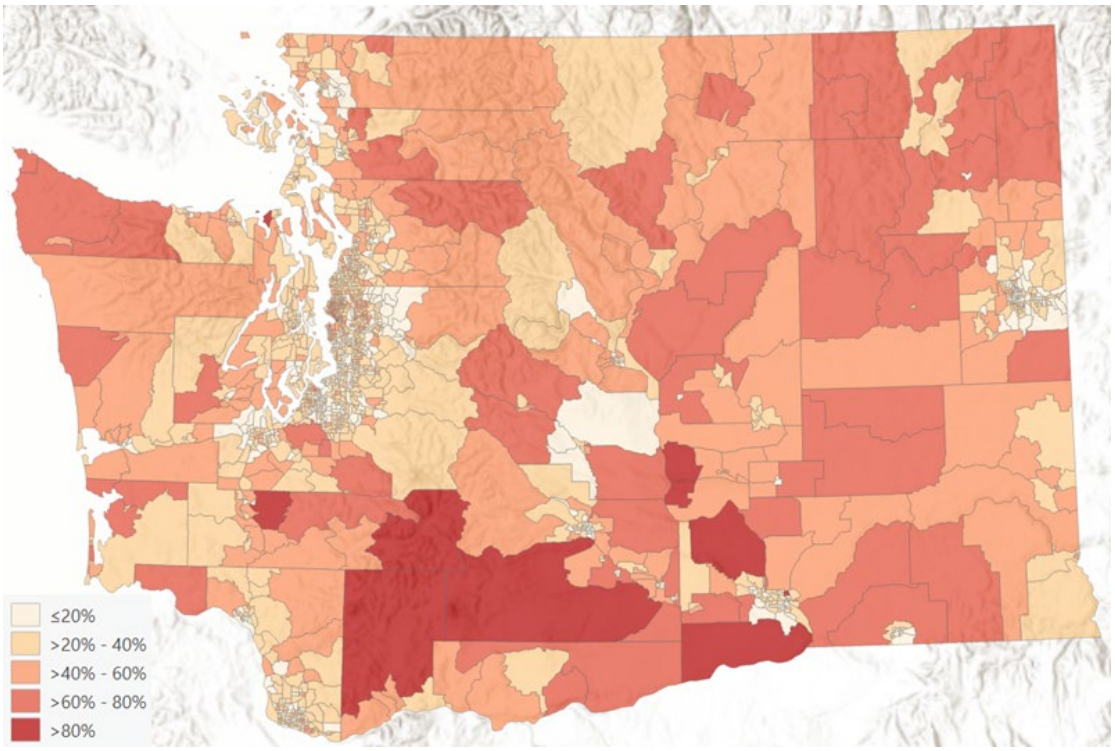


Figure C.8. Range of ETC index values by tract calculated over the 13 iterations.

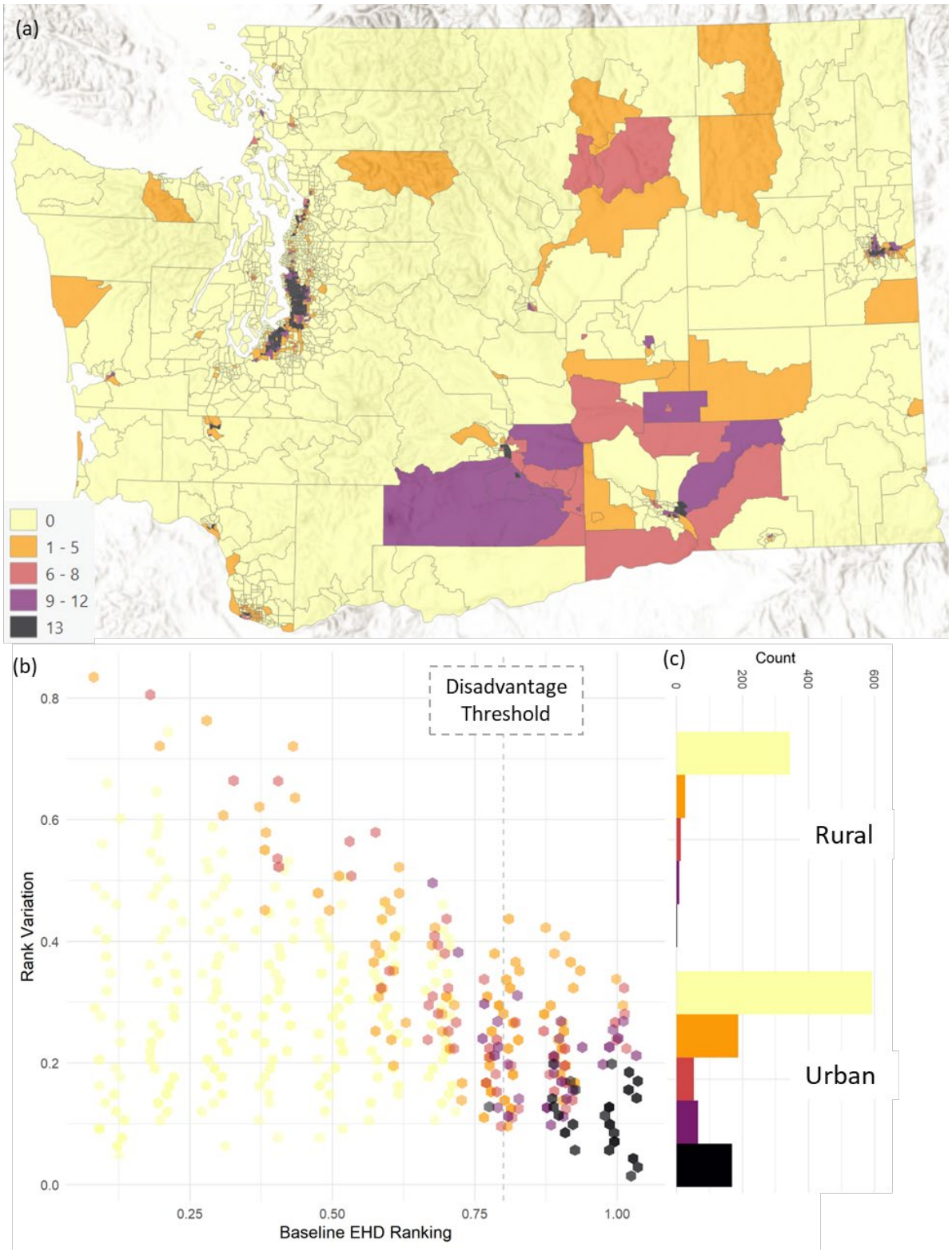


Figure C.9. Number of times in the 13 index iterations a tract is classified as disadvantaged by the top 20 percent threshold (a) mapped (b) plotted as point fill within a plot of current v.2.0 EHD ranking vs. range of rank variation over all 13 iterations (c) by urban/rural tract type.

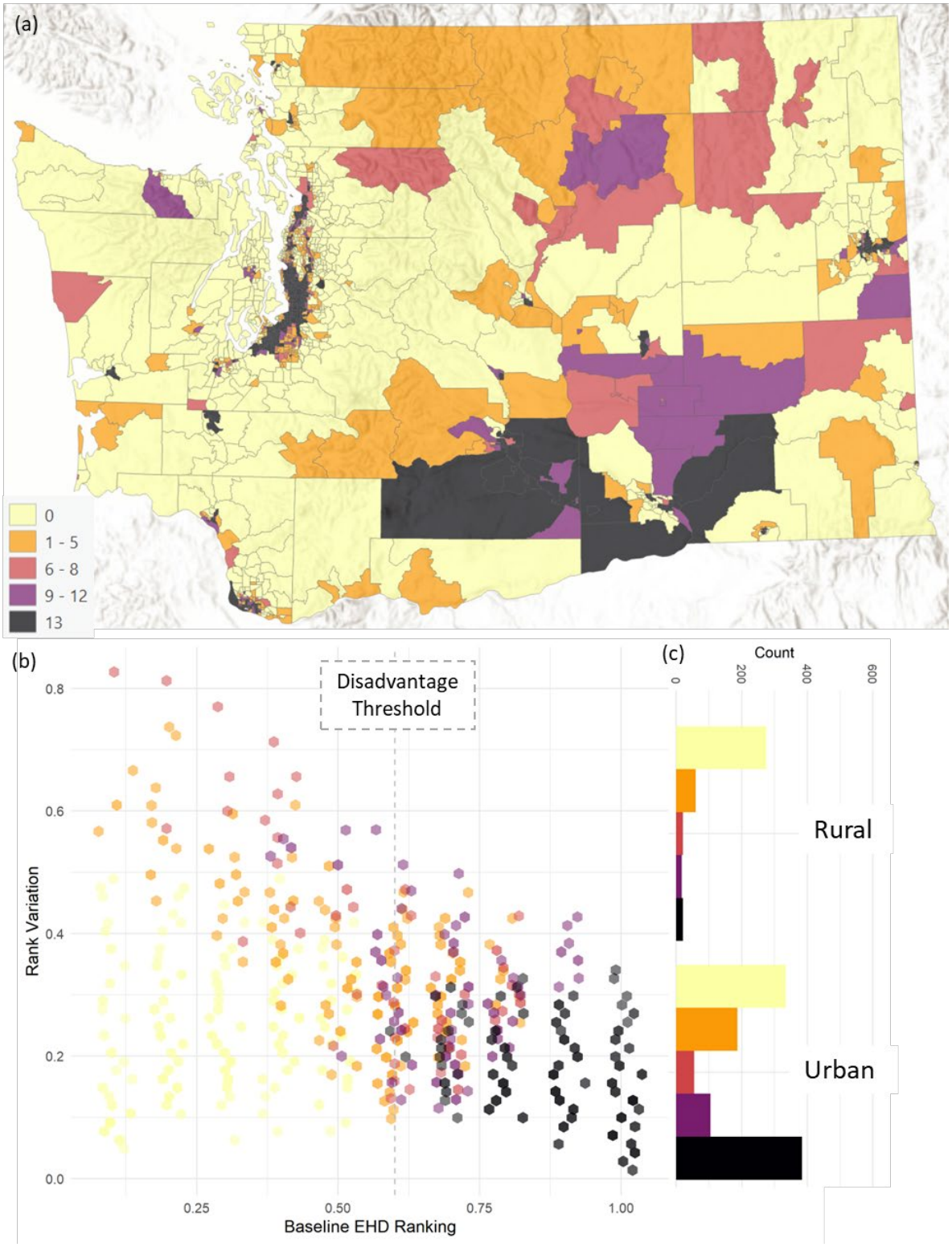


Figure C.10. Number of times in the 13 index iterations a tract is classified as disadvantaged by the top 40 percent threshold (a) mapped (b) plotted as point fill within a plot of current v.2.0 EHD ranking vs. range of rank variation over all 13 iterations (c) by urban/rural tract type.

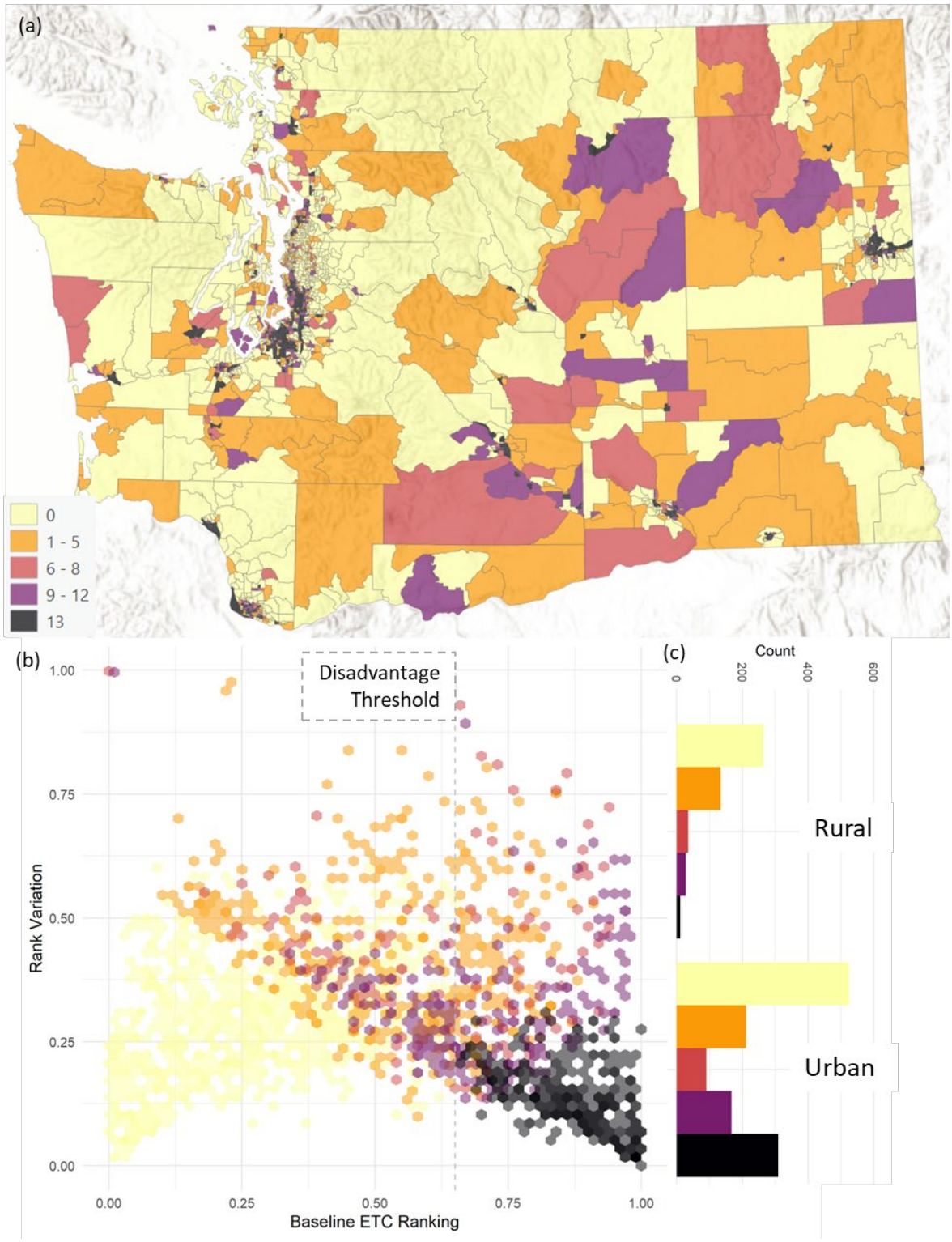


Figure C.11. Number of times in the 13 index iterations a tract is classified as disadvantaged by the 65th percentile threshold (a) mapped (b) plotted as point fill in a plot of the data download v.1.0 ETC ranking vs. range of rank variation over all 13 iterations (c) by urban/rural tract type.

C.4. GIS REFERENCES

Cutter, S. L., Ash, K. D., and Emrich, C. T. (2014). The geographies of community disaster resilience. *Global environmental change*, 29, 65-77.

Flanagan, B. E., Gregory, E. W., Hallisey, E. J., Heitgerd, J. L., and Lewis, B. (2011). A social vulnerability index for disaster management. *Journal of homeland security and emergency management, 8*(1), 000010220215477355179 2.

Frostad, J. (2023). Global Metrics, Local Estimation: Magnifying the Health Impact of Environmental Justice. [Doctoral dissertation, University of Washington, Seattle, WA]. ProQuest Dissertations & Theses Global.

Geospatial Research, Analysis, and Services Program (GRASP). (2022). *CDC/ATSDR SVI 2020 Documentation.* U.S. Centers for Disease Control and Prevention and Agency for Toxic Substances and Disease Registry, Washington, DC.

Kind, A. J., Jencks, S., Brock, J., Yu, M., Bartels, C., Ehlenbach, W., ... and Smith, M. (2014). Neighborhood socioeconomic disadvantage and 30-day rehospitalization: a retrospective cohort study. *Annals of internal medicine, 161*(11), 765-774.

McKenzie, B., Lehnert, E., Berens, A., Lewis, B., Bogović, S., Mirsajedin, A., ... and Kashani, M. (2022). *Technical documentation for the Environmental Justice Index 2022*. Centers for Disease Control and Prevention, Washington, DC.

Min, E., Gruen, D., Banerjee, D., Echeverria, T., Freelander, L., Schmeltz, M., ... and Seto, E. Y. (2019). The Washington State Environmental Health Disparities Map: Development of a community-responsive cumulative impacts assessment tool. *International journal of environmental research and public health, 16*(22), 4470.

Office of Environmental Justice and External Civil Rights (OEJECR). (2023). *Environmental Justice Mapping and Screening Tool: EJScreen Technical Documentation for Version 2.2.* U.S. Environmental Protection Agency (EPA), Washington, DC.

Office of the Secretary of Transportation (OST). (2023). *Equitable Transportation Community (ETC) Explorer: ETC Explorer Technical Documentation.* United States Department of Transportation, Washington, DC.

Singh, G. K. (2003). Area deprivation and widening inequalities in US mortality, 1969–1998. *American journal of public health, 93*(7), 1137-1143.

University of Washington Department of Environmental and Occupational Health Sciences (UW-DEOHS). (2019). *Washington Environmental Health Disparities Map: technical report.* for Washington State Department of Health (DOH), Seattle, WA.

White House Council on Environmental Quality (CEQ). (2022). *Climate and Economic Justice Screening Tool: Technical Support Document Version 1.0.* White House Council on Environmental Quality (CEQ), Washington, DC.

Zuzak, C., E. Goodenough, C. Stanton, M. Mowrer, A.Sheehan, B. Roberts, P. McGuire, and J. Rozelle. (2023). *National Risk Index Technical Documentation. Federal* Emergency Management Agency (FEMA), Washington, DC.

APPENDIX D. WSDOT PLANNER SURVEY

D.1. PLANNER SURVEY SUMMARY STATISTICS

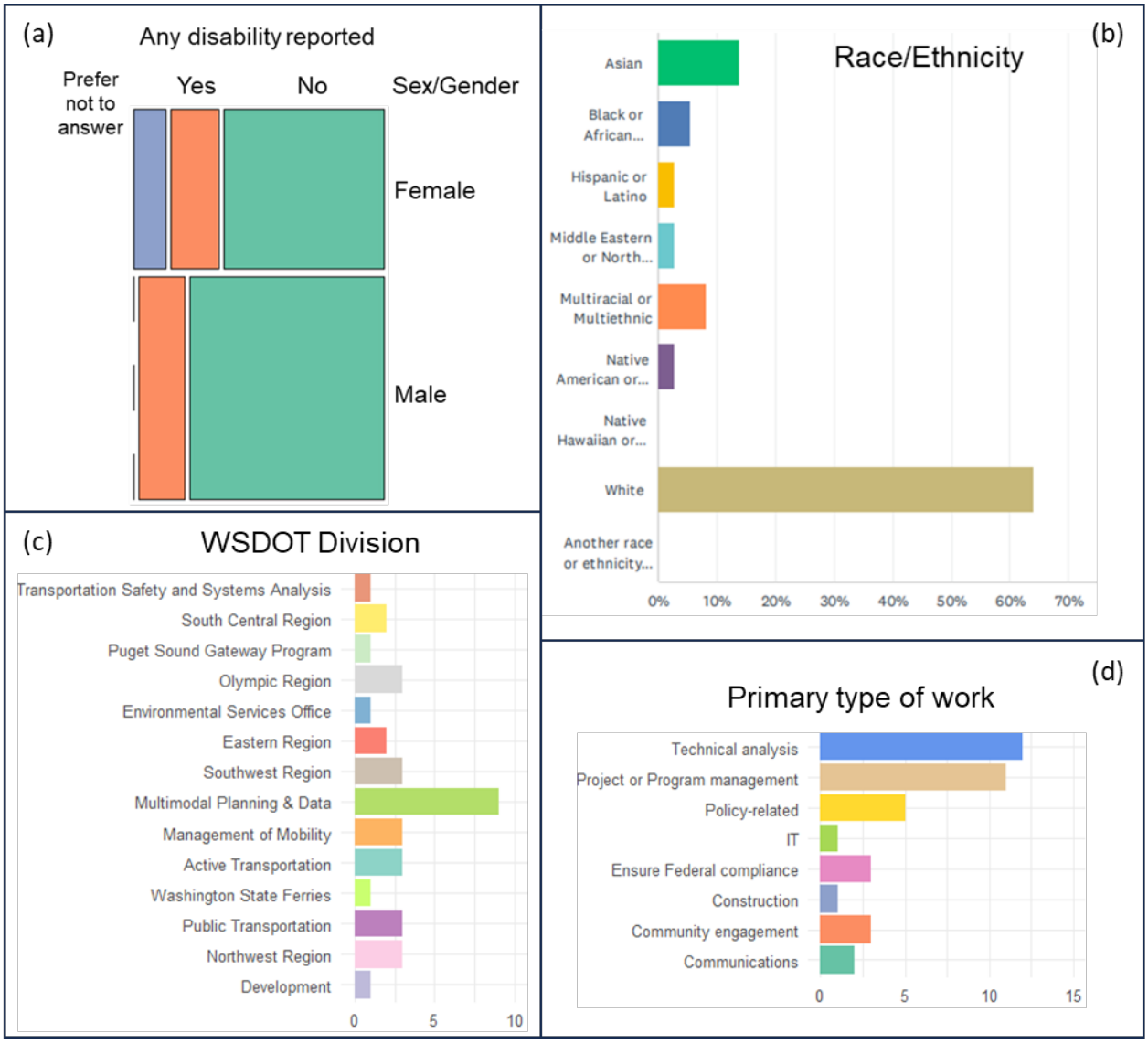


Figure D.1. WSDOT Planner summary statistics for responses for individuals who identified (a) by disability and sex/gender identity, (b) by race/ethnicity, (c) by WSDOT division, and (d) by the primary type of work they perform daily (n=36).

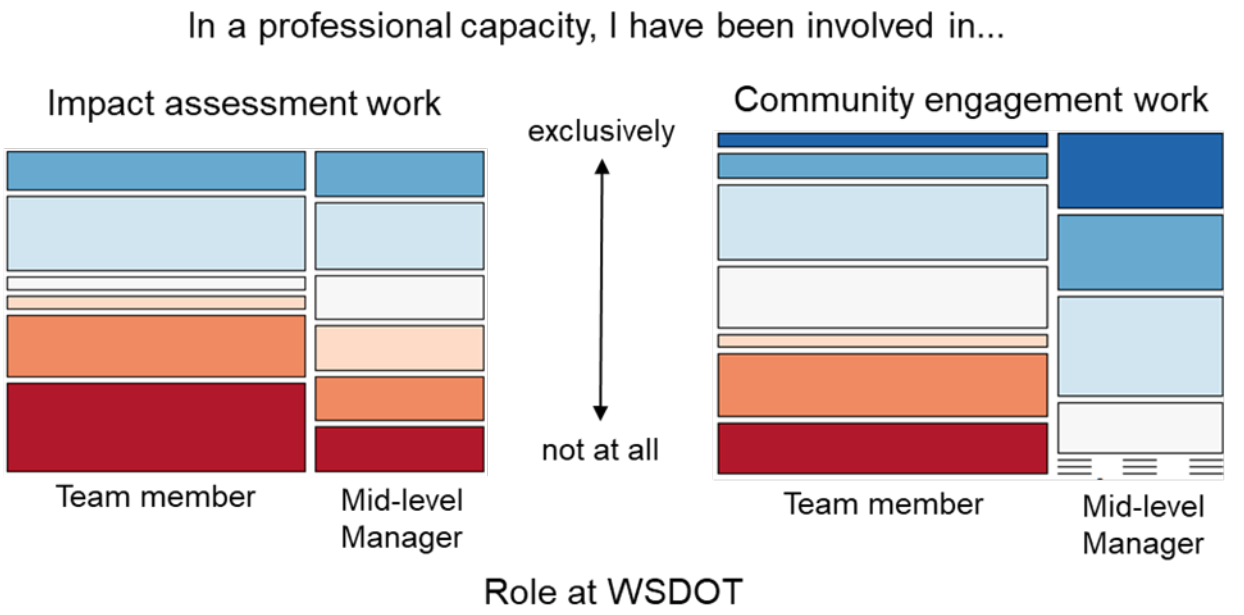


Figure D.2. Type of work planners have been involved in by magnitude of involvement broken out by role at WSDOT (n=31).

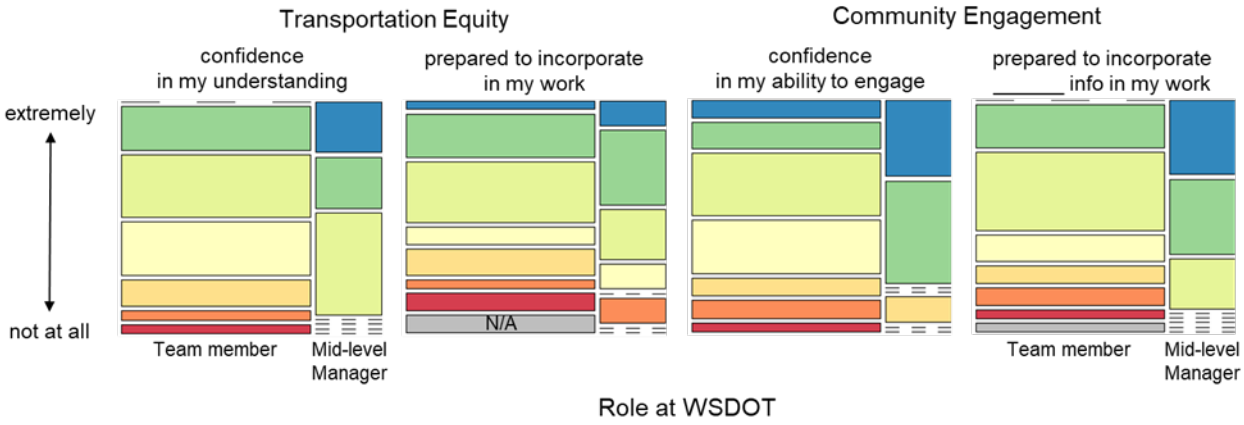


Figure D.3. Level of confidence and preparedness related to transportation equity and community engagement broken out by role at WSDOT (n=31).

D.2. FULL PLANNER SURVEY TEXT

UW IRB Exempt Status certified STUDY00018965: EiP Planners Survey

Community Experiences

In a professional capacity, I have been involved in impact assessment work (ex: environmental assessments, community impact assessments, environmental justice assessments). [Likert: exclusively - not at all]

In a professional capacity, I have been involved in community engagement work [Likert: exclusively - not at all]

As a private citizen, what types of individuals do you spend time with? [Likert for each: frequently - never]

- Individuals with relatively similar socio-economic status to mine
- Individuals with relatively lower socio-economic status to mine
- Individuals with relatively higher socio-economic status to mine
- Individuals with whom I share identities*
- Individuals whose identities* are different from mine
- Individuals with whom I share common interests and experiences
- Individuals with whom I share core values

*examples of identities include race, ethnicity, gender, sexuality, family, religion, (dis)ability

Equity-specific Preparation

How confident do you feel in your understanding of transportation equity? [Likert: extremely - not at all]

I feel prepared to incorporate transportation equity in my work. [Likert: not at all - definitely + NA]

How confident are you in your ability to engage with community members in a meaningful way? [Likert: extremely - not at all]

I feel prepared to incorporate information collected from community engagement in my work. [Likert: not at all - definitely + NA]

Guided Review

[leading indicators definition]

Please read the highlighted text on page 6 and all of page 7 [LINK]

Based on this review, how confident are you in your ability to…

- explain the concept of leading and lagging indicators of transportation equity? [Likert: extremely - not at all, did not review]
- Apply the concept of leading and lagging indicators of transportation equity in your work? [Likert: extremely - not at all, did not review]

(Optional) Please elaborate on what is helpful, what could be expanded, what could be explained better, or what could be removed. [open response]

[Transportation Equity Cycle]
Please review Figure 2.2 and Table 2.1 (and note that Section 2.2 provides accompanying text to explain the figures) [LINK]

Based on this review, how confident are you in your ability to…

- explain the components of transportation equity and how they relate to one another? [Likert: extremely - not at all, did not review]
- Apply the transportation equity planning cycle in your work? [Likert: extremely - not at all, did not review]
- Understand when it is or is not most critical to request community time and energy in the form of engagement? [Likert: extremely - not at all, did not review]

[OPTIONAL] Please elaborate on what is helpful, what could be expanded, what could be explained better, or what could be removed. [open response]

[Equity Standards]
Please read the highlighted paragraph in Section 3.1 and review Table 3.1 [LINK]

Based on this review, how confident are you in your ability to…

- explain the importance of explicit equity standards? [Likert: extremely - not at all, did not review]
- Recognize and apply equity standards in your work? [Likert: extremely - not at all, did not review]

Based on Table 3.1, which equity standard does the HEAL Act apply?

- Legal
- Pareto
- Pareto-plus
- Proportional equity
- Restorative equalization
- unsure

(Optional) Please elaborate on what is helpful, what could be expanded, what could be explained better, or what could be removed. [open response]

[Communities of concern definitions]
Please review Table 3.3 Communities of Concern identified in the transportation equity literature, rationale, and their relationship to the HEAL Act. [LINK]

Based on this review, how confident are you in your ability to…

- explain the concept of communities of concern? [Likert: extremely - not at all, did not review]
- identify communities of concern in the context of your work? [Likert: extremely - not at all, did not review]

(Optional) Please elaborate on what is helpful, what could be expanded, what could be explained better, or what could be removed. [open response]

[Example Table Review]

Please consider the following planning scenario OR think of a scenario related to your current work.
Example scenario: You are working on a corridor plan for a major arterial and want to incorporate leading indicators of transportation equity in your planning process.

Please review the two paragraphs highlighted on p. 26. Of the subsections mentioned, please review Table 3.10. Mobility and Economy measures and their potential as leading and lagging indicators of transportation equity. [LINK]

Based on this review, how confident are you in your ability to…
- Explain the subsections identified in the paragraphs? [Likert: extremely - not at all, did not review]
- Apply metrics defined in the tables in your work (using Table 3.10 as an example)? [Likert: extremely - not at all, did not review]

(Optional) Please elaborate on what is helpful, what could be expanded, what could be explained better, or what could be removed. [open response]

Post-Guided Review:
After reviewing the previous sections, how confident do you feel in your understanding of transportation equity? [Likert: extremely - not at all, did not review]
After reviewing the previous sections, I feel prepared to incorporate transportation equity in my work. [Likert: extremely - not at all, did not review]
After reviewing the previous sections, how confident are you in your ability to engage with community members in a meaningful way? [Likert: extremely - not at all, did not review]
After reviewing the previous sections, I feel prepared to incorporate information collected from community engagement in my work? [Likert: extremely - not at all, did not review]

What areas need to be improved on to better incorporate transportation equity in WSDOT planning efforts? [Likert for each: definitely - not at all + NA]
- More time allocated for technical components (ex: data management, statistical analysis, coding, GIS, etc.)

- More funds allocated for technical components (ex: data management, statistical analysis, coding, GIS, etc.)
- More staff allocated for technical components (ex: data management, statistical analysis, coding, GIS, etc.)

- More time allocated for non-technical components (ex: communication, community engagement, assessments of justice, identification of historical, political, and legal context, etc.)
- More funds allocated for non-technical components (ex: communication, community engagement, assessments of justice, identification of historical, political, and legal context, etc.)
- More staff allocated for non-technical components (ex: communication, community engagement, assessments of justice, identification of historical, political, and legal context, etc.)

- Technical skills for myself (ex: data management, statistical knowledge, coding, GIS, etc.)
- Technical skills for fellow employees (ex: data management, statistical knowledge, coding, GIS, etc.)

- Non-technical skills for myself (ex: communication, group facilitation, theories of justice, historical context, political and legal knowledge, etc.)
- Non-technical skills for fellow employees (ex: communication, group facilitation, theories of justice, historical context, political and legal knowledge, etc.)

Secondary Use Consent:
This question pertains to your consent regarding the storage of your response data for any potential, unspecified future analyses beyond the scope of the Equity in Planning study for which this data is being collected. This storage and potential, future, unspecified analyses are referred to as secondary use.

If you do not consent to your data being retained for secondary use, your responses will be permanently deleted from the final data set no later than December 31, 2023 and will NOT be included in the final data set delivered by the UW research team to the WSDOT project team. This means your full responses will only be accessed by the UW research team until the close of the Equity in Planning project and will only be reported in aggregate form within the final report for the Equity in Planning project.

Do you consent to your responses being retained for secondary use? [multiple choice]
- Yes - I consent to my responses being retained for secondary use
- Yes in part - I consent to my topic-related responses (all responses up to this point) being retained but I do NOT consent to any indirect identifiers (professional and socio-economic - all responses beyond this point) being retained for secondary use

- No - I wish for all of my responses (up to and beyond this point) to be withdrawn from secondary use

Professional Identifiers (OPTIONAL)
What is your role at WSDOT? [multiple choice]
- High-level manager
- Mid-level manager
- Team member
- Entry level/intern

What is the primary type of work you do on a day-to-day basis? [multiple choice]
- Technical analysis
- HR
- Project management
- Ensure Federal compliance
- Community engagement

What is the highest level of professional training you have completed in…
- Planning
- Engineering
- Communications
- Business
- Social Work
- N/A
- Other

[Highest level of education response options]
- Ph.D.
- Masters degree
- Some graduate-level work but no degree
- Continuing education seminars
- Undergraduate degree
- Some undergraduate-level work but no degree
- 2-year technical degree
- Other: [open response]
- None of the above

Years in current position ___
Years in current profession ___

Which agency planning group do you primarily work within?
- Active Transportation
- Aviation
- Construction
- Development
- Eastern Region
- Local Programs

- Multimodal Planning & Data
- North Central Region
- Northwest Region
- Olympic Region
- Public Transportation
- Rail, Freight, and Ports
- Southwest Region
- South Central Region
- Transportation Safety and Systems Analysis
- Washington State Ferries

Socio-economic Identifiers (OPTIONAL)
What year were you born? [numerical response]
What is your race? [multiple choice]

- Asian
- Black or African American
- Middle Eastern or North African
- Multiracial (Two or more races)
- Native American or Alaska Native
- Native Hawaiian or other Pacific Islander
- White
- Another race or ethnicity, please describe: [open response]
- Prefer not to answer

Are you of Hispanic, Latino, or Spanish origin? [multiple choice]

- No, not of Hispanic, Latino, or Spanish origin
- Yes, Mexican, Mexican Am., Chicano
- Yes, Puerto Rican
- Yes, Cuban
- Yes, another Hispanic, Latino or Spanish origin: [open response]
- Prefer not to answer

What is your first language? [open response]
How well can you speak English? [Likert: very well - not at all, Prefer not to answer]
Which of the following best describes your gender identity? [multiple choice]

- Female
- Male
- Transgender Woman
- Transgender Man
- Non-binary
- Other: [open response]
- Prefer not to answer

Are you deaf, or do you have serious difficulty hearing? [Yes/No/Prefer not to answer]
Are you blind, or do you have serious difficulty seeing, even when wearing glasses? [Yes/No/Prefer not to answer]

Because of a physical, mental, or emotional condition, do you have serious difficulty concentrating, remembering, or making decisions? [Yes/No/Prefer not to answer]
Do you have serious difficulty walking or climbing stairs? [Yes/No/Prefer not to answer]
What is your approximate average household income? [numerical response]
How many people live in your household? [numerical response]
Do you rent or own your home? [multiple choice]

- Rent
- Own
- Other: [open response]
- Prefer not to answer

Additional OPTIONAL Questions:
What barriers do you face that have prevented you from incorporating transportation equity in your planning practice? [open response]
What data do you currently use to incorporate equity in your planning practice? [open response]
What methods do you currently use to incorporate equity in your planning practice? [open response]
What tools do you currently use to incorporate equity in your planning practice? [open response]

Is there anything else you would like to add? [open response]

APPENDIX E. LIST OF GOVERNMENT AGENCY, PROGRAMS, AND DATA SET ACRONYMS WITH NOTES

Acronym	Full Text	Note
ACS	American Community Survey	All data from ACS 2015-2019 5-year data release - 2019 when possible to specify
ADI	Area Deprivation Index	developed in Singh (2004) and now maintained/disseminated via UWisc
AQS	Air Quality System	EPA's combined monitoring and modeled data
ATSDR	Agency for Toxic Substances and Disease Registry	
BCA	Benefit Cost Analysis	guidance provided by USDOT for US citizens' value of time by trip purpose and transit trip component
BIA	Bureau of Indian Affairs	housed in the DOI
BRIC	Baseline Resilience Indicators for Communities	
BTS	Bureau of Transportation Statistics	part of the USDOT
CDC	Center for Disease Control	
CEJST	Climate & Economic Justice Screening Tool	developed & maintained by the CEQ
CEQ	Council of Environmental Equity	Housed within the Executive Office of the President, created in 1969 as part of NEPA
CES	Consumer Expenditure Survey	annual data set re: fixed auto costs
CHAS	Comprehensive Housing Affordability Strategy	
CHDR	Center for Health Disparities Research	housed at the University of Wisconsin - maintains the ADI
COOP	Cooperative Observer Program	network of weather-observing stations overseen by the National Weather Service
DOE	Department of Energy	
DOE	Department of Energy	
DOH	Department of Health	GIS data sets for DOH
DOI	Department of the Interior	
DOL	Department of Labor	US federal department - maintains mine location data
EHD	Environmental Health Disparities	
EPA	Environmental Protection Agency	

Acronym	Full Text	Note
ETC	Equitable Transportation Community Explorer	designed to compliment CEQ's CEJST as part of the Justice40 initiative, created by Executive Order 14008 Tackling the Climate Crisis at Home and Abroad
FAA	Federal Aviation Administration	
FAF5	Freight Analysis Framework	
FARS	Fatal Motor Vehicle Accidents	a data set maintained by NHTSA
FEMA	Federal Emergency Management Agency	
FHWA	Federal Highway Administration	
FRA	Federal Railroad Administration	
FRS	Facility Registry Service	sites that pose environmental risk and fall under EPA jurisdiction
FTA	Federal Transit Administration	
FUDS	Formerly Used Defense Site	dataset maintained by the USACE
HIFLD	Homeland Infrastructure Foundation-Level Data	
HOLC	Home Owner's Loan Corporation	established redlines between 1935-1940
HPMS	Highway Performance Monitoring System	
HRVI	Hazard Vulnerability & Resilience Institute	housed at the University of South Carolina & maintainer/distributor of multiple hazard, vulnerability, & resilience data sets
HUD	Housing and Urban Development	
IBL	Information by Location	interactive online map that presents EHD and other WTN data
ICBA	Intercity Bus Atlas	data shared/presented via NTAD, but underlying ICBA scheduled GTFS data tables found here
IPCD	Intermodal Passenger Connectivity Database	BTS data product based on other NTAD data files
IRA	Inflation Reduction Act	passed in 2022 - EJScreen houses a layer following IRA assessment guidelines & based on combo of CEJST & 90th percentile EJScreen Supplemental Indices (state OR national comparisons)
IRSAD	Index of Relative Socio-Economic Advantage/Disadvantage	developed by ABS using a PCA
LAR	Land Area Representation	dataset maintainted by the BIA in the DOI designating land areas for Federally Recognized Tribes
LATCH	Land Area Transportation Characteristics for Households	data product published by the BTS
LEAD	Low-Income Energy Affodability Data	maintained by the DOE

Acronym	Full Text	Note
LHJ	Local Health Jurisdictions	spatial unit used by WA DOH
LQGs	Large Quantity Generators	hazardous waste proximity sources data
MDRS	Mine Safety and Health Administration	US federal administration
MRLC	Multi-Resolution Land Characteristics Consortium	maintain the NLCD
NAA	Non-attainment areas	designated by EPA
NARN	North American Rail Network	
NATA	National Air Toxics Assessment	EPA's modeled data
NCHS	National Center for Health Statistics	managed by the CDC
NCRC	National Community Reinvestment Coalition	
NHTSA	National Highway Traffic Safety Administration	
NLCD	National Land Cover Database	
NOAH	National Oceanic and Atmospheric Administration	
NPL	National Priorities List	Superfund Sites
NREL	National Renewable Energy Laboratory	product of DOE and Clean Cities coalitions and stakeholders - details
NRI	National Risk Index	the social vulnerability index used in the NRI is the one developed by ATSDR
NTAD	National Transportation Atlas Database	maintained by the BTS
NTD	National Transit Database	maintained by the FDA
NTM	National Transit Map	based on all scheduled GTFS data tables in US
NTNM	National Transportation Noise Map	a Volpe product maintained by the BTS
NWCC	Northwest Interagency Coordination Center	
NWS	National Weather Service	
OAQPS	Office of Air Quality Planning and Standards	part of the EPA
OFM	Washington State Office of Financial Management	
OPPT	Office of Pollution Prevention and Toxics	part of the EPA
ORLN	Oak Ridge National Laboratory	maintain LanScan for daytime population estimates

Acronym	Full Text	Note
OSPI	Washington Office of the Superintendent of Public Instruction	
OUST	Office of Underground Storage Tanks	part of the EPA
RMP	Risk Management Plan	facility proximity - derived from EPA's FRS
RSEI	Risk-Screening Environmental Indicators	model of environmental exposure risk maintained by the EPA
SEIFA	Socio-Economic Indexes for Areas	IRSAD is one of four (4) SEIFAs developed by ABS
SEMS	Superfund Enterprise Management System	database
STEAP	Screening tool for Equity Analysis of Projects	maintained by FHWA - interactive online GUI tool w/ simple buffer analysis report generator
TIAT	Transportation Insecurity Analysis Tool	a page of the ETC Explorer that aggregates and presents ETC data according to set or user-specified thresholds
TMAS	Travel Monitoring Analysis System	
TRI	Toxics Release Inventory	
TSDFs	Treatment, Storage, and Disposal Facilities	hazardous waste proximity sources data
USACE	U.S. Army Corps of Engineers	
USALEEP	U.S. Small-area Life Expectancy Estimates Project	seemingly only 2010-2015 data set developed by CDC
USCB	United States Census Bureau	
USDA	United States Department of Agriculture	
USDOT	United States Department of Transportation	
USTs	Underground Storage Tanks	also: LUSTs - leaking USTs
WSIO	Watershed Index Online	maintained by the EPA
WSIPP	Washington State Institute for Public Policy	conducted a comparative review of EHD to other state's and EJ Screen tools
WTN	Washington Tracking Nework	Data Portal contains an array of public-health related data from various sources - some are up-to-date, but many include indices (Community-Community-Neighborhood) or assessments (Community-Community-Emergency) that are single-date, out-of-date data sets

Title VI Notice to Public

It is the Washington State Department of Transportation's (WSDOT's) policy to assure that no person shall, on the grounds of race, color, or national origin, as provided by Title VI of the Civil Rights Act of 1964, be excluded from participation in, be denied the benefits of, or be otherwise discriminated against under any of its programs and activities. Any person who believes his/her Title VI protection has been violated, may file a complaint with WSDOT's Office of Equity and Civil Rights (OECR). For additional information regarding Title VI complaint procedures and/or information regarding our non-discrimination obligations, please contact OECR's Title VI Coordinator at (360) 705-7090.

Americans with Disabilities Act (ADA) Information

This material can be made available in an alternate format by emailing the Office of Equity and Civil Rights at wsdotada@wsdot.wa.gov or by calling toll free, 855-362-4ADA(4232). Persons who are deaf or hard of hearing may make a request by calling the Washington State Relay at 711.