Incorporating Social Equity in Transit Service and Capital Planning:

A Preemptive Analysis of Preliminary Bus Rapid Transit Corridor Design in King County, Washington

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Abstract

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This study presents an approach for the evaluation of the equity of transportation investments in King County, Washington, with attention to upgrades of existing routes to new “bus rapid transit” service. A review of philosophical and economic literature provides a theoretical foundation, while existing policy and law establishes a regulatory and practical framework that bounds this work. The author is particularly concerned with the extent to which service and capital investments for bus rapid transit expansion in southern King County can be integrated and evaluated across socioeconomic user groups. This study attempts to answer this question by employing a series of quantitative models that include network

analysis, transportation gap analysis, and life-cycle cost analysis to evaluate transit equity in southern King County, and specifically along the proposed RapidRide I Line bus rapid transit corridor. Ultimately, the study seeks to balance the ever-competing dimensions of efficiency and equity as they manifest in transit service implementation and offer a novel measurement tool that can ultimately inform route alignment.

Acknowledgments

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Chapter 1: Introduction

Public-sector transportation planners are increasingly concerned with the distribution of impacts from transportation planning and policy throughout jurisdictions and across users of varying abilities, age, and socioeconomic status. The concept of transportation disadvantage – that is, the range of potential transportation-related barriers that can limit an individual's level of mobility and ability to access employment, education, healthcare, and other services – is strongly tied to poverty, social exclusion, and social inequality. Indeed, in King County, Washington, and throughout much of the United States in general, public administrators are increasingly grappling with the reality that their fellow "residents do not enjoy the same health, resources, and opportunities because of their race and where they live" (Beatty and Foster 2015).[1]

In fact, the county formally recognizes the role of public transit, and transportation in general, as a determinant of equity – 2013 data from the county's transit agency, King County Metro Transit, reveals that low-income and minority riders are more likely than their higher-income or non-minority counterparts to depend on Metro for either "most" or "all" of their transportation needs (Beatty and Foster 2015). Thus, the effective provision of public transportation and mobility services should be considered a driver of social equity, insofar as adequate access to public transit can impact access to opportunity (employment, education, healthcare, and other services).

King County is the largest county in Washington State and the 11th largest in the United States, in terms of population. Seattle – the county seat – has led the post-recession recovery for the region, enjoying stunning population and employment growth over the past decade. Yet this growth has also resulted in adverse socioeconomic-, land use-, and transportation-related impacts (for example, increasing income

[1] For more examples on place- and race-based inequity in the United States, see Richard Florida's 2018 *CityLab* article titled "America's Worsening Geographic Inequality" (accessed via www.citylab.com) and a summary of findings (titled "Racial Disparities Among Extremely Low-Income Renters") from a recent (2019) report published by the National Low Income Housing Coalition (accessed via www.nlihc.org).

inequality, homelessness, residential and commercial displacement, and roadway congestion) that can be felt beyond jurisdictional boundaries. Given this basic understanding of social equity and vulnerability in Seattle and beyond, transportation planners at King County Metro Transit (hereafter referred to as "Metro") are progressively concerned with the extent with which the agency's planning efforts, service and capital investments, and high-level and political decision-making might contribute to the exacerbation of such impacts, and especially where impacts might converge. This attention is critical as Metro undergoes unprecedented organizational restructuring and system-wide growth. Effective January 1, 2019, the agency transitioned from a division *within* the King County Department of Transportation to its own cabinet-level Department directly under the oversight of the King County Executive. At the same time, the agency is rapidly expanding, both internally and externally, prioritizing the implementation of a recently adopted long-range plan, Metro Connects, and aggressively hiring full-time employment (FTE) staff to support this system expansion.

Metro Connects, adopted in 2015, outlines significant investments over the next 20 years to restructure, expand, and upgrade countywide transit service (King County Metro 2017). A substantial proportion of these improvements are planned in tandem with Sound Transit – a regional tri-county quasi-public transportation agency – and the voter-approved ST2 and ST3 transit initiatives, which mandate the construction and implementation of regional light rail, regional express bus, and commuter rail service across King, Pierce, and Snohomish Counties through 2040 (Sound Transit 2017). To complement Sound Transit's new Link and Express service, Metro will restructure and expand both fixed-route bus service and flexible local community service to optimize ridership and connectivity while minimizing potential service redundancies.

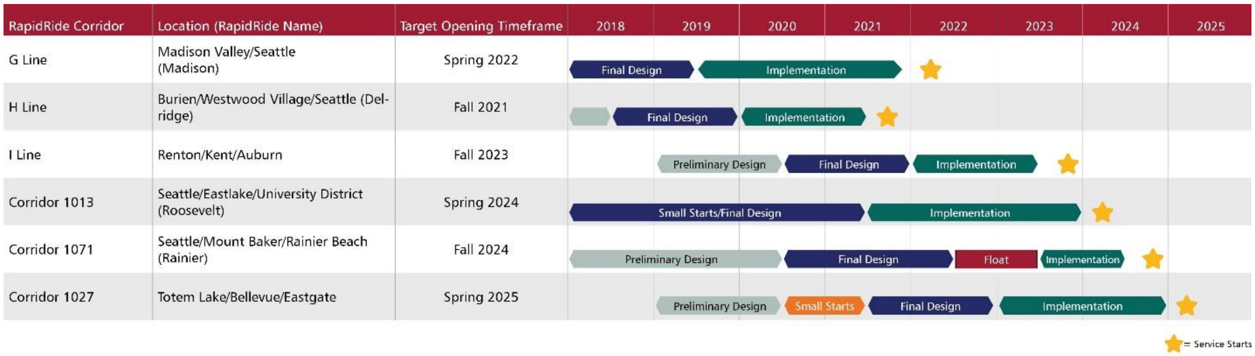

Figure 1: Project delivery schedule of new RapidRide service through 2025. Source: King County Metro Transit

At the same time, Metro Connects outlines an ambitious expansion of the agency's flagship trunk service: RapidRide – Metro's highest-frequency fixed-route service, greatly resembling bus rapid transit. In the short-term, Metro plans to implement six new RapidRide routes by 2025, with seven more by 2027, that will effectively upgrade existing frequent fixed-route corridors serving as trunk services both in Seattle and across the county (see Figure 1 above, courtesy of King County Metro Transit).

As the "G Line" (along Seattle's Madison Avenue corridor) and the "H Line" (Burien to Downtown via White Center and Delridge) approach final design phases, early planning efforts began in early 2019 for the newly-minted "I Line," serving a cross-jurisdictional corridor that stretches over 18 miles from the Auburn Sounder train station northbound to the Renton transit center via Kent. Set to open in the fall of 2023, very early planning efforts have kicked off with the release of a Request for Proposals (RFP) and a preliminary corridor-level report at the end of 2018. As of January, Metro is contracting out lead planning, design, and implementation with a major national consulting firm. Planning and alternatives analysis will be carried out through 2019, with a preferred alternative identified by September of that year (see Figure 2 for the latest I Line route alignment). As the I Line approaches design phase as early as July of 2019, Metro's Service Development Section is simultaneously implementing the Renton-Kent-Auburn Area Mobility Plan (RKAAMP), preemptively restructuring existing fixed-route service in parts of south King County ahead of the opening of the new RapidRide service.

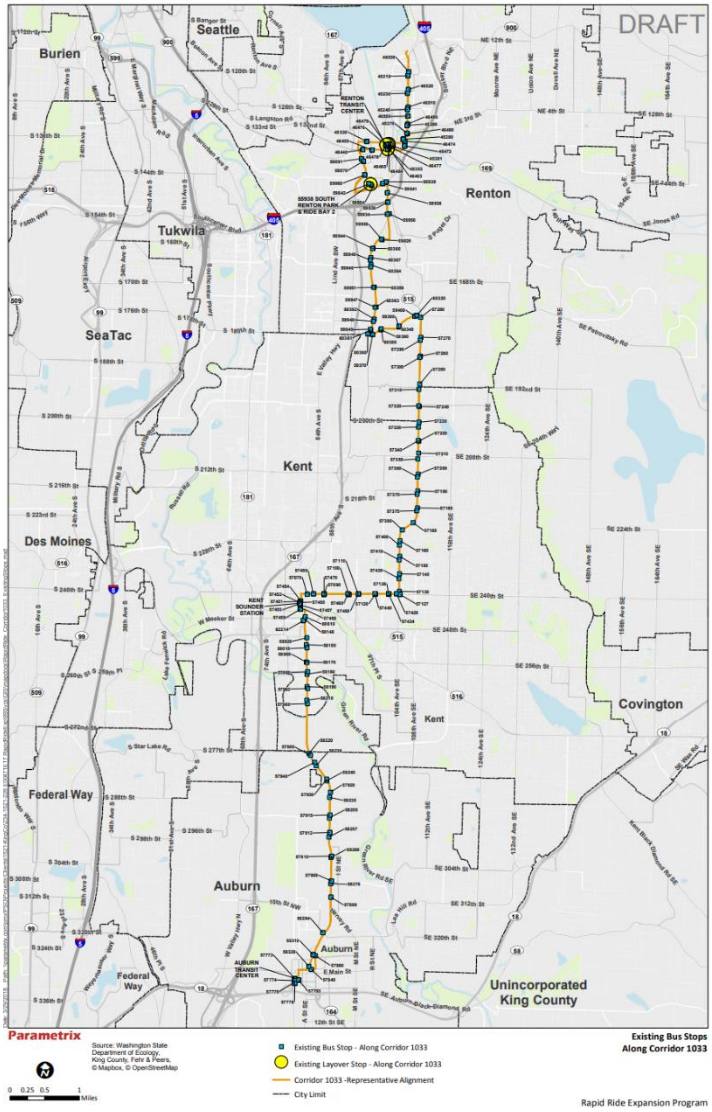

Figure 2: Draft Route and Stop Alignment (Parametrix 2018)

In line with Metro's long-range and strategic plans, as well as the county's broader equity and social justice (ESJ) goals, a project of this magnitude demands careful measurement of any predicted impacts and careful consideration of the affected communities and stakeholders. In attempting to apply such an equity lens to the RapidRide I Line, this thesis draws broadly on theoretical, empirical, and practical literature. There is a rich collection of academic research exploring the equity, or *fairness*, of the distribution of burdens (or costs) and benefits across a society; predominantly grown out of schools of economics, philosophy, and political science, scholarly work on equity is traditionally framed in terms of and as an outcome of the market. The theoretical underpinnings of the present work begin with Rawlsian economic theories, as well as philosophical definitions of justice and fairness. This is followed by a summary of key criticisms of John Rawls's principles of justice and other important considerations to note in the equity literature, before pivoting to the prevailing literature on social justice and transportation equity planning (both academic theory and relevant professional practice).

Transport equity literature, specifically, has proliferated internationally in recent years, with particular attention on spatial accessibility and the nexus of transport disadvantage, social exclusion, and well-being: this includes research from Australia (Currie 2010, 2004; Delbosc and Currie 2011), Canada (El-Geneidy et al. 2016; Foth et al. 2013; Litman 2018), Colombia (Bocarejo et al. 2012; Jaramillo et al. 2012), the Netherlands (Martens 2017), South Africa (Venter et al. 2018; Venter 2016), the United Kingdom (Lucas 2012), and the United States (Levinson et al. 2016; Golub et al. 2014; Cervero et al. 2011; Shen 1998), to name a few, but prominent, studies and authors that influence and inspire the following research.

In professional practice, transport and public transit equity analyses have largely focused on *service* planning and investment, and less so on *capital* planning. Impacts of capital investments are not as readily measured across user or population groups, but rather in terms of ownership costs and useful years of life. Yet capital investments, including enhanced bus stops and shelters, transit signal priority, dedicated transit lanes, new bus coach fleets, and the bases to hold them, are critical to the success of future RapidRide projects. As Venter et al. note, "BRT systems are widely acknowledged as being capable of improving urban mobility through a package of interventions, including busway improvements, efficient operations, and the upgrading of the urban environment..." (Venter et al. 2018). Capital investments carry permanence: in the same spirit of fixed guideway transit (rail, trolleybus, etc.), built capital assets represent a commitment to communities to provide the accompanying high-capacity, high-quality transit service. The measurement of the impacts of these capital investments is equally important to ensure decision-making is both accountable to the communities served and to the best and most productive use of constrained public resources.

Therefore, this study explores the following central research question:

- **How are operational and capital investments distributed across socioeconomic user groups in southern King County as a result of RapidRide bus rapid transit expansion (with attention to vulnerable populations and communities)?**

This central research question is supported by the following sub-questions:

- How does bus rapid transit expansion impact access to transit across socioeconomic user groups?
- How is King County Metro bus transit service distributed throughout the county across socioeconomic user groups and relative to social and transportation needs?
- How are equity and accessibility considerations accounted for in bus rapid transit planning practice at King County Metro?
- How can projected equity impacts influence King County Metro's capital planning and financing decisions for RapidRide implementation?

Ultimately, the purpose of this study is to explore theories of transport equity through the evaluation of new RapidRide transit service in southern King County. To answer these questions, this project presents and tests an innovative quantitative and geospatial model prototype designed to evaluate the equity of transit planning and investment decisions. The proposed model is made up of two main portions that measure operational and capital components of Metro's RapidRide I Line against socioeconomic user groups. The first is a straightforward network analysis throughout the entire study area, comparing levels of transit service with social and transport needs. Subsequently, the second component presents a novel approach for bus rapid transit planning that integrates capital cost choices for capital investments (in terms of estimated life-cycle cost values) with service network analysis against the same socioeconomic characteristics and mobility needs along the I Line Corridor. Ultimately, this proof of concept should present a view of transport needs, existing transit services, burdens and barriers to transit and accessibility, and impact of capital investments in King County, and along the preliminary I Line alignment.

Ultimately, this model's findings suggest that service and capital investments may not be evenly distributed across the I Line corridor in a socially equitably manner. However, these are preliminary results that successfully serve as a proof of concept for this unique model, providing a potentially valuable approach to integrate service and capital planning in an equity analysis.

Chapter 2: Literature Review

This academic endeavor is based on growing attention in both international literature and state of practice on issues of social equity, transportation disadvantage, and transportation equity. Academic theory and literature on social equity is rich and plentiful, with discussions of the *fairness* of the distribution of burdens (or costs) and benefits (or revenues) emerging from schools of economics and social sciences, political science and philosophy, and a multitude more. In recent decades, academic and practical attention to social equity has grown dramatically in public policy, namely in the fields of public health and transportation. As social inequities continue to widen in the United States, even beyond American urban centers, *place-based* policies, programs, and investments are earning increased attention in the study of education, healthcare, economic development, and beyond.

In the following chapter, I explore these varied, yet interconnected, threads and summarize a fraction of the extensive collection of scholarly and practical research centered around social inequity and injustice as it might intersect with, be derived from, or otherwise impact one's level of personal mobility and access to opportunity across physical and spatial landscapes. The chapter begins with a review of theoretical literature focusing on social equity, transportation disadvantage, and their overlap. Covering both classical and contemporary interpretations of social equity, multiple dimensions of equity are identified and defined. The discussion then shifts to the practical application of social equity in quantitative analysis, highlighting notable academic research on transportation and public transit issues that attempt to capture equity considerations in an empirically meaningful manner. This chapter closes with a brief review of the state of practice –primarily in the public sector – that attempts to center social equity in transportation planning, policy-making, and evaluation.

2.1. Theoretical Literature

2.1.1. Classical interpretations of social equity

For the most part, classical theory on social equity and distributive justice is dominated by three major schools of thought: socialism (or Marxism); liberalism; and libertarianism. Preeminent philosophers and economists alike have arguably attempted to address market imperfections and the distribution of benefits and burdens across society since the Industrial Revolution and the growth of the modern market economy.

Karl Marx's and Friedrich Engels' early contributions to this field cannot be ignored. Their collective works in the mid-1800s on class struggle under capitalist economic systems and the plight of the working class, as well as their calls for socialism, in many ways laid early groundwork for the development of robust theories on distributive justice. Equally foundational are the works of early classical economists in introducing concepts around market efficiency and utility (particularly, its maximization). In the decades since Adam Smith's seminal work *The Wealth of Nations* was published (1776), the field of classical economics flourished and gained widespread acceptance, later supported by liberal neoclassical theories of utilitarianism, put forth by Jeremy Bentham (1789) and, later, John Stuart Mill (1863), Vilfredo Pareto's efficiency and distribution principles (1896), and Arthur Cecil Pigou's conceptualization of externalities and the Pigovian tax (1920). By and large, social equity was broadly defined by classical and neoclassical economists in terms of maximizing utility for all members of society, while aspiring to treat all individuals equally. These utilitarian and egalitarian definitions of "equity" have arguably dominated traditional planning practice, including transportation planning. As Beatley points out, this framework "focuses not on who benefits or bears the costs of infrastructure programs or decisions, but rather their net result" (Beatley 1988). Until relatively recently, prevailing academic theories were rarely concerned with disaggregated distributions of utility (or rather, benefits and burdens) across society.

A discussion on the modern theoretical underpinnings of theories of social equity, however, is incomplete without an account of the works of John Rawls. Rawls' authoritative 1971 opus, *A Theory of Justice*, was particularly responsible for elevating the debate around market distributions and inequality to include consideration for the distribution of market-based benefits and burdens for different members of society. His "justice as fairness" theory applies his famous notion of the "veil of ignorance" to social contract theory, which, when taken together with his identification of a set of social primary goods (as opposed to natural goods) necessary for rational thought and action, provides some key principles upon which his theory is based (Rawls 1971; Martens 2017). Upon removal of the veil, the theory assumes that all members, or parties, to the social contract would observe the following principles, which Rawls introduces in *A Theory of Justice* (1971) and later refines in *Justice as Fairness: A Restatement* (2001), in this general logic and order:

1. All members of society have equal claim to the greatest possible combination of basic civil rights or liberties (including freedom of thought and speech, of mobility, of choice of occupation, etc.);
2. All members have a claim, or have access, to employment and positions of political or economic power, inasmuch as their capacity enables them to; and
3. Any differences in the distribution of income and wealth can only be tolerated if they are to the benefit of the most disadvantaged, or worst-off members of society.

Rawls' work here shows a deep commitment to egalitarian society in which actors are personally concerned with the rules of the game, and the fairness of opportunity and outcomes, to the extent that they are as likely as the next person to find themselves in a disadvantaged position. As definitive as this theory has proven to be, it shows some notable limitations, not least of which being his specific concern with the equal access of opportunity irrespective of income or wealth – in this case, Rawls fails to account for any additional factors that are found to determine inequities in society, let alone in the United States, namely race and gender, among others.

The "justice as fairness" theory was ground-breaking in terms of its impact on the broad advancement of contemporary social, economic, and philosophical thought. Rawls' principles have been directly adapted as normative frameworks to drive progress towards equity goals for the fields of healthcare (Daniels 2008), public policy (LeGrand 2006; Banerjee 2005), and transportation (Pereira, Schwanen, and Banister 2017), to name a few. At the same time, Rawls' theses have garnered valid criticism from an even broader audience, resulting in an expansion of this literature. Following the publication of *A Theory of Justice*, Robert Nozick wrote *Anarchy, State, and Utopia*, offering a defense of libertarianism and an argument for the protection of individual rights in society (Nozick 1974). A leading libertarian theorist, Nozick "does not consider the benefits of the poorest people and believes that in the case of free capital and ensured collective interest, equity is provided" (Behbahani et al. 2018). Friedrich Hayek, a philosopher and economist that prescribed to theories of classical liberalism and economic freedom, published his *Law, Legislation and Liberty* series over the rest of the decade, offering another important critique of Rawls' theory of justice. In fact, Hayek was a harsh critic of the concept of *social justice*, describing it as "vacuous," "meaningless," and "empty" (Hayek 1976). At the same time, for what it may be worth, Andrew Lister argues that while "Hayek and Rawls disagree about empirical (economic and political) questions," they find shared philosophical ground, noting that Hayek's "principles allow for policies that limit inequality and benefit the worst off" (Lister 2013).

Major works continued to emerge in the 1980s and 1990s – Ronald Dworkin's theory of equality of resources and Michael Walzer's theory of distributive spheres are notable examples – further developing the literature and offering unique conceptual frameworks for understanding social equity and distributive justice (Dworkin 1981, 2000). Walzer's theory is particularly interesting in that it offers an alternative to Rawls' idea of primary goods, instead claiming that social goods – those which have a prescribed social meaning or importance, like education – must be intentionally distributed to members of society, as opposed to basic material goods which are more reasonably bought and sold in a free market (Walzer 1983).

Frankly, this brief review barely scratches the surface of an expansive academic literature and a multitude of economists and philosophers with valuable contributions to our understanding of social equity, and particularly distributive justice as a means to achieve a level of social equity. For now, however, the works highlighted here offer some classical and foundational principles that help establish not only contemporary theories of equity, but more importantly equity and social justice in the practice of transportation and capital planning.

2.1.2. Defining equity

As the concept and study of social equity continues to expand, both academically and in professional practice, there tends to be confusion about the precise meaning and use of the term. Terms like "equity" and "equality" are commonly applied interchangeably (incorrectly so) while numerous variances have emerged. For example, equality – also known as *horizontal equity* – assumes that individuals are considered equals and treated equally, and impacts are distributed equally. This is largely the favored framework in public planning and policy-making: the notion that "public policies should avoid favoring one individual group over others" is a generally uncontroversial one (Litman 2018). Largely egalitarian, equality "is concerned with providing equal resources to individuals or groups considered equal in ability. It avoids favouring one individual or group over another and services are provided equally regardless of need or ability" (Delbosc and Currie 2011b). Applied to transportation projects, horizontal equity could be presented in terms of equal shares of benefits and burdens – that costs and benefits of transportation projects and facilities "ought to be distributed equally among individuals and groups in the community… [and] that individuals in the community ought to be required to make *equal sacrifices* in providing needed public infrastructure" (Beatley 1988).

On the other hand, Rawlsian social equity can be considered *vertical equity*, which "is concerned with distributing resources between individuals of different ability and needs…in order to make up for overall societal inequalities" (Delbosc and Currie 2011b). Vertical equity does not seek to treat all individuals or groups equally, but rather is concerned with the progressivity or regressivity of policies, and with differences in groups, particularly with regard to income, race, or social class. As Litman explains, "policies are equitable if they favor economically and socially disadvantaged groups in order to [compensate] for overall inequities" (Litman 2018). This same understanding of equity can also be applied to an individual's ability and level of mobility, concerned with the distribution of transportation benefits to individuals with disabilities, personal mobility limitations, and transit dependence (ie, individuals with an arguably greater need for public transportation service). With that in mind, this research is primarily concerned with the vertical equity of transit service provision in King County – that is, it evaluates the level of service that certain disadvantaged sectors of the population have access to.

There is a similar distinction between two typical objectives of social equity: *equity* (or equality) *of opportunity* and *equity of outcome*. The former is rather uncontroversial and is similar to horizontal equity or equality. According to Beatley, the notion of equity of opportunity encompasses "the belief that all individuals ought to be afforded the chance to enhance their life prospects and to develop and apply their skills and abilities to the fullest extent" (Beatley 1988). This is a particularly important concept in education and workforce policy, as access to opportunity is commonly framed in terms of employment (such as fair hiring practices) and education (on the achievement gap, for example) – the role of transportation in enabling and providing access to these opportunities, however, cannot be understated (Litman 2018). Equality of *outcomes*, on the other hand, is notably more difficult to define. Rawls was evidently concerned with equality of outcomes, recognizing that inequality could only be tolerated if it resulted in an increase in the well-being of those in society who are least well-off (Rawls 1971). A focus on outcomes implies an interest in results, whether that may be a program's rate of success or the configuration and distribution of an agency's funds and services across a region and population. In terms of outcome-driven equity in infrastructure and transportation planning, Beatley argues the objective "ought to bring about social and economic conditions that place individuals on an equal footing in terms of income and resources" (Beatley 1988).

Finally, the following distinct types of equity are also worth introducing and are particularly important to consider in public transportation. The concept of *procedural justice* is concerned with decision-making processes that are uniform, fair, and consistent – naturally, this is especially critical in the public sector

(Bullard and Johnson 1997). Alternately, the lasting impacts of the construction of infrastructure and transportation assets on the physical built environment raise questions not only about the lifetime of the asset, but more importantly *who* pays for and benefits from new infrastructure throughout its lifetime. As Beatley argues, a concern with *intergenerational equity* demands that "public infrastructure policies and decisions must protect for future generations a range of resources and social investments" (Beatley 1988). The equity of transportation plans and investments across generations is also closely connected with sustainability and *environmental justice* as well, as planners are increasingly expected to ensure that "[environmental] impacts on future generations are considered in decision-making" (Litman 2018). This relationship is particularly important to note, as evidenced by the now well-documented examples of environmental injustices borne out of American transportation planning over the past century (such as the construction of highways through predominantly low-income and minority neighborhoods and the adverse health effects of local tailpipe emissions on the adjacent communities, for example). In fact, Sanchez and Brenman explicitly link environmental equity or justice to "environmental racism," noting its effectiveness as a "framework for showing how low-income and minority communities face the brunt of negative impacts from transportation investments" (Sanchez and Brenman 2007).

2.1.3. Social equity and transportation

The study of transportation equity has rapidly proliferated internationally in recent years, with particular attention to transportation disadvantage and its nexus with social exclusion and well-being. Conceptually, transportation disadvantage is intractably tied to social exclusion, social inequality, and poverty; it manifests itself when an individual's level of mobility and ability to access employment, education, healthcare, and other services (often referred to as "opportunity") are limited by transportation-related barriers (Lucas 2012; Delbosc and Currie 2011a).

The multi-dimensionality of social and transportation disadvantage has long been acknowledged and observed in the United States. As early as the 1970s, the federal government recognized that "the segment of the nation's population that most critically needs basic community services is the same segment that tends to have the least physical access to these services" (Falcocchio and Cantilli 1974). Falcocchio et al. recognized this intersectionality of "disadvantage" in the United States, particularly among the *transport disadvantaged*. In *Transportation and the Disadvantaged*, the authors focus specifically on disadvantage as it manifests in low-income populations, individuals with cognitive and/or physical disabilities (or limitations), and the young and elderly, asserting that "each of the categories of the 'disadvantaged' is related to the others … [and] represent the 'outsiders' or 'fringe' members of society" (Falcocchio and Cantilli 1974).[2]

More contemporary work on this issue does not simply recognize the potential intersection of age, poverty, and disability, but is also increasingly concerned with the unavoidable dimension of race, a glaring omission in *Transportation and the Disadvantaged* (especially alarming considering the role of transportation in the Civil Rights Movement of the previous decade). Citing the 1896 Supreme Court case Plessy v. Ferguson upholding train car segregation; Rosa Parks and the Montgomery Bus Boycotts of the 1950s; the Freedom Riders of the 1960s; and the Los Angeles Bus Riders Union's successful civil rights lawsuit in 1994, Bullard and Johnson illustrate in *Just Transportation* the critical role of transportation in the American civil rights movement (Bullard and Johnson 1997). In his foreword in that book, Congressman John Lewis argues that "the legacy of 'Jim Crow' transportation is still with us. Even today, some of our transportation policies and practices destroy stable neighborhoods, isolate and segregate our citizens in deteriorating neighborhoods, and fail to provide access to jobs and economic growth centers (Bullard and Johnson 1997). Bullard and Johnson place race and class at the center of their research, following local politics and transportation policies from Los Angeles, CA, and Austin, TX, to Atlanta, GA, and New Orleans, LA.

[2] Rather than relying on terms like "outsiders" or "fringe," I opt to use "marginalized" or "vulnerable." When referencing social equity in practice in King County, these segments of the population are also broadly referred to as "priority populations" (an umbrella that is often expanded to include persons of color, persons with limited-English proficiency, women and single mothers, and members of the LGBTQ+ community).

A decade later, Sanchez and Brenman's *The Right to Transportation* further expands the study of transportation equity, with attention to urban income inequality, land use development patterns, transportation cost burdens on households, and the broad impacts of transportation planning and policy on low-income households and people of color at varying levels of government. The authors explore both *direct* and *indirect* effects of transportation policies on low-income households and people of color. Impacts borne from federal, state, and local policies and plans that promote the construction of freeways are often easy to identify, reducing residents' levels of accessibility (especially those without automobiles) and presenting tax burdens on households that receive little benefit. However, the authors argue, it is the perceived phenomenon of the *spatial mismatch* – the inability of disadvantaged residents to access work, education, and other forms of opportunity due to local development patterns, economic conditions, and transportation options – that can threaten already-marginalized populations' access to employment, education, health services, and housing (Sanchez and Brenman 2008).

Across the Atlantic, the publicly sponsored Social Exclusion Unit report published in 2003 in the United Kingdom established key links between social exclusion and transportation disadvantage, creating the legislative environment that mandated the consideration of equity in transportation at the local jurisdiction level. The report recognized the interaction of "causal factors which lie with the individual, … factors which lie with the structure of the local area, … and factors that lie with the national and/or global economy" (Lucas 2012). This is critical from the perspective of practitioners, as it reflects the nature of the values necessary to guide policy and the activities of agencies. Lucas posits that "the implication of this conceptualisation, therefore, is that its resolution primarily rests with the social agencies that are responsible for policy delivery," reflecting an action and policy-oriented argument that rests on institutional and redistributive justice (Lucas 2012).

Personal vehicle ownership presents an additional dimension to transportation challenges, especially in the United States. Falcocchio et al. recognized this as well, noting that "in many areas the almost universal dependency on the automobile for personal transportation has shut the poor out of opportunities…" (Falcocchio and Cantilli 1974). Urban sprawl caused by low-density development throughout the country "produces extensive physical separation between residences and jobs. … Dispersed land-use patterns necessitate high levels of automobile usage, leading to higher travel costs for individuals and households" (Sanchez and Brenman 2007). Despite the presumed ubiquity of vehicle ownership – and the reinforcement of the automobile as a pillar of the American experience – car-ownership continues to be cost-prohibitive for the most vulnerable populations (including not just those living in poverty, but also the very young and very elderly, and many individuals with disabilities). This sector of the population is therefore often considered to be *transit dependent*, and rely on public transportation to access work, education, healthcare, and any other service or commodity they require. In *Transportation and the Disadvantaged*, Falcocchio and Cantilli recognized the dialectic dynamic between public transportation and vehicle-ownership: that very same cultural automobile dependency was (and in many places continues to be) "a major factor in the rapid decline of public transit patronage practically everywhere in the country" (Falcocchio and Cantilli 1974).

Coupled with the issue of automobile dependence, transportation disadvantage becomes increasingly complex at the suburbs and outer fringes of metropolitan areas. Over the past decade, the so-called suburbanization of poverty adds yet another challenge for individuals facing transportation disadvantage. The Great Recession left lasting impacts across urban landscapes throughout much of the developed world; while many cities can claim an almost-complete recovery with unemployment levels back to normal and prosperous downtowns, the enduring effects can be seen in suburban and exurban communities of almost every major metropolitan area in the United States and beyond. As urban centers enjoy a renaissance, costs of living have grown significantly, resulting in broad displacement of low-income populations to more affordable cities and towns farther away from downtown – and farther away from quality transportation services.

Diane Jones Allen's *Lost in the Transit Desert* provides an exceptionally nuanced and sensitive view into this issue of "transit deserts" – mostly suburban neighborhoods that lack public transit service but are home to newly arrived transit-dependent residents – and the challenge of planning for this new sociodemographic paradigm at local and regional levels (Allen 2018). Transit deserts are generally found in neighborhoods that don't encourage walking or easy connections (due to density, land use and zoning mix, and physical form); where access is often difficult, there are long distances to travel, and long wait times for transit; and where demographics are indicative of vulnerability. Allen explicitly connects the development of transit deserts to over a century of racial discrimination in American cities, from the Great Migrations of African-Americans from the southern states to the development of public (segregated) housing and accelerated highway construction after World War II (Allen 2018).

Whether in dense metropolitan cities rich in transit or new suburban markets, the equity impacts borne from the construction of transportation infrastructure and investments in capital assets deserves equal scrutiny. Yet the transportation equity research rarely addresses capital components, and few adaptations of classical equity theory for capital planning exist. Timothy Beatley argues for the value of the Rawlsian ethical paradigm in accounting for equity. Rawls's work "directs planners and public officials involved in infrastructure decisions to adopt those financing and locational policies that serve to maximize benefits for members of the least-advantaged economic and social group" (Beatley 1988). However, some major issues can present themselves when applying such a framework to transportation infrastructure decisions. In general, the calculation of benefits and burdens, inflation, and discount rates is challenging across common capital assessment methods. Further, Beatley questions how "least-advantaged" groups are defined (and perhaps more importantly, accepted by stakeholders and decision-makers).

In his widely cited work, "Evaluating Transportation Equity," Todd Litman aptly recognizes the importance of maintaining a broad view of disadvantage, where he notes, "Disadvantaged status is multi-dimensional, so its evaluation should take into account the degree and number of disadvantaged factors that apply to an individual" (Litman 2018). Indeed, transportation disadvantage is anything but straightforward, with its multitude of components and dimensions requiring nuanced and detailed approaches. The following section of the chapter reviews the growing body of empirical literature, with particular attention to the range of methodologies and findings in contemporary published work.

2.2. Empirical Literature

2.2.1. Spatial accessibility analysis

In a sense, much of the research included in this paper is inspired by spatial accessibility analysis, with a major component of the methodology employed here designed to broadly measure access to transit. In "Evaluating Transportation Equity," Todd Litman states plainly that "… the ultimate goal of most transport activity is accessibility, which refers to people's ability to reach desired services and activities" (Litman 2018). Generally, spatial access is concerned with the use of transportation as a means to reach a wide range of "opportunities" (i.e., employment, education, healthcare, recreation, and the multitude of services, amenities, and commodities that make up modern day-to-day life) that are geographically distributed across a local landscape. According to Litman, "various factors can affect accessibility including mobility, transport network connectivity and affordability, the geographic distribution of activities, and mobility substitutes such as telecommunications and delivery services" (Litman 2018).

The measurement of accessibility has steadily developed into a "gold standard" of modern transportation planning and modeling, particularly in contrast to traditional transportation demand modeling (see Allen's *Lost in the Transit Desert* and Martens's *Transport Justice* for recent challenges to traditional transportation planning approaches). The framing of *accessibility* as the essential end goal of transportation in general, and public transit in particular, contrasts traditional approaches that were largely focused on speed or a street's level of service (which are often referred to as indicators of mobility, rather than access). In fact, mobility differs from accessibility in that the former is generally recognized as the ability to move people or goods from one location to another in a swift, safe, and cost-effective manner (and is measured in terms of travel speed, road capacity, transit service frequency and reliability, and the resulting time saved or volume increase). If accessibility is concerned with the *equity* of a transportation system, mobility is concerned with the *efficiency* of that system.

Analytically, spatial access is generally made up of three essential factors: the origin (usually one's home), the destination (the desired opportunity), and the transportation network and travel modes available. The origins of accessibility analysis can be traced back to Walter Hansen's simple summation function of accessibility, published in his influential piece "How Accessibility Shapes Land Use" (Hansen 1959). Hansen's model evaluates a measure of access for a single origin, given the level of opportunities or activities in every destination available and an impedance function that measures "travel cost" in terms of distance (though time and money can also be used). This model can then be applied to an almost infinite matrix of origins to measure the spatial accessibility of a city or region.

The measurement of accessibility has proven to be a valuable tool in transportation planning. However, Hansen's formula is limited in that it does not account for the size of a city, and the number of opportunities available. Falcocchio et al. acknowledge this relative nature of accessibility and offer a variation of Hansen's formula that incorporates a "gravity model" that conceptualizes a location's accessibility relative to that of other locations. The authors' model accounts for the fact that, logically, "accessibility increases with an increase in the number of jobs, or with a decrease in travel time" (Falcocchio and Cantilli 1974). Further, in an application to Vancouver's bus transit system at the time (operated by the Coast Mountain Bus Company), the model found that "about 11.5 percent of … unskilled unemployment in the CMBC Area is attributable to lack of adequate transportation to job sites" (Falcocchio and Cantilli 1974).

In the past decades, the application and refinement of accessibility measurement has steadily expanded. Two studies of accessibility in the Boston Metropolitan Area in the late 1990s and early 2000s, authored by Qing Shen, applied expanded Hansen models that accounts for travel mode choice, and emphasizes the effect of location, noting that a major limitation in Hansen's original formula is its failure to account for either demand potential or multiple travel methods (Qing Shen 2001, 1998). The models employed effectively disaggregate education level, job income levels, mode choice, and residential location, providing an expanded application of Hansen's formula. Shen's work validates the challenge presented by the dominance of automobile ownership, and the "critical importance of auto ownership in dispersing metropolitan economies" (Qing Shen 1998). Workers that commute by car generally have higher job opportunity accessibility than those who commute by transit. However, Shen found that "less-educated job seekers who resident in the central city still have, on average, somewhat better access to job openings than those who reside at the periphery of the metropolitan area" as most low-income employment opportunities are still concentrated downtown (Qing Shen 2001).

Further accessibility evaluations have explored different correlated factors and their predicted impacts on accessibility, again generally with a focus on vulnerable or disadvantaged populations. Ahmed El-Geneidy, David Levinson, and other authors expanded on the classic analytical approach to quantify spatial access by including transit fares in their travel cost impedance function (El-Geneidy et al. 2016). Applied in Montreal, Canada, the introduction of an economic dimension to travel cost found that even fare classes presented arguably unfair barriers to accessibility; when examined at the station level, entries to stations in high-income neighborhoods were predominantly paid with monthly fares, while entries to stations in low-income or minority neighborhoods with single or weekly fares, which tend to cost more per ride than monthly bulk passes.

Joe Grengs explored accessibility to both employment and non-work activities in Detroit in a series of papers published between 2010 and 2015. An analysis of residents' access to low-wage jobs revealed significant variation in accessibility throughout the inner-city, though it exhibited progressively lower accessibility as distance from the central business district grew (Grengs 2010). While transit scored modestly on the study's accessibility index in the central business district, it doesn't compare to the level of accessibility provided by the automobile (and in fact, the highest transit scores in the CBD only scored higher than some traffic analysis zones 30 miles or more from downtown (Grengs 2010).

The relationship between a city's or a county's built environment and its level of accessibility cannot be understated, either. Both existing land uses and road capacity can have significant effects on residents' access to employment or other necessary services. Transportation planning and modeling has traditionally relied on efficiency-focused measures such as a roadway's level of service or speed, trip generation, and mode choice, but this is arguably limited when planning for suburban and peripheral neighborhoods – for example, observations of mode choice are not as significant when residents have little choice to begin with (Allen 2018). In a comparison of the impacts of mobility (speed) and land use (density) for commuters traveling to work by car, Shen et al. find that the two factors affect accessibility in opposite ways, but that proximity presents net accessibility improvements (Qingyun Shen et al. 2012).

2.2.2. Transportation disadvantage and transportation equity research

Accessibility analysis is a profoundly powerful tool to measure the utility of multi-modal transportation systems with a social equity lens, and its broad recognition as an indispensable measurement in transportation research and practice is unsurprising. Yet as a research method, the complexity and often narrow focus of accessibility analysis can hinder not only its effective measurement but also the dissemination and consumption of findings.

At the same time, a significant proportion of transportation research over the last few decades offers a broad range of quantitative approaches to measuring transportation disadvantage and transportation-related disparities. Over the last decade, Graham Currie's work has expanded the understanding of transportation disadvantage in terms of transportation gaps, social exclusion, and well-being. In his 2004 study of transportation need and public transport provision in the small city of Hobart, Australia, Currie's Public Transport Gap Analysis model compares scores from a standardized and cumulative needs index with transit supply. While the study did not provide significant results on the temporal factor of transit service, Currie's analysis indicates that changes in service frequency "affect the severity of the needs gap" rather than the locations that have gaps (Currie 2004). In 2010, Currie refined his gap analysis model and applied it to a much larger metropolitan area. This time focusing on Melbourne, Australia, Currie's evaluation of "need-gaps" – areas found through a mismatch of social disadvantage, transportation need, and transportation supply level – in such a large metropolitan area offers a highly aggregated view of transit gaps (Currie 2010). This limitation was evidently significant, as Currie and fellow author and Monash University lecturer Alexa Delbosc note just a year later that such analyses "do not measure the impacts on individuals living in these locations," rendering it "difficult to isolate the specific impacts that geographic location can have individual outcomes [sic]" (Delbosc and Currie 2011a).

In fact, Delbosc and Currie have made multiple noteworthy contributions to the transportation equity research field together, co-authoring no less than three peer-reviewed journal articles on the subject in 2011 alone. A survey of residents of Melbourne (a major metropolitan area) and the Latrobe Council (a rural region) sought to gather self-reported and disaggregated data on transport disadvantage among residents living in the inner-city and at the urban peripheries, as well as residents who are auto-dependent. Among the survey's findings was a surprising number of residents in the fringe and rural areas missing opportunities and social activities due to transportation issues, despite high rates of automobile ownership among this population (Delbosc and Currie 2011a). Applying a Lorenz curve to measure inequality in transit supply in Melbourne, Delbosc and Currie find examples of "vertical equity advantages" in favor of low-income residents, the youth and elderly, and households without a vehicle, each sector displaying higher transit supply (Delbosc and Currie 2011b).

In an ex-ante study of the Corridors of Freedom bus rapid transit project in Johannesburg, South Africa, Venter presents an approach for measuring the effects of planned BRT implementation on employment access across a geographic area (Venter 2016). Given the context of the existing transit systems sharing the streets of Johannesburg, Venter must account for varying fare classes, the displacement and/or consolidation of informal private transit providers (a common but complicated challenge most cities in the Global South must contend with), and the introduction of formalized feeder systems. Venter ultimately finds that implementation is least disruptive and serves the population best when it is integrated with a frequent and local feeder service with "an integrated and progressive fare policy" (Venter 2016).

2.3. Literature of Practice

2.3.1. Federal social equity regulations

Public agencies at all levels of government across the United States are historically complicit in decades of racially-driven marginalization and oppression of their residents of color. Perhaps among the best documented, for example, is the discriminatory practice of redlining in the early and mid-20th century, in which banks and even the Federal Housing Administration engaged in and gave tacit approval for the denial of financial services to residents of color at a systemic scale.[3] This financial discrimination has resulted in cascading demographic and economic impacts on communities of color, effectively leading to the segregation of residential areas throughout the United States. Now, in most American cities, race and ethnicity are overwhelmingly leading predictors for high rates of economic inequality and disparities in access to healthcare and food (Hutchinson 1992; Eisenhauer 2001).

For years, local transportation agencies and authorities – through widespread segregation of their public facilities and services – actively and intentionally marginalized members of the very communities they were chartered to serve, stained by the legacy of the 1896 Supreme Court decision in Plessy v. Ferguson that upheld racial segregation of train coaches and cemented the "separate but equal" doctrine in the United States. Early racial and social justice movements in American transportation can credit the Montgomery Bus Boycott social movement in the 1950s sparked in Alabama by Rosa Parks's inspiring actions in demand of fair and just public transportation. The following decade, the Freedom Riders challenged the lack of enforcement of Supreme Court decisions of the previous decades, riding Greyhound buses from Washington, D.C., to New Orleans, LA, to uphold the desegregation of public transportation facilities and the prohibition of discrimination in interstate travel (Bullard and Johnson 1997).

[3] See Bill Dedman's Pulitzer Prize-winning series of articles published in 1988 by The Atlanta Journal and The Atlanta Constitution (http://powerreporting.com/color/) .

Timing proved to be critical for these movements – with the passage of the Civil Rights Act (1964), the Voting Rights Act (1965), and the Fair Housing Act (1968), the 1960s was a pivotal decade for civil rights in the United States. Of these, the Civil Rights Act's Title VI is particularly important for transportation policies at all levels of government, as it "prohibits discrimination on the basis of race, color, or national origin by recipients of federal financial assistance" (Sanchez and Brenman 2007). In other words, Title VI "broadly prohibits the use of federal funds by recipients to discriminate on the basis of race, color, or national origin" (Bullard and Johnson 1997). This includes discrimination by intent *as well as* by disparate impact, requiring agencies like King County Metro to report the extent to which minority populations are impacted by changes to transit service in a community. The federal government has since clarified the requirements for Title VI compliance, requiring agencies to "[identify] and [avoid] 'disproportionately high and adverse' effects on minority and low-income people" (Sanchez and Brenman 2007).

Because King County Metro, like most other public transit agencies, receives funding from the Federal Transit Administration (FTA), the agency is required to perform Title VI analyses with every major service change (generally twice per year) and submit a program report every three years. The FTA's guidance for Title VI compliance provides slightly more specific goals:

a. Ensure that the level and quality of public transportation service is provided in a nondiscriminatory manner;
b. Promote full and fair participation in public transportation decision-making without regard to race, color, or national origin;
c. Ensure meaningful access to transit-related programs and activities by persons with limited English proficiency. (King County Metro 2016a)

The Federal Transit Administration, in alignment with the requirements of Title VI, includes a checklist of items necessary for compliance, and includes notices to the public; transparent complaint processes; public participation plans; language assistance plans; monitoring requirements; facilities reviews; governance structure reviews; service standards and policies (T); demographics and service profiles (T);

survey-collected ridership and travel pattern demographics (T); public engagement processes for major service changes (T); and service and fare equity analyses (T) (King County Metro 2016a).[4]

2.3.2. Social equity and transportation in King County

The following discussion seeks to provide a brief review of current planning practice and the incorporation of equity considerations to public planning processes in King County, Washington. This marks a shift in the present discussion from the theoretical to the practice, providing necessary context for a key piece of this paper's analytical framework.

Formal equity and social justice (ESJ) body of work in the county can be traced back just over 10 years. Although various county departments have worked to address disparities in their work across the region, before 2008 it was rare that processes were formalized, and few departments coordinated in their efforts. Then-County Executive Ron Sims launched an equity and social justice initiative in 2008 that sought to incorporate equity considerations as an integral part of the county's work. In 2010, this was further formalized by a county ordinance under County Executive Dow Constantine, which "calls for county agencies to examine the causes of racial disparities and inequities and to create conditions for all individuals and communities to reach their full potential" (King County Metro 2016a). And in 2015, the Office of Equity and Social Justice (OESJ) was formed within the Executive's office, with the development of a seven-year Strategic Plan the following year. The county's pro-equity agenda prioritizes the inclusion of historically marginalized populations in decision-making, promotes transparent and fair governance practices, and seeks to ensure that capital planning and financing (through the Capital Improvement Plan) drive pro-equity results. The county's efforts seek to address inequities across King County at their upstream root causes with a focus on "expanding access to the County's determinants of

[4] The items listed with a "(T)" indicate specific requirements necessary of transit providers, while all other items apply to all other federally funded public programs and agencies.

equity," which include transportation and mobility services rendered by Metro (King County Office of Equity & Social Justice 2016).

King County Metro Transit (Metro) is a department agency in King County, headquartered in Seattle, WA, charged with planning, operating, maintaining, and funding transit service across the county. Although the agency is primarily charged with implementing bus service, it also operates the City of Seattle's South Lake Union and First Hill streetcars as well as Sound Transit's Link light rail and bus service. As a county department, internal planning practice and processes seek to reflect county growth patterns and community needs, and is accountable to taxpayers – county visitors, residents, and businesses – and the King County Council. As proclaimed in Metro's latest Title VI Program Report, "Metro is committed not only to nondiscrimination but also to actively promoting equity and social justice in all the services we provide" (King County Metro 2016a). As such, the agency has a stated and mandated commitment to equity and social justice and is expected to invest strategically to alleviate disparities in transportation access. For example, the 2015 implementation of ORCA LIFT – an internationally recognized reduced fare program – allows customers below the county's de facto poverty threshold (200 percent of the Federal Poverty Level) to access transit for the cost of about half the regular fare.

As described above, Title VI evaluations are a key equity component of existing service planning practice, generally employed to measure the likely impacts of planned service changes (usually implemented twice per year) on low-income households and residents of colors. In line with Metro's Strategic Plan equity goals, which largely reflect those found in the county's Strategic Plan, Metro also employs equity in its service planning through the agency's Service Guidelines, which "establish criteria and processes that Metro uses to analyze and plan changes to the transit system" (King County Metro 2016b). Along with indicators for productivity and geographic value, social equity measures – based on existing ridership within tracts with above-average proportions of residents of color and poor households – are used to set target service frequency levels for each route. When service changes are estimated to produce “disparate impacts” to minority and low-income populations, as defined by the Service Guidelines, modifications to proposed changes must be considered. Further, service changes are accompanied by communication and engagement plans that seek to serve and underserved customers and priority populations.

However, with a new generation of RapidRide corridors under development, the accompanying service network overhauls in the adjacent areas, and a county-wide push to implement rigorous evaluations of project or program equity impacts, the forthcoming RapidRide I Line and the complementary frequent and local transit network will see a slightly different service planning approach. The Renton-Kent-Auburn Area Mobility Plan exclusively integrates equity goals and analysis into the plan’s key objectives, the implementation of the service changes, and the project’s community engagement efforts. Throughout the implementation of the mobility plan, equity is centered in service planning, evaluation, and decision-making – ongoing analysis serves as a monitoring tool as the project advances, and ultimately supports outreach campaigns and and service decisions. On the other hand, new RapidRide routes have been largely identified in the long-range planning carried out for Metro Connects and are implemented by the RapidRide program in a staggered schedule, with significant support from consultant services. While equity measures were initially incorporated during the development of the Metro Connects network, considerations for equity impacts are not as prominently integrated into ongoing RapidRide planning efforts.

2.4. Metro RapidRide: Bus Rapid Transit in King County

With the growing popularity of bus rapid transit (BRT) among transit agencies across the United States, it is worth discussing the state of practice and scholarly work on the impacts these projects may present, not only for the rest of the transit network but on residents’ transit service supply. Bus rapid transit systems have proliferated widely throughout the world, first gaining traction in major cities of the Global South as a viable alternative to fixed rail transit for its similar system qualities and benefits, improved flexibility, and lower costs.

In response to the broad spectrum of systems that have emerged over the past few decades under the banner of BRT, researchers and practitioners have sought in recent years to codify and standardize these practices. The Institute for Transportation and Development Policy, a nonprofit research organization based in New York City with additional field offices in Latin America, Africa, and Asia, first released its "BRT Standard" tool in 2012 as a means to reinforce system features – including planning, infrastructure, stations, safety and access, and communications – under a common definition for BRT. The Standard has emerged as a key evaluation tool and planning guide for successful bus rapid transit ("The BRT Standard" 2016).

King County Metro's RapidRide bus service, often classified as bus rapid transit (BRT), is billed as the agency's premier frequent service. Made up of six lines across the county, the system is characterized by limited stop-spacing at about every half-mile, high service frequencies with arrivals every five to 15 minutes during peak hours, a distinct bus fleet with unique passenger amenities, and localized corridor enhancements (King County Metro 2017, 2014). Since service began in 2010, RapidRide has emerged as Metro's workhorse, carrying on average over 65,000 weekday riders in October 2018 ("Ridership" n.d.). In many ways, the system's success can be attributed to its unique infrastructure improvements and capital assets as much as the routes' greater service frequencies. And while the effectiveness of capital expenditures and investments in key assets, including transit signal priority, off-board payment, and restricted transit lanes, has been assessed, performance measures are singularly concerned with cost-effectiveness (King County Metro 2014).

This presents a clear gap in the planning and decision-making processes for the design and development of new RapidRide lines. While service planning for the area's future network (which includes the general alignment that is slated for RapidRide upgrade) incorporates pro-equity objectives throughout the project’s several phases and across work activities, the same cannot be said for the capital planning and financing required for RapidRide implementation.

Chapter 3: Methods

This thesis primarily seeks to evaluate the equity of transit planning and investment decisions in South King County, focusing on Metro's forthcoming RapidRide "I Line" and its predicted impacts on spatial accessibility for local residents. An equity lens is applied at a corridor-level to service and capital planning efforts and assumptions employed throughout the implementation of a new large-scale bus rapid transit project. In answering the research questions stated earlier (Chapter 1), both quantitative and qualitative approaches are employed to present local transport needs, existing transit services, existing barriers to transit accessibility, benefits gained from new transit service implementation, and comparative impacts of capital investments. Both existing and proposed service, as well as proposed capital investments, are identified and quantified at respective locations (namely at census tracts, bus stops, and routes). Much of the analysis design is driven by data availability, internal planning assumptions at Metro, and available scholarly research cited in Chapter 2 (see Figure 3). The following chapter provides a detailed description of the quantitative research performed through this project.

Given the broad scope of such an analysis, methodological descriptions and considerations are approached in multiple distinct sections, each with their own valuable by-products. First, I define the study area and target population in question, accounting for the existing demographics and transportation conditions of South King County, specifically focusing on the Renton-Kent-Auburn corridor and surrounding area. Given the selection of the study area, the socioeconomic focus, and the key geostatistical function used throughout this analysis, this research effort is composed of two central research activities – evaluating service and capital components of the RapidRide I Line and surrounding areas. The first half applies Currie's approach for measuring the supply of public transportation service and, especially, existing transportation gaps throughout various Australian cities. A measure of access to transit within the study area is evaluated, establishing a baseline scenario and comparing against Metro's proposed 2025 network. The second details a preemptive evaluation that seeks to integrate anticipated capital investments into transit supply analysis alongside service changes throughout the proposed

RapidRide I Line corridor. This capital component offers an opportunity to test a proof of concept for incorporating life-cycle cost analysis estimates into the same model, replacing costs (ie, investments) for trips.

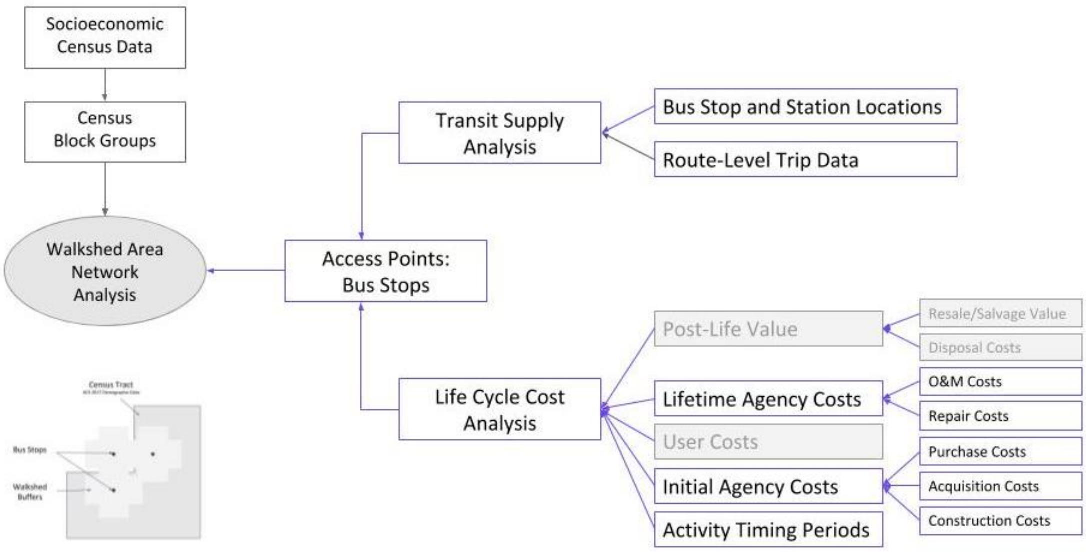

Figure 3: Simplistic model of research methodology detailed in this chapter

3.1. Defining the Study Area

Centered around Metro's I Line, the research detailed in this chapter is therefore primarily concerned with a corridor-level study (including the surrounding area). The I Line, one of six RapidRide projects set to be implemented by 2025, is a forthcoming bus rapid transit project that follows a predominantly north-south alignment, serving the cities of Renton, Kent, and Auburn, as well as unincorporated King County. Corridor 1033, as it is also identified in internal planning documentation, measures almost 18 miles in length and "upgrades" existing service provided by Metro Routes 169 (which connects the Renton Transit Center and the Kent Sounder Train Station) and 180 (connecting Auburn and Kent to the Burien Transit Center and the Seattle-Tacoma International Airport). The current preferred alignment – known as the "representative alignment" – originated in Metro's long-range plan, Metro Connects, where it was formally identified as a candidate line for the county's 2025 network vision. While the suburban corridor scored moderately in terms of service productivity and "geographic value" (which measures the number of employment and commercial centers and transit transfer points potentially connected), it scored among the top 25 percent of suburban corridors that would serve residents living below the Federal Poverty Level, indicating a clear equity justification.[5] Metro is currently in the Preliminary Design project phase, and is currently performing outreach for its alternative analysis that would provide a *preferred* RapidRide alignment as well as the complementary network of frequent, local, and flexible service.

Limiting the scope of the analysis to the project service area, defined internally by the Renton-Kent-Auburn Area Mobility Plan (RKAAMP), offers several advantages for the research outlined. In order to align this research with ongoing Metro planning efforts, the study area reflects that used in RapidRide planning and outreach activities (Figure 4). A polygon file sourced from Metro staff is used to isolate the census tracts and both existing and proposed transit networks – this file is primarily used for graphic communication and internal planning purposes, but functions well to define the study area and the transit network adjacent to the I Line corridor.

[5] King County Metro. 2016. "METRO CONNECTS Technical Appendices." (p. G-1-4). http://www.kcmetrovision.org/wp-content/uploads/2016/08/Metro-Connects-Appendices.pdf

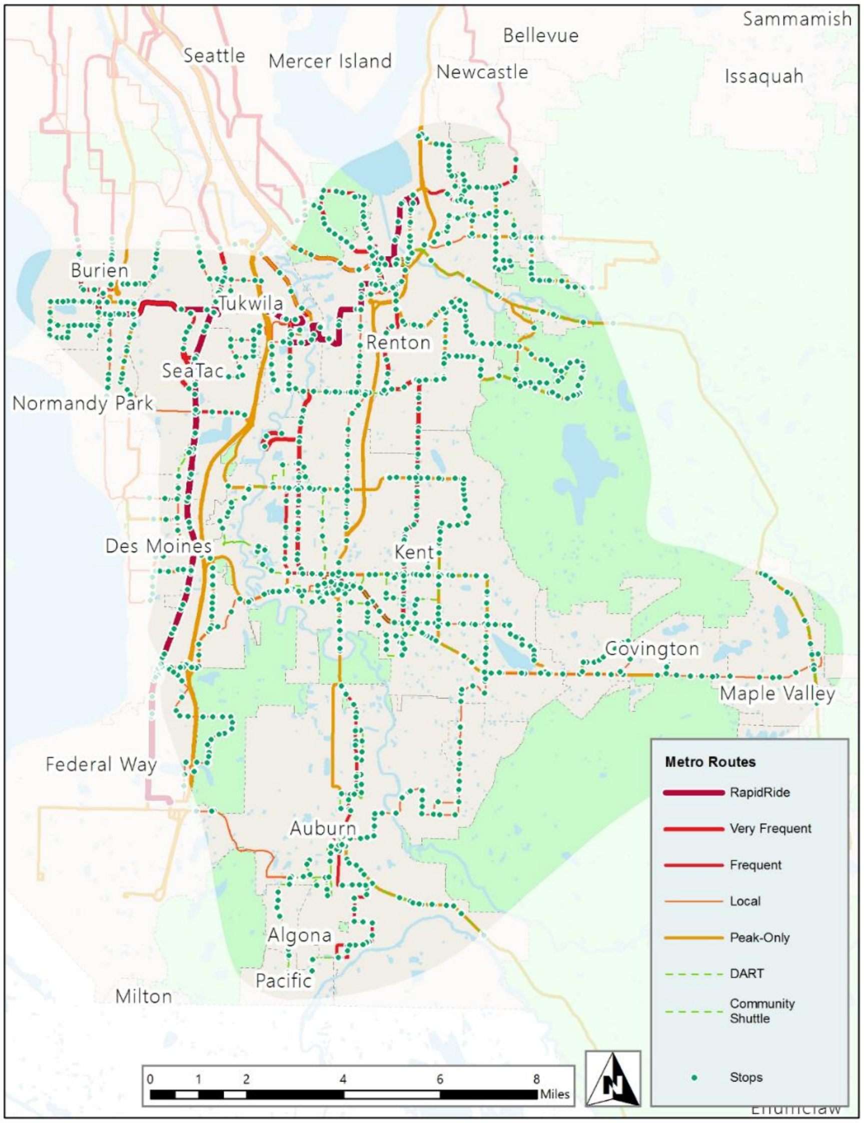

Figure 4: Existing Metro transit service in the RKAAMP Study Area

Dissolving the 102 tracts selected with Metro's polygon file, a new file is created in ArcMap and used to select both in-service stops in the existing network and proposed active stops in the 2025 network within and up to a quarter-mile outside of the defined study area. This approach helps define the relevant scope of the research, focusing on southern King County (and recognizing the history of underinvestment in the area). Focusing on Metro's network in the southwestern quadrant of the county also presents the added benefit of lower requirements for processing power – however, a proper transit gap analysis is worth performing for Metro's entire service network across the entirety of King County. Aligning with the quarter-mile walksheds used in the Network Analysis, this selection process operates with two major assumptions: that residents in tracts within the study area are willing to access bus stops outside of the area, but still within that accessible walkshed; and more incredulously, that all residents and households are evenly distributed within each tract. Future research can increase this level of detail by tying tract-, block group-, or block-level demographic data to residential address points.

3.2. Understanding Socioeconomic Vulnerability & Mobility Need

Transportation analyses that seek to employ an equity and social justice lens logically demand a nuanced understanding of the communities that are subject to the burdens (and benefits) imposed by the very planning or policy outcome in question. Placing social equity at the center of a transportation study – rather than service efficiency, for example – this research aims to identify and focus on the transportation needs of key local priority populations, particularly those that have been historically underserved and are most vulnerable to significant service changes. Ultimately however, this analysis is likely to scratch the surface of what should be a more extensive and holistic project equity impact review. While quantitative analysis helps provide a high-level view of potential impacts on particular populations from the implementation of public policies and projects, the findings here would ideally support the critical advocacy and outreach efforts, input and active participation from local residents and stakeholders, and other critical qualitative analysis that makes up a proper transportation equity study.

Given the demographic composition of the Renton-Kent-Auburn corridor and availability of data, this analysis is primarily concerned with estimating the impacts of transit investments among three key socioeconomic indicators: low-income residents; people of color; and households without access to an automobile, as supported by the varied theoretical and empirical works referenced in the previous chapter. These three key demographic indicators taken from U.S. Census American Community Survey (ACS) 5-year data are collected at the census tract level and are evaluated individually (as opposed to creating a weighted index, which present the risk of diluting the measures employed). Given data availability at the time of writing, 2017 ACS data is used in the present analysis, the most recent dataset released. This prioritizes timeliness of data, while sacrificing the spatial accuracy that would be found with decennial U.S. Census data – even at the census block. And although tracts may offer more accuracy in ACS estimates, they may be too large for the localized level of analysis in this work, risking the over-generalization of demographic characteristics for a given area.

The study's focus on a narrow set of socioeconomic indicators presents an important limitation worth discussing. Metro planning efforts generally account for a broad range of socioeconomic indicators to measure the equity of its programs and service changes, often going beyond Title VI requirements and measured both as composite scores or individually. This thesis employs a narrower approach by limiting the analysis to poverty status, race, and vehicle-ownership, and forgoes a composite weighted index to denote *vulnerability* or *priority populations* as they can dilute disaggregated differences between these individual measures. This decision is also prompted by the general challenges of using ACS data, which can present significant inaccuracies and often carry concerning margins of error – even at a tract level.

3.3. Network Analysis

At the center of this research, the powerful Network Analysis function in ArcMap is employed in both the baseline and the proposed components of this research. The present analysis assumes that an individual's complete transit trip actually begins with either a non-motorized (bicycling or walking) or a very short motorized (by car, van, or motorcycle) trip – this is understood as one's "access to transit." For both scenarios, Network Analysis is used to measure "access-sheds" – quarter-mile walksheds following the likely pedestrian travel network – centered around each bus stop in the project area (Figure 5). The tool provides an effective estimation of on-the-ground access to bus stops from origins by tracing paths along a network of "edges" and "nodes" based on the existing network of roadways and pedestrian pathways – this results in a more realistic walkshed than an as-the-crow-flies estimation.

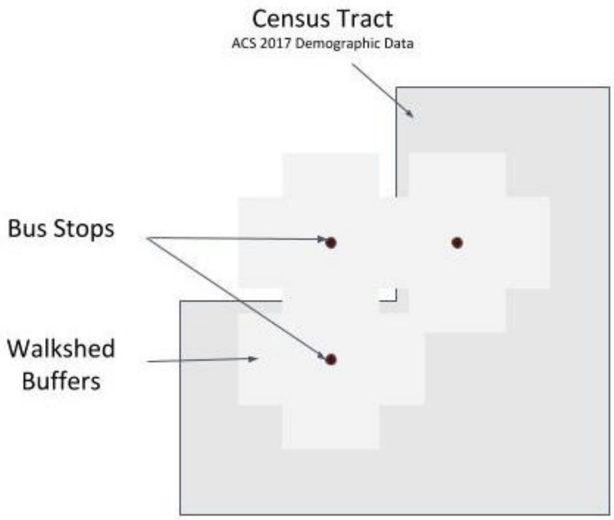

Figure 5: Simple diagram of walkshed transit supply measurement

Used for both the existing and proposed 2025 service network, as well as the I Line corridor, bus stops and RapidRide stations are selected as “facilities.” Rail lines and highways are omitted from the county’s existing real transportation network, providing a a relatively realistic street network that can be used to calculate likely pedestrian and/or motorized pathways. Evidenced by preliminary I Line corridor planning alone, however, there are significant sectors of the study area that are lacking sidewalks – a reality of the local built environment that is both unsurprising for particularly low-density areas yet concerning for a future high-frequency bus rapid transit corridor.

3.4. Transit Service Equity Evaluation: A Transit Gap Analysis

Using raw route-level trip counts as a simplistic measure of the supply of transit service available, for both the existing and the proposed network, supply scores (SS) are created. Based on Graham Currie’s iterations of transportation supply indexes employed in transportation gap analyses for urban areas in Australia, the index values are calculated for each tract (Currie 2010, 2004) and can be simply interpreted as a measure for the proportion of service or capital investment that entire tract will receive. The proportion of each census tract that is overlaid by the walksheds area is multiplied by the total weekly trips at each stop intersecting that tract, as such:

$$SS_{tract} = \left(\frac{Area_{walkshed}}{Area_{tract}}\right)\left(\sum_{n} SL_{walkshed}\right)$$

where,

SS signifies the transit service or capital investment supply score for any given tract;

Area measures the size of the tract and the walkshed, in square feet (this piece calculates the proportion of the tract covered by bus stop walksheds;

SL represents the transit service or capital supply level for each walkshed (bus stop);

n signifies the number of bus stops with walksheds within the tract over which the summation takes place;

walkshed signifies the quarter-mile network buffer area extending out from each bus stop within the given tract, representing the area a pedestrian could comfortably walk to reach transit service; and

tract is used to identify the census unit measured.

Applying Graham Currie's approach to analyze public transportation gaps in King County is relatively straightforward and presents a simple approach for quantifying both the level of transit service provided in an area and a partial measure of spatial accessibility. Using scheduled and completed transit trips as a measure of transit supply, and using the network analysis tool in ArcMap, quarter-mile catchment areas – or "walksheds" – are created from each bus stop to simulate a physically accessible walking distance for potential transit users. To evaluate the impact of future service adjustments, restructures, and investments currently in planning and outreach phases at Metro, this study first evaluates transit service changes across the study area, and then integrates the service results with a similar capital analysis for the I Line corridor – measured through a social equity lens.

3.4.1. Evaluating transit gaps in existing service network

In order to evaluate impacts of new transit service, a baseline is first established using existing transit service levels and route and stop alignment. Service data is sourced from King County Metro reporting software, joined to route- and stop-level shapefiles, and presented atop socioeconomic indicators at a census tract scale (Figure 6). This initial portion of the analysis uses ArcMap's powerful Network

Analysis function to perform a limited accessibility analysis that seeks to show a measure of access *to* transit (this can also be identified as a dimension of *person accessibility*).

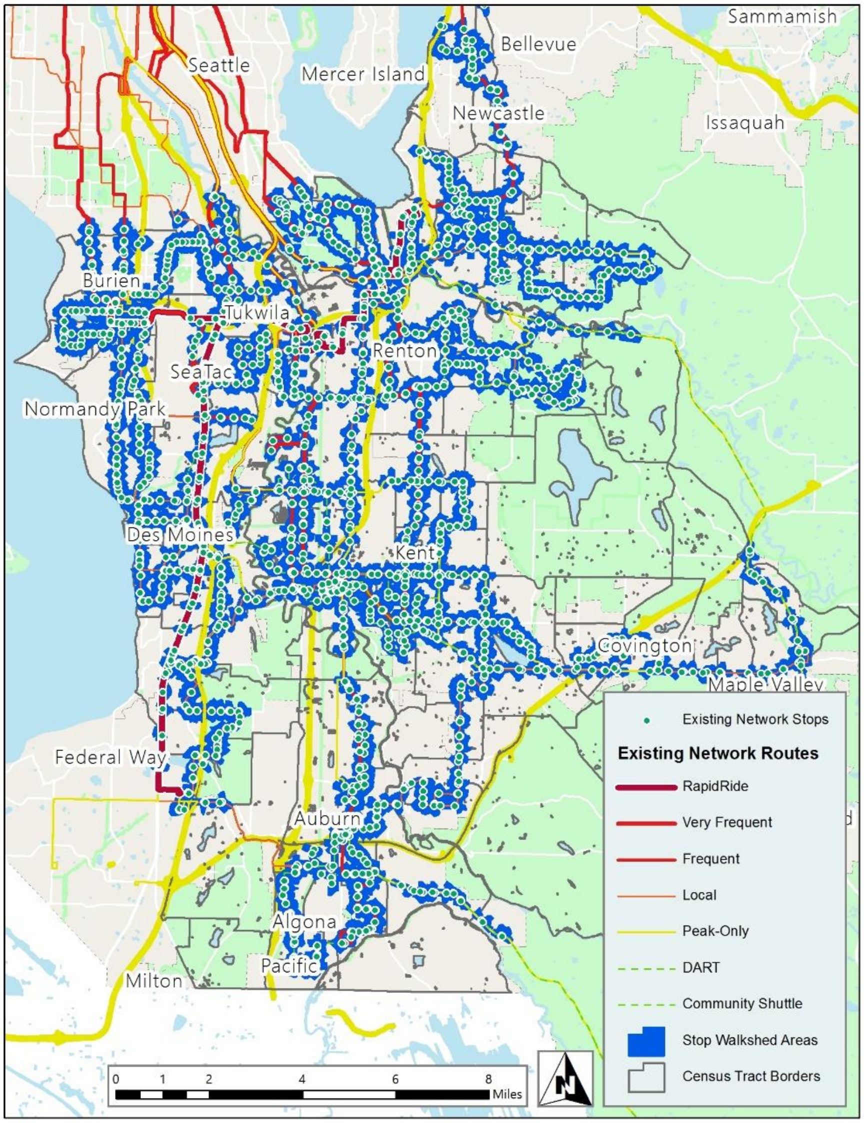

Figure 6: Metro's Existing (2018) Network and Walkshed Areas

The data utilized to represent the level of *existing* transit service in an area includes stop location; existing transit services by route, given day of the week and time of day; and transit quality, given frequency of service. This transit information can also be presented graphically to display general transit coverage across King County and along the I Line corridor, specifically. King County Metro stop and route data files contain a trove of information about the type of service provided at each stop and by each route, as well as additional characteristics – only some of which are necessary for this analysis. In some cases, the data can be duplicative, as it provides complete records for multiple service change periods. The files are pared down to the lists of stops and routes that are *currently* in service and are serving existing stops/routes and vice-versa. Excel's query functions are also used to modify the stops data file that provides a single observation for every route served at every stop. This allows us to connect service frequency information for each route to their respective bus stops.

Transit service data used in this analysis is sourced from King County Metro's "AllTrips" service database. This dataset provides an expansive collection of trip-level observations at all points of a bus trip, including revenue and non-revenue trips segments. The data corresponds with the Fall service change period of 2018, providing scheduled trip observations for service between September 22, 2018 to March 22, 2019 (this is the third service change of the year, hence "183"). Trips are limited to "service" trips – also referred to as "revenue" trips – that is, the segments of the trip that actually pick up and drop off passengers. This analysis presents service levels in terms of Metro's established "service frequency families." Trips are counted by the route direction and the time of day, as defined by Metro's Service Guidelines and System Evaluation reports, as such:

Route	Total Trips (Weekday)	Frequency Family
A Line	500	RapidRide
F Line	420	
101	235	Very Frequent
106	331	
120	367	
124	340	
150	359	
169	249	
107	243	Frequent
131	217	
180	243	
240	218	
105	171	Local
121	37	
128	221	
132	226	
148	109	
153	55	
156	139	
164	94	
166	167	
168	131	
181	189	
183	79	
631	34	Community Shuttle
635	63	

Route	Total Trips (Weekday)	Frequency Family
102	22	Peak-Only
111	17	
114	14	
122	14	
123	9	
143	14	
143	14	
154	8	
157	7	
158	12	
159	9	
167	9	
177	18	
178	15	
179	19	
186	20	
190	15	
192	8	
193	14	
197	16	
342	9	
952	8	
906	47	DART
907	18	
908	38	
910	36	
913	27	
914	30	
915	28	
916	30	
917	46	

Table 1: Routes and respective total weekday trips serving study area by frequency family

The quantity and quality of transit service provided by an agency can be evaluated from numerous perspectives. Service reliability and geographic value are key quantifiable indicators that inform important service investment decisions at Metro. On the other hand, indicators like customers' perceived sense of safety or facility cleanliness can be difficult to measure but can be equally indicative of the quality of transit service. This is especially the case from a user's perspective, who may be as concerned with reliability or speed of a route as they are with the cost and comfort of the trip itself. An ideal analysis would account for the multiplicity of transit service quality, providing a fuller picture of the transportation environment in the study area. For this analysis, weekly service trips is employed is employed as a proxy for transit supply in the study area. In future studies, service hours invested over time may prove to be a stronger measure; however, accurate service hour investment figures are not available at this stage in the project design. Moreover, as Delbosc and Currie found in their own analysis of public transport supply, this methodology presents an important limitation: this study uses number of trips – essentially, service frequency – to measure access to transit, but does not address destinations, which is ultimately the key outcome of travel and transportation (Delbosc and Currie 2011b). Here one finds the value of powerful accessibility analyses.

3.4.2 Evaluating transit gaps in the proposed 2025 service network

The bulk of the analysis performed in this research is centered on the *proposed* implementation of RapidRide I Line service. While the project is, at the time of writing, in its preliminary design phase, there are various planning documents and reports available with early service and capital investment proposals. Draft and unpublished planning outputs from Metro long-range planning efforts are used to generate GIS shapefiles with route and stop alignments. These preliminary alignments include anticipated weekday service frequency, in the form of scheduled trips, and are evaluated to produce measures of overall horizontal and vertical equity of the future system network, compared to the existing network. The transit gap model is replicated for a new network of routes and stops (which includes a net increase of more than 20 bus stops), generating new catchment areas that intersect the tract-level demographic layer (Figure 7).

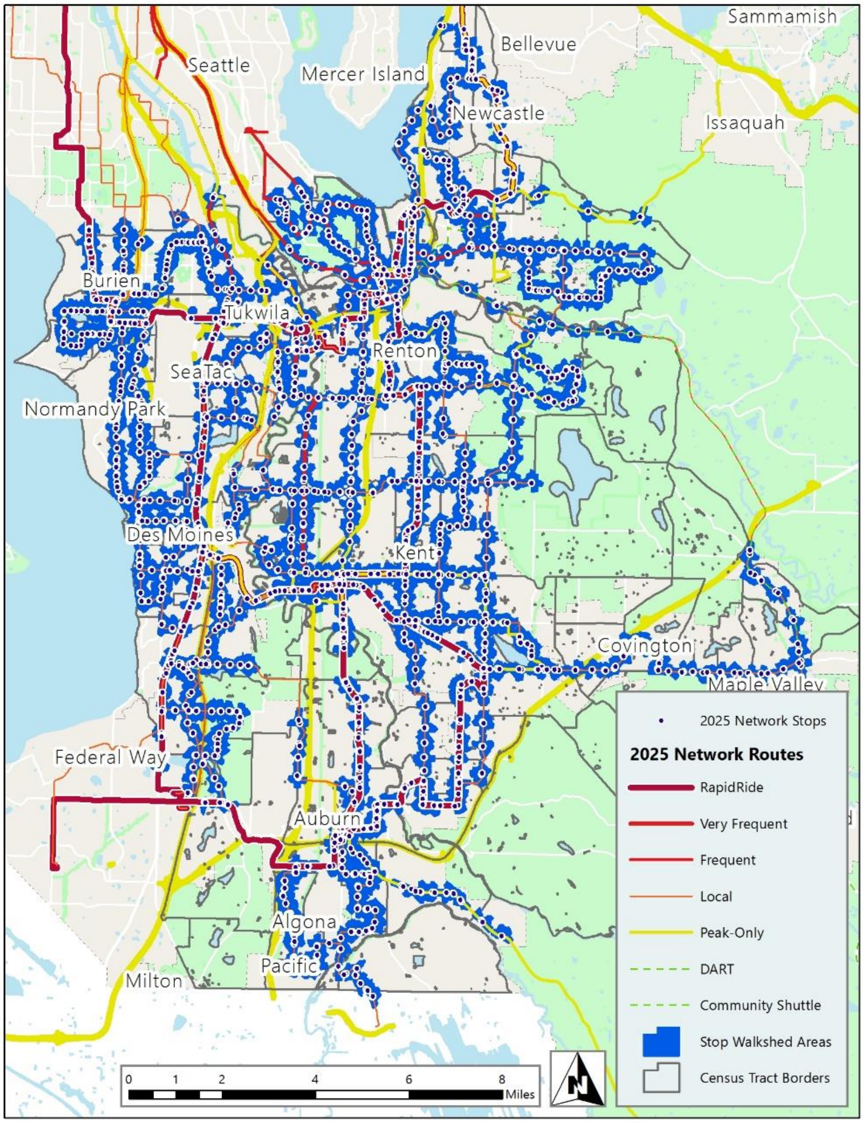

Figure 7: Metro's Proposed (2025) Network and Walkshed Areas

Although the I Line serves as the central focus of this work, Metro’s 2025 network anticipates multiple RapidRide route-upgrades in the study area. At Metro, preliminary service planning and development work is underway to identify and implement a network of frequent, local, and flexible service that can complement the new trunks. The most current alignments for the I Line and the complementary area service network are sourced from Metro’s early planning alternatives, which are largely drafted and communicated using Remix, a transportation planning platform. Remix is used to quickly and easily design service changes while accounting for fleet needs, service hours available for investment, and existing demographic conditions. The platform was used to draft the future networks that make up the

2025 and 2040 transit networks envisioned in Metro Connects and can provide shapefiles of the latest proposed alignment for the study area. Since the I Line is planned for a 2023 implementation, this analysis will use the 2025-vision proposals specifically.

While the future route won't see a formal upgrade to RapidRide service for several years, the service network for the area will be undergoing significant network and service level changes as early as next year. As the I Line approaches design phase as early as July of 2019, Metro's Service Development Section is simultaneously implementing the Renton-Kent-Auburn Area Mobility Plan (RKAAMP), preemptively restructuring existing fixed-route service in parts of south King County ahead of the opening of the new RapidRide service. This network is also sourced from Metro's Remix early planning products. This will provide valuable shapefiles that will not only offer adjusted route alignments, but also service frequency and even fleet requirements.

3.5. RapidRide I Line Capital Equity Analysis: Proof of Concept

Lastly, research activities for the study's capital component are described. The process outlines a preemptive evaluation of the distribution of anticipated capital costs for the RapidRide I Line, distributed across the bus stops currently identified in the corridor. Using a similar approach as the service analysis above that measures transit supply, this secondary research piece replaces trips with cost estimates for stop-level infrastructure and facility improvements to represent capital investments (ie, investments planned for the proposed scenario). A life-cycle cost analysis (LCCA) methodology is applied that accounts not only for initial design, construction, and acquisition costs, but for estimated operations and maintenance costs throughout the lifetime of the asset as well, along the proposed RapidRide I Line corridor. Whereas the service component of this analysis reflects typical service planning evaluations, the integration of proposed capital asset investments and lifetime costs presents a novel approach for evaluating the distribution of both operational and capital investments along bus rapid transit corridors.

Ultimately, the capability to evaluate both components simultaneously with statistical significance can serve to better inform preliminary RapidRide corridor-level planning decisions.

The I Line is one of several RapidRide upgrades anticipated in South King County, but with an anticipated implementation date of 2025 steadily approaching, it makes up the central focus of this analysis, and the singular interest of the capital component of this study. The new route largely reflects an alignment that is currently served by existing Routes 169 and 180, joined at their junction in Kent. The I Line will serve a long cross-jurisdictional corridor stretching over 18 miles from Auburn to Renton via Kent. Set to open in the fall of 2023, very early planning efforts have thus far produced a preliminary corridor-level report (submitted to Metro at the end of 2018). As of January, Metro is contracting out lead planning, design, and implementation with a major national consulting. Planning and alternatives analysis will be carried out through 2019, with a preferred alternative identified by September of that year.

Whereas service levels generally provide a measure for route-level investment that can be represented at the stop-level, proposed capital investments for the I Line must be localized to identify where specific infrastructure and facility improvements are made. Here again, the present evaluation relies on preliminary reports for the corridor, developed by an external consultant to guide early planning efforts. This Corridor Evaluation Report prepared for the I Line identifies infrastructure improvements necessary throughout the corridor, estimates quantities and costs for each item category, and summarizes this information at the stop-level. According to the report, “Order-of-Magnitude cost estimates are rough estimates that use parametric factors and broad assumptions of scope to identify anticipated costs” (Parametrix 2018), and are estimated for design, construction, staging, and right-of-way improvements necessary to install the station kit of parts and roadway improvements necessary for RapidRIde implementation. The categories of items identified for the package of capital improvements for the corridor include passenger facilities, non-motorized infrastructure needs (including sidewalks and bike lanes), roadway improvements, transit signals, and communications and technology (see the Appendix for a detailed list and record of cost estimates, sourced from the cited report).

The use of life-cycle cost analysis (LCCA) estimates total costs over the useful lifetime (or a predetermined analysis time period) of a capital asset. While the Corridor Evaluation Report's order-of-magnitude cost estimates provide *initial* costs of the improvements necessary at the station level to implement the future RapidRide corridor, best-practice LCCA requires additional cost items, such as operations, maintenance, and user costs, as well as residual value, and advanced financial estimating methods (Figure 3-1) – namely calculating net present value of costs using discount and inflation rates, as such:

$$NPV_{stop} = \frac{(Costs) * (1 + i)^n}{(1 + d)^n}$$

where,

> ***NPV*** signifies the net present value of costs throughout the useful life of the stop;
>
> ***Costs*** includes all costs, including initial acquisition or construction costs, operations and maintenance costs, user costs, and residual or salvage value;
>
> ***i*** represents the inflation rate, set at 3.00 percent per year;
>
> ***d*** represents the discount rate, set at 4.00 percent per year;
>
> ***n*** indicates the year the costs are borne.

To estimate operations and maintenance costs, work order records are collected from Metro's enterprise asset management (EAM) system, pulling cost values for both labor and material expenses associated with each work order. Records were limited to the RapidRide A Line, which also serves southern King County, mostly along Pacific Highway S. One of the first RapidRide lines to open in early October 2010, the A Line dataset provides just under nine years of maintenance costs (from October 1, 2010, to May 30, 2010). The majority of maintenance costs fall within the passenger facilities and the communications and technology packages (aligning with the Corridor Evaluation Report methodology), and include servicing, repair, refurbishment, and replacement of bus shelters, RapidRide-specific pylons, and stop signage, among other station components. stand-alone fare payment equipment (for the regional fare payment system, ORCA), the Intelligent Transportation System (ITS) equipment (at the aggregate route-level), signs, and even waste receptacles.

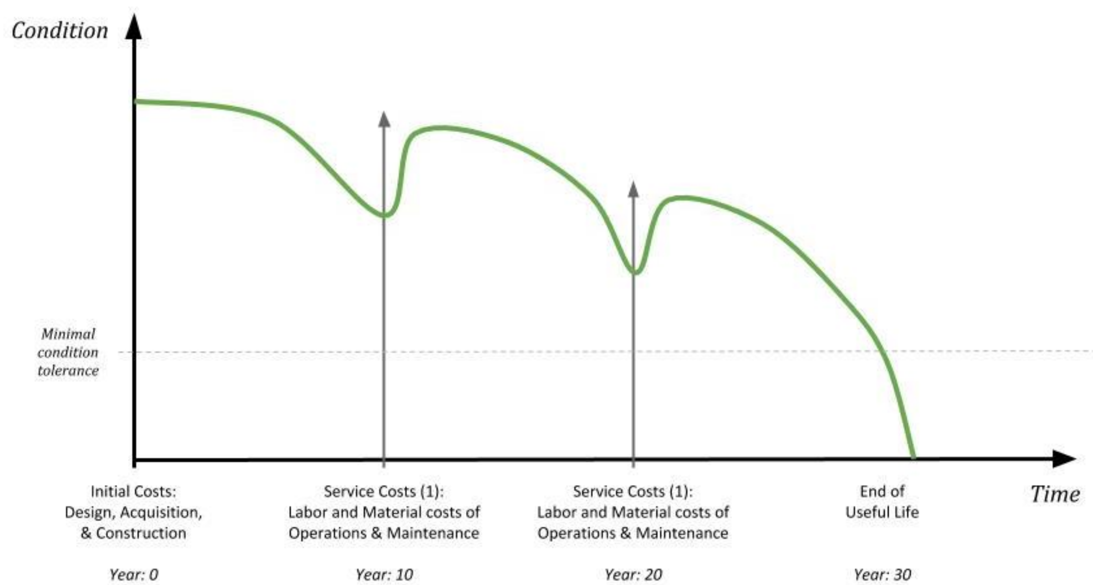

Figure 8: Simple graphic representing asset condition over time measured by LCCA

A deterministic analysis approach is employed, which relies on set values that are estimated and assigned to the different LCCA factors. A study analysis period of 30 years was selected based on the expected useful life of the new generation of the RapidRide station kit of parts, with major maintenance rehabilitation scheduled every 10 years (see Figure 8). Metro presently does not plan for salvage value in its asset management and capital financing practices – therefore no such value is assumed here. In order to compare expenditures that are made at different points in time, the net present value (NPV) of money is used, accounting for inflation and discount rates: labor and material costs are calculated to inflate 3.00 percent per year (this is slightly above Consumer Price Index growth trends, which have averaged 2.85 percent since 2000 and 2.90 percent from 2015-2018); the discount rate of 4.00 percent per year was assigned, pegged just above the highest bond rates recorded for the U.S. 10 Year Treasury notes (3.89

percent) in the past 10 years. As described, the function employed to calculate the net present value of capital-associated costs for each individual I Line station can be fully expressed as such:

$$NPV_{stop} = Initial\ Costs + \frac{(Service_1\ Costs) * (1+0.03)^{10}}{(1+0.04)^{10}} + \frac{(Service_2\ Costs) * (1+0.03)^{20}}{(1+0.04)^{20}}$$

Though this methodology presents an effective and fuller summary of stop-level costs related to the installation of RapidRide stations and the implementation of the new I Line, some clear limitations arise. Future analysis should incorporate accurate costs of new fleet investments, accounting for a bus coach's useful life benchmark (ULB) of 12 years (in compliance with Federal Transit Administration requirements). Similarly, future study should fully account for complete roadway and sidewalk costs, rather than for initial construction alone – specifically, costs should include regular pavement rehabilitation as well as consideration for which jurisdiction is responsible for this cost (as incorporated cities in King County generally own the right-of-way within their boundaries).

Regular cleaning and maintenance costs for continuous service activity should also be included in future studies, though this is likely not feasible as such costs may be broadly assigned to a program rather than a specific route or even stop. According to best-practice LLCA, as outlined in the Federal Highway Administration's primer on LCCA, analyses should include both costs borne by the agency and those borne by the public. Generally, "user costs of primary interest include vehicle operating costs, travel time costs, and crash costs" – however, this study assumes minimal impacts to the general traveling public and therefore does not incorporate user costs. Future analysis should also ensure it accounts for accurate user costs that may fall upon the traveling public due to construction activities, especially if comparing distinct alternatives. Finally, though a general inflation rate based on the Consumer Price Index (CPI) helps calculate a general present value of money, a more accurate inflation rate would reflect price indexes for transportation and construction.

Chapter 4: Results

The models employed here provide a glance not only at a broad measure of the equity of existing transit service supply in King County, but also into the equity of proposed transit investments in southern King County. The following chapter summarizes the results of the analysis described in the previous chapter. First, existing conditions are discussed, followed by a review of the transit service supply changes s observed in south King County across all tracts. These initial results are then further explored in the context of the three demographic vulnerability indicators utilized in this analysis – race, income, and mobility – with particular attention to areas with high concentrations of socioeconomic and transportation disadvantage. Finally, results for the proof of concept methodology are presented, integrating findings for capital investments alongside service changes, and further observed in terms of the socioeconomic indicators of interest.

4.1. Existing Demographic Conditions

As described in Chapter 2, the demographic focus of this evaluation centers around three key indicators that are often found to suggest socioeconomic and mobility disadvantage. The proportion of individuals below the federal and the county poverty levels (100% and 200% FPL, respectively) is used to observe income-based disadvantage. Given a clear history of racially discriminatory practices throughout the United States, race is similarly quantified in terms of each tract's proportion of residents of color. And a measure for mobility disadvantage (and potentially transit need) is calculated as a tract's proportion of households without vehicles.

This project operates under baseline assumptions and observations of demographic patterns and current transit service delivery across the county that are worth exploring further. For example, some of the county's most diverse communities can be found in South Seattle's Rainier Valley and in other South King County Cities, home to significant proportions of people of color and foreign-born residents.

Similarly, census data reveal concerning clusters of poverty just south of Seattle, with median household incomes below the county's poverty level, equivalent to 200 percent of the Federal Poverty Level (FPL).

Within the study area – a 102-tract area making up a large majority of southwestern King County – two of the three demographic indicators measured in the analysis average above the countywide mean (Table 2). Poverty levels are particularly concerning: 29 percent of residents are estimated to live under the county poverty level, while 12 percent live under the Federal Poverty Level (in 2017, the FPL was set at $24,600 for a family four). The same dataset estimates *numerous* entire tracts where one in four residents live at or below the FPL. Explored at a finer grain (granted, with greater potential for estimation error), in a block group shared between the cities of Renton and Tukwila, over two-thirds of residents have incomes below this level.

	Total Population	*Poverty (100% FPL)*	*Poverty (200% FPL)*	*Persons of Color*	*Households with no vehicle*
Total Population	*568,330*	*69,925*	*163,257*	*277,506*	*//*
Total Households	*205,568*	*//*	*//*	*//*	*13,636*
Average Study Area Proportion	*//*	*12%*	*29%*	*49%*	*7%*
Average County Proportion	*//*	*10%*	*22%*	*39%*	*10%*

Table 2: Aggregate Study Area Demographics

Further, just under half the study area's population (48.9 percent) is made up of people of color (specifically non-white and/or Hispanic or Latinx). Of the 102 tracts evaluated, 73 are estimated to exceed the countywide average (38.6 percent), while some even exceed proportions of 75 percent. Neither the presence of persons of color, nor the diversity of the study area are necessarily concerning in this analysis – rather, it is the intersectionality of these socioeconomic measures that is of particular interest. What is of concern is the single tract in northwestern Kent where one in four residents have incomes below the federal poverty level (among the highest rates in the county) while two in three are persons of color, according to American Community Survey estimates.

Given the largely suburban nature of the study area, the average rate of households without a vehicle is below the countywide average (6.6 percent, compared to 9.9 percent across the county). This is not particularly surprising, as the county's average is likely inflated by high numbers of households in Seattle without vehicles. What are particularly of interest in a study like this, and especially when estimating need for public transit, are the 22 tracts with above average no-vehicle households. For example, that same tract in north Kent has an estimated 22 percent of households reporting no personal vehicles.

Along the spine-like I Line corridor, these assumptions hold true. 2017 American Community Survey estimates indicate that people of color make up the majority of residents within quarter-, half-, and full-mile buffer areas from each bus stop, and about a third of residents (at all buffer scales) live at or below 200 percent of the Federal Poverty Level (see Table 3 for additional corridor-level demographic estimates). These estimates also significantly exceed estimates for the entire county, where 38.6 percent of residents identify as persons of color and 22 percent of households live at or below 200 percent FPL.

	Within __ mi. of Bus Stops in I Line Corridor:		
	0.25	***0.50***	***1.00***
Total Population	*34,578*	*69,237*	*127,513*
Number of Jobs	*36,576*	*61,774*	*98,705*
Residents with Incomes at or below 200% of the Federal Poverty Level (%)	*34.7*	*33.9*	*32.8*
People of Color (%)	*55.4*	*55.5*	*54.0*
Residents aged 65 and younger (Seniors) (%)	*11.4*	*11.3*	*11.1*
Residents aged 18 and younger (Youth) (%)	*23.5*	*22.9*	*23.0*
Residents with Limited English Proficiency (%)	*8.2*	*7.6*	*7.6*
Residents with Disabilities (%)	*12.2*	*12.3*	*12.0*
Residents without a Personal Vehicles (%)	*9.6*	*9.5*	*9.3*

Table 3: RapidRide I Line Corridor Demographics

4.2. Changes in Transit Service Supply

With service trips estimated at stop-level service areas, I am able to measure the proportional transit supply within walking distance for each census unit within the study area. The data can then be used to measure the horizontal equity of early planning assumptions of the coming network service changes. The study area is a significant size – despite focusing on a single corridor running from Renton south to Auburn, the rest of south King County's network must be accounted for as well as this area the surrounding neighborhoods will experience significant change in their transit service levels and network. The analysis is employed across an area made up of over 100 tracts, with many experiencing wide changes in the supply of transit service accessible for residents within a quarter-mile walk. Of all stops selected within the study area (1,957 in the Existing Network; 1,978 in the 2025 Network), total trips are expected to increase from 192,599 to 257,654, an additional 64,663 trips by 2025 (Table 4).

Existing Network: Total Trips for all Stops	*2025 Network: Total Trips for all Stops*	*Total Trips Change*
192,599	*257,654*	*64,663*
Existing Network: Mean Tract Supply Score	*2025 Network: Mean Tract Supply Score*	*Mean Trips Change*
1,884.432	*2,475.659*	*591.227*
Existing Network: Median Tract Supply Score	*2025 Network: Median Tract Supply Score*	*Median Trips Change*
1,150.684	*1,663.512*	*373.653*

Table 4: Transit Supply for the Existing and Proposed 2025 Networks

Measuring for the quarter-mile walksheds intersecting all 102 tracts, the average (mean) service supply score across all tracts in 2018 is 1,884.4 (Table 4). Accounting for planned bus stop expansion and service changes, tracts experience an average service supply change of just over 591 additional trips, with an average supply score of 2,475.7 by 2025. Comparatively, the equivalent median supply scores for the existing and 2025 networks measure notably lower, suggesting that both existing service and future service investments are potentially concentrated in particular tracts. With a median change calculated at a positive score of 373.7, however, the results indicate that, on the whole, more tracts *gain* service than lose service by 2025.

However, this does not necessarily equate to even transit growth across all tracts. As noted above, service supply and service changes are somewhat concentrated in some tracts. Some experience hundred-fold increases while a few lose about two-thirds or more. To effectively compare changes to the service supply score at each tract, the service change deviation from the mean (591.227) is calculated, both in absolute terms and as a ratio. This approach also serves to better highlight tracts that lose service supply or receive below-average investment, while offering a reasonable scale with which to compare above-average service growth.

Among the 10 tracts with the greatest nominal losses in service supply scores, all lose more than 300 trips, and four tracts post losses of at least half their current accessible service supply levels (see Table 5). Across the study area, about a quarter (25) of the tracts present losses in service supply, while two-thirds (66) show below-average service investment (where the change is less than the average tract supply score change of 591.2). On the other hand, results for the top 10 tracts with the greatest nominal increases in service supply scores show significant service growth, of over twice the average service change. The three tracts expected to exceed 10,000 service trips (within walksheds) in the 2025 Network will see as much as 13 times the average service change.

In fact, all tracts *gaining* service deserve closer examination, as the values for some appear to have disproportionate increases in service (for example, Census Tracts 293.07, 299.02, and 318 show increases of 36,000 – 55,000 percent). These tracts have transit service supply values of 1.2 or less and are expected to have over 300 times as much transit service by 2025, whether due to increased service hours or the implementation of new bus stops within these tracts. Results like this prompt a closer look at the extent and true comparability of the measurement. This can be largely attributed to the analysis approach employed in ArcMap to calculate catchment areas and measure their coverage within each tract; the high percentage value is capturing a modest nominal increase within a tract that had minimal service in the existing network to begin with. However, across the study area 77 tracts would receive increases in service supply, while 36 show above-average service investment (where the change is greater than the average tract supply score change). Among the tracts with the greatest nominal increases in service,

Census Tract	Total Population	Service Supply (trips)			Service Change Mean Deviation	
		Existing 2018 Network	Planned 2025 Network	Change (Δ)	Absolute	Ratio
Tract 253.01^	6,525.00	3,070.47	10,804.57	7,734.10	7,142.87	13.08
Tract 253.02^	5,360.00	10,858.77	18,371.55	7,512.79	6,921.56	12.71
Tract 262^	5,608.00	7,058.00	11,703.86	4,645.86	4,054.64	7.86
Tract 300.04	8,302.00	2,715.78	5,873.09	3,157.32	2,566.09	5.34
Tract 260.02^	8,590.00	6,571.84	8,872.66	2,300.82	1,709.59	3.89
Tract 290.03	5,700.00	3,099.99	5,258.18	2,158.20	1,566.97	3.65
Tract 295.02	7,671.00	1,710.86	3,715.24	2,004.38	1,413.15	3.39
Tract 292.03^	4,198.00	7,721.70	9,567.11	1,845.41	1,254.18	3.12
Tract 312.05	6,892.00	721.78	2,379.56	1,657.78	1,066.56	2.80
Tract 247.02	7,528.00	380.60	1,934.40	1,553.80	962.57	2.63
Tract 284.02	5,090.00	2,620.33	2,320.10	(300.23)	(891.46)	(0.51)
Tract 260.01	5,950.00	3,372.01	3,058.31	(313.69)	(904.92)	(0.53)
Tract 295.04^	5,970.00	3,690.66	3,257.02	(433.63)	(1,024.86)	(0.73)
Tract 257.01^	6,004.00	1,403.63	945.82	(457.81)	(1,049.04)	(0.77)
Tract 308.01^	7,126.00	2,835.06	2,318.95	(516.11)	(1,107.34)	(0.87)
Tract 257.02	3,510.00	873.44	237.13	(636.31)	(1,227.54)	(1.08)
Tract 307	3,916.00	2,835.67	1,987.95	(847.72)	(1,438.95)	(1.43)
Tract 258.04	3,628.00	2,296.32	1,140.88	(1,155.44)	(1,746.66)	(1.95)
Tract 308.02	3,894.00	2,407.94	1,024.18	(1,383.77)	(1,974.99)	(2.34)
Tract 272	2,608.00	2,533.80	908.40	(1,625.40)	(2,216.63)	(2.75)

^ Denotes tracts within I Line Corridor

Table 5: Top and Bottom 10 Tracts, by Greatest Change of Transit Service Supply (Top and Bottom 10 Tracts)

To better understand the distribution of impacts from a *vertical* equity perspective, service changes are further observed in the context of each individual socioeconomic indicator of interest.

4.2.1. Income Summary: Study area service supply changes and poverty levels

A review of American Community Survey data recorded an estimated 10.17 percent of King County residents living below the Federal Poverty Level (FPL) in 2017 – more than double that (22.01 percent) are living below 200% FPL (generally applied as the county poverty level throughout various King County agencies, including Metro).

Figure 9: Concentrations of impoverished households in South King County

In the study area, which makes up a significant portion of southeastern King County, the same measures are estimated to be above average – 12.41 percent of residents live below FPL; 28.97 percent live below the county's poverty level. In the figure above, tracts with high levels of poverty are exhibited, with the darker shaded areas (namely in Algona, Auburn, Des Moines, Kent, Renton, and Tukwila) representing tracts where one in four residents' annual earnings fall below the federal poverty level (Figure 9). Among the 102 tracts studied, estimates for proportions of residents living below FPL are above the county mean average (10.17%) in 55 tracts, while 67 tracts exceed the county average for residents living below 200%

FPL (22.01%). More specifically, 41 and 52 tracts exceeded the *study area* mean average for residents living below FPL (12.41%) and 200% FPL (28.97%), respectively.

Tables 6 and 7 display the top 20 tracts with the greatest and lowest proportions of residents living below the Federal Poverty Level. These samples serve as approximate quintiles for the variable under observation – in this case, the upper and lower fifths of the study area population. Both subsets have similar total populations (within about 10 percent) and effectively summarize some of the distribution of existing and proposed transit supply throughout the study area. While the 20 tracts with the lowest poverty levels would experience a larger percentage increase in transit supply (37 percent, compared to less than 25 percent), those tracts with the greatest poverty levels are still estimated to have far greater total nominal access to transit supply, both in the existing and the proposed 2025 networks. Further, while 10 of the 20 tracts with the highest poverty rates are expected to receive above-average service increases, the same can only be said for four of the 20 tracts with the lowest poverty rates. Particularly concerning, however, are the nominal reductions in transit supply observed in tracts with over 20 percent poverty rates, namely Tracts 295.04, 308.01, 307, 305.4, and especially Tract 272, which is estimated to lose almost two-thirds of its accessible transit supply (with a supply score change of more than 2000 trips below the study area average).

Census Tract	Total Population	Population below Poverty (100% FPL)	Tract Proportion	Service Supply: Existing 2018 Network	Service Supply: Planned 2025 Network	Service Supply: Change (Δ)	Service Change Mean Deviation
Tract 305.01^	1,762	562	0.33	1,029.95	1,500.98	471.03	(120.19)
Tract 290.04	3,938	1,286	0.33	2,016.63	3,478.02	1,461.39	870.17
Tract 295.03^	8,546	2,567	0.30	6,275.59	6,490.96	215.37	(375.86)
Tract 295.04^	5,970	1,652	0.28	3,690.66	3,257.02	(433.63)	(1,024.86)
Tract 308.01^	7,126	1,911	0.27	2,835.06	2,318.95	(516.11)	(1,107.34)
Tract 272	2,608	709	0.27	2,533.80	908.40	(1,625.40)	(2,216.63)
Tract 253.02^	5,360	1,443	0.27	10,858.77	18,371.55	7,512.79	6,921.56
Tract 292.03^	4,198	838	0.26	7,721.70	9,567.11	1,845.41	1,254.18
Tract 289.02	7,163	1,770	0.25	2,686.43	3,567.43	881.00	289.77
Tract 282	5,005	1,260	0.25	4,675.85	5,729.38	1,053.53	462.31
Tract 292.06	4,396	1,091	0.25	6,502.65	6,682.58	179.93	(411.30)
Tract 280	4,398	1,054	0.24	4,951.42	5,679.10	727.68	136.45
Tract 288.02	6,954	1,649	0.24	1,882.52	2,048.73	166.21	(425.02)
Tract 300.04	8,302	1,976	0.24	2,715.78	5,873.09	3,157.32	2,566.09
Tract 294.07^	4,697	1,080	0.23	2,209.73	2,763.88	554.15	(37.08)
Tract 260.02^	8,590	1,989	0.23	6,571.84	8,872.66	2,300.82	1,709.59
Tract 307	3,916	810	0.21	2,835.67	1,987.95	(847.72)	(1,438.95)
Tract 305.04^	4,396	890	0.20	913.31	808.96	(104.35)	(695.58)
Tract 273	5,846	1,153	0.20	4,378.76	5,037.96	659.20	67.97
Tract 296.01	6,914	1,346	0.20	688.01	2,123.92	1,435.91	844.68

^ *Denotes tracts within I Line Corridor*

Table 6: Poverty Summary 1: Top 20 tracts with greatest proportions of population living below Federal Poverty Level (100% FPL)

Census Tract	Total Population	Population below Poverty (100% FPL)	Tract Proportion	Service Supply: Existing 2018 Network	Service Supply: Planned 2025 Network	Service Supply: Change (Δ)	Service Change Mean Deviation
Tract 319.03	6,767	164	0.02	348.34	1,389.68	1,041.35	450.12
Tract 320.07	3,616	98	0.03	15.21	15.49	0.28	(590.95)
Tract 320.05	7,361	209	0.03	608.58	428.43	(180.15)	(771.38)
Tract 293.07	4,219	124	0.03	1.19	663.65	662.46	71.23
Tract 318	4,625	138	0.03	0.10	37.57	37.46	(553.76)
Tract 286	6,360	199	0.03	1,488.35	1,524.08	35.73	(555.49)
Tract 293.04	5,082	165	0.03	80.03	555.39	475.36	(115.87)
Tract 319.09	2,919	96	0.03	182.47	508.61	326.14	(265.09)
Tract 257.02	3,510	123	0.04	873.44	237.13	(636.31)	(1,227.54)
Tract 250.01	5,106	188	0.04	1,665.37	1,439.07	(226.30)	(817.53)
Tract 320.11	4,307	167	0.04	161.35	180.92	19.58	(571.65)
Tract 320.08	4,710	186	0.04	29.81	47.47	17.66	(573.56)
Tract 278	3,404	144	0.04	69.61	123.27	53.67	(537.56)
Tract 296.02	6,298	281	0.04	202.99	1,198.27	995.28	404.05
Tract 317.04	5,459	257	0.05	348.83	647.36	298.52	(292.70)
Tract 319.06	3,875	183	0.05	5.28	9.80	4.52	(586.71)
Tract 260.01	5,950	290	0.05	3,372.01	3,058.31	(313.69)	(904.92)
Tract 316.04	5,549	277	0.05	98.41	138.01	39.59	(551.63)
Tract 256.02	6,153	313	0.05	449.63	1,485.90	1,036.27	445.04
Tract 320.10	5,810	303	0.05	171.71	248.98	77.27	(513.96)

Table 7: Poverty Summary 2: Top 20 tracts with lowest proportions of population living below Federal Poverty Level (100% FPL)

Tables 8 and 9 display the top 20 tracts with the greatest and lowest proportions of residents living below the county's functional poverty level (equivalent to 200% FPL). Here again, both subsets have similar total populations, within about 5 percent. Similarly to the previous results for residents living below 100% FPL, while the 20 tracts with the lowest poverty levels would experience an even greater percentage increase in transit supply (43 percent, compared to less than 20 percent), those tracts with the greatest poverty levels are still estimated to have far more total access to transit supply, both in the existing and the proposed 2025 networks. Similarly, 10 of the 20 tracts with the highest poverty rates are expected to receive above-average service increases, whereas such service investments are only planned for three of the 20 tracts with the lowest poverty rates. Further, Tract 308.02 (where 45 percent of the population is below the county poverty level) appears particularly concerning, estimated to lose more than half of its accessible transit supply (a supply score change of more than 2000 trips below average), while Tracts 308.01, 307, and 295.04 would also experience changes exceeding 1000 trips below average.

Census Tract	Total Population	Population below Poverty (200% FPL)	Tract Proportion	Service Supply			Service Change Mean Deviation
				Existing 2018 Network	Planned 2025 Network	Change (Δ)	
Tract 290.04	3,938	2,355	0.60	2,016.63	3,478.02	1,461.39	870.17
Tract 292.06	4,396	2,583	0.59	6,502.65	6,682.58	179.93	(411.30)
Tract 308.01^	7,126	4,050	0.58	2,835.06	2,318.95	(516.11)	(1,107.34)
Tract 288.02	6,954	3,642	0.53	1,882.52	2,048.73	166.21	(425.02)
Tract 295.03^	8,546	4,436	0.52	6,275.59	6,490.96	215.37	(375.86)
Tract 305.01^	1,762	854	0.51	1,029.95	1,500.98	471.03	(120.19)
Tract 282	5,005	2,542	0.51	4,675.85	5,729.38	1,053.53	462.31
Tract 289.02	7,163	3,534	0.50	2,686.43	3,567.43	881.00	289.77
Tract 292.03^	4,198	1,594	0.50	7,721.70	9,567.11	1,845.41	1,254.18
Tract 280	4,398	2,108	0.48	4,951.42	5,679.10	727.68	136.45
Tract 261	8,310	3,952	0.48	4,061.04	3,883.56	(177.48)	(768.70)
Tract 253.02^	5,360	2,475	0.47	10,858.77	18,371.55	7,512.79	6,921.56
Tract 284.02	5,090	2,369	0.47	2,620.33	2,320.10	(300.23)	(891.46)
Tract 300.05	5,632	2,551	0.46	641.75	1,756.57	1,114.81	523.59
Tract 273	5,846	2,646	0.45	4,378.76	5,037.96	659.20	67.97
Tract 307	3,916	1,719	0.45	2,835.67	1,987.95	(847.72)	(1,438.95)
Tract 308.02	3,894	1,711	0.45	2,407.94	1,024.18	(1,383.77)	(1,974.99)
Tract 284.03	5,362	2,330	0.44	2,396.19	3,277.89	881.70	290.47
Tract 295.04^	5,970	2,572	0.43	3,690.66	3,257.02	(433.63)	(1,024.86)
Tract 260.02^	8,590	3,667	0.43	6,571.84	8,872.66	2,300.82	1,709.59

^ Denotes tracts within I Line Corridor

Table 8: Poverty Summary 3: Top 20 tracts with greatest proportions of population living below county poverty level (200% FPL)

Census Tract	Total Population	Population below Poverty (200% FPL)	Tract Proportion	Service Supply: Existing 2018 Network	Service Supply: Planned 2025 Network	Service Supply: Change (Δ)	Service Change Mean Deviation
Tract 320.11	*4,307*	*268*	*0.06*	*161.35*	*180.92*	*19.58*	*(571.65)*
Tract 319.06	*3,875*	*256*	*0.07*	*5.28*	*9.80*	*4.52*	*(586.71)*
Tract 278	*3,404*	*260*	*0.08*	*69.61*	*123.27*	*53.67*	*(537.56)*
Tract 320.10	*5,810*	*458*	*0.08*	*171.71*	*248.98*	*77.27*	*(513.96)*
Tract 286	*6,360*	*512*	*0.08*	*1,488.35*	*1,524.08*	*35.73*	*(555.49)*
Tract 293.04	*5,082*	*448*	*0.09*	*80.03*	*555.39*	*475.36*	*(115.87)*
Tract 247.02	*7,528*	*706*	*0.09*	*380.60*	*1,934.40*	*1,553.80*	*962.57*
Tract 320.08	*4,710*	*443*	*0.10*	*29.81*	*47.47*	*17.66*	*(573.56)*
Tract 250.01	*5,106*	*495*	*0.10*	*1,665.37*	*1,439.07*	*(226.30)*	*(817.53)*
Tract 257.02	*3,510*	*354*	*0.10*	*873.44*	*237.13*	*(636.31)*	*(1,227.54)*
Tract 320.05	*7,361*	*755*	*0.10*	*608.58*	*428.43*	*(180.15)*	*(771.38)*
Tract 256.02	*6,153*	*651*	*0.11*	*449.63*	*1,485.90*	*1,036.27*	*445.04*
Tract 316.04	*5,549*	*594*	*0.11*	*98.41*	*138.01*	*39.59*	*(551.63)*
Tract 319.03	*6,767*	*807*	*0.12*	*348.34*	*1,389.68*	*1,041.35*	*450.12*
Tract 319.09	*2,919*	*359*	*0.12*	*182.47*	*508.61*	*326.14*	*(265.09)*
Tract 299.01	*4,610*	*577*	*0.13*	*287.78*	*778.19*	*490.41*	*(100.82)*
Tract 319.07	*7,787*	*1,001*	*0.13*	*527.78*	*870.61*	*342.83*	*(248.40)*
Tract 289.01	*3,186*	*426*	*0.13*	*3,991.86*	*4,274.92*	*283.06*	*(308.17)*
Tract 320.07	*3,616*	*489*	*0.14*	*15.21*	*15.49*	*0.28*	*(590.95)*
Tract 251.02	*7,878*	*1,116*	*0.14*	*552.35*	*939.99*	*387.64*	*(203.59)*

Table 9: Poverty Summary 4: Top 20 tracts with lowest proportions of population living below county poverty level (200% FPL)

4.2.2. Race Summary: Study area service supply changes and people of color

According to ACS records, an estimated 38.59 percent of King County residents identify as persons of color (non-white and/or Hispanic or Latinx) in 2017. Within the study area, the same measure is estimated to be above average: almost half (48.83 percent) of the study area's residents are of color (Figure 4-6). Among the 102 tracts studied, estimates for proportions of residents of color are above the county mean average in 73 tracts, while 51 exceed the *study area* mean average for residents of color. In the figure below, tracts with high proportions of people of color are exhibited, with the darker areas (namely in Algona, Des Moines, Kent, Renton, SeaTac, and Tukwila) representing tracts where half of all residents are of color (Figure 10). The tracts with lighter shading further show the extent of the area's diversity, highlighting tracts with proportions of persons of color above the county average.

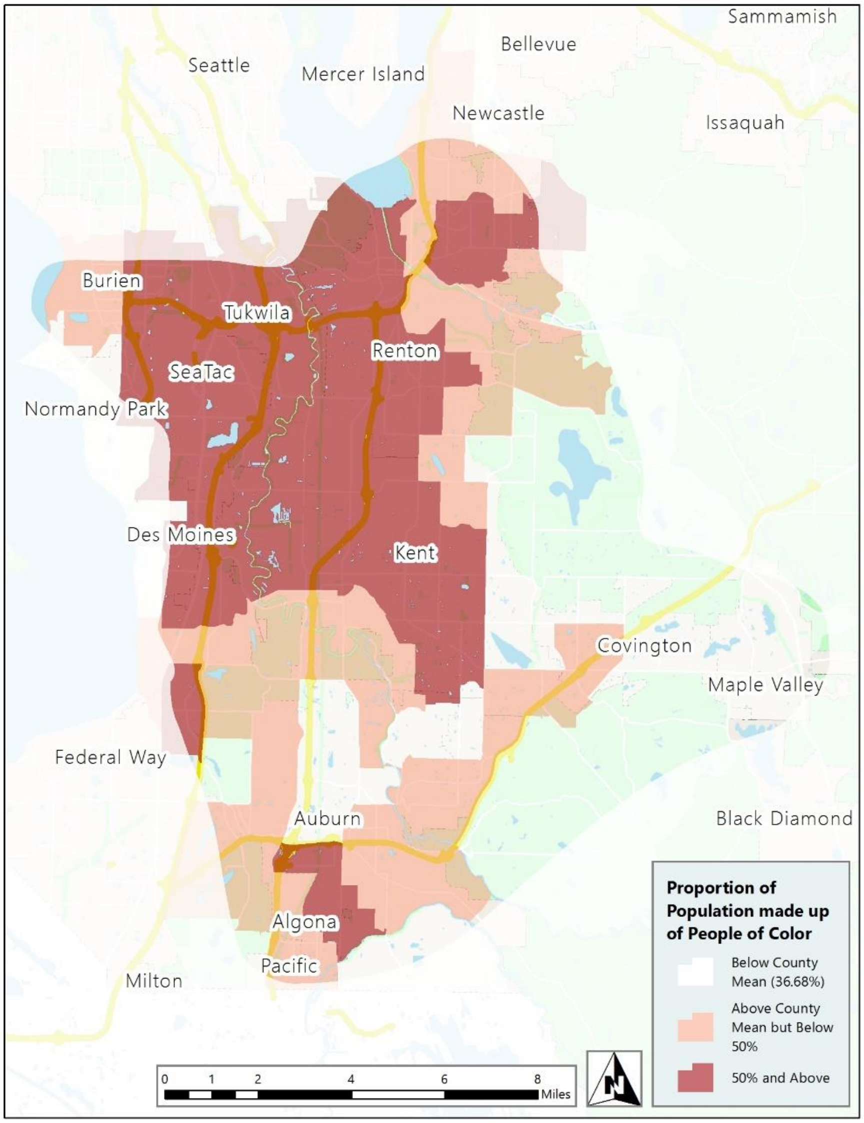

Figure 10: Proportions of residents of color in South King County

Tables 10 and 11 display the top 20 tracts with the greatest and lowest proportions of residents of color. Again, these samples serve as approximate quintiles for the variable under observation – in this case, the upper and lower fifths of the study area population. Both subsets have moderately similar total populations (within about 14 percent) and effectively summarize some of the distribution of existing and proposed transit supply among residents of color throughout the study area. Similarly to the results regarding poverty levels, while the 20 tracts with the lowest proportions of people of color would experience a far larger percentage increase in transit supply (38 percent, compared to less than 18 percent), those tracts with the greatest proportions of people of color are still estimated to have greater total access to transit supply, both in the existing and the proposed 2025 networks. Similarly, of the 20 tracts with the greatest proportions of residents of color, half would experience above-average increases in transit service supply, while only five of the 20 tracts with the lowest proportions would see the same investments. Reductions in transit supply are observed in Tracts 261, 284.02, 260.01, and especially Tract 272 (once again), which is estimated to lose almost two-thirds of its accessible transit supply (with a supply score change of more than 2000 trips below average). At the same time, results for Tracts 260.02 and 300.4 present significant supply score increases of well over three times the average.

Census Tract	Total Population	Persons of Color	Tract Proportion	Service Supply			Service Change Mean Deviation
				Existing 2018 Network	Planned 2025 Network	Change (Δ)	
Tract 261	8,310	6,656	0.80	4,061.04	3,883.56	(177.48)	(768.70)
Tract 281	2,693	2,127	0.79	1,788.58	1,955.20	166.61	(424.61)
Tract 260.02^	8,590	6,498	0.76	6,571.84	8,872.66	2,300.82	1,709.59
Tract 282	5,005	3,711	0.74	4,675.85	5,729.38	1,053.53	462.31
Tract 280	4,398	3,182	0.72	4,951.42	5,679.10	727.68	136.45
Tract 288.02	6,954	5,004	0.72	1,882.52	2,048.73	166.21	(425.02)
Tract 284.02	5,090	3,631	0.71	2,620.33	2,320.10	(300.23)	(891.46)
Tract 273	5,846	4,151	0.71	4,378.76	5,037.96	659.20	67.97
Tract 289.02	7,163	5,049	0.70	2,686.43	3,567.43	881.00	289.77
Tract 290.04	3,938	2,750	0.70	2,016.63	3,478.02	1,461.39	870.17
Tract 300.05	5,632	3,926	0.70	641.75	1,756.57	1,114.81	523.59
Tract 300.04	8,302	5,714	0.69	2,715.78	5,873.09	3,157.32	2,566.09
Tract 292.06	4,396	2,974	0.68	6,502.65	6,682.58	179.93	(411.30)
Tract 272	2,608	1,727	0.66	2,533.80	908.40	(1,625.40)	(2,216.63)
Tract 260.01	5,950	3,933	0.66	3,372.01	3,058.31	(313.69)	(904.92)
Tract 258.06^	5,086	3,355	0.66	3,050.59	3,677.22	626.63	35.40
Tract 284.03	5,362	3,498	0.65	2,396.19	3,277.89	881.70	290.47
Tract 294.08^	4,109	2,670	0.65	868.34	1,239.86	371.52	(219.71)
Tract 295.03^	8,546	5,551	0.65	6,275.59	6,490.96	215.37	(375.86)
Tract 256.01	5,457	3,537	0.65	802.02	824.87	22.85	(568.38)

^ Denotes tracts within I Line Corridor

Table 10: Race Summary 1: Top 20 tracts with greatest proportions of population identifying as persons of color (non-white and/or Hispanic or Latinx)

Census Tract	Total Population	Persons of Color	Tract Proportion	Service Supply: Existing 2018 Network	Service Supply: Planned 2025 Network	Service Supply: Change (Δ)	Service Change Mean Deviation
Tract 278	3,404	388	0.11	69.61	123.27	53.67	(537.56)
Tract 286	6,360	860	0.14	1,488.35	1,524.08	35.73	(555.49)
Tract 320.06	5,393	807	0.15	129.20	106.47	(22.73)	(613.96)
Tract 320.11	4,307	704	0.16	161.35	180.92	19.58	(571.65)
Tract 320.10	5,810	952	0.16	171.71	248.98	77.27	(513.96)
Tract 320.07	3,616	654	0.18	15.21	15.49	0.28	(590.95)
Tract 320.08	4,710	955	0.20	29.81	47.47	17.66	(573.56)
Tract 320.05	7,361	1,519	0.21	608.58	428.43	(180.15)	(771.38)
Tract 319.06	3,875	935	0.24	5.28	9.80	4.52	(586.71)
Tract 318	4,625	1,189	0.26	0.10	37.57	37.46	(553.76)
Tract 316.04	5,549	1,432	0.26	98.41	138.01	39.59	(551.63)
Tract 319.09	2,919	759	0.26	182.47	508.61	326.14	(265.09)
Tract 319.03	6,767	1,842	0.27	348.34	1,389.68	1,041.35	450.12
Tract 289.01	3,186	1,012	0.32	3,991.86	4,274.92	283.06	(308.17)
Tract 287	5,084	1,634	0.32	3,953.53	3,720.36	(233.17)	(824.40)
Tract 290.01	4,710	1,527	0.32	2,320.75	3,353.13	1,032.38	441.15
Tract 299.01	4,610	1,541	0.33	287.78	778.19	490.41	(100.82)
Tract 317.03	7,137	2,454	0.34	1,161.15	2,249.43	1,088.28	497.05
Tract 293.07	4,219	1,479	0.35	1.19	663.65	662.46	71.23
Tract 296.02	6,298	2,222	0.35	202.99	1,198.27	995.28	404.05

Table 11: Race Summary 2: Top 20 tracts with lowest proportions of population identifying as persons of color (non-white and/or Hispanic or Latinx)

4.2.3. Mobility Summary: Study area service supply changes and car ownership

According to ACS records, an estimated 9.86 percent of households in King County did not own a personal vehicle in 2017. In the study area, the same measure is estimated to be below average – 6.63 percent of residents do not own a vehicle. In other words, the study area presents a greater average rate of vehicle ownership than that of the entire county. In the figure below, tracts with rates of households without vehicles above the county-wide average are shown, while those with high proportions of households (one in five) without vehicles are highlighted in darker hatching (Figure 11). Among the 102 tracts studied, estimates for proportions of residents that do not own a car are above the county mean in 22 tracts.

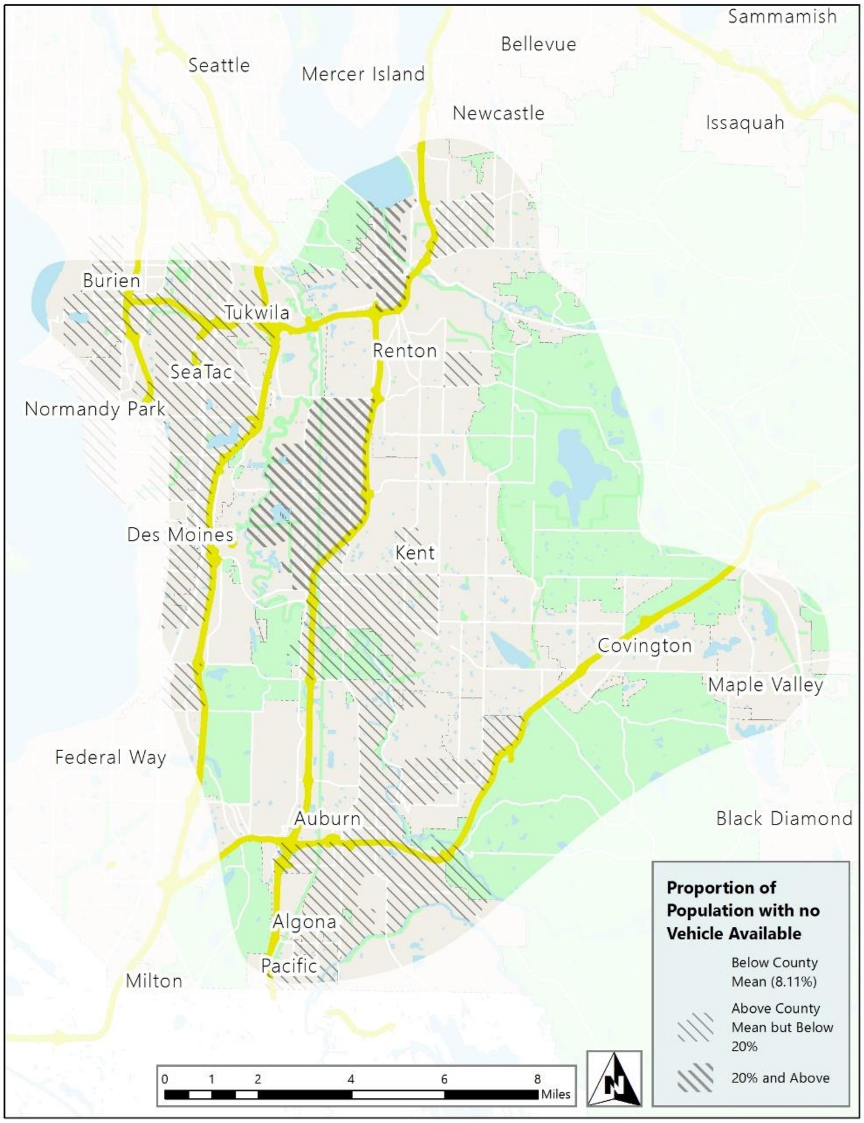

Figure 11: Proportions of households without vehicles in South King County

Tables 12 and 13 display the top 20 tracts with the greatest and lowest proportions of residents without access to a personal vehicle. This measure represents an evident mobility need, especially in suburban King County where land use is typically less dense, distances between destinations are greater, pedestrian infrastructure is often lacking, and car ownership is generally more ubiquitous than in the county on the whole – and certain more than in Seattle, where almost 17 percent of residents (whether by choice or not) do not own a car. Once again, both subsets have similar total populations, within about 10 percent. In this case, the 20 tracts with the highest rates of car-ownership (ie, the *lowest* proportions of households *without* vehicles) have a fraction of the transit service of those with generally lower rates of car-ownership. This is logical, as a majority of the tracts that show high proportions of households without a vehicle are clustered close to city centers, and are more likely to be near transit centers. With significant increases in transit supply throughout the county, even these tracts with the highest rates of vehicle-ownership are projected to almost double their existing transit supply (showing increases of 85 percent, compared to less than 25 percent for the tracts with the lowest rates of vehicle-ownership). Considering nominal changes in supply score, this measure provides interesting results as the numbers of tracts losing service as well as of tracts with above-average increases in service are about the same in both the top and bottom quintile of tracts in the study area (in terms of vehicle availability).

Looking closer, though, there is greater nominal supply score increase in tracts with higher rates of households without vehicles. Results for Tracts 300.04, 292.03, and 260.02 again present significant supply score increases of well over three times the average. Further, while Tract 253.02 presents a rate of over one-fifth of households without access to a vehicle, network service change results suggest the tract's supply score change is expected to exceed the study area supply change almost thirteen-fold. On the other hand, Tracts 284.02, 295.04, and 305.04 have higher rates of households without vehicles (at least one in 10 households do not have access to a vehicle), yet are likely to experience moderate decreases in their transit supply. However, Tracts 307 and 311 appear to be most concerning, as they are estimated to lose almost a third and two-thirds, respectively, of their accessible transit supply. For Tracts 295.04 and 307 in particular, these decreases equate to nominal supply score changes of more than 1000 trips *below* the average service change.

Census Tract	Total Households	Households without a Vehicle	Tract Proportion	Service Supply: Existing 2018 Network	Service Supply: Planned 2025 Network	Service Supply: Change (Δ)	Service Change Mean Deviation
Tract 305.01^	971	336	0.35	1,029.95	1,500.98	471.03	(120.19)
Tract 253.02^	2,711	600	0.22	10,858.77	18,371.55	7,512.79	6,921.56
Tract 292.06	1,991	439	0.22	6,502.65	6,682.58	179.93	(411.30)
Tract 300.04	3,255	648	0.20	2,715.78	5,873.09	3,157.32	2,566.09
Tract 292.03^	1,279	242	0.19	7,721.70	9,567.11	1,845.41	1,254.18
Tract 280	1,557	252	0.16	4,951.42	5,679.10	727.68	136.45
Tract 297^	2,805	442	0.16	2,115.04	2,233.07	118.03	(473.20)
Tract 295.03^	2,921	448	0.15	6,275.59	6,490.96	215.37	(375.86)
Tract 307	1,597	217	0.14	2,835.67	1,987.95	(847.72)	(1,438.95)
Tract 284.02	1,774	228	0.13	2,620.33	2,320.10	(300.23)	(891.46)
Tract 295.04^	2,088	268	0.13	3,690.66	3,257.02	(433.63)	(1,024.86)
Tract 288.01	730	91	0.12	2,665.30	2,779.71	114.41	(476.82)
Tract 290.04	1,314	163	0.12	2,016.63	3,478.02	1,461.39	870.17
Tract 288.02	2,339	286	0.12	1,882.52	2,048.73	166.21	(425.02)
Tract 294.07^	1,632	199	0.12	2,209.73	2,763.88	554.15	(37.08)
Tract 260.02^	3,040	367	0.12	6,571.84	8,872.66	2,300.82	1,709.59
Tract 311	2,666	298	0.11	217.24	74.98	(142.27)	(733.50)
Tract 306^	2,091	231	0.11	1,889.98	2,545.47	655.50	64.27
Tract 305.04^	1,978	215	0.11	913.31	808.96	(104.35)	(695.58)
Tract 255	2,026	217	0.11	4,754.52	5,233.13	478.61	(112.62)

^ Denotes tracts within I Line Corridor

Table 12: Mobility Summary 1: Top 20 tracts with greatest proportions of households that do not own a vehicle

Census Tract	Total Households	Households without a Vehicle	Tract Proportion	Service Supply: Existing 2018 Network	Service Supply: Planned 2025 Network	Service Supply: Change (Δ)	Service Change Mean Deviation
Tract 296.02	1,979.00	0.00	0.00	202.99	1,198.27	995.28	404.05
Tract 256.02	2,079.00	0.00	0.00	449.63	1,485.90	1,036.27	445.04
Tract 251.02	2,778.00	0.00	0.00	552.35	939.99	387.64	(203.59)
Tract 319.06	1,435.00	8.00	0.01	5.28	9.80	4.52	(586.71)
Tract 250.01	1,894.00	12.00	0.01	1,665.37	1,439.07	(226.30)	(817.53)
Tract 295.02	2,138.00	14.00	0.01	1,710.86	3,715.24	2,004.38	1,413.15
Tract 294.05	1,767.00	13.00	0.01	92.40	1,314.39	1,221.99	630.76
Tract 320.05	2,520.00	20.00	0.01	608.58	428.43	(180.15)	(771.38)
Tract 299.01	1,581.00	13.00	0.01	287.78	778.19	490.41	(100.82)
Tract 320.07	1,307.00	11.00	0.01	15.21	15.49	0.28	(590.95)
Tract 258.06^	1,733.00	17.00	0.01	3,050.59	3,677.22	626.63	35.40
Tract 316.04	1,818.00	18.00	0.01	98.41	138.01	39.59	(551.63)
Tract 320.06	1,985.00	24.00	0.01	129.20	106.47	(22.73)	(613.96)
Tract 257.02	1,239.00	15.00	0.01	873.44	237.13	(636.31)	(1,227.54)
Tract 247.02	2,959.00	39.00	0.01	380.60	1,934.40	1,553.80	962.57
Tract 320.08	1,583.00	21.00	0.01	29.81	47.47	17.66	(573.56)
Tract 299.02	1,412.00	20.00	0.01	0.19	75.16	74.96	(516.26)
Tract 320.11	1,451.00	21.00	0.01	161.35	180.92	19.58	(571.65)
Tract 300.03	2,416.00	40.00	0.02	873.23	2,040.06	1,166.83	575.60
Tract 293.07	1,312.00	22.00	0.02	1.19	663.65	662.46	71.23

^ Denotes tracts within I Line Corridor

Table 13: Mobility Summary 2: Top 20 tracts with lowest proportions of households that do not own a vehicle

4.3. Proof of Concept: Integrating I Line Capital Cost Estimates & Transit Service Equity

Ultimately, the goal of the research described herein is to design and test a model in which capital asset and infrastructure costs can be estimated, using life cycle cost analysis, and integrated into typical transit service equity analysis. This integration is performed by modifying transit gap or transit supply analysis so that the supply score is in terms of lifetime capital costs (i.e., investments) rather than service trips. The second half of this chapter summarizes the results from this modification and the integrated *Service+Capital* model, first describing the cost analysis results and ultimately summarizing the results in terms of the three socioeconomic indicators evaluated.

4.3.1. Life cycle cost analysis initial results

The several packages of cost estimates quantified for the capital analysis can be split into two basic groups: initial and service costs. The initial costs – also known as acquisition costs in life cycle cost analyses – are sourced from the Corridor Evaluation Report, and include design, construction, and right-of-way expenditures at the stop-level. Estimated service costs, which include labor and equipment, are aggregated for a 10-year period (approximately) and imputed using an average cost per stop based on maintenance work orders for the A Line over the almost nine years the route has been in service.

Initial costs are subdivided into five major packages – Passenger Facility; Access to Transit; Roadway and Signal; Communication and Technology; and Layover. Total costs for all I Line stops amount to $120,381,900, with over a third dedicated to the roadway and signal package, which includes roadway lane construction. Measured at the stop-level, initial costs appear to range from a high of $16,522,100 to as low as $81,000. Averaging $1,583,972 per stop, the distribution of costs is significantly weighted to a select few stops: costs exceed this average for fewer than 15 stops, while costs at stops 57090, 57100, 57120, and 60320 exceed $10 million (again, mostly dedicated towards roadway construction and signalization costs) (Figure 12).

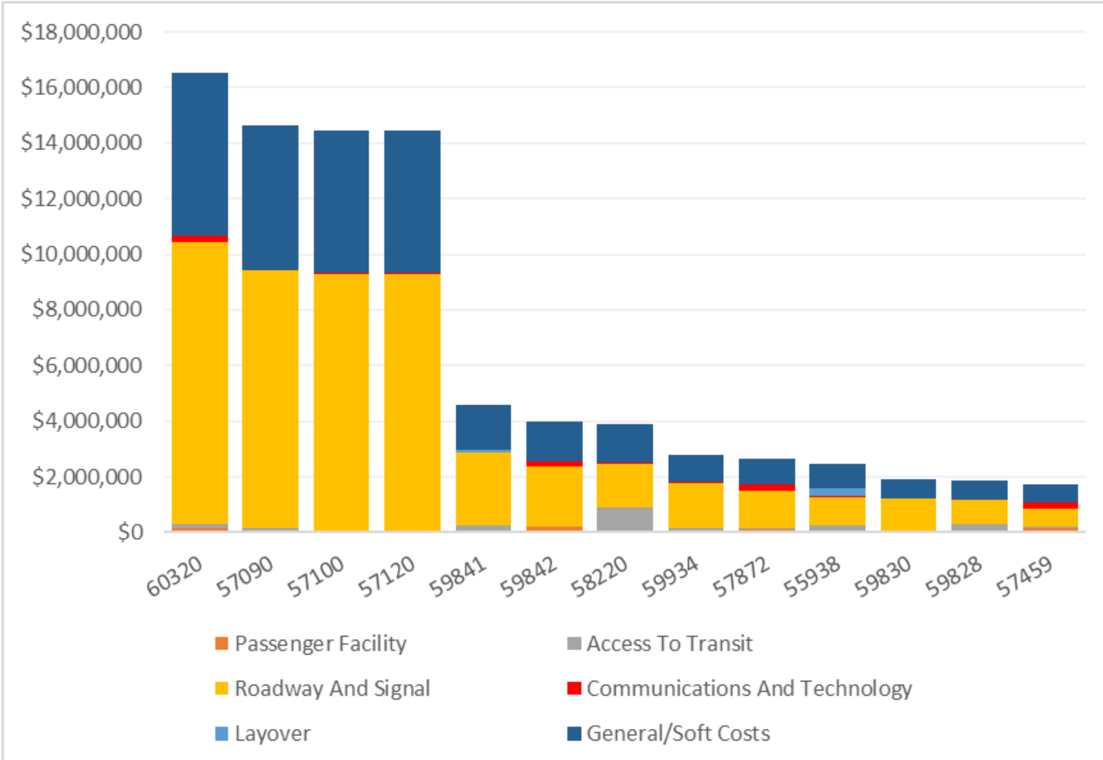

Figure 12: Initial costs by package for stops with above-average initial costs

The majority of maintenance costs fall within the passenger facilities and the communications and technology packages (aligning with the Corridor Evaluation Report methodology), and include servicing, repair, refurbishment, and replacement of bus shelters, RapidRide-specific pylons, stand-alone fare payment equipment (for the regional fare payment system, ORCA), the Intelligent Transportation System (ITS) equipment (at the aggregate route-level), signs, and even waste receptacles.

Total costs for all A Line maintenance records amount to $360,111, covering work performed at 48 stops as well as route-level technology costs (about $7,061 per stop, averaged across all 51 A Line stops). The largest notable cost item is material required for bus shelter replacements, found in four distinct stops (48949; 61180; 60680; 61300) and averaging $8,410 per work order. Of the 48 stops with work order records, 18 show greater than average maintenance costs, yet only six show costs exceeding $10,000 – these include stops 61180 ($35,458); 48949 ($32,206); 60680 ($20,344); 61300 ($19,775); 50480 ($17,257); and 60800 ($12,533) (Figure 13).

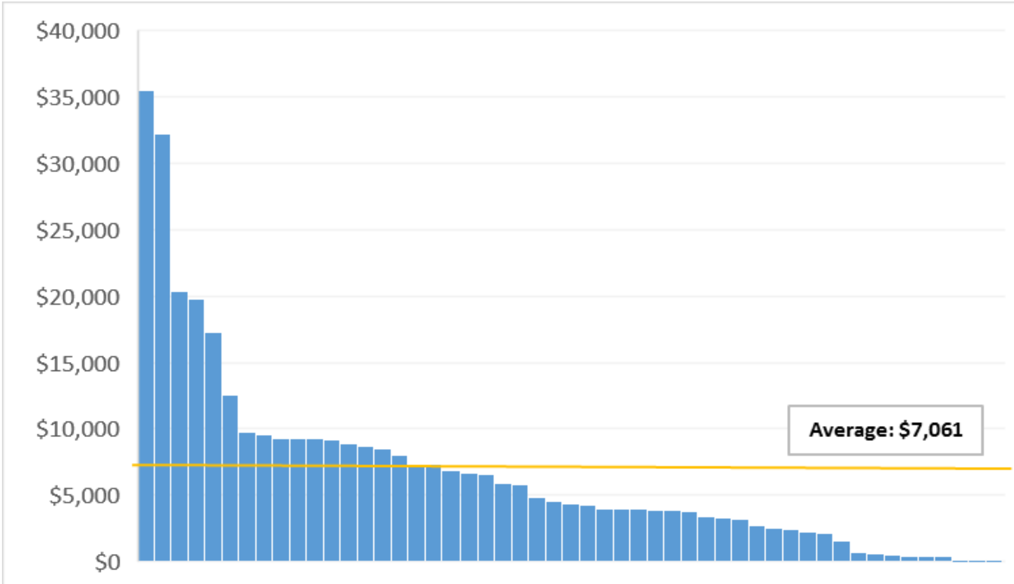

Figure 13: Total maintenance costs for all RapidRide A Line stops

Together, these calculations provide working estimates of the anticipated lifetime capital costs (or investments) for each station along the new RapidRide I Line corridor (Figure 14). While initial costs generally make up a significant majority of each station's total cost, best practices are increasingly accounting for operations and maintenance costs, whether that may be for recurring service or major one-time rehabilitation, in capital decisions. Given the life cycle cost analysis results, the average lifetime cost for each stop is $1,596,203.

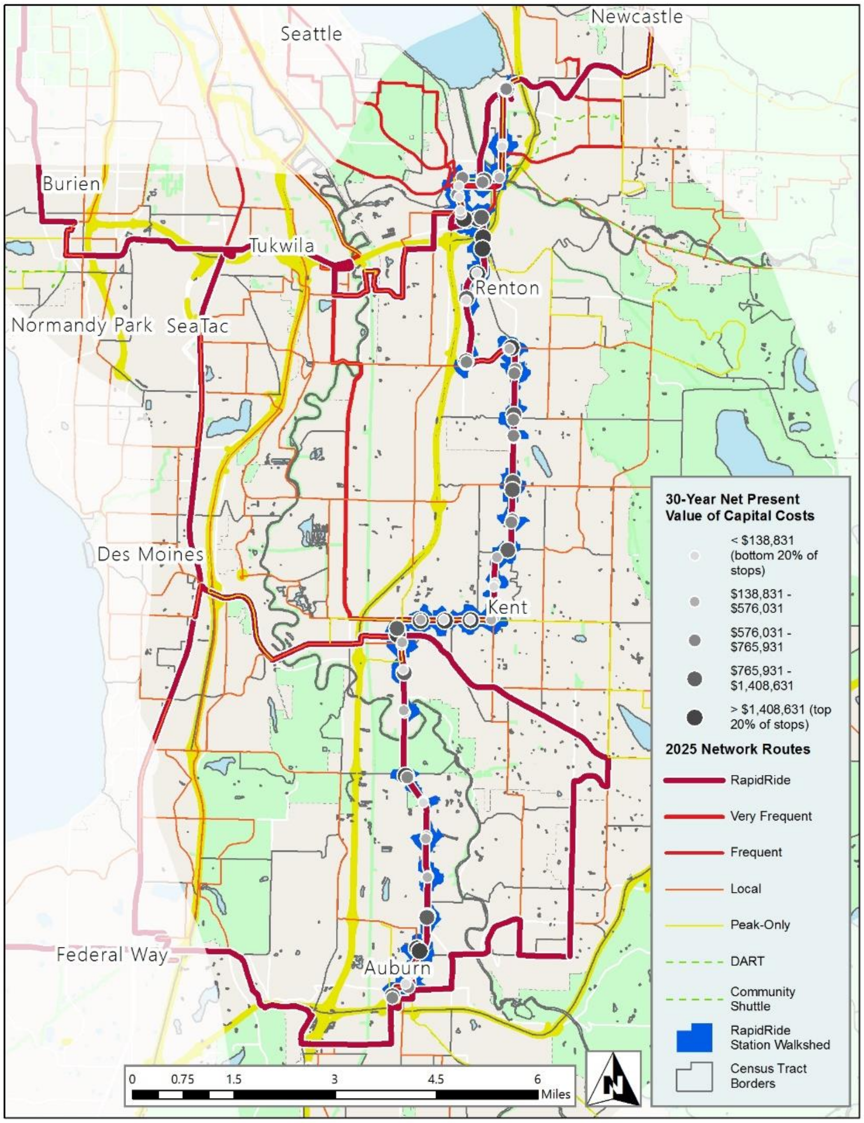

Figure 14: Anticipated stop-level capital infrastructure costs and walkshed buffers

4.3.2. Measuring transit capital supply

With lifetime capital costs now estimated at stop-level catchment areas, I am able to mirror the service analysis to measure the proportional capital investment supply within walking distance for each census unit along the corridor. This also allows the measurement of the horizontal equity of early planning assumptions of upcoming RapidRide upgrades. In comparison, the I Line corridor is significantly smaller than the study area, limited to less than a quarter of the tracts. This analysis is employed across an area of just 23 tracts that fall within a quarter-mile walking distance from a future RapidRide station, all of which are expected to experience wide changes in the supply of accessible transit service as well as significant public investments in capital assets and infrastructure improvements throughout their community. Among all 76 stops marked for future I Line station upgrades, total investments are estimated to range from around $93,230 to as high as $16,534,330, averaging $1,596,203 per stop.

Measuring for the quarter-mile walksheds intersecting all 23 tracts, capital supply scores for tracts range from a low-end estimate of $2,047 to a high of almost $12 million, with the average (mean) capital supply score calculated at $2,670,732.16. The integration of these capital cost values into the previous service supply model allows for a simultaneous consideration for planned bus stop expansion and service changes in the 2025 network. Among these 23 tracts, the average service supply score change is about 1,268 trips, perhaps unsurprising that this outpaces the same average for the entire service area given the significant service investments for the I Line. Ranging from some of the largest increases in the entire study area at over 7,000 trips to some moderate decreases of as much as 500 trips, the corridor's mean tract-level service supply in the 2025 Network is almost double that of the study area's (averaging 4,192.9 trips). In total, the I Line corridor tracts are expected to see service supply change of over 29,000 trips.

Once again, however, this does not equate to even transit capital investment or service growth across all tracts along the corridor. As noted above, service supply and service changes are somewhat concentrated in some tracts – the same holds for capital supply, as some stations receive far greater investment than others. Whereas most will see a fraction of the average estimated capital investment, seven of the 23 tracts studied show above-average investment, with four estimated to have almost three to four times that amount (with nominal investments of over $5 million above the average of about $2.7 million (Table 14).

Census Tract	Total Population	I Line Capital Supply	Capital Mean Deviation: Absolute	Capital Mean Deviation: Ratio	Service Supply: Existing 2018 Network	Service Supply: Planned 2025 Network	Service Supply: Change (Δ)	Service Change Mean Deviation: Absolute	Service Change Mean Deviation: Ratio
Tract 292.03	*4,198*	*$11,901,883.66*	*$9,231,151.50*	*4.46*	*7,721.70*	*9,567.11*	*1,845.41*	*1,254.18*	*3.12*
Tract 258.06	*5,086*	*$10,423,117.48*	*$7,752,385.31*	*3.90*	*3,050.59*	*3,677.22*	*626.63*	*35.40*	*1.06*
Tract 253.02	*5,360*	*$8,849,043.90*	*$6,178,311.73*	*3.31*	*10,858.77*	*18,371.55*	*7,512.79*	*6,921.56*	*12.71*
Tract 294.07	*4,697*	*$7,964,634.87*	*$5,293,902.71*	*2.98*	*2,209.73*	*2,763.88*	*554.15*	*(37.08)*	*0.94*
Tract 292.04	*7,229*	*$4,680,792.69*	*$2,010,060.52*	*1.75*	*793.80*	*1,715.01*	*921.21*	*329.98*	*1.56*
Tract 293.03	*7,423*	*$4,521,810.78*	*$1,851,078.61*	*1.69*	*1,166.04*	*1,919.65*	*753.61*	*162.38*	*1.27*
Tract 295.03	*8,546*	*$3,057,330.79*	*$386,598.63*	*1.14*	*6,275.59*	*6,490.96*	*215.37*	*(375.86)*	*0.36*
Tract 305.01	*1,762*	*$1,618,545.33*	*($1,052,186.83)*	*0.61*	*1,029.95*	*1,500.98*	*471.03*	*(120.19)*	*0.80*
Tract 305.03	*5,942*	*$1,565,923.17*	*($1,104,809.00)*	*0.59*	*840.17*	*659.51*	*(180.65)*	*(771.88)*	*(0.31)*
Tract 297	*8,051*	*$1,480,772.79*	*($1,189,959.37)*	*0.55*	*2,115.04*	*2,233.07*	*118.03*	*(473.20)*	*0.20*
Tract 294.03	*5,746*	*$1,172,617.06*	*($1,498,115.10)*	*0.44*	*1,063.00*	*1,612.01*	*549.01*	*(42.22)*	*0.93*
Tract 305.04	*4,396*	*$1,069,223.26*	*($1,601,508.90)*	*0.40*	*913.31*	*808.96*	*(104.35)*	*(695.58)*	*(0.18)*
Tract 306	*5,874*	*$941,652.47*	*($1,729,079.69)*	*0.35*	*1,889.98*	*2,545.47*	*655.50*	*64.27*	*1.11*
Tract 253.01	*6,525*	*$797,967.04*	*($1,872,765.13)*	*0.30*	*3,070.47*	*10,804.57*	*7,734.10*	*7,142.87*	*13.08*
Tract 293.06	*3,443*	*$477,013.85*	*($2,193,718.32)*	*0.18*	*489.50*	*1,431.05*	*941.54*	*350.31*	*1.59*
Tract 293.05	*4,215*	*$406,847.05*	*($2,263,885.12)*	*0.15*	*327.56*	*468.70*	*141.14*	*(450.09)*	*0.24*
Tract 258.05	*5,084*	*$325,584.52*	*($2,345,147.64)*	*0.12*	*1,021.35*	*1,528.88*	*507.53*	*(83.69)*	*0.86*
Tract 294.08	*4,109*	*$59,097.61*	*($2,611,634.56)*	*0.02*	*868.34*	*1,239.86*	*371.52*	*(219.71)*	*0.63*
Tract 295.04	*5,970*	*$46,833.83*	*($2,623,898.34)*	*0.02*	*3,690.66*	*3,257.02*	*(433.63)*	*(1,024.86)*	*(0.73)*
Tract 260.02	*8,590*	*$38,351.12*	*($2,632,381.04)*	*0.01*	*6,571.84*	*8,872.66*	*2,300.82*	*1,709.59*	*3.89*
Tract 262	*5,608*	*$14,798.82*	*($2,655,933.34)*	*0.01*	*7,058.00*	*11,703.86*	*4,645.86*	*4,054.64*	*7.86*
Tract 257.01	*6,004*	*$10,950.23*	*($2,659,781.94)*	*0.00*	*1,403.63*	*945.82*	*(457.81)*	*(1,049.04)*	*(0.77)*
Tract 308.01	*7,126*	*$2,047.46*	*($2,668,684.70)*	*0.00*	*2,835.06*	*2,318.95*	*(516.11)*	*(1,107.34)*	*(0.87)*

Table 14: All I Line corridor tracts, by the mean deviation of capital supply scores

4.3.3. *Service+Capital* in terms of transport disadvantage

With capital cost estimates and service changes analyzed similarly for each tract in the I Line corridor, the distribution of these impacts together can be evaluated from a *vertical* equity perspective, further observing the results in the context of the socioeconomic indicators of interest.

Tables 15 and 16 display all I Line corridor tracts by the proportion of residents earning incomes below the federal and the county poverty levels, respectively. Poverty rates for each tract range from 5 – 33 percent for residents at or below the federal poverty level and 14 – 58 percent for those under 200% FPL. Of the 23 tracts along the corridor, 15 have both federal and county poverty rates that exceed those for the study area; further, 19 and 20 tracts exceed the federal and county poverty rates for the county, respectively. Supply scores for both capital investment and service change appear to be moderately distributed across poverty levels, with high deviation scores on both ends of the distribution and low scores mostly concentrated among some dozen tracts in the middle.

Census Tract	I Line Capital Supply	Capital Mean Deviation	Service Change Mean Deviation	Total Population	Population below 100% FPL	Tract Proportion
Tract 305.01	$1,618,545.33	0.61	0.80	1,762	562	33.43%
Tract 295.03	$3,057,330.79	1.14	0.36	8,546	2,567	30.35%
Tract 295.04	$46,833.83	0.02	**(0.73)**	5,970	1,652	27.83%
Tract 308.01	$2,047.46	0.00	**(0.87)**	7,126	1,911	27.38%
Tract 253.02	$8,849,043.90	3.31	12.71	5,360	1,443	27.36%
Tract 292.03	$11,901,883.66	4.46	3.12	4,198	838	26.40%
Tract 294.07	$7,964,634.87	2.98	0.94	4,697	1,080	23.46%
Tract 260.02	$38,351.12	0.01	3.89	8,590	1,989	23.38%
Tract 305.04	$1,069,223.26	0.40	**(0.18)**	4,396	890	20.27%
Tract 294.08	$59,097.61	0.02	0.63	4,109	705	17.16%
Tract 305.03	$1,565,923.17	0.59	**(0.31)**	5,942	896	15.28%
Tract 262	$14,798.82	0.01	7.86	5,608	822	14.66%
Tract 306	$941,652.47	0.35	1.11	5,874	833	14.18%
Tract 294.03	$1,172,617.06	0.44	0.93	5,746	782	13.76%
Tract 297	$1,480,772.79	0.55	0.20	8,051	1,005	12.81%
Tract 258.05	$325,584.52	0.12	0.86	5,084	601	11.82%
Tract 293.03	$4,521,810.78	1.69	1.27	7,423	763	10.43%
Tract 257.01	$10,950.23	0.00	**(0.77)**	6,004	620	10.33%
Tract 253.01	$797,967.04	0.30	13.08	6,525	663	10.20%
Tract 292.04	$4,680,792.69	1.75	1.56	7,229	659	9.12%
Tract 258.06	$10,423,117.48	3.90	1.06	5,086	414	8.16%
Tract 293.05	$406,847.05	0.15	0.24	4,215	245	5.85%
Tract 293.06	$477,013.85	0.18	1.59	3,443	183	5.32%

Table 15: Service+Capital results for I Line corridor tracts, by proportion of population under federal poverty level

Census Tract	I Line Capital Supply	Capital Mean Deviation	Service Change Mean Deviation	Total Population	Population below 200% FPL	Tract Proportion
Tract 308.01	$2,047.46	0.00	**(0.87)**	7,126	4,050	58.03%
Tract 295.03	$3,057,330.79	1.14	0.36	8,546	4,436	52.45%
Tract 305.01	$1,618,545.33	0.61	0.80	1,762	854	50.80%
Tract 292.03	$11,901,883.66	4.46	3.12	4,198	1,594	50.22%
Tract 253.02	$8,849,043.90	3.31	12.71	5,360	2,475	46.93%
Tract 295.04	$46,833.83	0.02	**(0.73)**	5,970	2,572	43.33%
Tract 260.02	$38,351.12	0.01	3.89	8,590	3,667	43.11%
Tract 294.08	$59,097.61	0.02	0.63	4,109	1,636	39.82%
Tract 294.07	$7,964,634.87	2.98	0.94	4,697	1,831	39.78%
Tract 305.03	$1,565,923.17	0.59	**(0.31)**	5,942	2,138	36.47%
Tract 297	$1,480,772.79	0.55	0.20	8,051	2,736	34.88%
Tract 306	$941,652.47	0.35	1.11	5,874	1,949	33.18%
Tract 294.03	$1,172,617.06	0.44	0.93	5,746	1,758	30.94%
Tract 257.01	$10,950.23	0.00	**(0.77)**	6,004	1,847	30.76%
Tract 305.04	$1,069,223.26	0.40	**(0.18)**	4,396	1,333	30.36%
Tract 258.05	$325,584.52	0.12	0.86	5,084	1,423	27.99%
Tract 292.04	$4,680,792.69	1.75	1.56	7,229	1,976	27.35%
Tract 262	$14,798.82	0.01	7.86	5,608	1,478	26.36%
Tract 293.03	$4,521,810.78	1.69	1.27	7,423	1,686	23.04%
Tract 258.06	$10,423,117.48	3.90	1.06	5,086	1,129	22.24%
Tract 293.05	$406,847.05	0.15	0.24	4,215	819	19.57%
Tract 253.01	$797,967.04	0.30	13.08	6,525	1,261	19.39%
Tract 293.06	$477,013.85	0.18	1.59	3,443	512	14.87%

Table 16: Service+Capital results for I Line corridor tracts, by proportion of population under county poverty level

The distribution of capital and service investment by proportions of persons of color for all I Line corridor tracts is displayed in Table 17. I Line corridor tracts' proportions of persons of color range from 35 to 75 percent. Of the 23 tracts along the corridor, 16 exceed the study area average, while 20 exceed the county average proportion of residents of color. While the greatest capital supply scores are distributed among the 14 most diverse tracts, these tracts largely receive modest to low service changes. The greatest service supply scores are concentrated towards the mid-low end of the distribution, serving tracts with 45 – 55 percent populations of color.

Census Tract	*I Line Capital Supply*	*Capital Mean Deviation*	*Service Change Mean Deviation*	*Total Population*	*Persons of Color*	*Tract Proportion*
Tract 260.02	*$38,351.12*	*0.01*	*3.89*	*8,590*	*6,498*	*75.65%*
Tract 258.06	*$10,423,117.48*	*3.90*	*1.06*	*5,086*	*3,355*	*65.97%*
Tract 294.08	*$59,097.61*	*0.02*	*0.63*	*4,109*	*2,670*	*64.98%*
Tract 295.03	*$3,057,330.79*	*1.14*	*0.36*	*8,546*	*5,551*	*64.95%*
Tract 295.04	*$46,833.83*	*0.02*	***(0.73)***	*5,970*	*3,792*	*63.52%*
Tract 294.03	*$1,172,617.06*	*0.44*	*0.93*	*5,746*	*3,637*	*63.30%*
Tract 292.03	*$11,901,883.66*	*4.46*	*3.12*	*4,198*	*2,590*	*61.70%*
Tract 258.05	*$325,584.52*	*0.12*	*0.86*	*5,084*	*3,036*	*59.72%*
Tract 308.01	*$2,047.46*	*0.00*	***(0.87)***	*7,126*	*4,106*	*57.62%*
Tract 293.03	*$4,521,810.78*	*1.69*	*1.27*	*7,423*	*4,120*	*55.50%*
Tract 262	*$14,798.82*	*0.01*	*7.86*	*5,608*	*3,110*	*55.46%*
Tract 292.04	*$4,680,792.69*	*1.75*	*1.56*	*7,229*	*3,979*	*55.04%*
Tract 253.02	*$8,849,043.90*	*3.31*	*12.71*	*5,360*	*2,866*	*53.47%*
Tract 294.07	*$7,964,634.87*	*2.98*	*0.94*	*4,697*	*2,412*	*51.35%*
Tract 293.05	*$406,847.05*	*0.15*	*0.24*	*4,215*	*2,149*	*50.98%*
Tract 257.01	*$10,950.23*	*0.00*	***(0.77)***	*6,004*	*2,937*	*48.92%*
Tract 293.06	*$477,013.85*	*0.18*	*1.59*	*3,443*	*1,585*	*46.04%*
Tract 253.01	*$797,967.04*	*0.30*	*13.08*	*6,525*	*2,995*	*45.90%*
Tract 306	*$941,652.47*	*0.35*	*1.11*	*5,874*	*2,665*	*45.37%*
Tract 305.03	*$1,565,923.17*	*0.59*	***(0.31)***	*5,942*	*2,679*	*45.09%*
Tract 297	*$1,480,772.79*	*0.55*	*0.20*	*8,051*	*3,047*	*37.85%*
Tract 305.04	*$1,069,223.26*	*0.40*	***(0.18)***	*4,396*	*1,604*	*36.49%*
Tract 305.01	*$1,618,545.33*	*0.61*	*0.80*	*1,762*	*632*	*35.87%*

Table 17: Service+Capital results for I Line corridor tracts, by proportion of population of color

And finally, the distribution of supply scores by vehicle availability is presented in Table 18. Due to the I Line's lengthy alignment, the route is expected to serve both urban and low-density residential areas – therefore, the rates of vehicle availability vary widely. Along the corridor, the percentage of households without access to a vehicle for each tract ranges from less than 1 percent to over 34 percent. Of the 23 tracts along the corridor, 15 exceed the study area average while only 10 exceed the county average (recalling that the study area has a lower rate of households without vehicles than the county as a whole). Similar to the results given the poverty level distributions, supply scores for both service and capital investments appear be relatively evenly distributed across tracts, with high deviation scores throughout the entire distribution. Additionally, below-average investment and nominal service decreases are also somewhat distributed, albeit leaning towards the tracts with greater rates of households without a vehicle.

Census Tract	I Line Capital Supply	Capital Mean Deviation	Service Change Mean Deviation	Total Households	Households without a Vehicle	Tract Proportion
Tract 305.01	$1,618,545.33	0.61	0.80	971	336	34.60%
Tract 253.02	$8,849,043.90	3.31	12.71	2,711	600	22.13%
Tract 292.03	$11,901,883.66	4.46	3.12	1,279	242	18.92%
Tract 297	$1,480,772.79	0.55	0.20	2,805	442	15.76%
Tract 295.03	$3,057,330.79	1.14	0.36	2,921	448	15.34%
Tract 295.04	$46,833.83	0.02	**(0.73)**	2,088	268	12.84%
Tract 294.07	$7,964,634.87	2.98	0.94	1,632	199	12.19%
Tract 260.02	$38,351.12	0.01	3.89	3,040	367	12.07%
Tract 306	$941,652.47	0.35	1.11	2,091	231	11.05%
Tract 305.04	$1,069,223.26	0.40	**(0.18)**	1,978	215	10.87%
Tract 305.03	$1,565,923.17	0.59	**(0.31)**	2,129	210	9.86%
Tract 308.01	$2,047.46	0.00	**(0.87)**	2,394	228	9.52%
Tract 257.01	$10,950.23	0.00	**(0.77)**	2,893	227	7.85%
Tract 253.01	$797,967.04	0.30	13.08	3,026	231	7.63%
Tract 294.08	$59,097.61	0.02	0.63	1,617	108	6.68%
Tract 292.04	$4,680,792.69	1.75	1.56	2,554	140	5.48%
Tract 293.03	$4,521,810.78	1.69	1.27	2,950	139	4.71%
Tract 293.06	$477,013.85	0.18	1.59	1,285	59	4.59%
Tract 262	$14,798.82	0.01	7.86	2,247	102	4.54%
Tract 294.03	$1,172,617.06	0.44	0.93	1,933	74	3.83%
Tract 258.05	$325,584.52	0.12	0.86	1,928	59	3.06%
Tract 293.05	$406,847.05	0.15	0.24	1,332	32	2.40%
Tract 258.06	$10,423,117.48	3.90	1.06	1,733	17	0.98%

Table 18: Service+Capital results for I Line corridor tracts, by proportion of households without a vehicle

For added comparison, Figure 15 displays the distribution of service and capital supply scores across all four variables side to side.

Figure 15: Service+Capital results for I Line corridor tracts, listed by socioeconomic indicators (federal and county poverty level above; persons of color and households without vehicles below)

4.4. Summary

This analysis finds that overall, the distribution of service and capital investments is mixed across the three demographic indicators used to evaluate socioeconomic and mobility need in southern King County and along the I Line Corridor. To further summarize the model's overall results, average values of the service and capital supply score deviations are taken across two distinct subsets of the I Line tracts: tracts with socioeconomic indicator rates above the study area average and below-average. For example, average deviations are calculated separately for the 15 tracts with proportions of households without vehicles exceeding 6.63 percent and for the eight tracts with below-average rates of vehicle unavailability. For all three indicators, 15 or 16 tracts are found to have higher rates than the study area average, while seven or eight tend to be below.

In terms of service changes, average supply score deviation was greater for tracts with proportions of poverty and persons of color *below* the study area averages than it was for those with above-average proportions of these populations. Particularly concerning is the result for tracts with above-average poverty rates (at 200% FPL): their average service supply deviation is far below the average for the entire study area (268.8 compared to 591.2), while tracts with below-average poverty rates would see an average service change of over 1,400 trips. This trend does not hold when examining tracts by their proportion of households without access to a vehicle, however. In this case, the tracts with rates above the study area average of 6.63 percent also would experience a greater average increase in transit service.

Examining the same average deviation values for capital investments provides some different trends across the indicators of interest. Observing for poverty levels and vehicle availability, the results are similar with relatively low average deviations for both. The average deviation score is positive for tracts with below-average rates of poverty or proportions of households without a vehicle yet negative for tracts with high poverty and low access to cars. However, these values are relatively low, suggesting the distribution is actually quite even (within around $40,000 from the tract average of $2.7 million for poverty indicators; and within $100,000 for the vehicle availability measure). When examining the deviation averages for the race indicator, the results are vastly different, showing an average positive deviation of almost $700,000 for tracts with above-average rates of people of color and an average negative deviation of more than $1.5 million for tracts with below-average rates.

While these findings ultimately require further refinement and deeper exploration, immediate interpretations may suggest that anticipated service network changes and capital investments may not meet a Rawlsian definition of equity. Though this may not be the case when considering service changes in terms of households without vehicles or capital investments in terms of a tract's racial diversity, in general tracts with above-average rates in most indicators receive fewer service and capital benefits than those with below-average rates.

4.4.1. Statistical significance of results

To further understand the relationships between the key variables developed and used throughout this analysis, a simple ordinary least squares (OLS) regression model is applied. Evaluating service and capital supply values as dependent variables against multiple explanatory variables, this final exercise is employed to identify any existing correlational relationships between transit service supply, capital investment supply, and the three demographic variables of interest.

The dataset used for this final portion of the analysis measures levels of transit supply at the U.S. Census Tract level and includes transit service trip data, capital asset costs, and American Community Survey (ACS) demographic data, as manipulated and calculated throughout this analysis. The dataset includes a maximum of 102 observations of tracts in southwest King County (within the Renton-Kent-Auburn Area Mobility Plan study area). Service data is evaluated for all tracts, while capital investment data is limited to the subset of 23 tracts along the RapidRide I Line corridor. Socioeconomic data from the ACS was manipulated into percentage-based variables – race and poverty are measured at the individual person-level while vehicle availability is measured by households – and are calculated for entire tracts and within pre-measured walkshed catchment areas (in both absolute nominal and percentage terms).

The four regression models center around the service and capital supply deviation variables as dependent, or outcome, variables. Along with the socioeconomic indicators, they are also occasionally applied as explanatory variables. As outlined below, first service supply (Y) and capital supply (X) are each analyzed against socioeconomic explanatory variables, and then each is analyzed against the other, holding for all socioeconomic indicators, as such:

$$\hat{Y} = \widehat{\beta_0} + \widehat{\beta_1} poverty_1 + \widehat{\beta_2} race_2 + \widehat{\beta_3} mobility_3$$

$$\hat{X} = \widehat{\beta_0} + \widehat{\beta_1} poverty_1 + \widehat{\beta_2} race_2 + \widehat{\beta_3} mobility_3$$

$$\hat{Y} = \widehat{\beta_0} + \widehat{\beta_1} capital\ supply_1 + \widehat{\beta_2} poverty_2 + \widehat{\beta_3} race_3 + \widehat{\beta_4} mobility_4$$

$$\hat{X} = \widehat{\beta_0} + \widehat{\beta_1} service\ supply_1 + \widehat{\beta_2} poverty_2 + \widehat{\beta_3} race_3 + \widehat{\beta_4} mobility_4$$

Given the heavily manipulated variables and low observation counts, however, the OLS models presented mixed results. While the use of service supply scores for both the 2018 and the 2025 network as outcome variables provided strong r-squared scores of over 0.35 (suggesting a decent model "fitness"), this score dropped to an adjusted r-squared of 0.11. Evaluating the correlation between the socioeconomic indicators and the service supply change further reveals challenges for statistical significance: save for the coefficient for the vehicle availability rate variable (which is small but positive), the coefficients for race and poverty have high p-values (greater than 0.15) – thus, we cannot reject the null hypothesis that they are *not* correlated to service change differences. Despite this, only the variable for the rate of poverty (100% FPL) has a negative coefficient.

Results are even less insightful when applying OLS to the I Line subset of tracts. The decent r-squared scores for service supply variables are most likely due to a relatively higher observation count for all 102 tracts in the study area, because the same models for the I Line have notably lower scores. In fact, adjusted r-squared scores are negative when capital investment supply scores are analyzed as an outcome variable. On the other hand, with service supply as an outcome variable and capital supply, race, poverty, and vehicle unavailability as explanatory variables, the adjusted r-squared is 0.07 (and 0.24 unadjusted). Once again, the coefficient for vehicle availability is the only one with a p-value below 0.05 and has a small but positive coefficient, while the p-value for capital supply exceed 0.6.

To better evaluate the relationships between these variables, greater granularity should be considered, resulting in larger observation counts. Further, a wider application of this *Service+Capital* model, perhaps measuring the equity of multiple new bus rapid transit projects throughout the county with a larger service network analysis, could provide improved statistical significance in the measurement of the correlation between these variables. With greater statistical significance, a robust model could quantify the extent to which certain socioeconomic factors can predict future transit service and capital investment levels.

Chapter 5: Discussion

This thesis presents a novel approach to evaluate both transit service and capital planning decisions together from a social equity perspective. This integration is important due to the nature of current practice at many transit agencies, where such decisions are made separately, often in silos, rather than simultaneously. The prototype model employed here provides a proof of concept for this goal and, if further expanded and refined, could present valuable improvements to typical bus rapid transit planning practice.

Graham Currie's transportation gap methodology provides an effective, communicable, and generalizable approach to evaluate a range of existing public transportation services, using single trips as a unit of measurement. Arguably, this approach can also be applied to *future* service as well, allowing for preemptive comparison before a service change package is submitted. Granted, the operability of this application relies significantly on well-formed and robust planning regarding the potential allocation of service hours, which must ultimately account for operational considerations like fleet and bus base capacity, workforce availability, existing need and demand for service, or the "pot" of hours that is realistically available for the entire service network. Similarly, the availability of rough cost figures related to RapidRide implementation presented a unique opportunity to test the application of Currie's transportation gap methodology on future capital investments required for new bus rapid transit service. Using rough order of magnitude cost estimates and generalized maintenance costs for another in-service RapidRide route (A Line), the application of a life cycle cost analysis approach further bolsters the analysis by accounting for costs throughout the entire lifetime of capital assets.

The application of this equity analysis approach provides a unique proof of concept for the preemptive comparison of planned service and capital investments of bus rapid transit simultaneously. This provides a methodology for the integration of preliminary service and capital planning assumptions in service equity analysis. While this kind of evaluation may be typical for the planning of service, whether through the compliance of Title VI requirements or the application of an equity impact review on a project, it is not typical for capital. Further, the simultaneous evaluation also provides a departure from standard practice, in which service and capital are generally planned in sequence (and separately). Whereas service alignments may typically dictate *where* infrastructure is constructed or assets are installed, this unique model provides a way for the two to be compared and evaluated side by side, even allowing for extensive sensitivity analysis for both service supply and capital investment. And because capital often follows service, equity considerations in capital planning can be overlooked or assumed; this approach centers capital cost choice alongside service and operational alternatives in an equity analysis. The integration of such considerations into traditional capital and operational planning and project delivery practice could even have the potential to shift the way capital improvement planning and budget development is performed at Metro. Recognizing that in a financially constrained environment budgets increasingly reflect an agency's values, this model presents an innovative quantitative measure that can be employed to improve the way social equity is accounted for in Metro's service and capital projects.

5.1. Research Findings

As discussed in the previous chapter, when compared in aggregate, tracts with above-average rates in most indicators generally received less service and capital benefits than those with below-average rates. The model's immediate results suggest that anticipated service network changes and capital investments do not meet a Rawlsian definition of equity – that is, inequality in the distribution of public funds and services is not benefiting the least well-off. This reality prompts several important considerations.

At first, this may seem like a disingenuous misalignment from Metro's and King County's stated goals of addressing systemic and historic inequities through upstream investments and the recognition of public transit as a key driver of equity. However, it is also important to recall Metro's Service Guidelines, which are used in the development of service change packages and account not only for social equity, but for geographic value and route productivity as well. These two additional factors are critical for a public service that must constantly balance need with demand – at the end of the day, Metro is required to fund a significant proportion of its services through farebox revenue and thus is expected to maximize ridership. This is especially true for RapidRide's high-frequency service and even further complicated by the suburban nature of large portions of the I Line. Therefore, areas with denser land uses and residential populations are bound to receive greater service supply and capital investment; because these areas are increasingly expensive, this ultimately has the potential of excluding populations in the peripheries that may heavily rely on transit.

This is borne out in the model's results, which suggests that both existing service and future service investments are potentially concentrated in particular tracts. This is also why vehicle availability is included in the model, providing a proxy for mobility need, especially in suburban King County where car use is generally more common, distances are greater, and pedestrian environments are often unwelcoming. Yet even tracts with the highest rates of vehicle-ownership are projected to almost double their existing transit supply.

At the same time, changes in the existing public transit network can impact the relative accessibility that residents experience. Bus rapid transit projects may result in more frequent transit service with greater reliability for a certain corridor, but often require longer distances between bus stops and stations. While this may provide a higher quality service, greater travel distances to a stop could discourage or entirely exclude some transit users, potentially reducing a residents' access *to* transit facilities and accessibility overall.

5.2. Limitations and Generalizability

Though it presents a unique approach for the evaluation of transit equity, the model described here was designed to be simplistic in order to ensure its successful application. Given this simplicity, the research design presents some notably limitations. One of the major limitations facing this study is the availability and use of data. While the American Community Survey provides data for a broad range of indicators, its margins of error are often large enough to render some observation values obsolete. Further, the inherent inaccuracy of ACS data required the use of tracts, which are likely too large given the nature of the analysis and the size of the study area. Using tracts with a catchment area analysis of this type risks over-generalizing the socioeconomic characteristics for a given area by assuming a perfectly even spatial distribution of residents or households. Using blocks or block groups as the census unit (with greater data accuracy) would allow for a more accurate walkshed analysis while providing more observations (in terms of census units) to improve the effectiveness and fitness of the linear regression model.

The study's focus on a narrow set of socioeconomic indicators also presents a limitation worth discussing. Metro planning efforts typically account for a broad range of socioeconomic indicators to measure the equity of service changes, usually measured individually or as a composite index. This thesis employs a narrower approach by limiting the analysis to poverty status, race, and vehicle-ownership in order to facilitate its application. Future analysis should expand the measurement of transportation disadvantage to include the range of indicators Metro commonly evaluates for.

Some important methodological limitations also emerge. Most significant is the narrow definition of service investment as the supply of service trips. There are a wide variety of measures that could also be employed to signify not only the level of service investment but the quality or usefulness of the service as well, such as ridership, timeliness, reliability, and more. Even a measure of the accessibility provided by the system could be used to represent the quality or supply of transit service. On the other hand, more robust cost calculations would improve the capital component of the model. As the project advances, more accurate cost estimates are likely to improve the accuracy of the results. Further, greater granularity in the calculation of service costs, and the inclusion of user costs and salvage value, as is expected in life cycle cost analysis, would greatly improve the accuracy of the results.

In fact, the value of the model relies extensively on the quality and care taken in the preliminary service planning and capital cost estimation that produces the model's central figures: 1) both current and future scheduled trips at the time of implementation, and 2) accurate rough order of magnitude, budget, and definitive estimates for the implementation and construction of capital assets and infrastructure. Admittedly, the service and capital estimates used in this model are highly preliminary, presenting a significant limitation to the results described in this paper. However, the model's value can be properly tested as I Line and RKAAMP network alignments are more clearly defined, capital cost estimates are further refined, and service hour allocation is finalized. Conversely, the model can also be reversed to allow for a sensitivity analysis. Such an application could be used to evaluate different configurations of trip investments in order to arrive at a system that achieves greater equity in the distribution of service.

The model described here also provides further generalizability for future research. The effectiveness of Currie's transportation gap model lies in its broad applicability, as evidenced by its application on smaller-scale regions at greater detail or large metropolitan areas with less specificity. This prototype provides the same generalizability and could be used to preemptively evaluate not only service changes across the entirety of Metro's network but also planned capital investments for multiple RapidRide upgrades. Regarding the latter purpose, the use of inflation and discount rates in life cycle cost analysis further allows for the evaluation of incremental RapidRide upgrades and complementary network revisions over time.

Given the rapid demographic change King County is experiencing, American Community Survey data is generally limited by its low accuracy and timeliness. This model should also be revisited in future research as new U.S. Decennial Census data from 2020 becomes available. Providing improved accuracy for socioeconomic indicators, and at a finer grain, it is imperative that Metro planners and analysts apply that data rapidly, efficiently, and in innovative ways to ensure it is effectively leveraged and major agency strategic goals remain aligned to its stated values.

5.3. Planning for Bus Rapid Transit

While RKAAMP planning has only recently commenced (as of early 2019), preliminary service planning assumptions have existed since the development of the agency's long-range plan, Metro Connects. As agency staff progress with implementation efforts for both near- and long-term milestones, innovative processes and approaches begin to emerge. The identification of major, mostly suburban corridors that could serve high-frequency transit naturally presented an additional challenge: How would network service levels be regionally redistributed to support the new RapidRide transit trunks?

In his ex-ante study of Johannesburg's Corridors of Freedom, Christoffel Venter ultimately finds that implementation is least disruptive and serves the population best when it is integrated with a frequent and local feeder service with "an integrated and progressive fare policy" (Venter 2016). This finding is likely not unique to cities like Joburg, however. After all, Metro's broad network-focused approach will implement the supportive network as the corridor-level RapidRide upgrades are designed and constructed.

Perhaps equally applicable to Metro's RapidRide I Line project is Venter's finding regarding the importance of land use in the success of new high-capacity transit projects; the author notes that "access benefits are limited by the low-density nature of the corridors stretching between higher density nodal development at its endpoints," which could limit the potential benefits of such a project (Venter 2016). This is further supported by Shen et al.'s study of over 35 metropolitan areas in the United States evaluating the extent that density and speed can affect accessibility for commuters traveling to work by automobile. Despite the traditional American transportation convention favoring efficient and fast movement in a transportation system, the authors find that land use density has a dominant net effect on accessibility (Qingyun Shen et al. 2012).

The importance of supportive land use cannot be understated with any major high-capacity corridor-level transit project, whether rail or bus. While high-quality transit should ideally be provided to all residents, and certainly those who most need it, planners are likewise expected to meet the system's greatest areas of demand in order to support ridership numbers and farebox revenues. As Metro proceeds to implement new suburban RapidRide corridors over the following years, land use presents a critical component that deserves further examination. In the case of the I Line, the particularly low residential and commercial density outside of Renton’s, Kent’s, and Auburn’s central areas may not support the high frequency of RapidRide service.

Chapter 6: Conclusion

This thesis explores the effects of evaluating future transit service changes and capital asset and infrastructure investments tied to a new bus rapid transit project solely from a social equity perspective. As Metro's suite of upcoming RapidRide upgrades like the I Line are implemented over the next 20 years – as outlined in Metro Connects – the bus transit network in King County will increasingly emphasize very frequent service and reliability along major trunks and corridors, with incremental changes and re-routing of frequent and local services to complement both RapidRide implementation and the construction of Sound Transit's Link light rail. As the county grapples with unprecedented growth, increased traffic and road congestion, homelessness, and residential and commercial displacement, it is critical that these major service alterations and capital investments successfully leverage public funds to improve the role of transit – that is, to provide increased access to opportunities for as many people that can avail themselves of the service (and particularly for those with an arguable need for the service).

Ultimately, this analysis finds that average service supply score deviations were generally greater for tracts with *below-average* levels of the indicators measured, than it was for those with above-average levels (this result did not hold when examining tracts by their proportion of households without access to a vehicle). Similarly, the analysis results indicate positive capital supply score deviations for tracts with below-average rates of poverty or vehicle unavailability and negative score deviations for tracts with above-average rates. Although these are preliminary results derived from a simplistic model, an immediate interpretation of aggregate average deviations generally results in *fewer* service and capital benefits for tracts with above-average rates of socioeconomic and mobility need, suggesting that proposed service network changes and capital investments as they are currently designed do not meet a Rawlsian definition of equity. Granted, the variables used do present weak statistical correlation and significance. However, this could be due to the number of observations in the regression model, the way the variables are calculated and designed, the socioeconomic indicators used, the sheer simplicity of the model, or all of the above.

In fairness, the methodology proposed here tests a simple prototype, and the approach presents notable limitations. However, it is the potential for the successful integration of both service and capital components in an evaluation of the distribution of future RapidRide investments that is most promising in this study. This proof of concept suggests that it is possible to measure preliminary design-level estimates of service hours and capital asset and infrastructure costs, particularly in terms of transportation disadvantage, in order to inform RapidRide operations and alignment decisions. Further, this methodology could prove ven more valuable if investment decisions must be made between distinct alternatives, whether due to notable differences in the service package, changes in station-level improvements and costs, or varied operations and maintenance practices.

The research outlined in this paper presents a proof of concept for a novel approach to preemptively evaluate future transit service planning and capital investment decisions. The successful application of this model shows potential for expanding the way equity considerations are integrated into capital projects. This methodology presents a viable approach to simultaneously integrate service and capital planning assumptions and decision-making, especially in terms of evaluating for social equity, facilitated by the model described here.

The effectiveness of the model employed in this thesis is its applicability and generalizability, much like Currie's own transportation gap model. Similarly, this analysis could be applied throughout Metro's entire network and could be modified to even evaluate capital investment estimates across multiple RapidRide projects. While the primary goal of this study was to test the operability and applicability of such a research design, this study will ideally provide a foundation for the further expansion of similar social equity research as it can be applied in bus rapid transit implementation.

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