The London School of Economics and Political Science

Next Steps in the March Toward Transit Equity:
Essays on the Relationship between Public Transit and our Suite of Possible Life Experiences

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Declaration

I certify that the thesis I have presented for examination for the PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it). The copy right of this thesis rests with the author. Quotation from it is permitted, provided that full acknowledgement is made. This thesis may not be reproduced without my prior written consent. I warrant that this authorization does not, to the best of my belief, infringe the rights of any third party.

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State of Co-authored Work

I confirm that Chapter 2 was jointly written with Pablo Navarrete-Hernandez and Alessandro Balducci. Work on this chapter was distributed across the three of us in the following way. Balducci contributed to project conceptualization and is credited as the third author of the paper. Navarrete-Hernandez, the piece's first author, contributed to project conceptualization, methodology design, data collection, data analysis and interpretation, data visualization, and reviewing of text. I, second author, contributed to the piece's literature review, data analysis and interpretation, data visualization, writing of original draft, as well as reviewing and editing all subsequent text drafts.

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Abstract

Transit is a means by which movement is facilitated. A way to get from here to there. This statement, though accurate, captures but a tiny fraction of the many things that transit truly is and has power over. Transit influences who we spend our time with, our health and wellbeing, whether or not we tend to try new things, our feelings of self-worth, the scale of our aspirations, our ability to amass wealth, and even the extent to which we view others as comrades or competitors. It has memorialized histories and erased them, drawn lines of both belonging and exclusion. Under the discipline umbrella of transportation equity, this fuller suite of transit-impacted life-quality elements is receiving a growing amount of research attention. As are the ways that these elements and their consequences vary by place, space, and personhood. This dissertation, consisting of four distinct projects and an introductory overview of the transportation equity scholarship landscape, contributes to this growth largely focusing attention at the intersection of transit – services, policies, behaviors, outcomes – and race. These combined works pull from literature related to infrastructure and land value capture, public health, enforcement and surveillance, civic trust, travel mode determination, and gentrification.

The first of these four projects looks at the relationship between proximate positioning from rail stations and property pricing. By way of meta-analysis, the roles that the built environment, temporal factors, modelling techniques, socio-demographics, housing policy, and level of transit service play in shaping that relationship are measured. Findings reveal that factors of geography, data type, race, rent control policies, rail type, transit cost, and transit network expanse all significantly affect rail access uplift magnitude.

The second, responding to the heavily transit-impacting historical moment we find ourselves in, asks the following: how do COVID-19 safety measures in transit spaces affect riders' worry of infection? Using a photo-simulation approach to a randomized control trial, this study finds that safety measure type, level of compliance with those safety measures, and the conditions of transit spaces themselves significantly impact riders' levels of travel-related worry.

Through a series of focus groups, the third project is framed against the backdrop of an increased presence on the national political stage of public demand for police reform in the US. It explores how feelings toward camera technology stand among groups most marginalized by existing enforcement systems, and how those feelings vary by type of enforcement application? In particular, it asks how Black community leaders understand the potential use of automated camera enforcement for traffic and transit roadway violations. Receptiveness to a camera enforcement program exclusive to bus infrastructure that contributes to the eventual introduction of self-enforcing roadway design is found. This work culminates in a list of 11 Black-informed program design elements integral to any future program hoping to gain support.

The final project concerns itself with evolutions in travel behavior related to changes in settlement patterns. It tackles the following: how have the predictive strength of age, income, and racial identity on transit mode selection changed against conditions of rapid gentrification, and how do those changes differ by trip purposes? This work finds that, in general, transit selection likelihood has deceased among Black and Latinx travelers and increased among Asian travelers as compared to White travelers, young adults slightly increased their transit use likelihood over older adults, and low and middle income travelers' transit use likelihood has lessened compared to that of high income travelers.

Each of these projects offer recommendations for practitioners interested in using an evidence-informed understanding of transit's wide range of influence to operationalize values of inclusion, justice, repair, and collective wellbeing.

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CHAPTER 1: Introduction

"Mobility is a marker and maker of 21st century social life. Interconnected and intensifying flows of people, animals, good, information and waste, and the infrastructures and technologies that facilitate them, fundamentally shape everyday life, regional and national processes, and global and planetary orders." – *Nancy Cook and David Butz (2018, p.3)*

"Freedom of movement is the very essence of our free society – once the right to travel is curtailed, all other rights suffer." – *Said by William O. Douglas (Rickey, 1965, p.139)*

1.1 RESEARCH AIM AND MOTIVATIONS

Phrased in perhaps the most simple and true way possible, transit (e.g. passenger-carrying buses, trains, van pool services, ferries, cable cars) is important. Transit's quality and breadth, as well as the degree to which we are free and able to interact with it, have great influence over an array of life-quality factors. With proven ability to expand the diversity of people we spend our time with (Bissell, 2018) and increase our likelihood of trying new things (Li et al., 2023), transit can make our world bigger. It can also make our world healthier. In addition to scores of environmental benefits (Litman, 2024), transit use is associated with a number of positive physical and mental health outcomes, such as a decreased prevalence of obesity (She et al., 2017) and lessened feelings of loneliness and disconnection (Rambaldini-Gooding et al., 2021). Transit access can strengthen our ability to secure intergenerational wealth (Penyalver and Turró, 2018) and its use shapes social cohesion, such as by encouraging us to see people from other walks of life – our fellow riders – as comrades and allies rather than competitors and adversaries (Mouratidis and Poortinga, 2020; Rennert, 2021; Liu et al., 2023).

That said, transit is not a single-faced coin. The experiences it facilitates vary, and not all of them are positive. Transit often renders longer total trip times and lower user-satisfaction than other ground travel modes (St-Louis et al., 2014; Morris and Guerra, 2015; De Vos et al., 2016; Handy and Thigpen, 2019). As many transit fleets run on diesel and other harmful fuels, living proximately to bus depots and major transfer stations can increase one's likelihood of respiratory illness (Adar et al., 2015; Ahn and Kim, 2019). Transit spaces too often play stage to experiences of sexual harassment and assault (Hoor-Ul-Ain, 2020; Loukaitou-Sideris and Ceccato, 2022), as well as theft of personal property (Newton et al., 2015; Oliveira et al., 2023). Many who work in the transit industry have been found to be at high risk of poor mental health across indices such as stress and depression (Cendales et al., 2024). While transit's benefits do outweigh its pitfalls, the fact remains that though wonderfully rich in potential for catalyzing individual and collective wellbeing (Glaeser, 2012; Cervero, 2014; Davis, 2023; Walker, 2024), transit is not without its opportunities for significant improvement.

How these transit realities manifest differ by *personhood* and *place,* concepts which have many components: conditions of the built and natural environment, transit mode availability and service quality, social values, demography and associated settlement patterns, comparative quality of non-transit modes, and history of investment in the public realm, to name but a few. Still, for much the world over, the distribution of these transit-related goods and transit-related bads has generally entailed a disproportionately large share of transit's positive aspects being experienced by those with greater amounts of social privilege and power, and its negative aspects most acutely experienced by society's disadvantaged, marginalized, and disenfranchised groups (Lachapelle, and Boisjoly, 2023; Kirmizi, 2023; Martinelli and Medellin, 2007; Lucas, 2011; Suel et al., 2024; Venter et al., 2019; Pereira and Karner, 2021).

In the context of the United States, given legacies of racially prejudicial public policies and stringently segregated urban development practices (Taylor, 2019; Rothstein, 2017; Hirt, 2015; Massey, 2001), these groups have largely historically been – and continue to be – communities of color, Black communities in particular (Carter et al., 2023; Archer, 2020; Blumenberg, 2017; Rennert, 2016; Inwood et al., 2015; Haymes, 1995). This inequitable, unacceptable reality in combination with my past career form the underlying motivation for this work.

Prior to doctoral study, I was a US-based transit planner for a number of years. I worked in the public sector for the City of Boston Transportation Department. Prior to that, I worked in the private sector at Nelson\Nygaard, a transportation planning consulting firm. In these roles I led projects the touched many elements of transit. These included things like fare restructuring, bus rapid transit (BRT) implementation,

commuter rail parking pricing, train schedule changes, bus network redesigns and stop redistribution, first-mile last-mile connectivity, partnerships with rider-hailing companies for paratransit service provision, system electrification, and station-area overlay zoning. Both organizations had missions committed to improving conditions of transportation equity. Joyously for me, this translated into my being encouraged to prioritize projects in neighborhoods of color and projects that served high shares of transit riders of color.

There were many projects that I worked on across my roles at these two organizations for which the immediate benefit to marginalized constituencies that I was significant and the implications of improved conditions of transportation equity clear. Take for example: implementation of a new BRT line that served majority Black neighborhoods, better connecting them to the city's medical, education, and employment hubs; adoption of all-door boarding on the city's ten highest ridership routes – of which nine had a majority people of color ridership base – to decrease dwell times, lessen the occurrence of bus bunching, and improve service reliability; or extension of hours of operation and new route creation to better serve third shift workers and other late-night riders, the majority of whom earned below area-average incomes, and had a higher likelihood of being foreign born, of color, employed in a part-time capacity, and not speaking English as a first language than the average system rider. This was impactful work.

Unfortunately, however, the joy I felt upon completion of these projects was frequently short lived. Satisfaction at a job (theoretically) well done was quickly shadow by a flurry of concerning questions. Will the newly halved headways on this train signal an opportunity for increased profits to luxury condo developers? Will that then result in increased rents and housing cost pressures for the current riders we just worked so hard to engaged with and provide better service for? Will the new cross-provider fare payment products we helped launch trigger increased crackdown on fare evasion? Will that take the form of more police officers across the network, and if so, what will that mean for Black and Brown teens, so often the targets of this type of enforcement and victims of its brutality? Yes, a new streetcar line will bring Fashion Bee Hair (a Black beauty supply store along a business corridor that a project of mine served) new customers. But if current gentrification patterns persist, how many of those new customers will be relevant buyers, and what will that mean for Fashion Bee Hair's viability? What assurances can I realistically give the store owner? Has this project really helped her, or simply added significant precarity to her economic future? I loved my work and believed in the power of transit to bring about a more socially justice world (Rennert, 2016), but these unknowns regularly kept me up at night.

I took on this doctorate with the intention of answering some of the questions that I didn't have answers to as a planner. Questions that diminished the joy I should have felt at providing the communities I served with improved transit service and the elevated suite of quality-of-life outcomes associated with those improvements. To that end, this research aims to provide transit practitioners with resources that will help them confidently advance both transit and social equity in their work, particularly as it relates to race. In an effort to achieve this aim, I have taken on four specific research questions. The details of these practice-centered questions and the specific ways that they came about are discussed below.

Paper 1: Research questions and motivation.

Many of my past transit planning colleagues are acutely concerned with advancing social justice. Because of this, many of them prioritize projects that are in neighborhoods of color or serve particularly high shares of riders of color. This practice is wise and warranted. However, capacity limitations prevent many of these socially conscious transit planners from being able to know if, and to what extent, the service improvements they make may be impacting the housing security – and there in ability to remain in place if desired – of the very people they set out to serve with those improvements. As previously suggested, I myself often had the worry that my efforts to better serve my community, which at that time was Boston's

Black community, right now, may render adverse effects beyond the world of transportation over time. This concern shaped the research question for the first empirical paper in their dissertation. That question is the following: What factors explain the wide variation found across transit proximity premiums on residential property values, what role do levels of transit service play in the magnitudes of those premiums,, and how can past premiums research be utilized as a predictor of yet un-studied premiums?

Key to this specific question is its attention to providing a tool that lowers the analytic capacity requirements for answering questions of transit-impacted housing cost premiums for practitioners. To rely on the conducting of a full-scale research study every time one wants to get an estimate of the effect that transit service enhancement in a given context may have is an unreasonable lift and potential resource drain; if, for example, consultants had to be hired to run such an analysis. The need to hurdle these barriers contributed significantly to this choice of research question.

Paper 2: Research questions and motivation.

During the first year of my studies, the COVID-19 pandemic dealt the world of transit, and transportation in general, a mighty shock. Suddenly, being in confined public space, which transit systems could reasonably be categorized as, meant putting one's health at risk. While fear of virus contraction, stay-at-home orders, and new affordances in work-from-home capabilities kept many from travelling, this was not the case for everyone. Essential workers, care givers, and others who needed to keep making vital trips continued to be reliant on transit. Though this subject of study had not occurred to me when I was a planner, as such a condition had not previously occurred on this scale in my lifetime, there was birthed a clear and dire need for research to be responsive to the times.

Much of the COVID-transit scholarship in the pandemic's first two years focused on topics related to physical health (Shortall et al., 2022; Pervalo et al., 2022). Understandably, so did most of the response from practitioners (Gkiotsalitis and Cats, 2021). A friend working at Transport for London, the Greater London Area's transit provider, expressed that she was growing increasingly concerned that mental health and wellbeing were going under-considered during this time of mass panic and fear; that they were not being given enough weight in the decisions being made regarding rider safety. This pushed me to take on the following research question: How do COVID-19 safety measures in transit spaces affect travelers' worry of COVID-19 infection, and how do the conditions of transit spaces themselves influence this effect?

My rationale behind this particular question was the thinking that placing a focus on what transit practitioners have power over in the immediate term (i.e. COVID-19 safety measure regulations) as well as things with greater permanence that they have long-term control over (e.g. hallways, boarding platform design, bus stops) could provide both useful recommendations for rider wellbeing in response to the present crisis as well as those for general, prolonged rider wellbeing in times of either societal calm or a future crisis.

Paper 3: Research questions and motivation.

Before reentering academia as a doctoral student, I spent years engaging with the public, designing, advocating for, and implementing projects that had the potential to render positively transformative transportation realities for the communities they served. This potential, however, was often entirely dependent on how people interacted with these projects. Ideally, interaction is dictated by design. Think, for example, of parking-protected bike lanes, curb-separated center-running bus lanes, or bumped-out bus stops where the curb at a bus stop extends over the parking lane to meet the bus in its driving lane (NACTO, 2016). All of these disallow for the unwanted behavior of driving or parking in a space dedicated for more sustainable modes by way of creating physical barrier to that behavior with infrastructure (e.g. curbs, planters, vertical posts).

However, in cases where space, or resources, or political will prohibit design elements of this type, manner of use is dependent on other ways of conditioning behavior. Unfortunately, for the bus lanes, bikeways, and queue jumps that I worked on, that often called for some form of enforcement. In the US, enforcement of transportation regulations is typically handled by a municipality's police force or that of the transit providing agency (i.e. transit cops). These groups have disproportionately negative interactions with people of color, Black people in particular (Kamalu, 2016; Woods, 2021; Hinton, 2021). As previous stressed, most of my bus lane projects, offering potentially greatly improved travel experiences for riders, were in Black neighborhoods. This duality raised the need to explore alternatives to current, socially inequitable practices of law enforcement, and for those alternatives to be chiefly informed by those for whom the stakes were highest. Those who have repeatedly been denied a seat at the policymaking table. As a result, I sought to answer the following: How do Black community leaders in Boston understand the potential use of camera enforcement for traffic and transit roadway violations?

Paper 4: Research questions and motivation.

I grew up in Washington DC. Much of my family still calls that city home. Though no longer a resident of this area, I visit regularly and always take transit both to and around the city. Over the last 10-15 years in particular, the group of people that make up my fellow riders has changed. My cohort of co-riders has felt less age diverse and Whiter, and I less frequently hear languages other than English around me. Outside of its transit system, Washington DC is also noticeably changing (Helmuth, 2019; Summers, 2021). Its rapid gentrification is palpable, as historically Black neighborhoods get renamed, chain restaurants and retailers replace mom-and-pop stores, and new-build condos seem to spring up on every corner. Inspired by the changes in my peer groups – that is to say, my fellow transit riders – the following research question was formed: How have the gentrification-associated elements of race, age, and income changed as predictors of transit mode choice in the Washington DC metropolitan area during the last two decades of rapid gentrification?

The outcomes of this question have social equity implications that would serve as useful signals to transit planners that there is need for change in their work. For example, if Blackness, which has long been a strong likelihood predictor of transit use in the US, is seeing a comparative weakening of influence, this could signal a change in preference away from transit among Black riders paired with means by which to travel differently. Or it could signal a decrease in access to transit among this group. One of these conditions represents an increase in transportation freedoms, the other a lessening of them and a decrease in transportation and social equity. Neither condition is desirable from a transit agency perspective. These potential changes to a condition that has held consistently true in US urban history for so many decades – the relationship between being of color and the strength of influence that that identity facet has on one's likelihood of transit use (Dill et al., 2013; Hess, 2009; Mauch and Taylor, 1997) – need further examination for practitioners to be able to respond appropriately; meaning in ways that align with values of racially informed justice toward more equitable conditions. This line of research contributes to that.

A note on structure.

This dissertation, which is US-centric but not US-exclusive in its analytical context nor in its resultant implications for practice, is structured in the following way: the rest of Chapter 1 distills the transportation equity literature, within which this work ultimately sits, and provides a brief overview of the methodologies selected – and rationale behind those selections – for each of the four empirical analyses; these four projects comprise Chapters 2, 3, 4, and 5, each designed as standalone publications; and Chapter 6 concludes, reconnecting the findings from each empirical study to the overarching research aim and transportation equity literature, and featuring discussion of limitations of the work and reflections for future research.

1.2 EVOLUTION OF TRANSPORTATION EQUITY SCHOLARSHIP: A REVIEW

At its core, transportation equity is concerned with the distribution of burdens and benefits associated with transportation planning and infrastructure across different members of society. Scholarship on the topic has seen several distinctly varied evolutions over the last 30 years, and has come to include equity of transportation practices, policies, and related procedures of design and decision-making, as well as social equity related to or facilitated by transportation behaviors and resources. Though differences between these evolutions range from minute to sizable – from *reformative* to *transformative*, to borrow from Karner et al.'s, (2023) recent discussion of the topic's research landscape – each is fundamentally centered around four key questions:

1. Equity of what – exactly what is meant by 'transportation-related burdens and benefits'?
2. Equity for whom – across which elements of identity do distributions of transportation-related burdens and benefits matter?
3. Equity subject to what threshold – what degree of disparity is 'acceptable' and what underpins notions of 'acceptability' (e.g. sameness, fairness, capability, rightfulness)?
4. Equity determined by what means – how should it be measured?

These serve as the pillars around which transportation equity research is shaped, and in so being, they serve as the theoretical guide for four empirical works that comprise this dissertation. In this section I will attempt to synthesize the landscape of transportation equity scholarship to-date and layout my own approach to thinking about and operationalizing transportation – more specifically transit – equity.

1.2.1 The Building Blocks of an Emerging Discipline.

Though studies relating transportation to differences in behavior and life outcomes across different groups of people date back to at least the 1970s (Davies and Huff, 1972; Novaco et al., 1979; Rosenbloom, 1978), formalized emergence of 'transportation equity' as a focal topic of research could justly be cited to the 1990s. Further, Robert Bullard could reasonably be credited as a particularly pioneering voice on the subject during that time. He championed the idea that actions that govern the public realm are both subject to and contribute to inequities that play out societally and in our everyday lives. Linking transportation to then-active movements of civil rights and environmental justice, Bullard (1994a) argued that there are three types of equity that warrant attention in transportation: procedural, geographic, and social equity.

Procedural equity refers to process-related factors in decision making. For example, this includes the timing and location of public meetings, the languages in which information is shared, and, often as a result of factors such as these, which stakeholders are and are not ultimately included in planning efforts. Geographic equity refers to the distribution of costs and benefits across space, while social equity refers to said distribution across sociodemographic groups.

Cases of Bullard applying his own framing to practical examples are plentiful. In one such example, concentrating specifically on geographic and social equity, Bullard (2003) looked at differences in public spending on urban versus suburban rail as well as local roads versus interstate highways in the US between 1960 and 2000. He found that federal government investment was far greater, to the tune of some tens of billions of dollars, for transit services and roadway construction that served suburban areas than for those serving urban areas. He further stressed that due to US residential segregation patterns, this disparity translated to greater government subsidy for white travelers with higher incomes than for low-income travelers of color. This study is emblematic of the type of framing that much research published in this decade employed (Garret and Taylor, 1999).

Taken in aggregate, work during this earliest era of transportation equity scholarship attended to the four pillars in the following ways. Regarding *equity of what,* the transportation-related burdens of environmental degradation and risk to physical health (Landrigan et al., 1998; Bullard, 1994b), and the transportation-related benefits of government spending (Litman, 1996a; Bullard et al., 2000b) as well as civic power and participation (Langmyhr, 1997; Baeten, 2000) received significant shares of research focus. Poverty and unemployment, residential sorting, education attainment, and social services utilization were also discussed as being directly related to disparities in transportation resource allocation (Shen, 1998; Sanchez, 1999; Garrett and Taylor, 1999; Bullard et al., 2000a; Baum-Snow and Kahn, 2000), although equity-specific analyses along these lines were less common. Regarding *equity for whom*, race, income, and level of urbanity were the primary markers of identity centered during this time and were most often grouped into upper- compared to lower-income groups, white compared to of color persons, and urban compared to suburban or rural communities.

The *equity threshold*, that is, what degree of difference is deemed fair and/or reasonable, was left largely undefined in this research period. Most of Bullard's work at this time treated disparity and inequity as one in the same (Bullard et al., 2000a; Bullard, 2003; Bullard et al., 2004). Under that assumption, equality – for example of an outcome or of treatment – and equity similarly take on identical meanings. A layer of intricacy was added to that by those who posed that prolonged or by-design (i.e. systemic) disparity is what elevates a condition in which groups experience different levels of transportation-related burdens and benefits to one of in fact inequitably different levels (Hodge, 1995; Sanchez et al., 2003). Others positioned equity as less of an end-state and more of what is needed to reach equality. In that sense equity is the act of providing those with some notion of 'least' with the greatest degree of benefit-inducing and burden-shrinking support (Garrett and Taylor, 1999). While some scholars took on this least-most framing in their equity determinations, others centered their work around the idea of inequity as akin to disproportionate reception of burdens and benefits as compared to an identified mean or representativeness within a given population, such as that of a city or nation (Feitelson, 2002). This framing was, however, not particularly common across scholarship of the time.

The approaches to *equity measurement* during this research era were varied. There was a concentration on tracking gaps in public funding across different groups (Litman, 1996b; Khisty, 1996). Attention was also devoted to measuring differences in average travel times, primarily for work trips, and the financial costs of travel across identity markers (McLafferty, 1997; Preston et al., 1993; Dollar, 2001). Additionally, researchers of this era explored transportation-impacted health-related measures such as counts of deaths or hospitalizations and their differences by socio, spatial, and demographic classifications (Whitelegg, 1997; Grimshaw, 1995; McCray, 2001).

1.2.2 Social Exclusion and the Age of Accessibility

The early 2000s saw an expansion of many of these ideas. It also saw a more nuanced treatment of the ways that transportation inequities fit into a broader discussion of societal haves and have-nots, cans and cannots. While the previous era of scholarship was largely in part grounded in values of sustainability – a claim supported by the fact that environmental journals hosted the lion's share of papers published during that time – the roots of this era sat in the soil of good governance. Social equity posits that it is the responsibility of government, and decision-making bodies charged with providing for the public, to work towards conditions of fairness across all cohorts of people they serve (Frederickson, 1990). Though 'fairness' within social equity was arguably left unsolidified within the seminal works that elevated this concept in civic discourse, from a social equity foundation was birthed an extensive collection of transportation research concerned with policies, practices, and designs specific to social exclusion.

Social exclusion is most clearly understood by way of its antonym. Social inclusion is one's ability to participate fully in all aspects, most often framed as activities, of society. Therefore, social exclusion is the result of barriers and limitations to that fullness (Kenyon et al., 2002; Stanley and Lucas, 2008). Social exclusion has also been defined in terms of groups of people rather than individuals and with respect to only certain activities. For example, McCray and Brais (2007, p.398) define the concept as occurring "when sectors of the population are prevented from participating in activities that affect quality of life." In the case of either definition, social exclusion clearly has aspects of space and mobility associated with it. Because of this, transportation services and policies can either hurdle barriers to social inclusion or can exacerbate them (Lucas, 2004; Cass et al., 2005).

Transportation-related social exclusion, sometimes referred to as transport social equity, wed the related concepts of transportation disadvantage, social disadvantage, and transportation poverty. Though many definitions exist and vary slightly among themselves, transportation disadvantage ultimately reflects a condition of limitation in transportation choices resultant from factors of one's environment (e.g. infrastructure quality, information-scape, level of service). Social disadvantage encompasses the elements that impact one's ability to make certain choices due to facets of individual personhood and how those facets play out in society (e.g. limited education or having low-income). Transportation poverty is the overlapping nexus of the two (Currie and Delbosc, 2010; Lucas, 2012; Lucas et al., 2016). Though the principles underpinning these ideas were present in transportation equity scholarship prior to this time, they had not yet been explicitly placed in direct conversation with one another to this degree of clarity and persuasiveness (Lucas, 2004; Farrington and Farrington, 2005; Delbosc and Currie, 2011).

Stemming from this newly cemented foundation of social exclusion framing, the field took on an intensified commitment to understanding the relationship between the physical and spatial nature of being able to reach sites of interest, and the elements of transportation – spatial, infrastructural, or otherwise – that either ease and expand that reach or impede and restrict it. This relationship was eventually termed 'accessibility' (Handy, 2002; Handy and Clifton, 2000; Ewing and Hany, 2009; Van Wee and Geurs, 2011). The ways that accessibility and social exclusion interact can be thought of as follows: poor accessibility could make one subject to a comparatively high likelihood to suffer social exclusion, while those with strong accessibility likely suffer a lesser degree of social exclusion. Though highly related, accessibility has, perhaps for some, a more tangible air to it than social exclusion (Bhat et al., 2000; Preston and Rajé, 2007); accessibility *to* a place or *of* a certain service. It could be this tangibility that motivated what would go on to be over 100 studies from across the globe on measuring accessibility and its disparate extents across identity characteristics published in English and in the first decade of the 2000s alone.

If Robert Bullard was an era-defining thought leader of the previous scholarship period, Karen Lucas was such for this one. Lucas developed the interplay between transportation and social exclusion (Stanley and Lucas, 2008), catalogued its application in practice (Lucas, 2004; Lucas, 2006), and assessed its salience in geographies across both the Global North and South (Lucas et al., 2009; Lucas et al., 2011). As a further colossal contribution, Lucas (2012) provided the field with a visual tool illustrating the flows and interactions between social disadvantage, transportation disadvantage, transportation poverty, (in)accessibility, and social exclusion, as well as the forces of social norms and practices, economic and political structure, governance and decision-making frameworks that shape how these concepts commune with one another. Finally, her work was also some of the first to introduce the sophistication of temporal dynamism to the relating of transportation and social exclusion. This approach highlighted the need to look at equity beyond the past and present, which most work on the subject until that point had done exclusively, but to account for how transportation inequities of today could impact future outcomes and further shape future inequities in a sort of cycle; both for a space, such as a neighborhood, but also over the course of a person's life (Lucas, 2012).

So what did the guiding ideas of transport social equity, social exclusion, and accessibility mean for the field with respect to the four pillars? This era expanded the focus of up-until-then literature when answering *equity of what*. It was during this time that study of 'access to opportunity', a term and idea that would go on to have great influence over transportation equity research and practice for the decades that followed, gained heavy popularity (Sanchez et al., 2003; Cass et al., 2005; Gray et al., 2006; Lucas, 2006). Under this 'access to opportunity' banner, scholars widely explored economic opportunity in the form of jobs and sites of education. Some widened that lens to include accessibility of social opportunity and to social networks as well (Kenyon et al., 2002; Gray et al., 2006; Lucas et al., 2011), though studies with this focus were fewer in number. Digging deeper still, several researchers explored what it means to truly have 'access'. This group of thinkers looked beyond the spatiality of reach and examined equity of availability of information and service affordability (Preston and Rajé, 2007; McCray and Brais, 2007; Currie et al., 2010), plus level of transportation service and quality of transportation infrastructure as well (Litman, 2002; Dannenberg et al., 2003; Boyce, 2010).

On the topic of *equity for whom*, this research evolution tackled race, income, and urbanity/geography, as had work of the decade prior. In addition to those, however, this phase saw an increased focus on gender (Sanchez et al., 2003; Schönfelder and Axhausen, 2003; McCray and Brais, 2007) and disability (Casas, 2007; Litman, 2002; Sanchez et al., 2003), as well as youth and the elderly (Schönfelder and Axhausen, 2003; Titheridge et al., 2009; Cao et al., 2010). To a lesser extent, researchers of the time also highlighted transportation inequities across varied household sizes (Casas, 2007) and across different degrees of housing security (Lucas, 2012).

The previous era of transportation equity left much ambiguity around the determination of an *equity threshold*. This phase added some clarity via the introduction of horizontal and vertical classifications of equity. Horizontal equity holds that people with the same circumstances – which could refer to means as well as to needs or abilities – should be treated in the same way. Vertical equity refers to the idea that disadvantaged groups should receive a greater share of resources – more support – than those not deemed disadvantaged (Litman, 2002). Though still not entirely prescriptive, this framing at least contributed to the concreteness of an accepted equity threshold by arguing that equal treatment amongst alike groups was indeed equitable, and preferential treatment across unalike groups in favor of those with the most constrained set of transportation-related benefits was also equitable.

This framing positions equity as a type of treatment with equality of condition as the implied objective. However, that leaves a question of condition of what (e.g. transportation disadvantage, accessibility, social inclusion) unanswered. Preston and Rajé (2007) offered a potential response. They proposed that the condition of transportation equity is achieve when no one experiences quality of life deprivation as a result of their level of ability to engage with transportation services and infrastructures. Though soft-launched in this era, this idea would take far greater hold in the next evolution of transportation equity scholarship.

Approaches to *measuring transportation inequity* grew in complexity in the early 2000s. Attempts at demonstrating increasingly rigorous and comprehensive accessibility measures occupied much of the research landscape at this time. These different types of accessibility measurements fell into what Clifton and Handy (2001) defined as either cumulative opportunities measurements (e.g. count of points of interest reachable within a set of constraints), gravity-based measurements (e.g. degree of trip difficulty with respect to things like time or financial cost), or random utility theory-based measurements (e.g. determination of likelihood that an individual makes a trip based on its relative utility to a suite of other choices that individual can make). Qualitative measurement methodologies for equity determination were also used to greater extents during this decade than they had been previous by way of travel diaries, focus

groups, interviews, and self-mapping exercises (Schönfelder and Axhausen, 2003; McCray and Brais, 2007; Delbosc and Currie, 2011).

1.2.3 Transportation Justice

With the mid-2010s came a more explicit use of justice-based framing in transportation equity research. This elevated the importance of the role that power, freedom, and their distributions play in transportation realities. Turning once again to the teachings of environmental justice (Golub et al., 2013; Lowe, 2014; Karner, 2016; Beiler and Mohammed, 2016) and adding to that foundation principles pulled from disability justice (Pineda, 2008; Shaheen et al., 2017) and social justice scholarship (Golub and Martens, 2014; Manaugh et al., 2015; Wellman, 2015), researchers of this equity era largely committed to centering morality. This was a marked pivot in focus from shriving for what is 'fair' to what is 'right'. With morality being by no means a one-size-fits-all concept, several different philosophical ideas served as this period's base.

Rawls' Theory of Justice was one such idea. This theory is chiefly concerned with the role of institutions in resource provision of primary goods and services. Rawlsian equality supports concentrated effort (i.e. resource allocation) on maximizing benefit for society's disadvantaged groups once, and not in violation of the point at which, at least a set of 'basic rights' are equally secured for all (Rawls, 1991; Pereira et al., 2017). Phrased differently, this theory holds that an individual's quality of life related to engagement with goods and services, especially that of the socially disadvantaged, should be maximized to the greatest extent possible without infringing upon the basic rights of other individuals, and that a state of justice requires that that set of basic rights be met for all members of society (Rawls, 2001). It also notes that equality beyond a set of basic affordances, while a worthy objective, is likely unattainable as some of our innate, trained, and conditioned differences – and, in the contexts of this discussion, the ways that they relate to transportation behaviors and outcomes – cannot be made uniform by policy, programming, or resource distribution practices.

Another of the era's thought-groundings came by way of the Capabilities Approach to justice. At the heart of the Capabilities Approach, developed by economist Amartya Sen and expanded upon by philosopher Martha Nussbaum, is the conceptualization that *freedom of choice* is the fundamental building block that shapes the quality and fullness of a person's life. 'Capabilities' represent the freedoms – true ability and opportunity – that one has to engage with the suite of 'functionings' that a person could accomplish, achieve, or attain (Sen, 1993; Beyazit, 2011). Here, functionings can be understood as the gamut of experiences a person has reason to value: places they would like to go; things they would like to do, consume, or be. In other words, the suite of desired life possibilities. This approach allows for consideration and assessment of both actualized functionings and the freedom and opportunity (i.e. capabilities) to pursue unactualized functionings (Hananel and Berechman, 2016; Nahmias-Biran and Shiftan, 2020; Azmoodeh et al., 2023).

Justice, then, under the Capabilities Approach, is achieved when a minimum set of capabilities deemed required to live a "full and free life (Hananel and Berechman, 2016, p.83)" is secured by all members of society. Beyond this minimum set of capabilities, differences in suite of life possibilities do not signify an injustice (Nahmias-Biran and Shiftan, 2020). The difficulty in application of this approach enters here, at the need to determine a minimum set of capabilities.

Nussbaum (2007) suggested that capabilities, fall into ten key classifications and that each of the ten are necessary components of any minimum set. She identified these as the Central Human Capabilities. They include: 1) life – which primarily relates to length of life; 2) bodily health; 3) body integrity – which involves ideas related to freedom of movement and physical safety; 4) senses, imagination, and thought – which

includes such things as intellectual and artistic pursuits; 5) emotions and attachments; 6) practical reason – which involves engaging in critical reflection with respect to the planning of one's life; 7) affiliation – which entails being able to live and commune with others in society humanely and respectfully; 8) other species – which involves harmonious coexistence with nature; 9) play; and 10) control over one's environment – which consists of both political and material control. Each of these reflect factors – be they at the social level, the individual level, or across a combination of both – that transportation may contribute to (Cao and Hickman, 2020; Nahmias-Biran and Shiftan, 2020).

Even with Nussbaum's list as guidance, significant difficulties to minimum capabilities set determination persist. Capabilities, by their very nature, are person-dependent, culture-dependent, and society-dependent. That is to say, they are based, at least in part, on the elements of and individual's personhood that impact how they convert resources and opportunities into realized functionings, on their interests and aspirations, and the degree of true freedom of choice that they have, a condition often shaped by external factors such as the built environment and socio-structural dynamics. Though proponents of this approach to justice have stressed that society-specific values and norms must be taken into account when determining a satisfactory minimum (Sen, 2009; Hickman et al., 2017; Cao et al., 2019; Vecchio and Martens, 2021; Azmoodeh et al., 2023), they acknowledge that some degree of assumption making is required and do not offer a strategy for accomplishing this that can be applied in any sort of generalized way.

Additionally, cautioners of this approach warned that because the suite of experiences that one has reason to value is so deeply person-specific, establishing an assumed minimum set of 'full life' capabilities – as a researcher, practitioner, or other actor in such a position of power over others – runs the near-inevitable risk of being highly paternalistic (Pereira et al., 2017). Further issue then arises as paternalism stands in direct opposition to the foundation of this approach to justice, which holds that freedom of choice is the key shaper of one's quality of life. Nonetheless, the principles of the Capabilities Approach to justice, as well as those of Rawls's Theory of Justice, shaped much of the thinking and many of the transportation equity thresholds applied by scholars of this period.

As both Rawls' Theory and the Capabilities Approach demonstrate, this era was not without its ambiguities. Still, scholars of this phase did well to cut down on gray area left behind by previous periods of transportation equity study. They changed their tone from one of somewhat distant exploration to one of action and urgency. They established that decisions made by those with power and authority in the industry can only be one of two things: a contributor to transportation justice or a step away from it, deeper into the field's existing legacies of injustice (Martens, 2016; Shaheen et al., 2019; Lucas et al., 2019; Karner et al., 2020). In other words, one is either actively working toward making things better – more equitable, more just – or one is part of the problem. Scholars upheld this stance of accountability both with respect to research, and in their reflections on practice.

This period also featured a renewed focus on procedural justice, the importance of which was first emphasized by some 20 years prior but received less attention during the age of accessibility. This focus took several forms. Some researchers detailed how participatory planning methodologies are an essential part of any just process (Lowe, 2014; Manaugh et al., 2015; Sagaris et al., 2020). Others shed light on cases in which the lack of inclusion in transportation planning procedures directly contributed to measuredly unjust outcomes (Karner, 2016). Others endeavored to define what a just process must entail: "(1) needs and priorities must be identified through a community-led and appropriately resourced decision-making process, (2) they must be addressed with a dedicated near-term revenue stream, and (3) progress in meeting them must be tracked using appropriate metrics over time (Karner and Marcantonio, 2018, p.107)." Hananel and Berechman (2016) took this definition a step further in specifying that 'community-

led' meant the mandatory inclusion of disadvantaged and/or marginalized groups, especially in the establishment of decision-making criteria.

During this research period, the four pillars were dealt with in the following ways. As they had before, unemployment, health risks, access to education, environmental quality, social segregation, and travel times continued to fall within the collection of transportation-related burdens and benefits prioritized. However, *equity of what* grew to include time unwantedly spent away from home, exposure to crime, noise and visual intrusion, access to healthy and affordable food, as well as transportation-induced economic development (Jennings, 2015; Karner et al., 2020; Anciaes and Jones, 2020).

The second pillar, *equity for whom*, also saw both holdovers and points of expansion. Race (Golub et al., 2013; Lowe, 2014), income (Golub and Martens, 2014; Lowe, 2014), geography (Jennings, 2015), age and disability (Karner, 2016) all made frequent appearances. New identity markers of this era included family composition – for example single parenthood (Beiler and Mohammed, 2016), language proficiency – as compared to the context-specific language of political power (Beiler and Mohammed, 2016; Shaheen et al., 2019), and the temporal identities that influence time-sensitive travel (Shaheen et al., 2017) – such as being someone who works the nightshift.

At the era's onset, Martens et al., (2012) stressed that there was little evidence within the field of *(equity) threshold* setting. Aiming to change that, they proposed the Maximax approach as an equity determination strategy. The Maximax approach establishes that "the gap between the lowest and highest accessibility, both by mode and in space, should be limited, while attempting to maximize average access across all (Martens et al., 2012, p.684)." Support for this strategy was not unanimous among scholars of the time. Some demonstrated preference for a Maximin approach. Those in this camp felt that decision-making and resource allocation should instead maximize the minimum level of accessibility for the worst-off (Pereira et al., 2017). While this treatment would also shrink the gap between the 'best-' and 'worst-off' with respect to accessibility, a goal shared by Maximax supporters, it would not concern itself with prioritizing raising an average accessibility condition. As a result, in a Maximin framework, the 'best-off' could have their accessibility conditions worsened, and transportation equity would still advance as long as the 'worst-off' saw their conditions improve.

Other work, similarly wanting to contribute to threshold setting, proposed the establishment of a Transport Poverty Line (Golub and Martens, 2014). In this method, some minimum capability requirement – for example, let's say one needs to able to access a certain number of employment sites, healthcare sites, grocers, point of entertainment, libraries, parks, and schools – is agreed upon, and any level of afforded capabilities at or above that minimum, even if unevenly distributed, is deemed equitable (Hananel and Berechman, 2016). Golub and Martens (2014) ran a test-case using a transport poverty line of 0.33 across transit and car modes, meaning that transit users have access to one third the number of jobs of car users. They stated that geographies from which transit users have access to fewer than one job for every three car accessible jobs could be consider access impoverished. This transport poverty line approach results in the identification of 'communities of concern' which, the research team suggests, provides practitioners with a way to prioritize their resources equitably. It is worth noting, that the team that proposed this approach did not claim that a benchmark of 0.33 was the *right* ratio, they merely use it as a means of describing the Transport Poverty Line concept.

Producing the most comprehensive review of threshold application the field had yet seen, the team of Lucas et al. (2019) discussed the comparative strengths and weakness of the different aforementioned threshold approaches when set against the ideal of what is 'morally proper.' They categorized the era's threshold options using the following useful groupings: equality, proportionality, minimum standards,

maximum range, and basic needs coverage. Steering the field away from the great getting in the way of the good, this research team also fleshed out the idea of equalization for those wanting to advance transportation justice principles but stalled, perhaps by indecision, lacking measurement capacity, or lacking consensus on concrete benchmarks. Equalization accepts the moving away from current disparity levels without moving toward a yet unagreed upon degree of sameness.

Perhaps the most distinct difference related to *equity measurement* present in this evolution of scholarship compared to its predecessors was the role that research took on in advancing transportation equity beyond academia. In an effort to have research more directly impact practice, scholarship increasingly became judge and juror: project evaluator, and provider of best-practice toolkits (Lowe, 2014; Karner and Golub, 2015; Manaugh et al., 2015; Beiler and Mohammed, 2016; Shaheen et al., 2017). In a sense, this era of transportation equity scholars were hyper-intentional about contributing value not only to the conceptualization and understanding of justice, but also to its operationalization.

1.2.4 Mobility Justice

In the late 2010s and early 2020s, the field zoomed outward slightly, fixing its lens not only on transportation, but on the wider range of actions that constitute all types of human motion. Mimi Sheller established many of the definitions and foundational principles that gave this era its identity. She defined mobility justice as "an overarching concept for thinking about how power and inequality inform the governance and control of all forms of movement (Sheller, 2018, p.14)." This included a first-time focus on factors contributing to stasis, or non-movement, and to forced, involuntary movement. Scholars of this era posited that the capacity to self-determine one's movements – and non-movement – is dependent on intersecting systems of oppression such as racism, sexism, classism, and ableism, and that these intersections often played out in the transportation-related arenas of land use and housing (Sheller, 2018; Cook and Butz, 2018; Tiznado-Aitken et al., 2022). This contributed to greater discussion of mobility justice in the context of things like migration and gentrification.

It was during this period that the need for transportation equity scholarship to try and account for time was most fervently converted into research action. In dealing with the present, that demanded a responsiveness to current social and economic backdrops: "In some ways, neo-liberalization, planetary urbanization, the climate emergency, and now the COVID-19 pandemic have created the 'perfect storm' for questions regarding transport and mobility justice to become placed at the heart of broader discussions around fairness and justice (Verlingheiri and Schwanen, 2020, p.2)." In looking to the past, scholars of this era emphasized that movement does not exist outside of the forces of capitalism, colonialism, and extractivism. As such, they established that mobility justice must concern itself with addressing both ongoing and historical harms (Sheller, 2018; Verlingheiri and Schwanen, 2020; Bierbaum et al., 2021). Application of principles of restorative justice – which entails identifying these harms, measuring their impact, and attempting to atone for them (Rennert, 2016; Karner et al., 2020) – subsequently rose in prominence across the transportation equity research landscape during this time.

Accounting for temporality with respect to future mobility injustices, this period took to researching the ways that injustice embeds on a person and travels through time with them. For example, one study looked at the effects of not having access to a car during youth on adulthood economic outcomes. It found that adults who experienced carlessness as children had lower education attainment, less often worked for pay, and endured unemployment more often than their matched peers who experienced consistent car access during childhood (Ralph, 2018). This piece, and others like it that assessed the impacts of transportation disadvantage over the course of a person's life, spoke to the reality that transportation inequities shape intergenerational transmission of quality of life outcomes. Ultimately, injustice does not exist in a contained instant, and this era of scholarship demonstrated attunement to that fact.

Though not the first instance of research attention given to the topic, this era saw *equity of what* include feelings related to travel experiences to greater extents. Much of this work concentrated on the experiences of safety and security, and related feelings of fear. For example, Weintrob et al. (2021) explored the hidden costs that queer travelers face to be able to travel safely. The research team found that queer travelers often take less cost effective, more private modes of transportation, or less direct routes to avoid known conditions or locations of safety risk to them based on their identity. Similarly, Ralph et al. (2022b) highlighted how the increased likelihood of negative interaction with law enforcement agents experienced by Black travelers in the US contribute to inequities in feelings of fear across racial groups.

Equity conditions related to pressures of removal and dispossession also took on elevated import in this research period (Sheller, 2015; Yañez-Pagans et al., 2019; Enright, 2019). Put more poignantly, McCullough and Erasmus (2023) argued that transportation can be, and indeed has been, fashioned to carry out the violence of displacement. Work on this subject was related to the era's intensified commitment to understanding the unjust inputs to transportation realities (e.g. housing policies dictating segregation), not just the unjust outcomes of and processes active within transportation planning, infrastructure, and decision-making (Verlinghieri and Schwanen, 2020; Sheller, 2018; Tiznado-Aitken et al., 2022).

The mobility justice era brought with it two other major advancements with respect to what equity study ought to concern itself with. First, it took a broader modal focus. Pedestrian-specific transportation equity (Sevtsuk et al., 2022; McCullough and Erasmus, 2023) and cycling-specific transportation equity (Barajas and Braun, 2021; Barajas, 2023) both received more time in the sun – materialized into an increased rate of publication on these subjects – than during pervious scholarship evolutions. Second, it challenged previous presumptions and oversimplifications related to freedom and choice. Scholars of this phase were keyed in to the fact that optionality has value in the world of transportation – even if one only ever selects the same option – and that that value is worth comparing across groups, and that just because certain options are seemingly available to all does not mean that everyone is at the same liberty to act on those options (Sheller, 2018; Weintrob et al., 2021; Tiznado-Aitken et al., 2022). Through these works, the continue influence of the Capabilities Approach to justice – at least in its framing of freedoms, actualities, and possibilities – is made evident.

On the subject of *equity for whom,* this period offered a greater focus on religion and on intersectionality across multiple demographic identities than ever before. For example Mohebbi (2019) looked at the mobility and motility experiences of Muslim women, and Cochran (2020) at those of the disabled elderly. The period also expanded the discussion of queer mobilities (Weintrob et al., 2021) including some of the first explorations of equity specific to trans-mobility realities (Verlinghieri and Schwanen, 2020; McCullough and Erasmus, 2023). Study of freedom of movement by citizenship status was also expanded during this time (Cao et al., 2019; Liu et al., 2021; Tiznado-Aitken et al., 2022; Barajas, 2023). As was interest in determining equity across visitor identities – for example comparing travel experiences of tourists, with comparatively extensive freedom of movement, and migrants, with comparatively limited movement freedom (Sheller, 2018).

The restorative equalization standard was presented as a worthy *equity threshold* in this era. Restorative equalization "requires prioritizing historically disadvantaged communities to receive a disproportionate share of benefits to mitigate prior inequities (Karner et al., 2020, p.442)." Though this premise had been discussed as much as a decade earlier, this era termed the idea and added clarity to it, moving from framing of the 'least well-off' to the 'historically disadvantaged'. This era also increased the emphasis placed on inclusive process established by the prior scholarship era to a call for redistribution of decision-making power away from institutions and political actors toward communities (McCullough and Erasmus, 2023;

Lowe and Jones, 2023). Without this, some scholars of the time noted that justice efforts could only really be considered performative (Lowe et al., 2023).

Regarding *measurement techniques*, familiarity was prioritized during this phase. Inequality indices popular in economics, and in some cases more mainstream, such as the Gini coefficient, Palma ratio, and Lorenz curve were not uncommon in studies of this time (Cao et al., 2019; Gori et al., 2020; Karner et al., 2023a). Though less widely used, methods of equity measurement like the Atkinson index, the Pietra ratio, the Schutz coefficient, and the Theil index also made appearances in this era (Cao et al., 2019). This heightened borrowing of analytical methodologies from other fields would continue into the next evolution of transportation equity scholarship.

1.2.5 The Era of Wellbeing

Since 2020, there has been a significant uptick in focus on wellbeing within transportation equity research. Scholars of this present-day period have emphasized the power that systems of mobility have to impact meaning-making. Originating in psychology, meaning-making refers to the process by which we make sense of life events, understand relationships, and construe our sense of self (Park, 2010). Some researchers have proposed that through their roles in meaning-making, transportation and systems of mobility affect our ability to experience joy, feel respected, to be hopeful about the future, even to internalize a sense of purpose (Dargin and Mostafavi, 2020; Verlinghieri and Schwanen, 2020; Pereira and Karner, 2021; Karner et al., 2023a; Karner et al., 2023b). They go on to suggest that these effects are frequently subject to inequitable distributions. Others have argued that transportation inequities impact not only our individual wellbeing but also our societal wellbeing. More specifically, social cohesion (Mouratidis and Poortinga, 2020; Liu et al., 2023); whether we hold shared values and view one another, particularly those we perceive as different from ourselves, as comrade or competitor, ally or adversary.

In thinking about how this era relates to the thematic timeline of transportation equity scholarship, it is important to note that much like mobility justice was not a break from transportation justice – rather, it enveloped transportation justice as but one of its many parts – transportation-impacted equity of wellbeing is similarly not a break from the previous period. It, too, sits nestled within the world of mobility justice.

Thus far into this scholarship era, e*quity of what* has grown to include measures of life satisfaction. Work from Ralph et al. (2022a) offers demonstration of this. They find that life satisfaction is negatively associated with travel time costs, that people with disabilities inequitably suffer travel time cost premiums as much as 50 percent higher than travelers without disabilities, and that this cost premium translates into a transportation-impacted life satisfaction depreciator. This period has also gone beyond the notions of enjoyment and comfort while travelling previously touched on in both the transportation justice and mobility justice eras, introducing equity of transportation-impacted dignity and life-fulfillment (Karner et al., 2023b; Lewis et al., 2021) in addition to the related subject of meaning-making previously mentioned.

There has also been a circling back to concentration on race and income similar to that which typified the 1990s. This hyper-focus regarding the pillar of *equity for whom* could be fueled by the fact that equity crises along the lines of race and income are particularly pronounced in much of the world at the moment, well beyond the subject of transportation. Rising fascism and xenophobia has contributed to budding civil unrest (Mamun and Griffiths, 2020; Beck, 2022). As have skyrocketing costs of living, housing insecurity, and economic instability (Krstic et al., 2020; Ding et al., 2022; Aurand et al., 2023) – the burdens of which are routinely disproportionately shouldered by low income and of color communities. These crises all work their way into transportation planning, services, and decision-making. Scholars may be responding to this as best they feel they can by spotlighting inequities experienced by communities specifically within these worst-affected identity groupings.

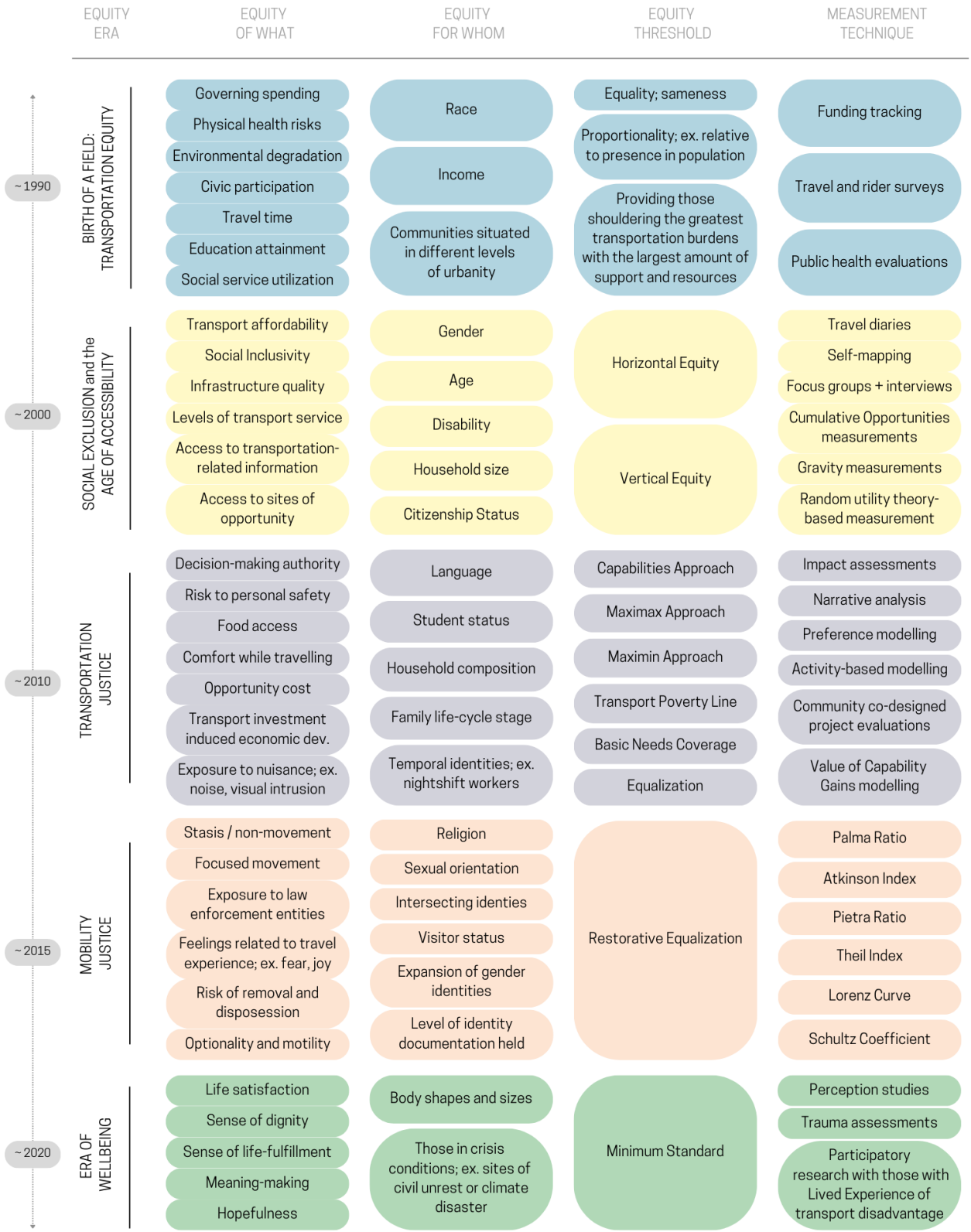
Both egalitarian and sufficientarian approaches to *equity thresholds* have been adopted in the current research phase. Egalitarianism concerns itself with equality. That can mean a sameness of treatment, of access, or opportunity, and/or of outcomes for all members of society. Sufficientarianism is not so much interested in relative inequalities as in meeting of a minimum acceptable standard for all identity cohorts (Pereira and Karner, 2021; Karner et al., 2023a); the Capabilities Approach is one example of a sufficientarian framework. It makes sense that these two approaches to justice have found traction in the era of wellbeing as they are particularly convincing from a public health perspective. Afterall, what gap in, say life satisfaction or hopefulness between members of different races, those with different levels of education attainment, or body size could reasonably be deemed acceptable? The framing of a 'reasonable gap' alone presents a sizable moral, to say nothing of political, problem (Lewis et al., 2021).

Advances in *measurement techniques* of this era largely sit in the realm of epistemic justice. Epistemic justice relates to knowledge: whose knowledge is valued, what information constitutes knowledge, to whom is information provided, and to what degree is that information truly accessible. Exhibited to greater extents than in earlier phases of transportation equity scholarship, this era of wellbeing championed lived experience as valued expertise. Take for example this statement from work by the team of Lowe et al. (2023, p.3) as evidence to this point: "Beyond its utility in understanding actually experienced accessibility, we make a normative claim for valuing lived expertise held by structurally disadvantaged people." The research team used focus groups to understand how BIPOC and low-income riders feel about their travel experiences across a range of metrics, and how those reflections compared to what transportation providers had in the planning pipeline relevant to those same communities.

Work like Lowe et al.'s (2023) that featured self-reporting on mobility experiences are indicative of another era-specific change related to measurement technique: the increased treatment of perceived realties as valid, actionable, desirable data. This newfound valuation has resulted in a handful of perception studies – many of which borrow self-reported wellbeing assessment techniques from the field of psychology – having already been published in this young transportation equity scholarship era (Vanderschuren et al., 2019; Oviedo and Sabogal, 2020; Ralph et al., 2022a; Barajas, 2023; Nadimi et al., 2023). Additionally, Liu et al. (2023) highlight that one key reason that perception of mobility justice and equity is so important is that our perception of how benefits from transportation resources and investments are distributed can affect our views toward one another, in turn impacting our social unity. In this sense, they suggest that perception could be key to mending societal rifts or to further dividing us. With such potentially socially transformative findings, more perception studies are sure to come as this scholarship period matures.

Figure A presents a cumulative – read from top down as building from 1990 onward – distillation of the transportation equity scholarship landscape as detailed in this section. This landscape visual does not claim to be an exhaustive list of every equity-related element ever to appear in the literature. Rather, it captures the most commonly featured and era-defining elements in English published research on the subject across each era delineated by each of the four pillars of equity posed at this section's opening.

Figure A: Summary of transportation equity scholarship landscape since 1990.
Features in each column are cumulative as you read downward. Each of the 5 eras includes the elements of the previous era.



1.3 TRANSIT EQUITY AS I SEE IT

The review of the previous section naturally leads to the question of how my work is positioned within this thematic landscape of transportation equity scholarship. The four projects that comprise this dissertation all sit under the banner of what I am calling transit equity. The rationale informing use of this term begs further explanation. En route to that explanation, two questions surface.

Question one: why the transit-specific focus? Across much of the last 30 years, there has been a fixation with looking to transit as the great inequity solution. Transit has been tasked with leveling the playing field and righting the wrongs of other – almost always single occupancy vehicular – modes and urban development practices. This assumes that transit is, in itself, equitable. In short, it isn't. One train station's art features and soundscape are not necessarily as enjoyable as that of another, the cleanliness and heat protection enjoyed by riders using one bus stop may not be available to those of another. Even within transit, there are distributions of benefits and burdens that warrant close attention. My work looks at these within-transit inequities; identifying them, measuring their magnitudes and impacts, highlighting the broader implications of those impacts, and offering solutions to mitigate and minimize them. I take this on because I agree with those who champion transit's mighty capacity for social equity advancement at large. It is because of this great potential power that more intramodal study of transit is needed to offer more finely tuned solutions.

Question two: why an equity and not justice framing? My justification for this choice is two-fold. For starters, Karner et al. (2020) and Enright (2019) both note that 'transportation justice' is more commonly used among activities, advocates, and community organizations, while 'transportation equity' is the phrase of choice among governing actors. Informed by this observation, and the fact that my primary intended audience are public sector decision-makers and planning practitioners, I position my work under the equity umbrella in hopes of giving my work the best chance possible of reaching its intended audience and falling on receptive ears..

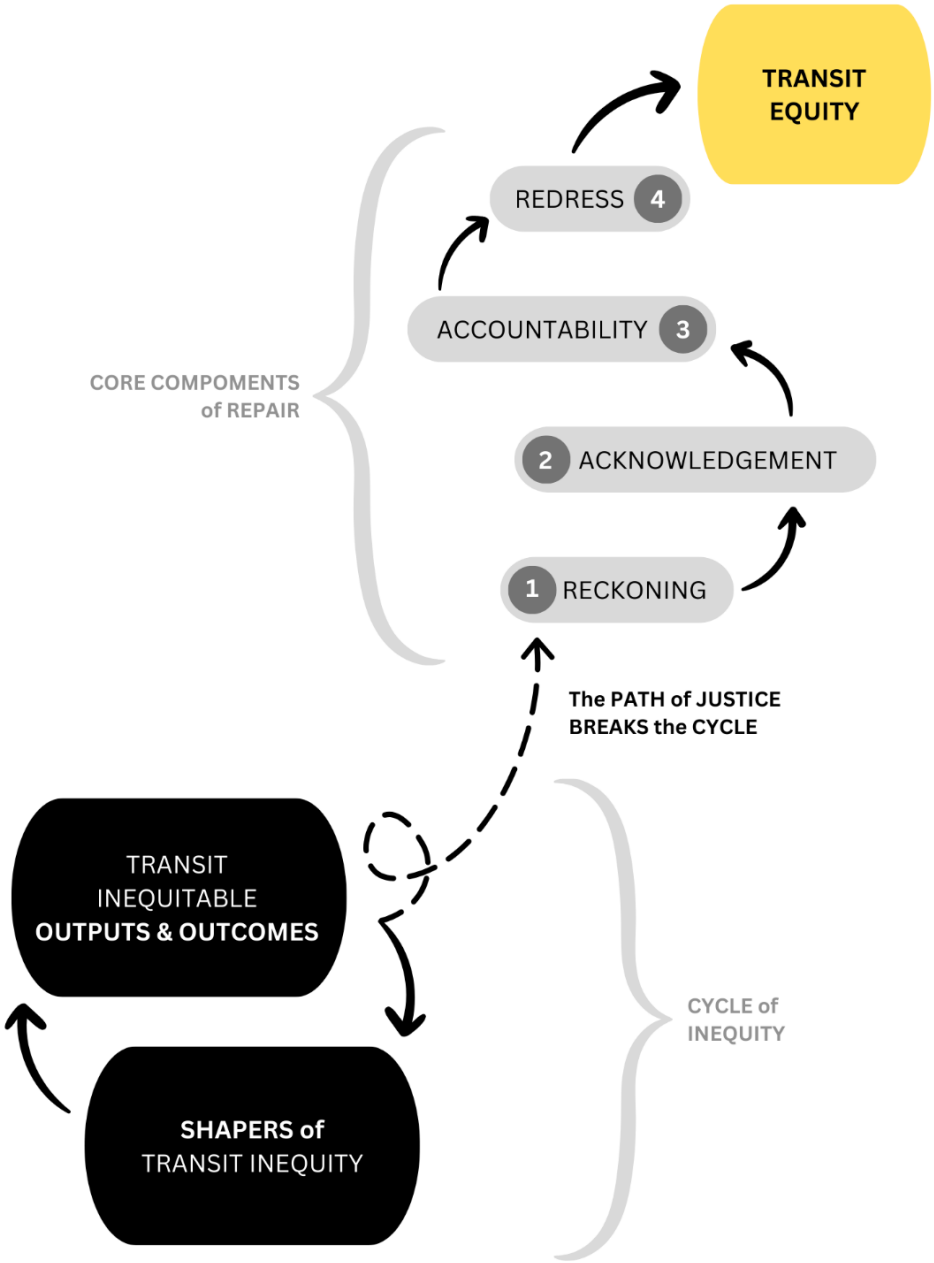
Additionally, while some scholars have taken the stance that "justice cannot be achieved without equity (Pereira and Karner, 2021, p.275)," the inverse of that statement has greater resonance with me. I see justice as the set of actions needed to reach a state of equity. In this sense, equity is a condition, an outcome, and in so is passive, a noun. Justice is dynamic, demanding energy and doing, a verb. One could also think of it in the following way: to reach what is fair (i.e. equitable), we must do what is right (i.e. just). This conceptualization of the relationship between justice and equity draws from scholarship, teachings, and philosophy if trust building through solidarity movement building (Wolterstorff, 2015; Brown and Akin, 2016; Kandi, 2021; Wise, 2021). I offer Figure B as illustration of the journey from our current state of being locked into a cycle of transit inequity to a future state of transit equity by way of justice in alignment with this framing.

The four elements of justice shown in Figure B are an adoption of the 'core components of repair' established by Liberations Ventures, a field-building organization committed to achieving reparations for Black residents of the US (Florant, 2023). The importance of each of these components in achieving social repair for past and ongoing harms – which transit-related equities can reasonably be cited as having contributed to in much of the world, certainly in the US – has been articulated by experts across the disciplines of reconciliation (Datta, 2019; Wilson-Raybould, 2022), forgiveness (Satne, 2022; Green, 2024), and civic peace (Santa-Barbara, 2007; Biletzki, 2012).

Reckoning deals with understanding. In this case, that entails deepening our knowledge of what transit inequities are, what systems have facilitated their proliferation, who the winners and losers of these systems

have been, and what have been the magnitudes of their impact. Acknowledgement demands admission of harms done. Collective understanding that transit inequities exist and are wrong need be voiced by those that have both suffered and benefitted from them. Accountability deals with ownership. It involves entities of power taking responsibility for their roles in supporting transit inequities. Finally, redress speaks to acts of restitution. This includes things like rehabilitation (e.g. healthcare provision for those living near highways, establishing vegetation planting minimum requirements along rail right-of-ways), recompense (e.g. subsidized fares for divested communities, property gifting to those displaced by mobility infrastructure projects), and reform (e.g. reprimand and removal of leadership of agencies found to violate mobility-related civil rights, convert some appointed positions governing transportation choices to elected ones, change decision-making processes). As I see it, all four components of repair – applied to a given place's particular context – are vital parts of justice work needed to reach transit equity.

Figure B. Journey to transit equity – *read from bottom left to top right corner*



Keeping this framing in mind, my vision of transit equity treats the four pillars in the following ways. On the subject of *equity of what*, transit equity maintains attention to the many transportation-related benefits and burdens centered over the different eras from 1990 onward (see Figure A). That said, though all the elements listed in Figure A are important, I do not pretend to focus on all of them in equal measure. As a part of this dissertation specifically, my transit equity research engages with wealth creation capacity (paper 1), user and non-user costs (papers 1 and 3), travel behavior (paper 4), travel experience (papers 2, 3, and 4), civic participation (paper 3), mental health (papers 2 and 3), and safety and its perception (papers 2 and 3).

Regarding *equity for whom*, again I continue the focus established by previous eras on different combinations of identity elements. I center factors such as income, level of urbanity, age, gender, employment and student status, disability, access to different types of vehicles, and household size across my four empirical pieces. However, as a whole, these works concentrate race most poignantly, with further elevated focus on transit realities facing Black America.

Where my approach to transit equity steps most away from an alignment with previous eras is the third pillar: *equity threshold* setting. I argue that a principle I am calling Reparative Maximization should be prioritized by those working to break from ongoing cycles of transit inequity. This idea is perhaps best explained via discussion of how it relates to particularly prevailing approaches to equity threshold setting from previous eras of transportation equity scholarship, namely those of restorative equalization and the Capabilities Approach.

Reparative Maximization is much like restorative equalization – foundational to both the Mobility Justice research era and the Era of Wellbeing – in that it concerns itself with accounting for past inequities and wrongdoings across the three key parties of the wrongdoer, the wronged, and the collective geo- and socio-spaces they inhabit; these spaces have been called different things, such as 'community' and 'society' (Menkel-Meadow, 2007). The two are also alike in that they call for a preferential treatment, or reception of a disproportionately large share of benefit, for disadvantaged parties and the redistribution of decision-making power away from its current holders and legacy positions toward the historically and systematically disenfranchised (Karner et al., 2020; Lowe and Jones, 2023).

They differ, however, in their ultimate objective. Restorative equalization has also been termed restorative correction. This assumes that there was a point at which – before transportation decisions were made and resources allocated – 'correctness' existed and, by way of different decisions and allocations, can be returned to. Or it assumes that past and current conditions of inequity and injustice can be made objectively correct (Martens and Golub, 2021). Reparative Maximization does not share these assumptions. Rather, it holds that what has been done can never be undone or made right (Rennert, 2016). However, through reckoning, acknowledgement, accountability, and redress, relationships across members of society – in this case as they relate to transit-impacted aspects of life – can be improved to the point that they are made well. Here, 'correctness' and its implication that some sort of moral (justice) or fair (equity) point of actualization exists, is not the objective. Reparative Maximization, by being relational, instead holds healing between differently advantages members of society as its core objective.

Reparative Maximization also holds points of alignment and dissention with the Capabilities Approach, which has informed much of the transportation equity literature with respect to threshold setting over roughly the last fifteen years (Hickman et al., 2017; Vecchio and Martens, 2021). Reparative Maximization is similar to the Capabilities Approach to justice in that one's conditions of personhood are chiefly important in determining what a state of fairness entails, and that freedom of choice is a critical unit of import regarding influence over quality-of-life.

These two thresholds are dissimilar in where they concentrate power. As previously detailed, in the Capabilities Approach, power is concentrated in the hands of the advantaged (e.g. the state, the institution, the corporation, even the researcher), as that is who ultimately decides what constitutes a minimum acceptable standard of capabilities for a 'full' life. The problematically paternalistic nature of this has been stressed (Wright, 2000; Pereira et al., 2017).

Reparative Maximization avoids the pitfall of paternalism by having power most concentrated in the hands of the wronged. More specifically, in this approach, the benchmark of repair – what processes, what distribution of outcomes and freedoms of choice is acceptable – is determined collaboratively by disadvantaged and advantaged persons, but with a specific set of roles. The disadvantage party in a given scenario ultimately sets the terms of 'acceptability'. Maximization, however, requires willful concession of the advantaged party to this set of terms. Unwilful compliance with benchmark terms does not maximize repair, though it may still contribute to more equitable distribution of outcomes. In this approach to threshold setting, the state of equity being strived for is a condition in which all members of society can self-report feeling that they receive fair treatment from others as well as from entities of authority, occupy a fair station in society, and are subject to a fair suite of life possibilities. Reaching such a condition both requires interpersonal and social healing of wounds past dealt and is unquestionably transportation-related.

It is important to note that the empirical work in this dissertation does not explicitly set out to operationalize Reparative Maximization. As previously stressed, these four works have the chief objective of responding to questions pressingly facing transit practitioners in their current planning and policy work. Rather, the recommendations for practice that each project offers based on the findings drawn from its respective analysis are shaped in accordance with Reparative Maximization principles. In other words, the Reparative Maximization approach to transit equity that I have proposed here serves as the theoretical North Star for what are four very practical transit planning research questions.

With respect to *measurement techniques*, the final equity pillar, my vision of transit equity as actioned by the four projects that make up this dissertation uses two methods seldom used in previous scholarship eras. I run a meta-analytic regression model (paper 1) and a photo-simulated randomized control trial (paper 2), I also use some tried and true techniques widely deployed in previous eras. Those include focus groups (paper 3) and travel diary analysis (paper 4). The rationale behind the selection of these methods of analysis are the focus of the next section.

1.4 BRIEF OVERVIEW OF METHODS

Each of this dissertation's four papers was designed with a practitioner-motivated question in mind. Collectively, they are all housed under the larger, overarching questions of: How can transit practitioners work toward advancing transit equity with greater confidence that these very actions will not inadvertently worsen social inequity and social injustice conditions either within or beyond matters of transportation? What information, tools, understanding, relationships, and resources would foster this confidence, particularly as it relates to race?

Though overviewed in the section below, the most comprehensive discussion of research methods used, including specific discussions of researcher positionality and project limitations, can be found within the 'Methodology' section of each empirical studies' respective chapter.

1.4.1 Methodology Overview

In pursuit of the previously mentioned research aim, four distinct, practice-centric research questions were explored. The first of which was: What factors explain the wide variation found across transit proximity premiums on residential property values, what role do levels of transit service play in the magnitudes of those premiums,, and how can past premiums research be utilized as a predictor of yet un-studied premiums? A meta-analysis was deemed best-suited to answer these questions. A meta-analytic regression model – also referred to as a meta-regression – is a quantitative method of combining the results of independent studies who share a common objective and synthesizing their conclusions (Borenstein et al., 2021). Others who have studied the impact that proximity to transit may have on property values have used methods the likes of difference-in-differences (DID) estimators, hedonic pricing models such as an ordinary least squares approach (OLS), and structural equation modelling (SEM).

A difference-in-differences method has the benefit of serving as a pseudo-natural experiment, or system shock – like the opening of a new subway station – whereby one can attribute the observed difference between a treated and untreated group before and after said shock to the shock itself. This cuts down on the potential for capturing confounding contributors within one's measure of effect size (Dubé et al., 2018; Wing and Dreyer, 2024). However, because of the conditions needed to run this model, such as a scenario where the assumption of parallel trends between treatment and control groupings hold (Ryan et al., 2019), results from this analysis approach tend to be hyper-local. DID also requires a system shock with available data corresponding to a sufficient amount of time before and after the change (Dimick and Ryan, 2014). This can be a major challenge to acquire.

Both OLS and SEM approaches present potential for gaining insight into the relationship between proximity to transit and property values. However, that alone did not make them reasonable choices for this analysis. The literature on OLS and other forms of hedonic pricing models warns that this type of analysis may not be appropriate for direct comparisons across different housing markets, and that using it for such purposes invites significant amounts of bias into one's model (Chau and Chin, 2003). Structural equation modelling, which combines the principles of multiple regression and factor analysis, allows for examination of both causal pathways – observed effects – and interdependencies among variables – latent effects (Thakkar, 2020). This gives it an advantage over an OLS approach regarding suitability to the research question of interest. However, the accuracy of SEM has been found to be particularly sensitive to sample size, requiring a large number of inputs to render sufficient certainty of outcomes (Schumacker and Loma, 2004; Tomarken and Waller, 2005; Freeman and Zhao, 2019). This presents a significant risk to the quality of any analysis with a small n, which, an n of 100 or fewer could reasonably be considered.

Meta-analysis offers several advantages over these methods, advantages that made it particularly conducive to the specific research question and larger research aims of this work. For one thing, a meta-analysis methodology is apt to explain conflicting results across studies (Lee, 2019). This is particularly important as results from the transit proximity premium research vary widely, including findings of no significant effect, significant negative effect, significantly yet minimally positive effect, and significantly and sizably positive effect. Additionally, meta-analysis can speak to a wide range of contexts, as opposed to a single, localized scenario. In other words, it supports some degree of generalizability (Finfgeld-Connett, 2010). This serves the research aim of this dissertation by lessening the capacity requirements of practitioners who want to investigate this question in their own contexts yet might have analytical skill or data availability gaps, or who want to be able to compare their context to others. Finally, meta-regression allows for analysis of effect size based on both previously studied measures (i.e. moderators) as well as newly added ones (Ewing and Cervero, 2010). Given that the question governing this research calls for both an explanation of past findings and an examination of newly introduced, transit service-related

moderators, this feature of meta-analysis is particularly useful. Because of these many advantages in suitability, a meta-regression was ultimately selected over potential methodological alternatives.

In actioning this method, literature informing this meta-analysis was identified using Scopus. The following keys were used: "transit proximity premium"; "proximity to transit and land value uplift"; "impact of transit on property value"; "proximity to rail on property values"; "accessibility to transit and property prices"; and "impact of transit investment on property prices." This resulted in the identification of 178 relevant publications. Using snowballing technique, an additional 41 resources were identified, totally 219 publications for initial inclusion in this analysis. These studies were then made subject to a set of model-specific inclusion criteria (see page 51 for comprehensive discussion of inclusion criteria). This was the final stage of input determination and rendered 66 transit proximity premiums for use as meta-regression inputs. Further detail regarding how this methodology was carried out can be found on page 51.

The second research question tackled was: How do COVID-19 safety measures (CSM) in transit spaces affect travelers' worry of COVID-19 infection, and how do the conditions of transit spaces themselves influence this effect? To answer this, a photo-simulated randomized control trial was run using a specialized research platform (www.urban-experiment.com) designed for image-based experiments. Different widely deployed CSM – more specifically, face mask use, physical distancing, risk reduction behavior information dissemination, and the provision of hand sanitizer – were introduced into photo-simulated scenarios. In these scenarios, these CSMs were positioned across different transit modes and within different physical spaces that one is likely to encounter while traveling via transit in the cities that this research focused on. Images of these spaces were further modified to reflect varied CSM combinations and varied levels of compliance – no one in the image complies, some people in the image comply, everyone in the image complies – with CSM regulations. Worry of COVID-19 infection was then measured using the psychometric scale developed by Taylor et al. (2020) to determine the level of perceived risk of infection that project participants associated with each scenario they engaged with (all images used in the project can be found on page 96). Mixed regressions, fixed-effects and random intercepts, were then used to identify significant differences in worry across these varied conditions of CSM type, transit spaces, and CSM compliance levels.

Participation in this randomized control trial was carried out in three stages. Stage 1: all participants signed an online consent form and completed a questionnaire on demographic and socio-economic characteristics, travel patterns and mode choice behaviors, and self-assessed COVID-19 vulnerability. Stage 2: participants were randomly assigned to one of three conditions; two of which were treatment groups, one of which the control group. Stage 3: participants rated 19 (out of a potential 76) randomly assigned photo-simulated scenarios. For each photo-simulated scenario, participants rated their worry in the presented space on a ten-point scale: from 'not at all' to 'extremely worried' about contracting COVID-19. Additionally, each participants rated their worry in several scenario images of empty transit spaces (featuring no additional travelers), which served as the baseline worry of COVID-19 infection for each participant and in each type of transit space.

Participant recruitment was conducted online through paid social media advertisements restricted to people over 18 years of age and located in London (United Kingdom), Milan (Italy), and Santiago (Chile), with the results gathered between November 10th, 2020 and January 10th, 2021. Cities from both hemispheres were intentionally selected as seasonality had been found to impact the number of active COVID-19 cases (Liu et al., 2021), and in so, worry too was hypothesized to be seasonally affected. Furthermore, these three cities were selected because they were the sites where the three researchers conducting this work were located and where they had the greatest capacity for setting up the social media

advertising relationship instrumental in the dissemination of information regarding opportunity to participate.

A total of 564 people participated in this study: 49.3% of participants were from Milan, 40.3% from Santiago, and 5.8% from London. An additional 4.5% of respondents are from other cities in the world, as the link must have been reshared on social media beyond the cities of interest. This 4.5% of responses were dropped from the analysis. The resultant participant cohort produced 11,283 image ratings, with an average time of 5 minutes and 37 seconds taken to complete the experiment. No payments were offered to participants. Participants accessed the experiment through a link on their device (desktop, tablet, or mobile phone) and were prompted to read the study protocol, and all participants signed an online informed consent form prior to being sorted into a treatment or control group and rating their randomly assigned photo-simulated scenarios. Further detail regarding how this analysis methodology was carried out can be found on page 72.

Other methods for conducting this work were considered, but fell short of offering the many advantages present in the photo-simulated randomized control (PSRCT) methodology. The most seriously considered alternative approach involved running a pilot and conducting a subsequent survey or interviews with riders. Pilots host the benefit of more realistic experiential conditions than other, simulated, experiment methods (McAslan et al., 2021). This can be particularly important in studies related to feelings (Mutz, and Müller, 2016). Additionally, one of the greatest advantages of pilot projects is their capability for risk or uncertainty reduction in the eventual full adoption of a program or policy, as they facilitate end-state program and policy design decisions based on direct observation (Turner, 2005). Both of these methodological benefits would suit the context and guiding questions of this particular study well.

However, setting up a pilot directly within transit spaces would require an agreement with transit agencies to test different CSM across their systems. At the time in the COVID-19 pandemic during which this project was conducted, agencies were largely focused on keeping riders safe. Functionally running a real-world experiment involving riders' wellbeing during a global state of emergency did not feel appropriate, nor did it feel conducive to the objective of maximizing rider safety. Also, in a pilot format, the researcher capacity requirements would has have been much larger to be able to survey or interview riders on their feelings across a big enough sample size of different transit spaces, different CSM policies, and different levels of compliance.

With these limitations in mind, a PSRCT rose to the fore as the clear frontrunner approach for this work. A PSRCT would support the collecting of worry data from current transit riders, would-be riders, past riders who have left the system, and 'never' riders as well as, unlike a pilot, participants would not need to directly be positioned within the transit network to experience the range of test conditions. This is hugely useful for transit practitioners, as mode shift toward transit is an ongoing goal of essentially any transit providing agency or sustainability-committed planner. With that goal in mind, one can see how, to a transit planner for example, knowing how potential patrons feel (worry, in this case) about the system is nearly as important and knowing how current patrons feel. Relatedly, a PSRCT facilitates the analysis of both actual and imagined realities. This, too, is useful for practitioners in particular as this method allows them to gain a sense of rider worry levels of approaches that they may not yet have implemented, saving the trial portion of trial and error that would be present in, say, a pilot.

Perhaps PSRCT's most notable comparative advantage is its allowing for the weighting of worry to be done at the per person level (Navarrete-Hernandez et al., 2021). As previously mentioned, all participants ranked a base case scenario of least worry. All of an individual's responses were then gauged in relation to their own response to the lowest COVID contraction risk condition. This removes the potentially

confounding factors that different elements of personhood, which could have nothing to do with CSM, may have on responses that participants log related to worry. Because of the deep breadth of research finding that indeed feelings of emotions like fear, stress, anxiety, and worry in public space are conditional on elements of personal identity and how those elements are treated within society (e.g. Carmona, 2010; Yavuz and Welch, 2010; Loukaitou-Sideris and Ehrenfeucht, 2011; Pain and Smith, 2016; Ratnayake, 2016), this capacity of PSRCT alone made it the best methodological option for this work.

Third of this dissertation's four lines of questioning was the following: How do Black community leaders in Boston understand the potential use of camera enforcement for traffic and transit roadway violations? To gain insight into this, a series of virtual focus groups were run. Six virtual focus groups, each ranging from 90 to 115 minutes long, dependent on participant schedules, were convened. These groups were comprised of community leaders who all racially self-identified as Black. In this case, 'community leaders' referred specifically to individuals who served in an elected, unpaid capacity on the boards of Boston neighborhood associations. These individuals are entrusted with acting on behalf of their constituents and neighbors. They host community meetings, are tasked with information dissemination, and are entrusted to collect concerns held by their constituents. Knowing that these individuals were accustomed to thinking beyond themselves, sharing collectively held views, and prioritizing community wellbeing, it was hoped that featuring them would allow amplification of many more Black voices, a sort of multiplier effect.

Participant recruitment entailed the following. 103 Boston neighborhood associations were sent an email invitation to participate in this research pending their eligibility: having at least one elected board member who identifies as Black. As of November 1st, 2021, when invitations to participate were drafted, this list of 103 encompassed all active neighborhood associations in Boston with a public-facing web-presence of any kind: website, Facebook page, mention on the official City of Boston's neighborhood-specific information web pages. This initial wave of invitation emails resulted in 44 responses. Of these, 25 respondents self-identified their association as ineligible due to not having any Black board members. The 19 eligible respondents expressed interest in participating; all of whom were eventually included in the project's participant cohort. One month after the initial invitation was sent, a follow-up invitation was sent to all neighborhood associations who had not yet responded. This second wave of recruitment resulted in an additional eight eligible participants interested in being included in the research. In total, this process rendered 27 total focus group participants representing 22 different neighborhood associations. For further detail regarding how this process was carried out as well as researcher positionality to the group of participants, see page 104.

In addition to having the benefits of being comparatively inexpensive, flexible, and quick to set up when conducted virtually (Robson and McCartan, 2016), focus groups have several advantages over one-on-one interviews, which were also considered as a method of analysis for this work. Focus groups have proven particularly useful in situations where the topic of interest was awkward, taboo, or highly politicized as less inhibited members may break the ice or provide support, encouraging active participation (Hopkins, 2007). Camera enforcement could certainly be considered as one such topic (Wall and Linnemann, 2014). That classification becomes ever more sensitive when race is introduced into the equation. Another relevant strength of the focus group methodology is its allowance for learning via the back-and-forth communication of participants. The value of this is well exemplified in the following passage: "Had the data been collected by interviews the researcher might have been faced with 'arm-chair theorizing, but in a focus group, ideas can be explored 'in situ' with the help of research participants (Kitzinger, 1994, p.107)."

The logistical design elements of this project's focus groups were shaped both by advised best practices, and operational practicality. There is little consensus among scholars regarding the ideal number of participants for a fruitful focus group. However, the range of no fewer than two and no greater than twelve

encompasses the full set of advised group sizes found, with between five and eight participants most regularly cited as preferable (Fern, 1982; Osborn, 1953; Krueger, 2002; Merton et al., 1956). Because of this peer advice, and the sense that 90 minutes would not be enough to comfortably create enough space for eight participants to contribute fully, intention was placed on forming groups of five or six. Schedule alignment among participants was such that five groups of five community leaders each, and one group of two were what was feasible.

Transcripts from these focus groups were then made subject to a thematic analysis. Thematic analysis is a highly iterative process that seeks to uncover salient themes in a text at different levels through the creation of a set of thematic networks (Attride-Stirling, 2001). These networks can be thought of as web-like links between ideas that build upon one another, traveling toward the identification of primary themes central to the description of the phenomenon of interest (Daly et al., 1997). Within the thematic analysis framework, an inductive analytical approach was taken. Within the thematic framework, an inductive analytical approach was taken. This entailed the application of a data-driven interpretation by which the raw transcripts were read many times over to allow themes to emerge (Boyatzis, 1998). Inductive analysis was selected because it takes on an exploratory orientation and is often applied when attempting to decipher meaning-making and understanding (Guest et al., 2014), as opposed to deductive, or confirmatory analysis which is hypothesis-driven, allowing the researcher to study a specific idea or hypothesis that they have generated prior to any data analysis (Crabtree and Miller, 1999). Given the specific research question of this work, an exploratory lens was favored to the explanatory one.

Additionally, thematic analysis' demonstrated rooting in excerpts from the raw data ensures that interpretation remains directly linked to the words of participants (Patton, 1990); a principle central not only to the establishment of rigor and credibility, but also central to the respecting of research participants (ibid; Thomas and Harden, 2008). Finally, thematic analysis, when adequately documented, lends itself well to being built upon by future research (Nowell et al., 2017). Aware that this work could never claim to have exhaustively examined the relationships that camera enforcement has with race and transportation – neither in the context of the US nor beyond it, it was deemed important that this research be conducted in such a way as to encourage furthered exploration of the topic.

The final practice-focused research question taken on within this dissertation was as follows: How have the gentrification-associated elements of race, age, and income changed as predictors of transit mode choice in the Washington DC metropolitan area during the last two decades of rapid gentrification? Exploration of this question was carried out using data from a regional household travel survey paired with travel diary data from 2007 and 2017. Changes in transit use predictive strength of a collection of characteristics (e.g. personal, trip, work and school policy, built environment, transit service accessibility, and household characteristics) across the decade was assessed using a binomial logit model. The gentrification-related characteristic of race, income, and age (Kirkland, 2008; Finio, 2022) were focused on specifically. Additionally, these changes in transit predictive strength were broken out into different trip purposes. This included work and school trips, errands, leisure and dining trips, and a grouping of 'all other trips' that did not fall into any of the previous three categories. Any trip made using rail, bus, or paratransit services was defined as a transit trip.

Data collection for this analysis involved contacting the National Capital Region Transportation Planning Board and the Metropolitan Washington Council of Governments (the Washington DC-area metropolitan planning organization) via email with a data request. This MPO has conducted a random-selection regional household travel survey approximately every ten years since 1968. The two most recent of these pertain to 2007 and 2017 and include personal travel diary information as well. Furthermore, this decade spans

the period of fastest rate of gentrification for the DC region (Richardson et al., 2019), making these years of travel data particularly fitting for this analysis.

This two-part data collection process, which covered 22 jurisdictions across the states of Virginia and Maryland and the District of Columbia, rendered a dataset that captured demographic and journey information at the household, person, and individual trip levels. A household travel survey – part 1 – and personal weekday travel diary – part 2 – combined to paint a comprehensive picture of how people in the DC Metropolitan Area, at this time, were making trips of every type. An example of what types of information each of these two parts provided is as follows: the household travel survey gave information on household size, number of vehicles available, whether or not a household had children in it; the personal travel diary gave information about age, race, travel mode, workplace- and school-offered transportation subsidies, trip time of day, and trip purpose at the level of the individual and geography of the census tract. Unique identification numbers allowed for the linking of trip, personal, and household level data across the two data collection instruments.

In preparing the data, certain exclusion criteria were employed to minimize the effect of outliers and to ensure that all inputs used were appropriately comparable across the two data collection years. Trips were excluded in the following cases: (1) if any part of their household survey or travel diary was filled out incompletely or was missing geo-spatial information; (2) if a trip was made as part of professional driving (e.g. truck or ride-hailing drivers; note that the ride-hailing trip would be counted, but in the passenger's trip log not the drivers); (3) if a trip origin was located outside of the DC Metro Area (defined by the 22 jurisdictions served by the MPO); (4) if travel was logged for someone under the age of 5; (5) if a trip lasted over 3 hours; (6) if a trip destination purpose was defined as 'return home'. This inclusion determination process resulted in 81,949 trips across 10,718 households in 2007 and 117,965 trips across 16,855 households in 2017.

Logistic modelling is a particularly widely applied method across research related to travel behavior and mode choice (e.g. Ton et al., 2019; Ko et al., 2019; Ha et al., 2020; Shin, 2020; Dong et al., 2022). A multinomial logit model was considered. This would have offered the benefit of being able to assess not only changes in transit use but changes in use across different modes of transit (Al-Salih and Esztergár-Kiss, 2021). Ultimately, this was decided against due to inconsistencies in data tabulation and classifications related to transit modes between the 2007 and 2017 collection efforts.

It is important to note that while travel surveys and travel diaries offer many benefits – for example, they are collected at regular intervals, what information gets collected is typically highly standardized, participants are randomly selected, and they cover a wide geography because data collection is administered by the MPO as opposed to by a city, town, or the transit provider, all of whom have smaller service areas – they are not the best means of analysis for topics related to gentrification and travel behavior. Arguments in favor of using displacement as the key-most piece of gentrification-related research have been eloquently made (Brown-Saracino, 2017). Those taking this stance largely recommend running longitudinal panel studies; multi-year studies that follow the same set of individuals over time, monitor their outcomes, and engage – either via survey or interviews – with them regularly (Laird, 2020). This approach would be a borrowing of methodology from fields such as health, climate and environment, and economics, all of which conduct this type of research more often does than the world of transportation scholarship.

This methodology offers many advantages. Firstly, it drastically lessens the risk of confounding influences impact on measure effect size (Elliott et al., 2008; Hikichi et al., 2021). In this case, it would allow for greater confidence in attributing observed changes in transit use to the hypothesized influence of gentrification, by

way of displacement. Secondly, longitudinal panel study would allow for being able to separate travel behavior changes that are voluntary from those that are forced (Kearns and Mason, 2013; Adhikari et al., 2020). This is important to practitioners as it allows them to know where and to whom resources need to be concentrated to best expand traveler choice and freedoms, compared to those who, in not choosing to use transit, are already enacting their freedom of choice.

Panel studies are not without their significant shortcomings. In conducting these projects, it can be difficult to maintain engagement with participants over time. Issue of attrition are stressed across the literature relevant to this type of research design (Young et al., 2007; Wu and Jia, 2021). On top of that, these studies, though rigorous and rich is the certainty of outcomes they provide, are lengthy, multi-year processes. Though actioning this type of analytical approach would have been preferable to the method ultimately chosen for this work, the timeline capacity needed to execute this effectively was unfortunately not feasible within the confines of doctoral study. For additional detail regarding the methodology deployed in search of an answer to the specific research question guiding this project, see page 137.

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CHAPTER 2: Paper I

A Meta-analysis of the Impact of Rail Stations on Property Values: Applying a Transit Planning Lens

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2.1 INTRODUCTION

We derive value from transit services. That value can take many forms. For example, time savings (Bajic, 1983; Leclerc et al., 1995), direct financial savings (Lewis-Workman and Brod, 1997; Dunphy et al., 2004), optionality (Weisbrod, 1964), sentiments of pride and belonging (Hidalgo and Yepes, 2005), or simply comfort and convenience (Fu and Juan, 2017). Whatever its source, a portion of that value gets absorbed by property markets and is reflected in pricing. The extent to which this relationship manifests is impacted by, among other things, our ease of access to transit systems. One determinant of that ease is spatial distance: proximity.

The body of literature discussing the impact that proximity to transit stations has on property pricing, a phenomenon that will be referred to from here on out as a 'transit access premium', is extensive. Since 1970, over 200 studies have been published on the subject, most focusing specifically on rail. The access premiums found within these rail studies vary widely. Some have identified slightly negative premiums (Du and Mulley, 2007; Nelson, 1992; Landis et al., 1994); meaning that being located proximately to rail stations has a depreciating effect on property price. Others have found no significant evidence of a premium at all (Gatzlaff and Smith, 1993; Clower and Weinstein, 2002; Adair et al., 2000). The lion's share of studies, however, have uncovered positive access premiums. Yet even within this group, there exists a sizable range of findings. Some studies have uncovered positive rail access premiums below 2% (Cervero and Duncan, 2002; Gu, 2007; Lewis-Workman and Brod, 1997) while others have found premiums in excess of 40% (Cervero, 2006).

How does one explain such wide variation in premium magnitudes found across the rail access literature? Despite a rich collection of case study findings, few have tried to systematically put these studies in conversation with one another in such a way as to provide generalizable conclusions about the nature of transit's relationship with property markets. To date, only four attempts at such an analysis have been made. These efforts, all of which utilize a meta-analytic regression approach, have focused on explaining the variation in the effect size of premiums through examination of built environment contextual factors, temporal factors, modelling techniques, rail type (e.g. light, heavy), property type, and data treatment. Surprisingly, none have assessed how variations in the conditions of transit service might impact associated premium magnitudes. This work, which also deploys a meta-analysis methodology, chiefly concerns itself with filling this gap in the literature.

Building on the four previously conducted rail access meta-analyses, this work contributes to our understanding of the transit-access/property market relationship in the following ways: it includes premiums data spanning four decades, 1980 to 2020, where the most previously looked at was three; examines the potential impacts of the Global Financial Crisis of the late 2000s; and widens an otherwise US-centric body of research to include 18 countries across four continents. Finally, this work's primary contribution comes from its expansion of the field's collection of premium-influencing variables with the introduction of 10 new moderators pertaining to demography, housing policy, and, most extensively, transit service – e.g. frequency, fare, reliability. By introducing these features of transit planning, this work answers the call made by Landis et al. (1994) and Xu and Zhang (2016) for an increase in the applicability of premiums research outside of scholarship. It also positions transportation planning practitioners as active agents in a relationship within which they have previously been treated as passive or reactionary.

This study finds that factors pertaining to geography, housing data type, race and ethnicity, rent control policies, rail type, transit cost, and transit network expanse all significantly affect rail access premiums ranging in absolute value magnitude from 0.21 to 9.6 percentage points.

The relevance of transit access research like this has most commonly been framed in terms of 'value capture' – a public financing mechanism that facilitates the recovery of some or all of the value that public infrastructure generates for private landowners (Smith and Gihring, 2006; Sharma and Newman, 2018; Cordera et al., 2019). Ending the discussion there fails to highlight that understanding the specific ways these factors impact the transit-access/property-market relationship is vital to the ongoing struggle for equitable urbanity. The dynamics explored here host socio-spatial implications regarding market-driven displacement and gentrification (Baker and Lee, 2019), current widespread trends in the suburbanization of low-income communities (Bailey and Minton, 2018; Allard, 2017), and, consequently, increased transportation subsidization of the wealthy.

This paper is structured in the following way. Section 2 showcases primary findings from the literature. Beginning with a discussion of case studies, it highlights points of disagreement as well as those of general consensus. The section then turns its attention to summarizing the meta-analysis literature. Section 3 looks at model design addressing inclusion criteria, definition of moderators, and meta-analyses as a methodological approach more broadly. Section 4 presents results. Section 5 concludes with a discussion of the implications of findings as well as uncovered opportunities for future research.

2.2 LITERATURE REVIEW

2.2.1 Case Study Literature

Rather than catalog the specific rail access premiums uncovered by the many case studies under this research umbrella – an effort already undertaken by several others (Diaz, 1999; Goetz et al., 2009; Du and Mulley, 2007; Hess and Almeida, 2007; Forouhar and Hasankhani, 2018) – this section is instead dedicated to an exploration of how rail access premium studies differ as well as what commonalities exist across them. This serves to establish a foundation upon which to build a comprehensive meta-analysis model.

2.2.1.1 Explaining Difference

Perhaps the most stark divergence in magnitude among premium findings exists along the lines of property type. Rather intuitively, the land-use classification of the property in question – residential versus commercial, for example – influences access premiums. The same is true of whether one is discussing sale prices or rental prices, single versus multi-family housing, and whether one is using price data associated with actual transactions or from an assessor's database. While the ways that these different typologies perform in relation to one another is not completely uniform, commercial access premiums are generally much larger than residential property premiums, and multi-family premiums tend to be larger than single-family premiums. Their prominence within the literature varies as well. Due largely in part to data availability, transaction data is used more often than assessor's data, and the number of studies dedicated to housing sales far outweigh those of housing rentals or commercial property sales (Duncan, 2008). These variables influence the calculation of premiums, and therefore need to be acknowledged in any discussion of variation among premiums within the literature.

Contextual factors of time and place also have a hand in premium determination. It is reasonable to propose that in our present day, sustainable modes may be more highly valued than in times past as efforts toward Environmental Justice and Going Green gain popularity (Kumar et al., 2012). This temporal influence may also be interacting with geographical ones. Though examples of this line of research hail from every rail-hosting corner of the globe, certain regions have dominated the literature at different points in time. Prior to 2010, rail access premium studies were primarily US-centric. To put that claim into perspective, of the 66 studies used as inputs within this meta-analysis, 64% of those published prior to 2010 analyze US rail networks. Of those published between 2010 and 2020, analyses of Chinese rail networks

make up the largest share of studies, accounting for 32%. This shift in focus comes as no surprise as Asia-Pacific nations, China in particular, have expanded their rail transit offerings through the addition of both new stations and the opening of entirely new systems at a rate far eclipsing any other region of the world over the last decade (International Association of Public Transport, 2019; Zhou and Zhang, 2021). This place-time relationship across the literature may serve as a further explanatory factor of the range of access premiums measured.

The influence of geographical context doesn't end there. Mobility behavior, a crucial piece in the access premium puzzle, varies from one place to the next. Different levels of dependence on, affection for, as well as comfort and familiarity with transit services across much of Europe and Asia over car-centric locales in the US and Australia, for example, likely contribute to varied values placed on living proximately to rail services across these areas (Taylor and Fink, 2013).

Neither the impacts of time and differences in travel behavior, nor the differences in data type, fully explain the wide range in positive rail access premiums found. Differences in measurement methods and analytical models play a part as well. In tackling the question of how proximity to rail stations impacts property price, different studies have taken to measuring 'proximity' in different ways. Some have measured proximity continuously in linear distance extending outward from a station to the point at which an impact is no longer discernible (Hess and Almeida, 2007; Golub et al., 2012; Lewis-Workman and Brod, 1997). Others have applied distance bands radially surrounding a station. Each band exclusionary of the one prior, for example 0-250m followed by 251-500m, and all properties within a given band assumed to experience the same premium (Xu and Zhang, 2016; Mayor et al., 2012; Dubé et al., 2014; Zhang et al., 2014).

A third 'proximity' measuring technique applies a single radial buffer and measures the average value difference of properties within that station-area catchment buffer – i.e. treatment group – compared to those beyond it – i.e. control group (Diao et al., 2017; Martinez and Viegas, 2009; Du and Mulley, 2007). Adding nuance to this approach, some studies have used a propensity scores matching technique to determine treatment and control areas (Yen et al., 2019; Perdomo, 2011). Rather than assume that just because an area falls beyond a certain distance from a station that it makes for a suitable control spatiality, this method uses a probit model featuring neighborhood characteristics to match statistically comparable areas near stations to those outside station catchment zones. The different assumptions about the uniformity of premiums across space that these measurement techniques make likely contribute to the wide range of premiums found.

Similarly, a multitude of analytical strategies have been deployed in the effort to unpack the question of value impact. Three different model types dominate the literature. Hedonic price modelling is used most widely. This highly versatile method allows for the attainment of many observations of property values but is highly susceptible to failings of omitted variable bias (Diao et al., 2017). In an effort to mitigate this susceptibility, several studies have deployed a repeat-sales approach (McMillen and McDonald, 2004; Welch et al., 2018; Ge et al., 2012; Zhou et al., 2021). This model compares sale prices of the same property across different time periods. Studies that use this model compare the changes in sale prices of properties proximate to rail stations to the changes in sale prices of properties falling outside of a determined station access zone. Though this model avoids the endogeneity issues of the hedonic price model, it falls subject to sample selection bias, suffers from generally low numbers of available observations (Wang and Zorn, 1997), and fails to account for the influence that any renovations or improvements to the property made between measurement cycles have over its change in value.

In recent years, a difference-in-differences (DID) approach has gained popularity (Gibbons and Machin, 2005; Mohammad et al., 2017; Im and Hong, 2018; He, 2020). This quasi-experimental approach allows

for the treatment of proximate access to a rail station to serve as an exogenous shock, capturing both observed and unobserved impacting factors. The limitations of this model lie in its data and condition requirements. Its appropriate use calls for property sale data from before a station was introduced to a neighborhood as well as after it became operational and that the composition of treatment and non-treatment groups before and after the station-access shock remain stable (Dubé et al., 2014). Case studies that have examined both a DID model and a hedonic price model subject to the same study parameters find that DID modelling techniques demonstrate lower access premiums (Mohammad et al., 2017; Trojanek and Gluszak, 2018). Any attempt at a cross-study comparative analysis of access premiums would need to include accommodations for modelling variations such as these.

2.2.1.2 Drawing from Convergence

It has been widely observed within the case study literature that the relationship between rail access and property price is subject to a nuisance effect. This effect suggests that being situated within roughly 250m of a station may in fact be a dis-amenity. This has been attributed to station-area noise – both people and train generated, heightened levels of pollution, and an increase in the presence of 'loiterers' linked to the perception of increased crime (Chen et al., 1998; Golub et al., 2012; Ke and Gkritza, 2019).

Consistent findings have also been made with respect to the proximity limit at which access to a rail station no longer has an impact on property values, and at which specific point within this impact zone access premiums reach their peak. Irrespective of varied location contexts and analyses methods, premiums were nearly never observed to extend beyond 2km from a station. Most commonly, the upper extent of impact zones was measured to be 1.6km with steep decreases in premiums occurring after 1-1.2km (Chalermpong, 2007; Duncan 2011; Zolnik, 2020). Similarly, shared findings of premium peaks around 500m from stations, about a five minute walk, abound (Wen et al., 2018; Martinez and Viegas, 2009; Wang, 2016).

Both the pedestrian environment surrounding stations and the type of rail service available at stations further impact access premiums. The quality of the journey from property to station – influenced by the presence of elements like tree canopy coverage, attractive street furniture, high visibility crosswalks, varied and small-scaled commercial offerings, lighting, etc. – consistently has a positive effect on access premium size (Duncan, 2011; Xu and Zhang, 2016). Additionally, premiums associated with commuter rail service tend to be significantly larger than those linked to light rail or metro service (Landis et al., 1994; Cervero and Duncan, 2002; Zhong and Li, 2016). One justification for this may be that many commuter rail services are co-located with highway infrastructure access points; a reality that only about 50% of case studies account for. Scholars such as Voith (1993) have found that access to other, non-transit mobility facilities is also capitalized into property values. In this sense, commuter rail accessible properties may be reaping the value uplift effects of both rail and highway proximity. It could also be attributed in part to a larger competitive advantage with alternative modes. Trips taken via commuter rail tend to be longer than trips taken on light rail or metro services and more closely align with peak congestion travel times (Yu and Machemehl, 2010). As a result, the car alternative for these trips may be particularly unappealing – the costs (financial, comfort, convenience, etc.) associated with long drives, parking, and heavy traffic may make the train mode choice an exceedingly valuable option.

A second tier of less widely explored factors that nonetheless offer shared findings across the case study literature are similarly worth drawing upon to inform the design of a robust meta-analysis of rail access premiums. These include attention paid to the influences that neighborhood demographics, relation to central business districts (CBD), and perception of distance have over the construction of value. Among studies that included income in their analysis, there is general agreement that neighborhood income characteristics of the station area have a significant impact on access premiums. The directionality of that impact varies, however. While some studies have found that higher income areas experience larger

premiums (Brandt and Maennig, 2012; Siripanich et al., 2019), others have found that premiums are larger in lower income areas (Forouhar and Hasankhani, 2018; Wang, 2016). Conversely, great uniformity has been found regarding the way that neighborhood racial and ethnic composition influence rail access premiums. Across studies from North America, Europe, the Middle East, and Southeast Asia alike, the larger the percentage of minority or foreign born persons in a station area neighborhood, the smaller the premium (Pan et al., 2014; Landis et al., 1994; Dziauddin et al., 2013; Cervero and Duncan, 2002; McMillen and McDonald, 2004; Brandt and Maennig, 2012).

The case of consistent findings of significance accompanied by varied directional impact on premiums applies to station proximity to a CBD. Some – for example Efthymiou and Antoniou's (2013) study of Athens and Ma, Ye, and Titheridge's (2014) study of Beijing – have found that for stations outside of the CBD, premiums decrease as distance from the CBD increases. Others, particularly those from US cities that experienced post-industrial urban flight the likes of Hess and Almeida's (2007) study of Buffalo, found that premiums increase as station distance from the CBD increases.

Finally, perception of closeness was occasionally explored and found to be more impactful over access premiums than actual closeness with respect to travel time to station (Armstrong, 1994). This idea evolved in more recent studies and took the form of examining the difference in transit premiums measured along a street network distance from stations versus a straight-line (Euclidean) distance. Network distance measurements commonly render smaller access premium values than straight-line distance measurements (Hess and Almeida, 2007; Dziauddin et al., 2013). This is counter-intuitive. While 500 meters, for example, of street network distance from a station may take 5 minutes to traverse on foot, 500 meters of straight-line distance almost always corresponds with more than 500 meters of actual on-foot travel. With both distances falling beyond the nuisance effect impact area, the shorter distance should render a higher premium. The fact that it does not speaks to the power of perception – homeowners may be perceiving the travel times of straight-line distances and street network distances differently. The research team of Krizek et al. (2012) found that for journeys of 1 to 5 minutes, traveler estimates of trip time along network distances were only 51% accurate and tended to be overestimations while straight-line trip time estimates were 63% accurate and tended toward underestimations. Similar findings rang true for journeys 6 to 10 minutes in length. This relationship between distance measurement type and perceived travel time no doubt interacts with questions of proximity-dependent value, and therefore premium magnitudes.

2.2.2 Meta-analysis Literature

A handful of scholars have tried to combine the disconnected pieces of this rail access premium puzzle to provide a systematic, causal explanation of the variation in findings across the case study literature (Debrezion et al., 2007; Hamidi et al., 2016), and to explore how factors potentially omitted from the case study literature might contribute to the nuance in our understanding of transit infrastructure-impacted property pricing (Mohammad et al., 2013; Park et al., 2016). They have each deployed meta-analyses as their method of choice in this endeavor.

Meta-analysis is a regression approach that synthesizes previous studies focused on a common research question to derive conclusions about that body of research (Haidich, 2010). In addition to being well suited to identifying sources of diversity of findings across related studies (Cook et al., 1992), this approach offers the benefits of the ability to enhance the power of small or inconclusive studies (Turner et al., 2013) and to detect deficiencies in the design, analysis, and interpretation of research (Ioannidis and Lau, 1999). This approach is not, however, without its limitations. Because the analysis is dependent on other research as its primary inputs, it is highly susceptible to publication bias – an occurrence in which the results of research impact the likelihood of that research to be published, and therein, made most readily available (Dickersin,

1990). Though often a difficult task due to inaccessibility, this issue may be circumvented through the inclusion of unpublished research within the meta-analysis input data (Melo et al., 2009).

Despite the many benefits of a meta-analytic research methodology, only four efforts at this type of analysis with respect to rail transit access premiums have been undertaken to date. Due to differences in variable definition and regression design, the impact coefficients found within these studies cannot be cross-compared directly. However, the significance and impact directionality of the moderators featured in each are indeed comparable and are summarized in Table 1. As a collection, they each feature a different set of strengths worth highlighting and learning from.

Beyond pioneering the use of a meta-analytic approach to analysis of the impact of proximity to transit stations on property values, Debrezion et al.'s (2007) work offers impressive clarity in its model design and recommendations for how best to interpret meta-analysis findings. This work also explores two different treatments of an access premium – one treating distance from a station as continuous and another using a single station-area buffer. This both allows for comparison across the two most widely used measurement methods within the case study literature and provides practitioners wishing to make use of these findings with options of varied applicability.

Drawing from Debrezion et al.'s study, Mohammad et al. (2013) introduce additional explanatory moderators into their analysis, widen their input dataset by including land sale pricings, and expand the geographical lens of relevance applied to this line of research by incorporating studies from not only North America, but Europe and Asia as well. This piece also succeeds in avoiding publication bias by including unpublished research as model inputs.

Three years after Mohammad et al.'s work, two additional meta-analyses were published that both placed specific focus on the contextual influences that the built environment and urban form may have over the relationship between transit access and property value. Hamidi et al. (2016) propose that both population size and density of case study cities may be impacting access premiums – a reasonable assumption based on the notion that both the number of participants in the property market and density of those participants could shape demand within that market. Park et al. (2016) similarly embrace the potential power of built environment factors by testing a wide range of New Urbanist design ideals as access premium moderators. Including population and compactness measures, as Hamidi et al. did, Park et al.'s study adds to the literature an exploration of land-use diversity and roadway density, and expands on Mohammad et al.'s already impressive number of observations collected as input cases.

Despite different contributions with respect to best practices, there are a number of commonalities across the findings from this body of literature. For example, in every meta-analysis that featured it as a moderator, the mode classification of commuter rail was always found to have a significant and positive impact on access premiums (Debrezion et al., 2007; Mohammad et al., 2013). Variables measuring accessibility for non-transit vehicles – for example highway access – were similarly consistently significant, regularly demonstrating negative impacts on premium magnitudes (Debrezion et al., 2007; Mohammad et al., 2013; Park et al., 2016). Finally, in all cases that accounted for them, both zoning characteristics (Debrezion et al., 2007; Mohammad et al., 2013; Hamidi et al., 2016; Park et al., 2016) and semi-log as compared to linear model treatment (Debrezion et al., 2007; Mohammad et al, 2013) proved significant.

The rail access premium meta-analysis constructed within this study builds upon a foundation largely informed by these four works.

Table 1. Rail access premium meta-analysis literature summary

Study	Geo.	Studies Used	Total Obs.	Premium Interpretation	Moderators Analyzed	Lu	Z	M	Di	Dt	T	B	Tr	Ph	A	Sd	Significant Moderators	Reference Case for Dummy Moderators and Impact Direction	
Debrezion et. al, 2007	US	-	55	Property value premium experienced within 400m of a station	12	x	x	x	-	-	x	-	x	-	x	x	Commercial Property	Residential Property	+
																	Commuter Rail Mode	Light Rail	+
																	Accessibility Variables	Models without	-
		-	57	Property value premium experienced every 250m closer to station													Commercial Property	Residential Property	-
																	Commuter Rail Mode	Light Rail	+
																	Bus Rapid Transit Mode	Light Rail	-
																	Semi-log Model	Linear Model	+
																	Accessibility Variables	Models without	-
																	Race or Income Variables	Models without	-
Mohammad et al., 2013	Asia Europe North America	23	102	Land/property value premium experienced 501-805m from a station compared to land/properties more than 805m away	28	x	-	x	-	x	x	x	x	x	x	-	Study of Property Value	Study of Land Value	-
																	Commercial Property	Residential Property	+
																	Commuter Rail Mode	Light Rail	+
																	Stabilized System	Systems less than 1yr old	-
																	Accessibility Variables	Models without	-
																	Europe	North American studies	+
																	East Asia	North American studies	+
																	Cross Sectional Data	Panel or Time Series	-
																	Semi-log Model	Linear Model	-
																	Double-log Model	Linear Model	-
Hamidi et al., 2016	North America	45	81	Single-family property value premium experienced every 100ft closer to a station	9	-	-	x	-	x	x	x	x	-	-	-	Distance to station	n/a	+
																	Squared station distance	n/a	-
																	Published after 2002	Published 2002 or before	-
																	Compactness Index	n/a	+
Park et al., 2016	US	52	139	Property value premium experienced within 400m of a station	17	x	x	-	x	-	-	x	-	-	x	-	Distance to Institutions	n/a	-
																	Population Density	n/a	-
																	Dwelling Density	n/a	-
																	Ratio of Industrial Use	n/a	-
																	Street Density	n/a	-
																	Land-use Diversity Index	n/a	+

Moderator Categories Featured Meta-analyses

Lu: Land-use Typology, **Z:** Zoning Distinction, **M:** Regression Model Type, **Di:** Distance Measurement Distinctions, **Dt:** Data Type, **T:** Time effects, **B:** Built Environment Characteristics, **Tr:** Transit Mode Distinction, **Ph:** Phase of Transit Intervention, **A:** Non-transit Accessibility, **Sd:** Socio-demography

2.3 METHODOLOGY: Meta-analysis Design

2.3.1 Input Studies

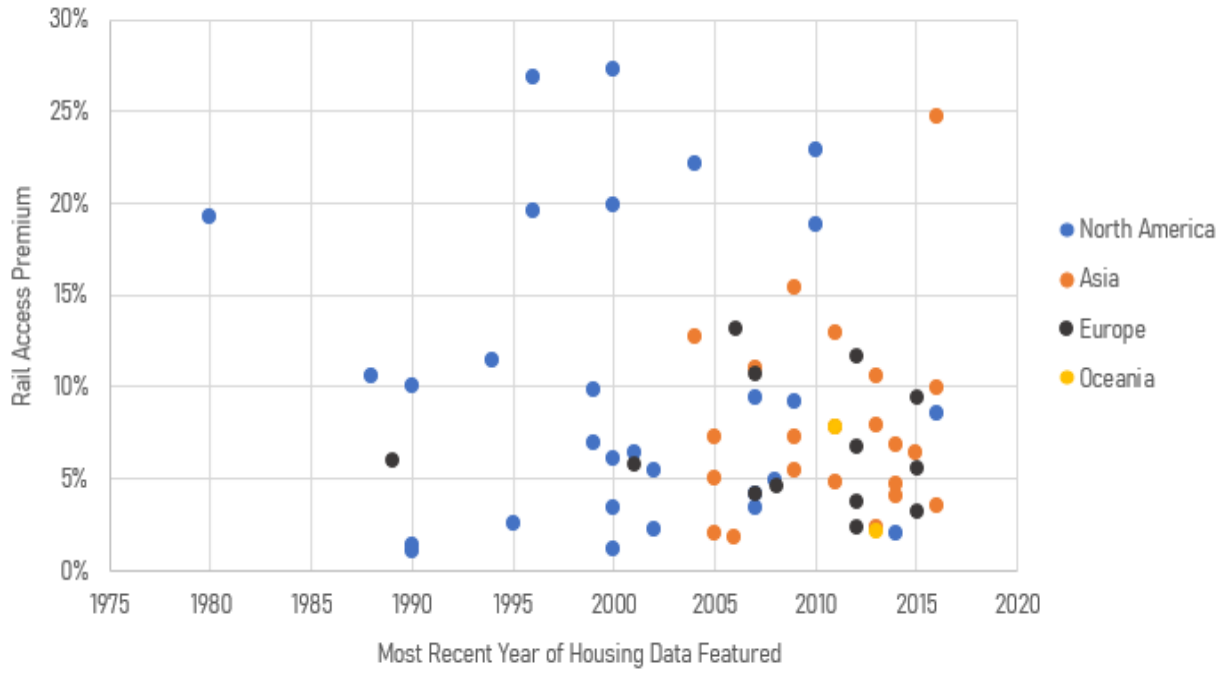
To be included within this meta-analysis, case studies had to adhere to the following criteria. No access premium based on an examination of fewer than five rail stations, or that did not include housing characteristics (e.g. property size, number of bathrooms, property age, etc.) was included. All premiums were based on residential zoning and sale pricings. Only premiums based on property values were used. This excluded the few case studies that derived access premiums from analyses of land values. These choices were based on the performance of rental, non-residential, and land-value treatments in prior studies and the belief that these treatments represent fundamentally different markets (Ahlfeldt et al., 2019; Hilber and Vermeulen, 2016). In most analyses that include these elements, they take on outlier qualities – e.g. land-value access premiums have been found to reach magnitudes of as much as 120% (Cervero and Duncan, 2002).

The case study premiums included all applied to fully operational transit systems. While some studies have found that value absorption of rail investment into the housing market is realized as early as the announcement phase of a project, findings are not consistent as other studies find high volatility in both capture magnitude and significance level during all pre-operational phases (Gatzlaff and Smith, 1993; Billings, 2011; Golub et al., 2012; Ke and Gkritzka, 2019). Though transit takes many forms, only premiums pertaining to rail-specific modes were included here. This was done because different modes have distinctly different scopes of influence with respect to how access to them is internalized by the property market. For instance, while rail stations generally experience a nuisance effect within 250 meters of a station resulting in a depreciation of property values, bus stations are generally found to either not have a discernible access premium at all, or to only have a measurable impact up to about 300m (Mulley and Tsai, 2016). Finally, only studies in which premium standard errors were provided or calculable were included, as these were required for weighting within the meta-analysis regression.

In order to be able to conduct this meta-analysis and draw findings from its result, all input premiums needed to be measured in comparable units. This comparable unit consisted of two parts. Firstly, all premiums needed to take the form of a percentage change in property value. While many were calculated this way in their original case studies, several premiums were reported as changes in monetary values (e.g. in $US). In these cases, conversion was necessary. This was accomplished by comparing the property values at the station-area point of interest to the average property values at points determined to be outside of the station-area impact zone. This segues into the second part of the determination of a comparable premium unit. In this study, the access premium was defined as the value of properties situated 500m from a rail station – specifically, at 500m not within 500m – compared to those situated beyond 1.6km from a station. The selection of these distances as points of interest for comparison was based on findings from the case study literature. These findings identified that 500m represents the point at which premiums tend to experience their peak value while 1.6km represents the point at which most studies no longer experienced a discernable impact of station proximity on property prices. This premium definition can be internalized in more tangible terms in the following way: the difference in property value that comes from living about a five minute walk away from a station versus a twenty minute walk away from one. Case studies in which insufficient information was provided to calculate this comparable unit were excluded from the analysis.

This dependent variable definition and set of inclusion criteria resulted in a collection of 66 premiums gathered across 46 studies that ranges from 1.1% to 27.3%. How this range behaves temporally and geo-spatially is depicted in Figure 1.

Figure 1. Rail access premium by most recent year of housing data used in case study



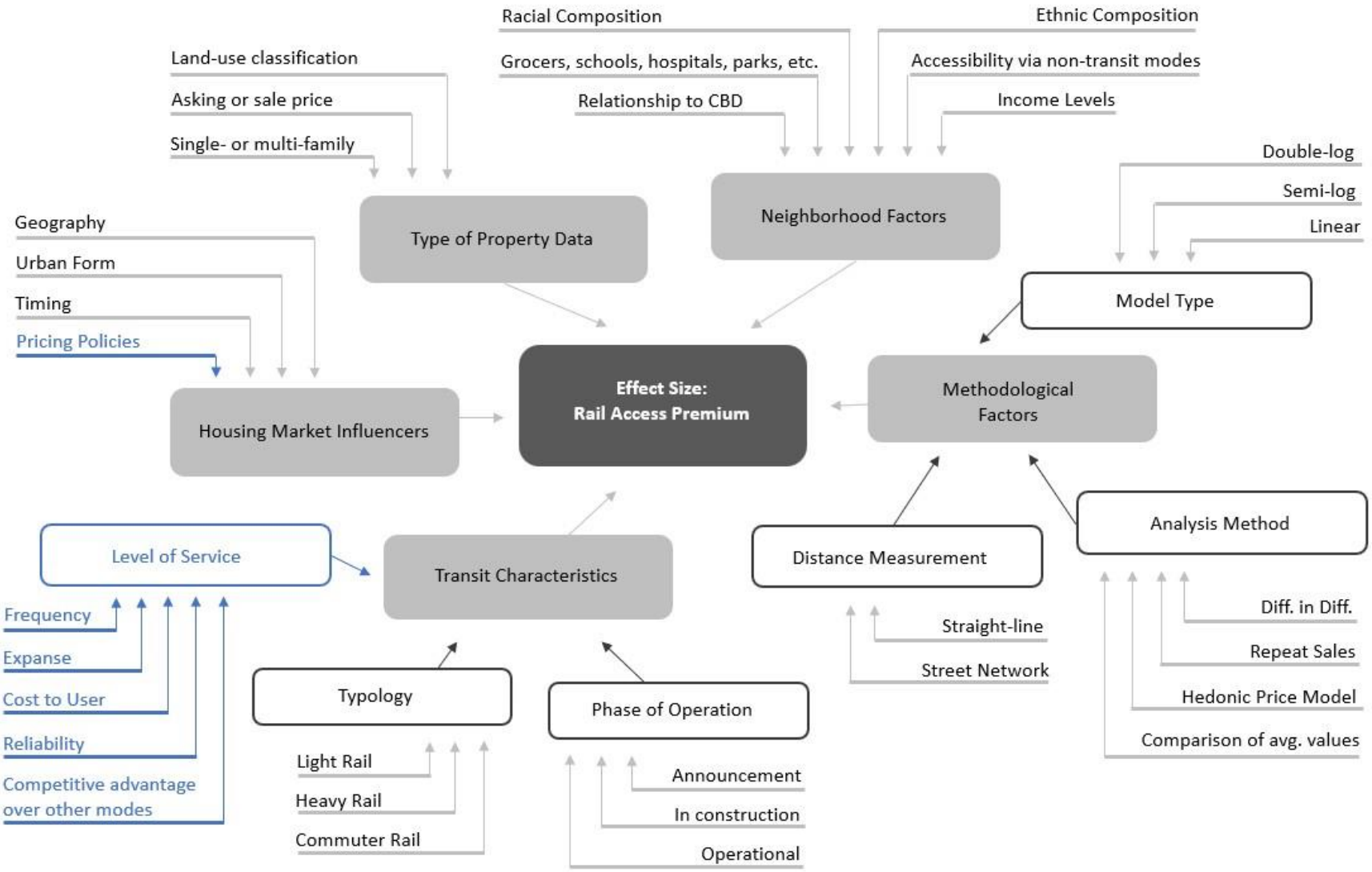
Among the case study inputs that make up this meta-analysis, 18% were not published in academic journals. This cohort includes findings from working papers, dissertations, conference proceedings, and non-academic reports most often submitted to municipal transportation departments. Inclusion of these studies serves to avoid the potential impacts of publication bias in the analysis (Berlin and Ghersi, 2005).

2.3.2 Moderators

Rail access premiums are contributed to by a large host of factors. Some have their rooting in the physical world – contextual factors, while others exist in the analytical framework used to measure these premiums – methodological factors. Modelled in Figure 2 is an agglomeration of all of the contributory factors that past meta-analyses have explored in some form or another. In blue are the primary contributions of this meta-analysis to the collective moderator web. These represent moderators that have not previously been tested. The rationale behind the introduction of these new moderators and their anticipated impacts on access premiums are the focus of this subsection. How they, as well as all other moderators used within this analysis, are defined is specified in Table 2.

The following logic led to the inclusion of a new moderator within the impact grouping of 'Housing Market Influencers'. Surely the amount of available housing supply, local purchasing models and requirements (e.g. restrictions on owning more than one property, credit-dependent loan eligibility), and policies that dictate price setting freedoms (e.g. rent control, land for sale by public entities) all influence the sale prices of property; proximate to rail stations or otherwise. Of these elements, a focus was placed on rent control policy – which here encompasses both rent caps and rent stabilization policies – for three reasons. Firstly, feasibility of data acquisition. Mohammad et al. (2013) highlight the difficulty associated with finding housing market influencing information across a large range of case studies spanning several decades. Fortunately, policies the likes of rent control tend to be archived as a part of public record and remain largely unchanged over long stretches of time. These characteristics contributed to data accessibility.

Figure 2. Framework of factors that affect the impact that proximity to a rail station has on property value



Secondly, rent control has the rather universal objective of avoiding both fast and large upward shifts in housing costs within at least a portion of the housing market. This universality – both in objective and execution, as these policies tend to be set at the level of local (city-level) government – allows for reasonable comparison across both time and geography. Finally, any findings associated with rent control policies on rail access premiums can, in principle, be acted upon by practitioners with some immediacy (not to side-step due process, of course). In that sense, the implementability of rent control strengthens its value as a moderator. Given the restrictive influence that rent control policies are designed to have on potential profits garnered from participating in ownership within the housing market, it is anticipated that this moderator will have a depreciative impact on rail access premiums.

With respect to transit characteristics, nearly all of the meta-analyses that deal with rail access premiums delineate premiums by the type of rail offered at the stations under study. Most typically this results in the categories of light, heavy, and commuter rail. While this treatment is certainly reasonable and necessary – a claim supported by consistent findings of significance, especially of the commuter rail classification – it is not a sufficient encapsulation of the variance in transit quality that could be impacting the value associated with proximate access to transit service. To gain a more detailed understanding of this relationship, this meta-analysis includes moderators associated with frequency, expanse, fares, reliability, and comparative advantage of transit over other modes.

High frequency demands less stringent trip planning from travelers and offers shorter average wait times. There is also a higher degree of emotional comfort that comes from access to high frequency service. Unsurprisingly, missing a train or bus in conditions of poor frequency is associated more closely with negative emotions such as anxiety and anger than doing so under high frequency conditions (Van Lierop et al., 2018). Against this backdrop, this analysis anticipates a positive valuation placed on access to higher frequency service, and, subsequently an appreciating effect on premiums. The moderators associated with testing this hypothesis are divided into four groups: frequencies of 3 minutes or less, 4 to 6 minutes, 7 to 10 minutes, and the reference group of frequencies greater than 10 minutes. This choice was based on past findings that only 'high' frequency service, a classification defined in the literature by ten minute or better headways, has a significant effect on surrounding property values (Gallo, 2018).

The number of destination points one can reach when travelling by transit affects the level of desirability and usefulness of that service (Guerra and Cervero, 2011). Similarly, the ease with which you access transit services affects their value. In an attempt to capture this, the moderator of number of same-mode stations within a system was included in the analysis. While not all stations provide access to the same density of destination points of interest, it is reasonable to assume that the larger the number of stations the generally more expansive the reach of a potential trip, the greater the trip flexibility, the more plentiful the transfer options, and the less obstructive a service change or interruption (due to greater rerouting optionality). This value – a network effect (Mulley et al., 2017) – is proxied by the variable defined as 'available connections'; each station representing a point at which to connect with the network. Only same-mode stations were included because different modes tend to be priced differently, and because intermodal transfers are internalized differently – specifically, much less favorably – than intramodal ones (Liu et al., 1997).

Table 2. Definitions of moderators used in this meta-analysis (Total N = 66)

Moderator	Definition	N
Neighborhood Factors		
Income°	1 if income controls included, 0 if not	24
Race, ethnicity, citizenship°	1 if race, ethnicity, or citizenship controls included, 0 if not	11
Access to other transport	1 if study controlled for access to non-transit mobility infrastructure (e.g. highway on-ramps), 0 if not	38
Neighborhood amenities	1 if neighborhood amenity controls included, 0 if not	41
CBD	1 if study analyzed stations in the CBD, 0 if not	43
Model Parameters		
Transaction property data‡	1 if used transaction prices used, 0 otherwise	54
	Reference: data from assessor's pricing inventory	12
Network catchment°	1 if street network distance measurement used, 0 otherwise	18
	Reference: straight-line distance measurement used	48
Single-family	1 if only single-family properties analyzed, 0 otherwise	15
Multi-family	1 if only multi-family properties analyzed, 0 otherwise	9
	Reference: mixed housing style dataset	42
Analysis Methods		
Semi-log model	1 if semi-log model used, 0 otherwise	33
Double-log model	1 of double-log model used, 0 otherwise	8
	Reference: linear model used	25
Difference-in-differences	1 if difference-in-differences model used, 0 if not	10
Rail Modes		
Heavy rail (metro)	1 if heavy rail service analyzed, 0 otherwise	36
Commuter rail	1 if commuter rail service analyzed, 0 otherwise	8
	Reference: light rail service	22
Temporal Factors		
2010-2020‡	1 if property data is from 2010 or later, 0 otherwise	24
	Reference: property data from before 2010	42
Geographical Factors		
Europe	1 if study is of Europe, 0 otherwise	13
Asia: excluding East Asia	1 if study is of Asia: excluding East Asia, 0 otherwise	8
East Asia	1 if study is of East Asia, 0 otherwise	14
Oceania‡	1 if study is of Oceania, 0 otherwise	2
	Reference: study is of North America	29
Settlement Factors		
Population density°	1000 people per square mile in study city during first year of property data used	-
Rent control‡	1 if city studied hosted any rent control policies that limited either the rate at which or extent to which rents could increase during timeframe of property data used, 0 if not	17
Transit Service		
Expenditure share‡	Annual transit costs (assume 2 trips per weekday) as share (percent) of average annual income during first year of property data used in city studied	-
Age of service°	# of years between start of service studied and first year of property data used	-
Available connections‡	# of same-mode stations within the system studied during first year of property data used	-
Urban core driving speed‡	Average peak period driving speed in urban core of city studied during first year of property data used measured in miles per hour	-
Frequency: under 5 mins‡	1 if service studied offered peak-period frequency of under 5 mins, 0 if not	29
Frequency: 5 to 10 mins‡	1 if service studied offered peak-period frequency of between 5 and 10 mins, 0 if not	23
	Reference: service studied only offers peak-period frequency greater than 10 mins	14

‡ These variables have not been used in previous rail access meta-analyses.

° These variables have been used in previous rail access meta-analyses, however, not to the level of detail that is featured here.

The cost of transit service likely influences its attractiveness. In this analysis, cost takes the form of 'expenditure share': annual transit costs as a percent of mean annual income within the city featured in each case study during the first year of housing data used. Annual transit costs were calculated by using the full price one-way fare of each service studied during the first year of housing data used. That fare was assumed to be expended twice a day per weekday. While this determination of annual transit costs most closely embodies a middle-income, white, male, traveler strictly using transit for their work commuter – see (Mauch and Taylor, 1997; Handy and Tal, 2005; Chakrabarti and Joh, 2019) for research on how gender and income, race, and parenthood influence transit travel behavior, respectively – because this moderator serves as a representative proportion and is calculated the same way across all case study inputs it is not distorted by this single traveler profile embodiment. It is anticipated that expenditure share will have a depreciating effect on premiums. This is influenced by the following hypothesis: the higher the expenditure share on transit the presumably more attractive its mode competitors (e.g. bike, walk, drive, rideshare), and the less enticing the use of transit the less valuable is living proximately to a station.

Congestion further speaks to the cross-modal competitive value of transit access. Heavy roadway congestion decreases travel speeds and increases trip times for road-using travel modes, namely cars. Therefore, congestion increases the appeal of modes that are not subject to roadway conditions. This includes nearly all rail transit, though some tramlines run in mixed roadway traffic. To capture this relationship, average driving speeds during peak travel times of day within a city's urban core – a representation of congestion levels – were included in the model. This information was sourced from a combination of TomTom Traffic Index data, INRIX traffic data, World Bank data, and direct data requests from municipal planning and transportation departments. It is anticipated that this moderator and rail access premiums interact inversely.

The competitive advantage offered by bicycle travel was not included as a moderator for two reasons. The first is the difficulty that comes with sourcing a metric that represents the quality of bike infrastructure across a span of four decades. The second is that biking and transit use are, generally, though there are exceptions, complementary modes, not full substitutes. That is to say, cyclists also tend to be transit users. (Singleton and Clifton, 2014). As a result, though quality cycling infrastructure may increase the attractiveness of the bike mode for a given traveler, it does not necessarily diminish the value that that same traveler extracts from living close to transit.

The final new moderator under the umbrella of 'level of transit service' featured in this model is service age. This variable is defined as the number of years between the operational start of the service in question and the first year of housing data used by each respective case study. This moderator serves as a proxy for reliability. While most consistently true within the US context, older systems tend to fall victim to reliability issues more frequently than younger systems and suffer slower repair speeds. In the absence of access to on-time performance data or rolling stock information for all systems within the input cohort during the timeframe in which they were studied, age of service was deemed a suitable, if not ideal, proxy for service reliability. Under the belief that poor reliability lessens the value of transit access, this moderator is anticipated to have a depreciating effect on premiums.

Though not a new moderator, it is worth making clear that the temporal factor of housing data sourced 2010 or later, compared to the reference case of pre-2010, was used to account for the potential impacts on the property market attributed to the Global Financial Crisis of the late 2000s; specifically spanning 2007 to 2009. This temporal factor, selected for the universal nature of its felt impact, was also used by Zhang and Yen (2020) in their examination of bus-specific access premiums.

2.3.3 Regression model

The interaction between these moderators and the rail access premiums found in the case study input dataset was examined using a random-effects meta-analytic model. A random-effects treatment was deemed best suited given that most of the input studies report just one premium estimate each, vary substantially in their model design, and that these inputs represent a sample – as opposed to the entirety – of the premiums literature (Hunter and Schmidt, 2000; Borenstein et al., 2010; Cheung, 2014). Within this random-effect model, effect sizes were weighted by the inverse of the square of the standard errors of each case study in accordance with recommendations by Stanley and Doucouliagos (2015) and as done by both Debrezion et al. (2007) and Mohammad et al., (2013) in their rail access premium meta-analyses. The resultant regression model is shown by Equation 1.

$$P_i = \alpha_0 + \boldsymbol{N_i' b_1} + \boldsymbol{M_i' b_2} + \boldsymbol{A_i' b_3} + \boldsymbol{R_i' b_4} + D_i b_5 + \boldsymbol{G_{ij}' b_6} + \boldsymbol{S_{ij}' b_7} + \boldsymbol{T_{ij}' b_8} + \varepsilon_i \quad (1)$$

where:

P_i = effect size (percent) of the impact of railway station proximity on property values experienced 500m from a station compared to 1.6km or more in study *i*
α_0 = constant term
N_i = meta-regressor of neighborhood factors in study *i*
M_i = meta-regressor of model parameters factors in study *i*
A_i = meta-regressor of analysis method factors in study *i*
R_i = meta-regressor of rail mode in study *i*
D_i = meta-regressor of temporal factors in study *i*
G_{ij} = meta-regressor of geographical factors of city *j* in study *i*
S_{ij} = meta-regressor of settlement factors in city *j* hosting study *i*
T_{ij} = meta-regressor of transit service factors in city *j* hosting study *i*
ε_i = model disturbance term

Bold terms denote vectors of variables and parameters

2.4 RESULTS AND DISCUSSION

The results of modelling the effect of rail access on property values for properties located at 500m from a station compared to those located 1.6km or more from a station are shown in Table 3. The coefficients rendered within this table represent modifications upon the reference case. The reference case is the following: a light rail system in a non-rent-controlled North American city whose premium pertains to assessor's housing data priced before 2010, does not account for neighborhood factors (demography, access, amenities, or CBD closeness), was measured using straight-line distance, was not modelled using a DID method, and features peak period frequency of 1 train or fewer every 10 minutes. On average, the value of a residential property subject to these reference conditions situated 500m from a station is 18.8% higher than an otherwise comparable property situated 1.6km from a station.

Table 3. Effect of rail access on property values located 500m from a station compared to those 1.6km or more from a station

Factor Type	Moderator	Coefficient	t-stat
	Constant	0.1878*	(2.46)
Neighborhood Factors			
	Income	0.0001	(0.01)
	Race, ethnicity, citizenship	-0.0598*	(-2.06)
	Access to other transport	0.0111	(0.59)
	Neighborhood amenities	0.0236	(1.07)
	CBD	-0.0252	(-0.88)
Model Parameters			
	Transaction property data	-0.0521*	(-2.00)
	Network catchment	-0.0031	(-0.15)
	Single-family	0.0310	(1.01)
	Multi-family	0.0453	(1.52)
Analysis Methods			
	Semi-log model	0.0183	(0.79)
	Double-log model	0.0345	(0.94)
	Difference-in-differences	-0.0401	(-1.88)
Transit Modes			
	Heavy rail	0.0402*	(1.97)
	Commuter rail	0.0958*	(2.17)
Temporal Factors			
	Property Data from 2010-2020	-0.0495	(-1.73)
Geographical Factors			
	Europe	-0.0269	(-0.76)
	Asia: excluding East Asia	-0.0137	(-0.34)
	East Asia	-0.0742*	(-2.18)
	Oceania	-0.0857	(-1.55)
Settlement Factors			
	Population density	0.0014	(1.50)
	Rent control	-0.0527*	(-2.15)
Transit Service			
	Expenditure share	-1.431*	(-2.61)
	Age of service	-0.0003	(-0.71)
	Available connections	0.00021*	(1.99)
	Urban core average driving speed	0.0008	(0.35)
	Frequency: every 4 mins or less	-0.0516	(-1.23)
	Frequency: every 5 to 10 mins	-0.0234	(-0.66)
	Observations	66	
	R-squared (between-study variance explained)	0.31	

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

2.4.1 Previously Examined Moderators

Inclusion of station area neighborhood composition with respect to race, ethnicity, or citizenship has a significant negative impact on rail access premiums. Studies that account for any of these three demographic factors demonstrate, on average, premiums 6.0 percentage points lower than those that do not. The only other meta-analysis to test the moderating power of any of these factors – Debrezion et al. (2007) include race as a moderator – similarly found it to be significant and to have a depreciating effect on access premiums.

Studies that included these factors most likely did so because of a known racial, ethnic, or xenophobic tension in the area of interest. This tension could be influencing premiums in two ways. On the one hand, transit in these areas may be hyper-stigmatized as being a service specifically for marginalized minority groups, and, as a result of this stigma, other groups may devalue the service and access to it. On the other hand, racist or xenophobic preferences regarding the choice of one's neighbors may be depreciating the housing market in areas with a larger share of minority residents irrespective of a positive valuation of transit service by property buyers. The body of literature that explores this interaction between housing markets and ethno-racial prejudice is extensive, widely international, and hosts findings that frequently support this claim. For examples, see Taylor (2019) for North American context, Flage (2018) for European context, Seekings (2008) for Sub-Saharan African context, Munir et al. (2021) for South Asian context, and dos Santos Oliveira (1996) for Latin American context.

Interestingly, while earlier meta-analyses found a significant effect of access to non-transit roadway infrastructure on premiums, no significant impact of that moderator is found here. It is possible that the inclusion of the congestion-related moderator 'urban core average driving speed' present in this model and absent from all others dilutes the potential effects of this factor. That is to say, while proximate access to a highway may be valuable to a driver, that value decreases sizably if that driver faces consistently heavy traffic.

Access to commuter rail is associated with higher premiums than access to light rail systems; 9.6 percentage points higher on average. Similarly, heavy rail systems also render higher access premiums than light rail systems; an average of 4.0 percentage points higher. This aligns with the findings of past meta-analyses. One possible explanation for this is that light rail services may be viewed as comparatively less permanent. Given that many light rail tracks across the world have been dug up or paved over and replaced by roadways, this is a reasonable perception. Another, as previously mentioned, may be that some light rail services operate in mixed traffic. In doing so, they lose some of their mode-competitive advantage which could depreciate their access value. A third explanation may lie in the nature of light rail service. Light rail systems generally provide more of a local service than either heavy or commuter rail, stopping more frequently and running at slower speeds. Finally, whether based in reality or not, commuter rail may be being associated with higher quality features – more comfortable seating options, cleaner cars and stations, less on-board crowding due to larger vehicles and lower rider-to-car ratios. Such an association could result in its appreciated access premiums.

Geographical comparison of effect sizes reveals that all regions from which premium data was collected – Europe, Asia, and Oceania – are associated with lower premiums than those hosted by North America. Though each geographical moderator is negative, only the influence of East Asia proves significant. Rail access premiums in East Asia are, on average, 7.4 percentage points lower than those in North America. This may, at least in part, be attributed to the drastically varied travel behavior exhibited across the two regions. Whether due to preference or urban form – almost assuredly both – the combined mode share of walking and biking across much of East Asia dwarfs that of even the most pedestrian-centric North American cities. Compare, for example, the 2020 combined walk-bike commute share of 11% in New York

City to that of 40% in Shanghai. Living proximately to transit may be less valuable if one's trip needs are well served by foot travel.

It is worth highlighting that several moderators found not to have a significant effect on the impact that access to rail stations has on property values in this work were similarly deemed insignificant in past meta-analyses. Here, being located within a city's central business district does not significantly impact premiums. The same was found by Mohammad et al. (2013). Single and multi-family housing distinctions were found to be insignificant by Debrezion et al., (2007), as is the case here. Finally, Park et al. (2016) tested how using street network measurement techniques as opposed to straight-line measurements might influence premiums. In neither their study nor in this one was a significant effect revealed.

2.4.2 Newly Introduced Moderators

Focusing on the moderators newly introduced within this study, the following results were found. The type of price data used – transaction sale price versus assessor's listed sale price – impacts premium effect size. Specifically, premiums measured using prices of actual transactions are 5.2 percentage points lower, on average, than those measured using assessor's data. This effect on premium size aligns with the anticipated impact of this moderator as assessor prices – a value generated in the absence of buyer/seller negotiations – generally reflect an upper bound estimate of a property's value to prospective buyers outside of a handful of high demand, highly competitive housing markets (Cypher and Hansz, 2003).

On average, studies of station access value situated in cities and time periods where rent control policies exist host premiums of an average of 5.3 percentage points lower than those that do not. The directionality of this impact aligns with expectations. In these areas, while living 500m from a rail station may indeed be a valued access amenity, the extent to which that value can be absorbed by the housing market and financially profited from may be bounded.

Expenditure share, the portion of an average annual income spent on transit within a given city, also has a significant and negative impact on access premium size. Every 1 percentage point increase in annual expenditure share of transit is associated with a 1.4 percentage point decrease in access premium. Phrased differently, the more expensive a transit service relative to income, the less valuable living within walking distance of a station becomes. Part of this relationship may be that in cases where transit is more costly, the competitive advantages of other modes – namely walking, cycling, and ridesharing – increases substantially and may even outweigh those of transit.

The only other transit service element that has a significant impact on access premiums is the number of available connection points within the transit network. For every 10 additional stations, premiums are, on average, 0.21 percentage points higher. It is important to understand that this particular impact on premiums occurs on a systemwide scale. The addition of 10 stations anywhere within a transit systems network has a 0.21 percentage point uplift on station-proximate properties across the entire network; even those far away from the new station sites. That is not to say that access to all stations is uniformly useful or important; indeed some stations – for example those serving multiple lines – may be of greater access value than others. This finding represents an average across a system.

The age of transit service does not render statistically significant impact on access premiums. This may be the result of this moderator encapsulating dual, competing effects: reliability effects and maturity effects (Zhang and Yen, 2020; Trojanek and Gluszak, 2018; Arnold et al., 2017). The reliability logic here, as previously discussed, is that older systems may be more susceptible to delays brought on by malfunction or general lacking maintenance. The maturity logic, conversely, suggests that older systems may more positively have their value absorbed by the property market as their service quality has been tried and

tested and their ability to contribute to value retention of properties surrounding them through times of general market crisis proven. Disentanglement of these effects, allowing for the measurement of their influence individually, is needed to best paint a full picture of transit service elements' impacts on access premiums.

Surprisingly, none of the moderators relating to service frequency demonstrate a significant impact on access premiums. This could be because only the effect of best peak-period frequency available was tested. Perhaps all-day average frequency is what property owners internalize the value of instead. Additionally, the cut off point for what is considered high and low frequency utilized here is 10 minutes. While this choice was informed by past findings of significant value and behavioral difference at this threshold, it is possible that a difference in value of access to transit service sizable enough to affect property prices fluctuates at a lower frequency point; perhaps somewhere between 10 and 15 minutes. Furthermore, though none of the varied levels of high frequency service render a significant impact on premium values, there is something valuable to be gained from this result. It suggests that planners can aim to provide the best frequency possible without fear that doing so will contribute to premium-driven displacement. This is empowering information to the transit planning practitioner who may not have much say in zoning regulations or housing policies, but cares about the equity implications of their work.

2.4.3 Interpretation

Through a set of test cases, one may best gain a practical sense of how these results can be useful – for example, to a homeowner living in an area slated for a new rail station wanting to estimate the value uplift they can expect, or a researcher tasked with explaining variation in premium size across studies. While interpreting the forthcoming test cases, keep in mind that 500m from a rail station, the site where this work calculates transit access premiums, reflects the distance at which premiums are their highest; the value uplift peak.

As stated at the opening of this section, the reference case for this analysis is a light rail system in a non-rent-controlled North American city whose premium pertains to assessor's housing data. On average, the value of a residential property subject to these conditions situated 500m from a station is 18.8% higher than an otherwise comparable property situated 1.6km or further from a station.

If instead these conditions were applied to a heavy rail system (+4.0 percentage points) with 145 stations (+0.21 percentage points per 10 stations) whose fare corresponded with an average annual transit expenditure share of 6.7% (-1.4 percentage points per one percent share), and which was situated in an environment hosting pronounced racial tensions (-6.0 percentage points), this meta-analysis suggests that an access premium of 10.4% could be expected. These augmentations to the reference case reflect Chicago in the year 1999 and apply to the case study analysis of the city conducted by McMillen and McDonald (2004). This case study analyzed housing data from 1997 to 1999 and found an access premium of 9.8% at 500m from a station compared to at 1.6km or further from a station.

Using this meta-analysis model, the case of light rail in Beijing in 2009 based on transaction data would render an average access premium of 5.5%. This case would be comprised of the following parts in comparison to the reference case: East Asian geographical context (-7.4 pp), 187 stations (+0.21 pp per 10 stations), a transit expenditure share of 3.3% (-1.4 pp per 1% share), and the use of transaction data (-5.2 pp). The team of Zhang et al. (2014) ran an analysis of this case under these conditions using housing data from 2006 to 2009. They too calculated an average access premium of 5.5% at 500m from a station compared to at 1.6km and beyond.

A test case of commuter rail in Europe rounds out this demonstration of applicability. A look at Lisbon in 2007 calls for the following changes to the model's reference scenario: commuter rail (+9.6 pp), transaction data (-5.2 pp), 168 stations (+0.21 pp per 10 stations), 8.1% annual transit expenditure share (-1.4 pp per 1% share), and the presence of rent control policies (-5.3 pp). For this case, the model returns an estimated 10.1% access premium. Martinez and Viegas (2009) found an access premium of 10.7% at 500m from a station – compared to 1.6km and beyond – in their analysis of Lisbon's commuter rail-proximate properties in 2007.

In this way, findings from this study can be tailored to one's specific context of interest and inform access premium estimates.

2.5 CONCLUSION

Utilizing a random-effects meta-analytic methodology, this work examines the impact that being located 500m, compared to 1.6km or more, from a rail station – termed a 'rail access premium' – has on residential property sale prices. This model finds that elements of demography, data type, place, and planning all impact rail access premium magnitudes. The following significant relationships are revealed. Premiums based on the inclusion of neighborhood racial, ethnic, or citizenship composition are lower than those that exclude area demographic information by 6.0 percentage points on average. Transaction informed premiums are generally 5.2 percentage points lower than those based on assessed sale prices. Premiums in East Asia are an average of 7.4 percentage points lower than those in North America. Cities hosting any form of rent control policy generally feature premiums 5.3 percentage points lower than those that do not. On average, commuter rail premiums and heavy rail premiums are 9.6 and 4.0 percentage points higher than light rail premiums, respectively. Finally, with every one percentage point increase in annual expenditure share on transit, premiums decrease an average of 1.4 percentage points, and for every 10 additional stations within a network, premiums are 0.21 percentage points higher.

The finding that ethno-racial context influences property prices is not surprising, as it has been explored and confirmed time and time again in a wide geographical range of urban settings. What is interesting is that that relationship holds true even when the amenity of transit access is introduced into the equation. This finding speaks to the need for a closer look at the intersection or race, transit, and wealth accumulation via property ownership. While the findings rendered here make clear that accounting for race matters in the transit-access/property-market puzzle, a greater understanding of exactly to what extent specific station-area racial composition is causal of property devaluation may allow policy makers to determine a precise percentage to which homes within minority-dominant, transit-proximate areas are being under-appraised. Such knowledge could form the base of a set of concrete, Reparative actions.

In addition to allowing for direct comparison of markets across geographical regions, the revelation that place directly impacts access premiums is of value in that it too highlights areas in which further research would be a powerful contribution to the field. While this piece was not able to feature any premiums gathered from South America or Africa, these regions have introduced several new rail systems since 2010, and as these systems age, their value uplift may solidify and become more readily measurable. A greater representation of the Global South within the case study literature would make for a more comprehensive meta-analysis and could provide increasingly fine-grained information on how transportation infrastructure and housing costs interact subject to varied contexts.

The finding that cities hosting rent control policies experience lower premiums of 5.3 percentage points is useful beyond explaining variation in premiums found across the case study literature. Drilled down to its

core, it suggests that if your objective is to limit the risk of low-income communities or existing residents being priced out of their transit-proximate homes, the introduction of rent control policies not only directly at the site of interest – perhaps in the form of a Station Area Overlay District – but also at a more general city-wide scale should indeed perform favorably even if that protective policy does not apply directly to the focal site. In this sense, rent control for some increases staying power for all.

The choices that transit planners make – some implementable in the short-term, others more distant – necessarily impact housing costs. This work's significant findings associated with rail type, service cost, and network expanse suggest that transit planners should not be sidelined in matters pertaining to housing pricing. Rather, those in the field of housing and field of transit should collaborate in their efforts, be they focused on infrastructure financing or supporting equitable housing landscapes.

Circling back to matters of related further research, recent analysis conducted by the team of Zhou et al., (2022) has found that in areas relatively distant from rail stations (~1.2km) where bike sharing serves as a complement to transit services, a positive bike-induced housing price premium is observed. This overlap in area of influence suggests that future studies of transportation network-impacted housing price premiums should consider looking at mobility systems more comprehensively, assessing them in their multi-modal rather than single mode forms. In doing so, the 1.6km cut-off used within this meta-analysis to reflect the point at which properties no long experience direct transit premium impact may need to be reconsidered; likely expanded.

Finally, with the rising global popularity of Bus Rapid Transit, increased research attention to how this mode influences property values could be of great use to practitioners presently planning for entirely new systems and services soon to be implemented, and therefore, well-timed for premium-impacting decisions. Case study research of BRT access premiums is currently being championed by Corinne Mulley and her collaborators at the University of Sydney. The only known meta-analysis dedicated specifically to BRT access premiums has been conducted by Zhang and Yen (2020). With 181 cities worldwide now hosting BRT service – 42% of which began operation in the last decade alone – and 210km of dedicated BRT right-of-way being added annually to the global total (GlobalBRTdata, 2021), continued work in this realm could be hugely influential over the world's station-area property values of the next ten years, and likely well beyond.

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SUPPLEMENTARY MATERIALS: Paper I

Transit Service Moderators – Measurement Definitions and Example Data Sources

Moderator	Variable Definition	Sample Set of Primary Data Sources
Expenditure share	Annual transit costs (assumes 2 trips per weekday) as share (percent) of average annual income in city studied during first year of property data used.	• US Bureau of Labor Statistics • China City Statistical Yearbooks • Archival fare data request directly from transit service provider.
Age of service	Number of years between start of service studied and first year of property data used.	• Archival station opening data request directly from transit service provider.
Available connections	Number of same-mode stations within the system studied during first year of property data used.	• Archival station opening data request directly from transit service provider.
Urban core driving speed	Average peak period driving speed (mph) in urban core of city studied during first year of property data used.	• TomTom Traffic Index • INRIX Global Traffic Scorecard
Frequency	Best peak-period headway (in minutes) offered on rail service studied during first year of property data used.	• Archival service schedule data request directly from transit service provider.

CHAPTER 3: Paper II

An Evaluation of the Impact of COVID-19 Safety Measures in Public Transit Spaces on Riders' Worry of Virus Contraction

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3.1 INTRODUCTION

COVID-19 has significantly altered transportation-related behavior. We have seen impacts on the ways people make trips, the places to which they make them, and the frequency with which they are made (Hunter et al., 2021). With over half of the world's population being asked to stay at home or restrict their movement in public during 2020 (Sandford, 2020), public transit systems have seen their ridership levels drop to unprecedented levels. During the first several months of the pandemic, with travel widely restricted to all but essential workers, it was not uncommon for transit networks to see ridership drop by as much as 85 to 95 percent compared to the same months in 2019 (Community Mobility Reports, 2021). For example, ridership fell 87% in Bogotá (Sanchez, 2020), 89% in Delhi (Aloi et al., 2020), 88% in both Milan and Madrid (Global Public Transit Report, 2020), 85% in Singapore (Mahtani et al., 2020), and 90% in both London and New York City (ibid.). As mobility restrictions were broadly relaxed towards the end of 2020 and into the start of 2021, some transport systems saw recovery of 40 to 50 percent of their 2019 ridership levels (Muoio, 2020; Wilbur et al., 2020; Qi et al., 2021). Unfortunately, global recovery trends were, on average, below this range (Ritchie et al., 2022).

The coronavirus pandemic went on to alter the very nature of work, school, and play – how, when, and where we do them – and the ways we use public transit systems to facilitate trips of those purposes. As such, it is uncertain if transit systems will fully recovery to pre-pandemic ridership rates, even in a potential post-COVID future (Bagdatli and Ipek, 2022; de la Garza, 2020). This naturally raises the question: What are the implications for the world of transit if these trends continue to persist? Transit practitioners have suggested that persistent drops in ridership could lock us into a concerning downward spiral in which ridership falls, revenue drops as a result, service provision decreases due to diminished operating budgets, and ridership in turn falls further (Sadik-Khan and Solomonow, 2020; Verma, 2020). With many of the world's largest transit providers reporting weekly losses in the high tens of millions of US dollars (DiNapoli, 2021; Nugent, 2021; Burroughs, 2020), and systems from Paris and Washington, D.C. (Mahtani et al., 2020) to Ulaanbaatar (Null and Smith, 2020), Addis Ababa (Abubaker, 2020), and Johannesburg (Nkosi, 2020) operating with service levels at 50% capacity or less, the patterns exhibited toward the end of 2020 and on into 2021 (Bliss, 2021) suggest that this cycle has already begun.

The pattern of decreased ridership, decreased revenue, decreased service, repeat also has major implications for transit equity. Essential workers and socially vulnerable communities (e.g. the elderly, low-income earners, racial minorities, women) make up a disproportionately large share of the during-pandemic global transit ridership body (George et al., 2021; Bliss, 2021; Morales-Burnett and Freemark, 2021; He et al., 2022; Asian Development Bank, 2020). Because these riders continue to depend on transit to meet their travel needs, the burdens associated with service cuts – burdens such as lengthened waiting times, decreased or discontinued early morning and late-night service, dropped transfer/connection opportunities, increase total trip times – are largely being shouldered by these communities. This lowering of transit trip quality contributes negatively to existing states of transportation equity across these socio-demographic lines as those with means and alternative options increasing exercise the privilege of being able to work remotely or of selecting a different mode that offers a less compromised travel experience.

The concerning effects of transit's spiraling trajectory do not stop there. Thus far over the course of the pandemic, the environmental narrative has been largely positive. Travel restrictions and decreases in production seen around the world have contributed to improvements in air and water quality in particular (Isaiah, 2020; Anjum, 2020; McGrath, 2020; Saadat et al., 2020). Additionally, there has been significant growth in the adoption of sustainable modes of transport – e.g. bicycles and e-scooters – which has further contributed to decreased emissions (Hu et al., 2021). However, studies have explored people's intended means of transport as restrictions lift and needs change, and have found travel by car to be the dominant

substitute mode-choice for travelers whose primary pre-pandemic mode was public transport (Pryzbylowski et al., 2021; Thomas et al., 2021). If this mode shift toward private cars persists and the downward cycle of transit is not reversed, these recent positive environmental outcomes could be undone (Andersen et al., 2021), and there is a risk that a significant part of the progress made towards sustainability goals of cities around the world may be undermined (De Gruyter et al., 2016; UN, 2020).

Well-aware of these circumstances and committed to regaining stable footing, transit agencies have implemented a host of interventions that focus on virus spread-risk reduction and rider comfort to incentivize continued and returning ridership. These have included temperature checks at bus stops (World Economic Forum, 2020), portable self-cleaning stations at system access points (Economic Times, 2020), limited on-board passenger capacity (Schwartz, 2020), increased frequency of vehicle cleaning and improved ventilation (ibid.), contactless payment/ticketing options and rear-door-only circulation offerings to minimize contact with vehicle operators (Null and Smith, 2020).

Of the many COVID-19 safety measures (CSMs) implemented in transit spaces, the most widely adopted have been the introduction of mandatory face masks, floor and seat markers defining physical distancing, and the provision of hand sanitizing materials (Null and Smith, 2020). Due to the low cost, ease of implementation, and high multi-modal versatility of these measures, they were adopted in comparatively early stages of the pandemic, and have become commonplace globally. These measures have been evaluated with respect to their impact on rates of virus spread and have ultimately been deemed effective (Fazio et al., 2021; Milne and Xie, 2020). For example, research has found that COVID-19 spreads 10 to 35 times faster in the absence of social distancing (Courtemanche et al., 2020). Further research has demonstrated that the extent to which these interventions have reduced the risk of spread is dependent on the combination of measures in place and levels of adherence (Thu et al., 2020). However, while we now understand the epidemiological efficacy of these measures, their impacts on the emotions of transit users remains much less widely studied.

From the wide range of possible emotional responses that could be considered, the feeling of worry was selected as the focus of this research as it plays a critical role in an individual's transportation mode choice. Mode choice is impacted by many factors, from socio-demographics (Ouali et al., 2020; Lubitow et al., 2020) and the built environment (Cervero, 2002), to attitudes toward travel (Stewart et al., 2012; Lanzini and Khan, 2017) and personal health conditions (Schmöcker et al., 2008). However perception of risk has been cited as one of the most pertinent and influential of these factors (Muley at al., 2020; Delbosc and Currie, 2012; Ceccato et al., 2021; Ozbilen et al., 2021). The perception of risk is, in turn, intimately linked with feelings of worry: several studies have shown that worry is the most important contributor to the ways in which we interpret and assess risk (Moen and Rundmo, 2006; Khosravi, 2020; Dryhurst et al., 2020). Additionally, feelings of worry have been found to be consistently induced during epidemics and public health crises (Hansen, 2009; Jalloh et al., 2015; Klemm et al., 2016). Studies specific to the COVID-19 pandemic have similarly found this to be true (Serafini et al., 2020; Klos-Adamkiewicz and Gutowski, 2022). Worry is also directly related with not only short-term but also long-lasting behavioral changes (Lee, 2020). Taken together, these factors demonstrate that feelings of worry stand as a central element in influencing transit ridership trends.

A mobility behavior case study of Gdansk, Poland explores this relationship between worry and transit ridership in the context of COVID-19 acutely. During the mid-summer of 2020, via random sample survey, the research team of Przybylowski et al. (2021) asked transit riders about their travel choices as well as their feeling of "safety and comfort" while using transit. They found that about 90% of respondents fully resigned (47%) or limited (44%) their usage. This is not surprising, given the early stage of the pandemic in which this study was conducted, and aligns in magnitude with the global trends discussed earlier in this

section. When asked about the reasons for their decreased transit use, the most common answer (49% of respondents) involved a switching of work and/or schooling from an in-person model to a remote one. The second most commonly cited reason (40% of respondents) was a fear of coronavirus infection. Interestingly, 75% of this respondent cohort stated that they planned to return to their pre-pandemic levels of usage "when the epidemic situation has stabilized." The other 25% had "lost hope" that transit will ever be COVID-safe. This study speaks directly to the relationship between perceived safety, fear, and concern and transit ridership.

It is against this backdrop that this research is positioned. By using a photo-simulation approach in a randomized control trial, the following question is explored: How do CSMs in transit spaces affect travelers' worry of COVID-19 infection, and how do the conditions of transit spaces themselves influence this effect? For transit planners and policy makers, this work offers insight into the effectiveness of widely adopted CSMs in mitigating riders' concerns. Such knowledge could help providers fine-tune their interventions, better direct their resources, and, most pressingly, quicken the rate at which riders return to their systems. While some urban populations are transitioning towards herd immunity, an examination of this intersection of COVID-19, safety interventions, and transit ridership remains relevant, particularly in geographical contexts where vaccination rollout is limited or where new variants of the coronavirus are spreading.

This paper is structured in the following way. Section 2 highlights the primary findings from relevant literature on the perceived risk of COVID-19 infection. Section 3 lays out the randomized control trial methodology of the study including details of participant sampling, data collection methodology, and data analysis. Section 4 presents the results and reflects on the limitations of the research. Section 5 concludes with a discussion of the policy implications, and identifies opportunities for future research.

3.2 LITERATURE REVIEW

This study is situated within a new and growing line of research whose objective is to better understand the psychological underpinnings of mobility behavior during the COVID-19 pandemic. The past two years have seen the publication of a number of such studies, with their primary focus being perceptions of risk of COVID-19 infection in varied transportation settings.

In the very early stages of the pandemic, the team of Ozbilen et al. (2021) looked at perceptions of risk of infection associated with different travel modes in Columbus, Ohio. This study entailed an online survey that ran from April to May of the pandemic's first year. It explored how stated levels of perceived risk, measured by a five-point Likert scale, were impacted by factors of age, gender, level of education, employment status, and household income. Among the socio-demographic characteristics tested, age and income levels proved to have a significant impact, with decreasing levels of perceived risk for increased age and higher incomes. The authors hypothesized that income-related findings were a function of access to better health insurance. Rather unsurprisingly, across all socio-demographic classification, perceived risk was significantly higher for shared transportation modes than for private modes, with transit – in this case only buses – rendering the highest perceived risk of all.

Further into the first year of the pandemic, Zafri et al. (2022) deployed a similar method – using an online survey and Likert scale measurements – exploring risk perception across mobility modes in Bangladesh in July and August of 2020. Their findings aligned with those of Ozbilen et al., (2021) with respect to the effects of age and income on perceived risk. However, they found that gender also had a significant impact with women perceiving greater levels of risk across all modes studied. Additionally, Zafri et al. (2022) expanded on previous work by including questions about how feasible respondents felt it was to achieve

COVID-19 safety recommended behavior in public transit environments. Among the 804 respondents, 75% disagreed or strongly disagreed with the statement 'Social/physical distancing is possible in public transport', with only 16% of respondents agreeing with this statement to any degree.

Research from Turin, Italy by Gnerre et al. (2022) continued this line of inquiry. Engaging online survey participants between January and March of 2021, this work focused specifically on perception of risk associated with transit. It expanded on past efforts by combining an exploration of risk perception of COVID-19 infection with stated satisfaction levels, and comparing these stated risk and satisfaction levels across three different time period: pre-pandemic, the present, and a projected post-emergency phase of the pandemic. The results showed the perceived risk of COVID-19 to be higher in transit vehicles than in waiting areas, and that this perceived risk existed not only at that present moment, but also for the riders' projected non-emergency future scenario. This line of questioning introduced to the literature evidence of the need to assess the potentially lasting, persistent nature of COVID-induced effects on transit use.

Expanding on these studies further, Parady et al. (2020) assessed how the impacts of COVID-19 on travel behavior differed by trip purpose. Focusing on the Tokyo metropolitan area during the first year of the pandemic, this research looked at perceived risk in the form of COVID-19 'dread', finding that dread motivated a "non-negligible increase" in probability to decrease travel overall, irrespective of mode. The authors articulated that, with fewer necessary activities – for example grocery shopping, work, and schooling – requiring travel outside of the home, transit rider return may have an increased dependence on choice trips. Maximizing ridership therefore necessarily depends on encouraging the making of non-essential trips. Parady et al.'s (2020) findings suggest that, at least in part, that requires efforts in minimizing dread.

The experiment conducted as a part of this research draws from and expands upon the literature presented above in several ways. First, this research follows the established methodology of testing the impact of age and gender. These two socio-demographic factors were most consistently found to have a significant impact on perceptions of risk of COVID-19 in transportation settings. On a second point of similarity, this research uses a Likert scale as the measurement technique for its variable of interest. However, this study differs from existing literature in that it is the first to test variation in COVID-related worry across different transit modes and spaces, to test the impact of CSMs and compliance levels, to introduce a randomized control trial methodology, and to incorporate the use of visuals (photo-simulated images).

With the aim of providing the first evaluation of the effectiveness of CSM policy in impacting riders' feelings, this research builds upon the groundwork laid by earlier studies. As recommended by Gnerre et al. (2022), this study tests whether an increase in information provision might impact rider feelings. As recommended by Zafri et al. (2022), the potential influence of discrepancies in COVID-19 immunity between individuals is examined. Finally, this study takes place in a cross-geographical context, incorporating recommendations made by Parady et al. (2020) to consider multiple cities within a single experiment.

3.3 METHODOLOGY

3.3.1 Conceptual Model

This research set out to assess how different CSMs affect people's worry in public transit spaces. To attain this objective, the widely deployed CSM interventions of required face mask use, physical distancing, risk reduction behavior information dissemination, and hand sanitizer dispenser provision were simulated. These CSMs were positioned across different transit modes and within different physical spaces that one

is likely to encounter while traveling via transit. These spaces were modified to reflect varied CSM combinations and levels of compliance with restrictions. Worry of COVID-19 infection was then measured using the psychometric scale developed by Taylor et al. (2020) to determine perceived risk of potential infection.

The specific interventions of face mask use, physical distancing, hand sanitizer dispenser provision, and information dissemination were chosen for simulation as they have each formed a central part of the landscape of COVID-19 safety measures undertaken worldwide, particularly in dense urban areas (Null and Smith, 2020). Face mask requirements and physical distancing markers in particularly were widely implemented (ibid.). While studies suggest that compliance with hand sanitization measures may in fact be low (Guellich, 2021; Nguyen and Pojani, 2021), it was nevertheless hypothesized here that the presence of dispensers might play an important psychological role in reducing worry of COVID-19 infection because of their high visibility and the sense of hygiene control they offer to users in an otherwise highly uncontrollable situation (Moen and Rundmo, 2006). For example, while a rider may not be able to choose how often the hand railing on a bus gets cleaned, they can choose to sanitize their own hands before, during, and/or after they ride the bus. Regarding the provision of information, several randomized controlled trial studies indicate that an increase in information presented to the public can be a powerful and cost-effective strategy to change perceptions and behavior around an issue (Andersen et al., 1998; Blamey et al., 1995; Bursztyn et al., 2020), including risk expectations (Shrestha, 2020). It is for these reasons that these CSM were centered within this work.

Participation in this randomized control trial was carried out in three stages. Stage 1: all participants signed an online consent form and completed a questionnaire on socio-economic characteristics, travel patterns, and self-assessed COVID-19 vulnerability. Stage 2: participants were randomly assigned to one of three conditions. Under one condition, participants were presented information indicating that hand sanitizer was provided in all metro and train stations and at bus and tram stops. Under the second condition, information was provided on the reduction in risk of transmission achieved by social distancing of one meter or more and face mask use. The third condition offered neither hand sanitizer nor risk reduction information. Stage 3: participants rated 19 (out of a potential 76) randomly assigned photo-simulated scenarios. These scenarios featured different levels of compliance with CSM guidelines across four modes of public transport (metro, train, tram, and bus), plus one image of an empty park that all participants rated. For each photo-simulated scenario, participants rated their worry of COVID-19 infection in the presented space on a ten-point scale: from ‘not at all’ to ‘extremely worried’ about contracting COVID-19.

Four different scenarios were simulated: 1) empty transit spaces, which served as the baseline worry of COVID-19 infection in each space; 2) a no-CSM compliance scenario, in which no people in the simulated image were physically distancing or wearing face masks; 3) partial CSM compliance, in which some people in the image adhere to the physical distance markers, and some wear face masks, with some masks not appropriately covering both nose and mouth; and 4) full CSM compliance, in which all people comply with physical distance markers and wear face masks correctly. These four scenarios were simulated across nineteen common typologies of public transport spaces (e.g. connection hallway, ticket office, stairs, platforms, seating areas, inside coaches) encapsulating the diversity of spaces that a transit user may engage with while traveling (see Image 1 for examples and Image 2.A in the Supplementary Material section for the full set of images used).

Additionally, an empty, daylit public park – with no people and no seating area – was included. This served as a baseline of minimum worry of COVID-19 infection in a public space, against which worry in transit spaces and the impact of CSMs were compared. An empty park was selected as a baseline for two reasons. First, virus contraction has been directly linked to the presence of other people, the presence of frequently

touched surfaces, and a lack of ventilation; therefore it seems reasonable to present the public park – a well-ventilated outdoor area, with no people and no objects such as public bins or seats – as a public space that, while both familiar and regularly frequented, is able to provide the lowest possible opportunity for contracting COVID-19.

Second, this choice was motivated by the very nature of what it means for a space to be *public,* and the implications that that has for levels of personal *control* over a space. At least in concept, all have access to a public space, and a public body is charged with the authority to make changes in, assign rules and regulations over, and to enforce said regulations within that space. This is true in both the case of the park and most transit spaces. In both cases, one's worry is, at least in part, derived from not knowing who used the space previously nor who you may end up sharing the space with, and having no real power over the behavior of others within that space. Given these two points, worry of infection in the public park provides a convenient means of understanding the minimum possible achievable worry of infection in a potentially shared space open to the public.

Along similar lines, this was deemed a more useful comparison for policy makers than, for example, a comparison to worry felt while using a private vehicular mode. In the private vehicle case, the vehicle operator would have much more control (e.g. able to make decisions about who else enters the car) and therefore much more direct influence over the COVID-related riskiness of a given situation. Given how important a contributing factor to worry perceived control is (Moen and Rundmo, 2006), we argue the low control environment of the park makes for a better COVID-riskiness comparative with the low control transit scenarios.

3.3.2 Sampling Method

Participant recruitment was conducted online through paid social media advertisements restricted to people over 18 years of age and located in London (United Kingdom), Milan (Italy), and Santiago (Chile), with the results gathered between November 10th, 2020 and January 10th, 2021. This online method of data collection facilitated access to participants across the three cities, and social media advertising allowed for a wide reach, exposing recruitment offers to a sizeable sample of participants.

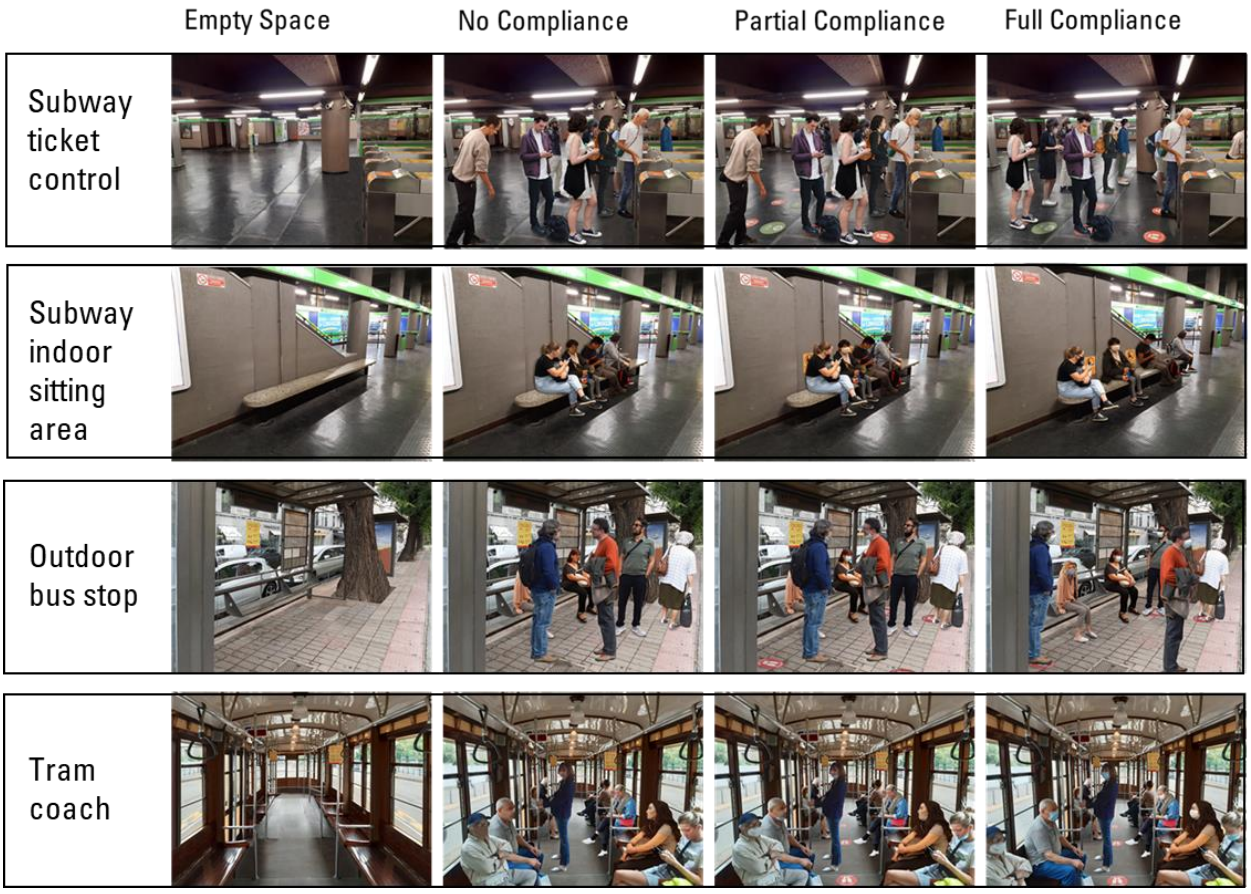
The three major cities selected as focal sites all have major transit networks including train, metro, and bus options. Milan additionally has a comprehensive tram network. In all cities, face masks were compulsory, and physical distancing was encouraged. In Milan and London, hand sanitizer dispensers were available at all train and metro stations, while in Santiago these were not widely provided. These cities also offer contrasts in their contexts of geography, public health, and transit use. Cities from both hemispheres were intentionally selected as seasonality has been found to impact the number of active COVID-19 cases (Liu et al., 2021). At the time of data collection, Milan and London were entering their 'second wave' winter peak of COVID-19 infections with London reaching just over 35,000 daily cases and Milan just over 20,000 cases/day, while during most of this period Santiago was recording a low number of infections; just shy of 1,500 cases/day during the southern hemisphere summer. COVID-related death trends also differed during this period: the UK experienced an upward trend, reaching 800 deaths per day at the end of data collection, while in Italy this trend was reversed, decreasing from over 700 deaths per day to fewer than 500. In contrast, Chile maintained a comparatively flat rate, remaining below 50 deaths per day.

As the UK and Italy entered their second waves of COVID-19 infections, tight mobility and lockdown restrictions were present during most of the data collection period in both cities. In contrast, only light mobility restrictions were imposed in Santiago, with no lockdowns occurring throughout the data collection period. Regarding impact on public transport use, the three cities experienced a significant loss

of public transport riders in 2020 all maintaining monthly average ridership volumes below 50% of the corresponding months from 2019, and large numbers of commuters reported using public transport less often than they had previously (London: 39.2%; Santiago: 44.8%; Milan: 42.2%) (Global Public Transit Report, 2020). A global app-based survey of commuters conducted by Moovit, found that measures to increase social distancing throughout the transit travel experience were the most important factors in returning to public transport for commuters in both Milan and Santiago. London-based commuters ranked this CSM as the second most important influencer over their potential return to transit behind increasing vehicle frequency to reduce onboard crowding (ibid.).

A total of 564 people participated in this study: 49.3% of participants were from Milan, 40.3% from Santiago, and 5.8% from London. An additional 4.5% of respondents are from other cities in the world, as the link might have been reshared on social media. This participant cohort produced 11,283 image ratings, with an average time of 5 minutes and 37 seconds taken to complete the experiment. No payments were offered to participants. Participants accessed the experiment through a link on their device (desktop, tablet, or mobile phone) and were prompted to read the study protocol, and all participants signed an online informed consent form prior to being sorted into a treatment group, and finally rating their randomly assigned photo-simulated scenarios.

Image 1. Example of photographic simulations of compliance with COVID-19 safety measures.



A specialized research platform (www.urban-experiment.com) was used to run this image-based experiment. The platform maximized full-screen display of images on any device used. To ensure participants were balanced across CSM scenarios, a double randomization process for the images was

introduced. First, the research platform randomly allocated the order of appearance of the 20 categories of spaces presented to each participant. With this, the order of all the presented images was balanced, thus minimizing the impact of potential participant attention or fatigue effects. Second, as is customary in randomized controlled trials, only one image was randomly selected and rated by participants for each category of image. This double randomization process allowed for, in a single experiment, the conducting of multiple control trials testing CSMs across several transit scenarios, maximizing data collection while eliminating potential confounders.

3.3.3 Data Collection

Data pertaining to three categories was collected: 1) participants' background characteristics, transport patterns, and attitudes towards COVID-19; 2) experimental condition measures; and 3) participants' feelings of worry about COVID-19 infection. Participant data included their gender, age, country of residence, educational level, and commuting mode before and after the onset of the pandemic. Additionally, COVID-19-specific data was collected. This included information on participants' self-declared level of use of face masks on public transport, whether they are or live with someone classified as 'high-risk' with respect to COVID-19 exposure and susceptibility, their known prior proximity to a person infected with COVID-19, and having been infected themselves at any point. Experimental conditions included treatment status, image category (from 1 to 20), image order of appearance, time of each response, and date of participant access to the experiment. 'Worry' was represented by the stated worry of COVID-19 infection felt in the scenario presented in each image (see supplementary Table 1 for variable descriptions).

3.3.4 Data Analysis

Mixed regressions (fixed-effects and random intercepts) were used to identify significant differences between CSM effects. Random effects at the individual level controlled for differing baseline levels of worry of COVID-19 infection between participants. Four fixed-effect controls were applied: 1) at the image level – to account for each image having a potentially different average score; 2) the order of appearance – to account for the fact that image ratings might depend on the sequence of appearance; 3) date of response – to account for evolution of the pandemic, which may have impacted participants' perceptions; and 4) participant city – to be able to account for differing COVID-19 infection rates, deaths, and policies in each country that might influence responses. The resultant model took the following form:

$$(1) \qquad Worry_{ij} = \beta_1 Compliance_i + \beta_2 X_i + U_j + E_{ij}$$

where $Worry_{ij}$ is the declared perception of worry of COVID-19 infection of participant j for image i. Compliance is a categorical variable from one to four if the ith image contains an empty transport space, one for an image with no compliance, two for partial compliance, and three for full compliance. β_1 is the coefficient of interest that captures the impact of CSMs on participants' worry of COVID-19. X_i is the fixed effects of image ID, order of appearance, date of response, and city of the respondent for the ith image rated. U_j is the random intercept associated with the jth individual. E_{ij} is the error term.

Note that groups of participants rating different CSM scenarios were comparable in observable and unobservable characteristics. Two strategies were deployed to ensure that the presented images were the only element measurably influencing participants' responses. While the randomization of images ensures that the control and treatment groups are balanced and comparable, an empirical proof of this provides further validity. Statistical tests were therefore conducted to check that control and treatment groups were balanced across CSM scenarios for the 19 transit spaces in all observable characteristics for each CSM. Of the 144 balance tests, 3 were significant at 5%, which represents successful randomization. As the observable characteristics are balanced, by extension, unobservable covariates are also expected to be

balanced. Therefore it is fair to assume that the groups rating CSMs are indeed comparable. Additionally, the regression analyses were first conducted without and then with controls, including all twelve covariates. Estimations of worry of COVID-19 infection that remained stable to the addition of all relevant observable covariates in the model are presented (see Supplementary Material).

In the following section, worry rating results are compared against the established baseline of worry of COVID-19 infection in an empty public park space. Only results that present a significant difference above 5% in both mixed-regression models with and without controls, and whose estimates remained stable in both models, are discussed.

3.4 RESULTS

3.4.1 CSM and Worry Ratings

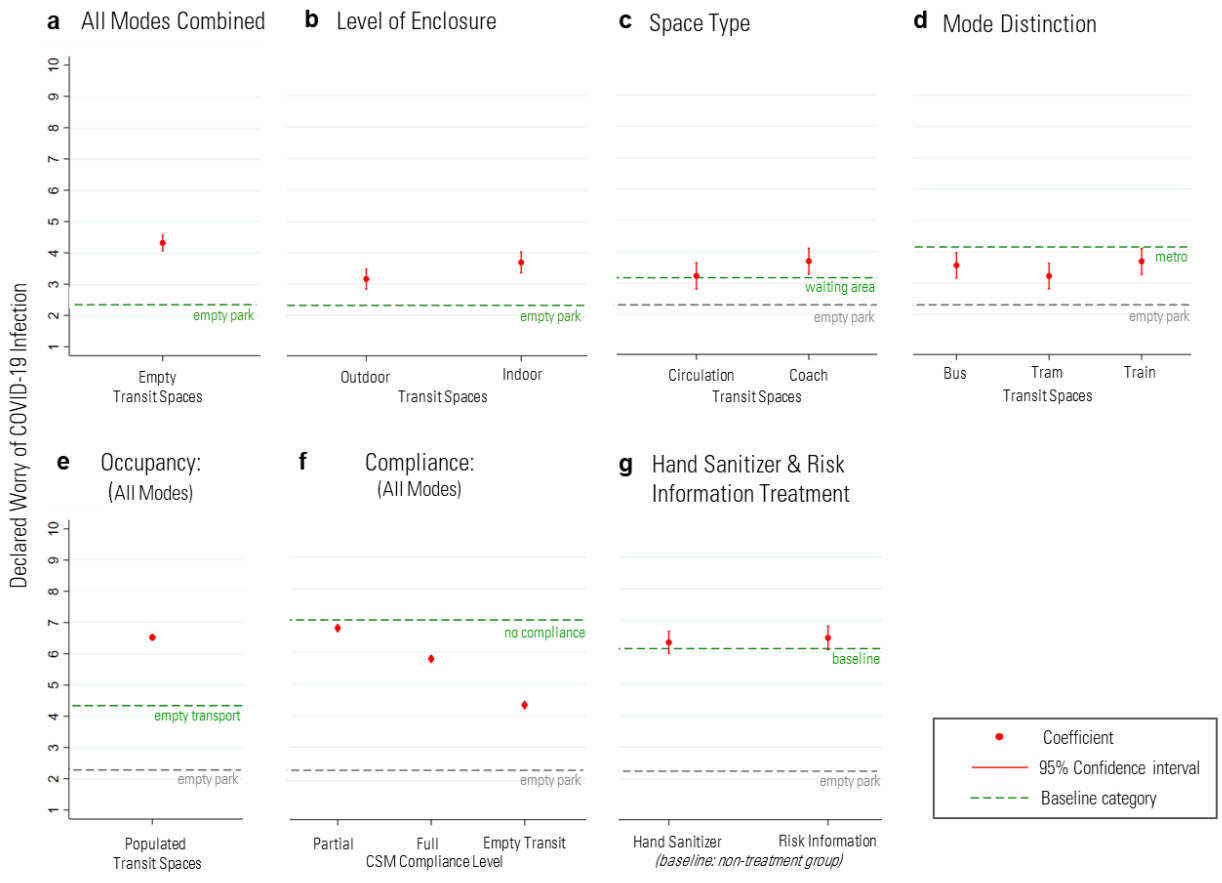


Figure 1. The declared worry of COVID-19 infection across different public transit scenarios. Results are presented on a 1 to 10 scale where 1 represents "not worried at all" and 10 "extremely worried". **a**–**g**. Results are shown for the following explanatory variables: empty transport (**a**); level of enclosure in the space (**b**); type of public transit space (**c**); public transit mode (**d**); occupancy across public transit mode (**e**); level of travelers' compliance with CSMs (**f**); and provision of hand sanitizer and CSM risk-reduction information (**g**). The regression coefficients are represented by dots and 95% confidence intervals around coefficients. Mixed regression estimates with controls can be found in Supplementary Tables A.1-A.7. **c-g** plot in grey the mean of the empty park category (W=2.69) as a reference point of minimal worry of COVID-19 infection in a public space.

Public transit space induces COVID worry.
This experiment reveals that, compared to unpopulated parks, transit spaces are perceived as unsafe with respect to risk of coronavirus contraction, even when empty (worry estimate [W]= 1.637, P<0.001) (Fig. 1a). Travelers are particularly worried about COVID-19 infection in enclosed (W=1.368, P<0.001), as opposed to open-air (W=0.841, P<0.001), transit spaces. This holds true even when these spaces are empty (Fig. 1b). Worry is particularly high within vehicle coaches (W=0.528, p<0.023), with no significant difference between areas of high human circulation (W=0.0582, p=0.786) and waiting spaces at platforms and bus/tram stops (Fig. 1c). Though all transit modes render higher levels of COVID-19 worry than the empty park baseline scenario, not all modes are equally concerning to riders. Worry is highest in metro (subway) spaces. Compared to metro spaces, worry is significantly lower in bus (W= -0.586, p=0.004), train (W= -0.460, p<0.030) and tram spaces (W= -0.928, p<0.001) (Fig. 1d).

Full compliance with CSMs is needed to reduce worry.
The incorporation of other people into transit spaces substantially increases traveler worry of COVID-19 infection associated with those spaces (W=2.184, p<0.001) (Fig. 1e). The results show that, along with reducing the probability of virus contraction, the combination of wearing face masks and social distancing significantly reduce worry of COVID-19 infection. However, for worry to drop sizably, all users of a space must comply with these CSMs (W= -1.227. p<0.001) as conditions of partial compliance reveal only mild worry reduction effects for travelers (W= -0.260, p<0.001) (Fig. 1f). As Figure 2 shows, this requirement of full compliance with CSM to significantly reduce worry of infection is consistent across all the three cities studied (W-Milan: -1.545, p<0.001; W-Santiago: 0.763, p<0.001 ; W-London:-1.337 , p<0.001).

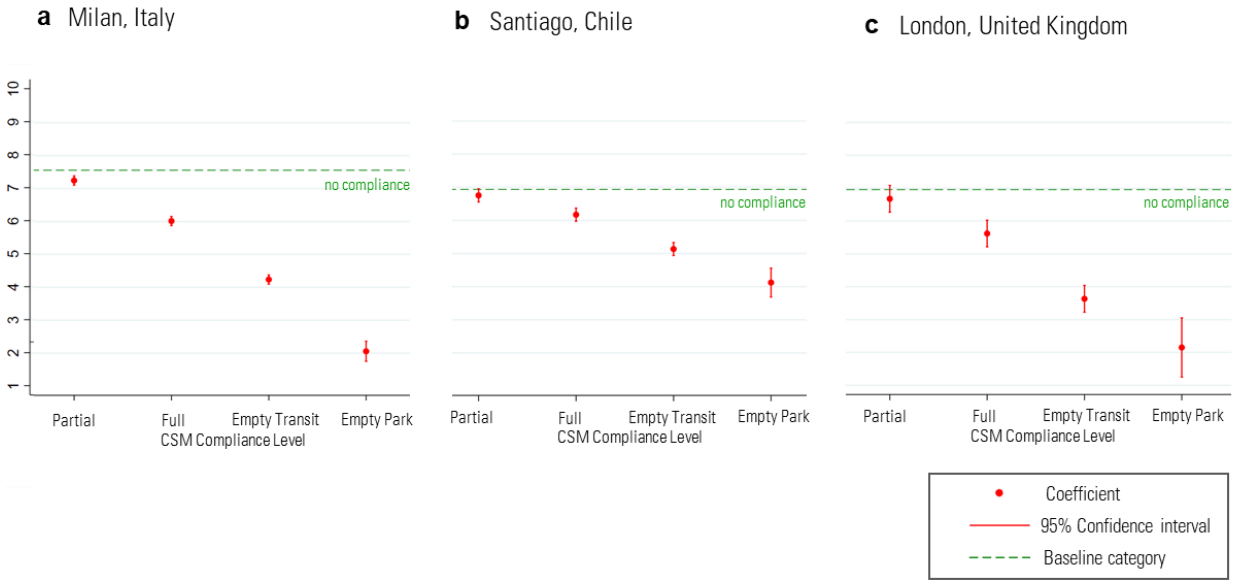


Figure 2. The declared worry of COVID-19 infection across different geographic locations. Results are presented in a 1 to 10 scale where 1 means "not worried at all" and 10 "extremely worried". **a**–**c**, Results are shown for the level of travelers' compliance with CSM in (**a**) Milan; (**b**) Santiago; and (**c**) London. The regression coefficients are represented by dots and 95% by error bars around coefficients. Mixed regressions estimate with controls can be found in Supplementary Table A.8.

Neither hand sanitizer nor information provision reduce worry.
Regarding the availability of hand sanitizer at metro and train stations and bus and tram stops, participants do not demonstrate a significant difference in worry of COVID-19 infection in scenarios where hand sanitizer was available, compared to cases in which it was not (W=0.196, p=0.271) (Fig. 1g). This lack of

a significant impact is consistent across all transit modes (Fig. 3a). This result stands in opposition to the intuition that more people having the opportunity to use hand sanitizer means fewer, less heavily contaminated surfaces and therefore a lower perceived likelihood of infection. While a definitive explanation for this lack of impact cannot be made, one potential explanation is that hand sanitizer use is difficult to monitor in crowds. Because of this, individuals in this treatment group may have assumed low levels of hand sanitizer use by their fellow riders, despite its availability.

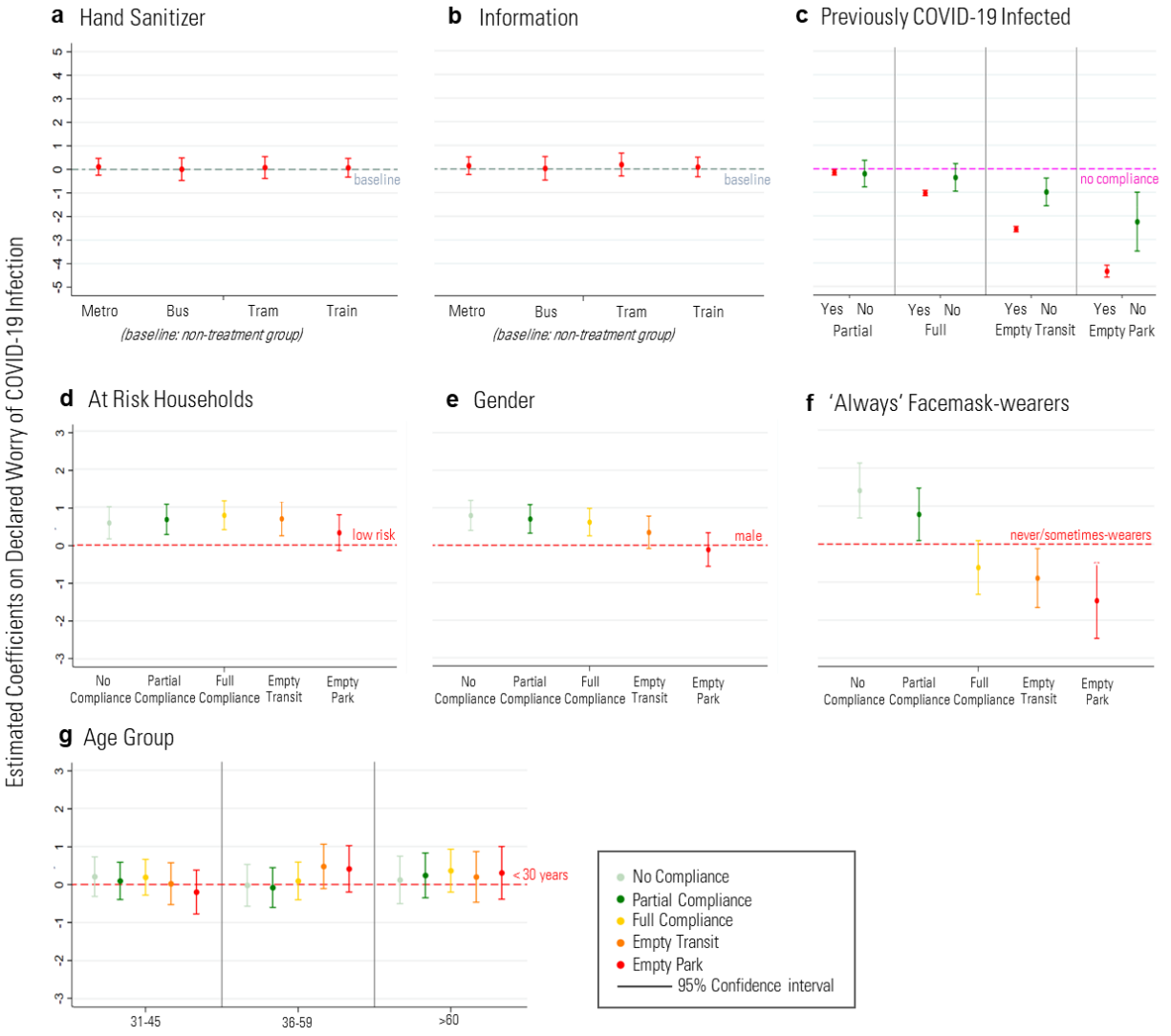


Figure 3. Estimated effect sizes of various explanatory variables on travelers' declared worry of COVID-19 infection. For all graphs the estimated effect size for each explanatory variable shows the difference in points compared with a baseline category represented by a horizontal line. Estimated effect sizes are derived from mixed regressions. An effect size of <0 suggests that a given variable reduces travelers worry of COVID-19 infection compared with the baseline, and if it is >0, the variable increases worry. 95% confidence intervals are represented by error bars around coefficients. a–f, Results are shown for the following explanatory variables: availability of hand sanitizer for different public transit modes (a); provision of information about the effect of CSMs on risk of COVID-19 infection (b); whether the traveler had previously contracted COVID-19 or not (c); whether the traveler lives with a person classified as clinically extremely vulnerable (d); gender of the traveler (e); the level of the travelers' use of face masks in public transit (f); and the age group of the traveler (g). Mixed regression estimates with controls can be found in Supplementary Table A.9-A.14.

Similarly, the provision of information about the effectiveness of face mask use and social distancing in reducing COVID-19 infection fails to render a significant impact on passenger worry when compared to the case of no information provided (W=0.339, p=0.074) (Fig. 1g). This lack of significant impact against the no-information baseline treatment holds true even when delineated by transit mode (metro: W=0.140, p=0.534; bus: W=0.028, p=0.914; tram: W=0.188, 0.445; train: W=0.085, p=0.686) (Fig. 3b).

Past contraction of COVID-19 makes people feel safer.

At the time of this experiment, many people had contracted and recovered from COVID-19, and extensive vaccination programs were in the midst of being rolled out. Furthermore, cities were reaching herd immunity at different rates, and new variants were causing different parts of the world to exit and re-enter lockdown conditions in waves, as contagion risk ebbed and flowed. This raises the question of how worry is impacted by CSMs under different conditions of immunity. To inform this question, this experiment analyzed worry of COVID-19 infection among those who have the highest likelihood of functional immunity by way of having previously contracted and recovered from the virus (Dan, 2021). While it is understood that previous contraction of COVID-19 does not render an individual fully immune to re-contraction, particularly given the spread of variants of the virus, the low number of cases of confirmed re-infection do suggest that those previously infected are likely to be particularly resilient against future infection (ibid.). In this sense, using previous COVID contraction as a proxy for immunity – and more specifically, for the *perception* of immunity – is reasonable. Within the participant cohort, 5% were classified as immune via this prior-contraction proxy.

Among these perceived immune participants, just as among those who had never knowingly contracted COVID-19, worry of infection is higher in public transit spaces than in the empty park scenario, even when those transit spaces are empty (W=1.426, p=.011). However, in both cases, overall worry levels are lower among the immune than the non-immune: when compared against a baseline of non-compliance, neither partial (W=0.202, p=0.480) nor full compliance (W=0.365, p=0.222) with CSMs have a significant impact on worry for travelers who have previously contracted the virus (Fig. 3c).

Household risk, gender, and behavioral patterns.

Households in which at least one member is highly vulnerable (e.g. people who are undergoing cancer treatment, who have a respiratory condition, or who are immunocompromised) have a higher level of worry of contracting the virus in transit spaces than households with no highly vulnerable members (W=0. 667, p<0.001) (Fig. 3d). None of the different levels of CSM compliance have a significant impact on this outcome. Furthermore, women worry more about contracting the virus in transit spaces than men (W=0.655, p<0.001), and again, CSM adherence does not have a significant effect in reducing this gendered difference (Fig. 3e).

Compared with those who sometimes or never wear face masks in transit spaces, travelers who always use a face covering are more worried about infection in scenarios of no compliance (W=1.410, p<0.001) and partial compliance (W=0.783, p<0.026). This gap closes, however, in a full-compliance scenario (W=-0.615, p=0.088), supporting the claim that the correct face mask wearing has worry-mitigating impacts not only as a measure of perceived self-protection, but also as an observed collective behavior (Fig. 3f). Finally, regarding age, no significant differences in worry of getting infected are found across different age groups in the participant cohort (31-45 years: W=0.173, p=0.410; 46-58 years: W=0.028, p=0.900; >60 years: W=0.270, p=0.286); this is true for the results overall, and also when considering scenarios with different levels of compliance with CSMs (Fig. 3g).

3.4.2 Limitations

This experiment relies heavily on the use of digital images to represent real-world transit experiences. This was primarily due to an inability to conduct studies in the field due to travel and lockdown restrictions. Video and sound were not included, as we were unable to guarantee via the virtual experiment platform that people would in fact listen to any audio offered, or watch any videos in full. More comprehensive results might have been obtained in more immersive scenarios that more closely mirrored real life. Nonetheless, this image-based experiment serves as a suitable, if conservative, proxy, as studies show that image evaluation is correlated with real-life emotional reactions (Rossetti and Hurtibia, 2020; van den Brink et al., 2017).

Additionally, the scenarios simulated in this experiment unfortunately do not reflect transit images that are well-representative of the majority of transit spaces within each of the different participant cities. The images supporting the photo simulations were derived from particularly well maintained transit areas in central Milan. The images all showed appealing, clean, well-lit transit realms. While these features may be accurately representative of some transit spaces, it is unlikely that they accurately reflect the majority of transit spaces that participants encounter. Future iterations of this experiment should strive for images that most closely mirror real-life transit experiences. While we keep cleanliness levels constant for each public transport space, it may be the case that cleanliness itself is as a relevant factor in affecting worry of COVID-19 infection, and thus the results of this study might vary across different contexts of cleanliness. Further studies could investigate this effect, modifying the image conditions to photo-simulate different scenarios of cleanliness.

Crowdedness is one additional factor that deserves further attention. Commuter surveys show that reducing crowdedness in coaches is an important measure to increase transit use following the pandemic (Global Public Transit Report, 2020). However, any policy change in this direction would need to be contrasted with the potential counterbalancing effect on personal safety concerns. That is to say, while a reduction in ridership volumes may make riders generally feel more COVID-safe, reduced ridership may cause some riders – notably women-identifying riders (Loukaitou-Sideris and Fink, 2009) and members of other socially vulnerable populations (Brownson et al., 2001; Clancy et al., 2001; Craig et al., 2002) – to feel less physically safe irrespective of the coronavirus. Unfortunately, testing the intersections between COVID-specific and non-COVID-specific safety concerns (e.g. crowdedness, time of day/night of travel) goes beyond the financial restrictions of this research, as it would have necessitated a significant expansion of the number of photo-simulation scenarios (CSMs x Crowdedness; CSMs x Night Conditions; CSM x Crowdedness x Night Conditions) and of the experiment's sample size. These broader intersecting rider worries, though a limitation in this particular research, would be a worthy focus of future photo-simulation randomized control trial studies.

In this study, the potential impact of sharing information with riders regarding increased ventilation throughout transit spaces is not tested. This choice was made because this CSM – ventilation information dissemination – though present in some systems, is not one of the more widely used across the world's transit networks. Still, given the efficacy of ventilation practices in lowering spread rates of COVID-19 in indoor spaces, as emphasized by studies from a range of research disciplines (Sun and Zhai, 2020; Fadaei, 2021; Querol et al., 2022), we feel that this study is limited by its omission of investigation of the effects of improved ventilation and relevant information dissemination on levels of worry in transit environments.

While data was collected from participants in London, Milan, and Santiago, direct cross-city comparisons of findings unfortunately cannot be made. Since data was collected from participants recruited through paid social media advertising, the participant sample is not representative of each city's general demographics. While this experiment, as with any randomized controlled trial, still has high internal

validity, future studies could conduct this experiment on a more representative sample to overcome this limitation.

Finally, while CSMs might reduce the worry of COVID-19 infection, there remains the possibility that these measures have the opposite effect, inducing or increasing worry. For example, by simply seeing others wearing face masks, travelers may be reminded of their risk of infection, in turn raising their levels of worry. While this research accounts for this potential bi-directionality by estimating the aggregate effect of CSMs via comparison of full, partial and no compliance scenarios, it cannot disentangle the specific impact of CSMs as facilitators of worry from their impact in reducing worry of virus infection.

3.5 DISCUSSION AND CONCLUSION

Perceiving transit to be a high-risk mode of transport for COVID-19 infection, many travelers have switched to private vehicular modes. If this modal switch persists, the financial sustainability of public transit, as well as the social and environmental benefits it facilitates, stand in jeopardy. While most public transit agencies have, at some point in the pandemic, implemented measures to offer a higher likelihood of safe travel through transit spaces – the most common being compulsory face mask wearing, the presence of physical distancing markers, and the provision of hand-sanitizing equipment – it is unclear whether their capacity to provide travelers with a decreased perception of risk is pervasive enough to encourage a return to transit. This assessment of traveler worry regarding COVID-19 infection in transit spaces, and the ways in which the aforementioned COVID safety measures impact these feelings, offers some insight.

This work's central finding is that across all transit modes, mask-wearing and social distancing measures do indeed significantly decrease riders' worry of infection, but that that impact is dependent on the full compliance of travelers with these CSMs. It is worth noting that this effect is not observed for the population with perceived immunity to COVID-19. Still, the all-or-nothing nature (full compliance vs all other levels of compliance) of this finding suggests that CSMs should continue to be required as perceptions of immunity – be that from vaccination or having contracted and recovered from the virus – increase globally; notably in countries where vaccination rates remain low, and as new variants of the coronavirus appear. Furthermore, these results prove consistent across all three cities studied suggesting that full-compliance is required to reduce worry of infection across a diversity of cultural, social, and COVID-19 trend contexts.

In the absence of full trust in other travelers to comply with all CSM regulations, enforcement is likely necessary to effectively reduce traveler worry. Careful attention should be paid to exactly what form this CSM enforcement takes. Thus far in the pandemic, several different enforcement practices have been tested with varied levels of success. In some cases vehicle operators have been tasked with enforcement of face mask wearing, leading in some instances to their being verbally berated, physically assaulted, or forced to suspend and interrupt services to deal with non-compliant passengers (Schultz and Bryon, 2021). Though common in the early stages of the pandemic, this practice has gradually been abandoned due to drivers expressing discomfort with the resulting confrontation and fear of physical endangerment, as well as inconsistencies in strictness of adherence to regulations across operators, and union disputes over drivers taking on additional responsibilities without additional compensation (Kershner and Johnston, 2021). In other cases, law enforcement agents – i.e. police officers – have been tasked with enforcing mask wearing in transit spaces. In these cases, the penalty for non-compliance has most commonly been a fine and removal from the vehicle or transit station (Topham, 2021). This method has similarly been deemed unsatisfactory. In addition to accounts of violence towards police and discomfort with increased police

presence in public space associated with feared brutality and misconducted by police (Schultz and Bryon, 2021), low officer capacity and low willingness to enforce have contributed to particularly low compliance rates – often below 50% – in several municipalities using this approach (ibid.; Phillips, 2020).

Southeastern Pennsylvania Transportation Authority (SEPTA), transit provider for the Greater Philadelphia Area, has taken a unique approach to face mask enforcement across their network, deploying what they call a "speak-softly-and-carry-a-box-of-masks" technique (Fitzgerald, 2021). In this strategy, enforcement is handled by SEPTA employees from many departments. Some are planners, some are administrators, and some are social workers initially hired to facilitate connecting those using SEPTA facilities for shelter with social services (Suzuki, 2020). These workers directly distribute masks and offer COVID-safety educational materials within their assigned transit space to any people not wearing a face covering. There are no fines or removal penalties if passengers refuse to engage with workers or wear the free mask. In January 2021, SEPTA conducted a 4,000-rider compliance audit across their subway trains, buses, and trolleys, with a compliance rate of 90% reported (Fitzgerald, 2021). Innovative strategies like this that pull from a wider-reaching workforce – or that employ an entirely new workforce – and encouraging face mask use through the deployment of individuals trained in de-escalation, customer assistance, consensus building, and education techniques may be a sustainable and effective way forward in the future of the pandemic (Suzuki, 2020; Kershner and Johnston, 2021).

The question of the best placement of enforcement efforts within transit spaces is also important. Findings reveal that feelings of worry vary across different transit modes and commuting spaces: subway areas are associated with the highest levels of worry, and tram spaces the lowest. Moreover, worry is at its highest in transit spaces that are enclosed and host high levels of human circulation, particularly within carriages. This suggests that transit providers would see the largest impact on riders' COVID-related worries if enforcement efforts were concentrated in subways, on board vehicles, and in tight, hallway spaces. This differs from current practices, as most systems with enforcement in place focus those measures at station entrances with little specificity across mode types.

The enforcement of social distancing presents particular difficulty, as its success functionally conflicts with transit service capacity – when vehicle frequency remains the same, or with operational cost – when vehicle frequency is increased. Both cases impact the financial sustainability of transit agencies. Providers will no doubt need to balance the value of these trade-offs. Nonetheless, different enforcement, encouragement, and incentivization techniques have resulted in different levels of compliance. These variations can inform agencies going forward. In particular, floor and seat markers that can be stood or sat on, and in that sense can be functionally ignored, have rendered lower compliance rates than spacing designs that make non-compliance physically difficult or impossible (Nocco et al., 2020). Design solutions, as opposed to enforcement personnel, then could be prioritized by agencies addressing social distancing across their infrastructure.

Though this study's findings encourage the continued implementation of face mask and social distancing CSMs, the use of hand sanitizer and provision of information regarding CSM efficacy are measures that could be lifted and/or remain unenforced without a major effect, at least with respect to their role in impacting rider worry. Both of these measures demonstrated no significant impact on feelings of worry across any socio-demographic categorization, across any transit mode specification, or across compliance levels. This aligns with past research that has found inconsistencies between transit riders' interpretation of information provided to them. Dong et al. (2021), for instance, found that some riders take comfort in increased knowledge regarding COVID-19, while for other riders, an increase in knowledge led to sensationalizing and catastrophizing. These directionally competing outlooks may contribute to the finding

that provision of COVID risk reduction information in public transit spaces led to no significant impact on worry about infection within this experiment.

In line with results from existing literature (Zafri et al., 2022; Gnerre et al., 2022), this experiment finds that levels of perceived risk vary by gender. Travelers who identify as women experience significantly higher levels of worry in populated transit spaces than those who identify as men, and CSMs do not have a significant impact on mitigating this gender disparity. Additional findings confirm results of past studies at the intersection of risk perception and health vulnerability (He et al., 2021), concluding that members of households in which an individual is immunocompromised or highly COVID-vulnerable are more worried about infection in public transit than members of otherwise lower-risk households. As in the case of gender, CSMs fail to significantly shrink the worry-gap between these two groups. Results further reveal that people who always comply with face mask rules are more worried about contracting the virus in these spaces, however this disparity closes when all other commuters abide with CSMs. It is in this last cohort where we may see the continuation of CSMs being more effective in retaining or bringing back rider numbers. These findings can help informing transit providers of disparities in the effects of CSMs, allowing them to make informed decisions around implementation of measures in future.

An element of hope can be extracted from the finding that those who have already contracted and recovered from COVID-19 at some point during the pandemic are less worried about contracting COVID in transit spaces than those who have not, with CSMs no longer having a significant impact on this group. In keeping with the previously discussed connection between worry and mode choice, this suggests that, as a larger share of the population has at some point either contracted and recovered from COVID-19 or has been vaccinated, transit agencies can reasonably expect an increase in ridership. Further research is needed, however, to project the magnitude of riders expected to return under scenarios of different scales of immunity proliferation.

Finally, it is important to note that while a safe return to high capacity operations may be necessary to reverse the current downward spiral of transit (Sadik-Khan and Solomonow, 2020), CSMs – their design, duration, enforcement structures, and the combination of measures used – are on their own unlikely capable of returning ridership to pre-pandemic levels. CSMs only tackle a piece of the ridership puzzle. It is possible that ongoing changes to working, schooling, and recreational practices continue to alter the transit-use landscape for the foreseeable future. As such, a more structural rethinking of how our transit systems function may be required to regain healthy, sustainable ridership levels.

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SUPPLEMENTARY MATERIALS: Paper 2

Table A.1: Worry of COVID-19 infection in empty public transit.

VARIABLES	1	2
Empty Park (baseline)		
Empty Public Transit	1.64***	1.64***
	(0.13)	(0.13)
Other Public Transit Scenarios	3.82***	3.82***
	(0.12)	(0.12)
Controls	NO	YES
Constant	2.69***	2.15***
	(0.14)	(0.76)
Observations	11,283	11,283
Number of groups	582	582

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.2 Worry of COVID-19 infection in empty public transit outdoor and indoor spaces

VARIABLES	1	2
Empty Park (baseline)		
Public Transport (Outdoor)	0.84***	0.89***
	(0.16)	(0.16)
Public Transport (Indoor)	1.37***	1.38***
	(0.17)	(0.17)
Controls	NO	YES
Constant	2.32***	2.53**
	(0.15)	(1.02)
Observations	3,260	3,260
R-squared		
Number of groups	578	578

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.3: Worry of COVID-19 infection in empty public transit by type of space

VARIABLES	1	2
Waiting Areas (baseline)		
Circulation	0.06	0.22
	(0.21)	(0.19)
Coach	0.53**	0.48**
	(0.21)	(0.20)
Control	NO	YES
Constant	3.16***	3.52***
	(0.20)	(1.09)
Observations	3,260	2,696
Number of groups	578	575

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.4: Worry of COVID-19 infection in empty public transit by transport mode

VARIABLES	1	2
Metro (Baseline)		
Bus	-0.59***	-0.63***
	(0.21)	(0.20)
Tram	-0.93***	-0.95***
	(0.21)	(0.21)
Train	-0.46**	-0.45**
	(0.21)	(0.21)
Public Park	-1.83***	-1.84***
	(0.16)	(0.16)
Controls	NO	YES
Constant	4.15***	4.37***
	(0.20)	(1.03)
Observations	3,260	3,260
Number of groups	578	578

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.5: Worry of COVID-19 infection in public transit with and without users

VARIABLES		1	2
Public Transport (Empty)			
	With Users	2.18***	1.94***
		(0.05)	(0.05)
	Empty (Park)	-1.64***	-1.48***
		(0.13)	(0.14)
Controls		NO	YES
Constant		4.33***	3.46***
		(0.14)	(0.79)
Observations		11,283	8,631
Number of groups		582	579

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.6: Worry of COVID-19 infection in public transit by compliance with safety covid measures

VARIABLES		1	2
No Compliance (baseline)			
	Partial Compliance	-0.26***	-0.26***
		(0.06)	(0.06)
	Full SDM Compliance	-1.23***	-1.22***
		(0.06)	(0.06)
	Empty Public Transport	-2.69***	-2.68***
		(0.06)	(0.06)
	Empty Public Park	-4.32***	-4.32***
		(0.13)	(0.13)
Controls		NO	YES
Constant		7.02***	6.43***
		(0.14)	(0.76)
Observations		11,283	11,283
Number of groups		582	582

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.7: Worry of COVID-19 infection in public transit under hand sanitizer provision and risk information display

VARIABLES	1	2
No Hand Sanitizer or Information		
Hand Sanitizer	0.20	-0.10
	(0.18)	(0.19)
Risk Information	0.34*	-0.05
	(0.19)	(0.20)
Controls	No	Yes
Constant	6.11***	5.57***
	(0.18)	(0.87)
Observations	8,023	8,023
Number of groups	580	580

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.8: Worry of COVID-19 infection in public transit by compliance with safety covid measures by city

	Milan		Santiago de Chile		London	
VARIABLES	1	2	3	4	5	6
Partial Compliance	-0.314***	-0.304***	-0.180*	-0.180*	-0.279	-0.369*
	(0.0709)	(0.0707)	(0.101)	(0.101)	(0.208)	(0.206)
Full SDM Compliance	-1.545***	-1.538***	-0.763***	-0.754***	-1.337***	-1.365***
	(0.0703)	(0.0703)	(0.101)	(0.101)	(0.207)	(0.202)
Empty Public Transport	-3.323***	-3.310***	-1.799***	-1.797***	-3.324***	-3.374***
	(0.0710)	(0.0710)	(0.0997)	(0.0998)	(0.208)	(0.204)
Empty Public Park	-5.504***	-5.506***	-2.811***	-2.799***	-4.805***	-5.022***
	(0.156)	(0.155)	(0.222)	(0.222)	(0.460)	(0.452)
Controls	NO	YES	NO	YES	NO	YES
Constant	7.560***	8.827***	6.934***	6.691***	6.957***	10.68***
	(0.157)	(1.331)	(0.195)	(1.181)	(0.474)	(1.733)
Observations	5,566	5,566	4,551	4,551	660	660
Number of groups	280	280	242	242	33	33

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.9: Worry of COVID-19 infection in public transit under hand sanitizer provision and risk information display by transport mode

	Metro		Bus		Tram		Train	
VARIABLES	1	2	3	4	5	6	7	8
No Hand Sanitizer or Information								
Hand Sanitizer	0.11	-0.04	0.01	-0.09	0.08	0.11	0.07	-0.05
	(0.18)	(0.18)	(0.24)	(0.24)	(0.24)	(0.24)	(0.20)	(0.20)
Risk Information	0.14	0.03	0.03	-0.04	0.19	0.22	0.09	-0.03
	(0.19)	(0.19)	(0.25)	(0.25)	(0.25)	(0.24)	(0.21)	(0.20)
Controls	NO	YES	NO	YES	NO	YES	NO	YES
Constant	5.42***	5.31***	5.38***	5.61***	4.43***	3.80***	6.15***	5.13***
	(0.18)	(0.83)	(0.22)	(1.14)	(0.21)	(1.11)	(0.19)	(0.91)
Observations	6,208	6,208	1,125	1,125	1,132	1,132	2,254	2,254
Number of groups	581	581	564	564	567	567	573	573

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.10: Worry of COVID-19 infection in public transit for infected and not infected users

	No Infected		COVID-19 Infected	
VARIABLES	1	2	3	4
No Compliance (baseline)				
Partial Compliance	-0.15***	-0.15***	-0.20	-0.15
	(0.06)	(0.06)	(0.29)	(0.28)
Full SDM Compliance	-1.03***	-1.03***	-0.36	-0.32
	(0.06)	(0.06)	(0.30)	(0.29)
Empty Public Transport	-2.56***	-2.56***	-0.98***	-1.01***
	(0.06)	(0.06)	(0.30)	(0.29)
Empty Public Park	-4.35***	-4.35***	-2.25***	-2.28***
	(0.13)	(0.13)	(0.64)	(0.62)
Control	NO	YES	NO	YES
Constant	6.98***	7.12***	7.17***	11.96
	(0.14)	(0.76)	(0.73)	(7.82)
Observations	10,715	10,715	568	568
Number of groups	552	552	30	30

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.11: Worry of COVID-19 infection by household risk

	No Compliance		Partial Compliance		Full Compliance		Empty Transit		Empty Park	
VARIABLES	1	2	3	4	5	6	7	8	9	10
Low Risk (baseline)										
High Risk Household	0.59***	0.58***	0.67***	0.63***	0.78***	0.72***	0.69***	0.74***	0.33	0.27
	(0.22)	(0.22)	(0.20)	(0.21)	(0.19)	(0.20)	(0.23)	(0.23)	(0.24)	(0.24)
Controls	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Constant	6.61***	4.96***	6.35***	4.85***	5.39***	4.94***	3.09***	5.33***	1.96***	4.21***
	(0.20)	(1.05)	(0.20)	(0.96)	(0.18)	(0.90)	(0.21)	(1.06)	(0.17)	(1.12)
Observations	2,652	2,652	2,665	2,665	2,706	2,706	2,696	2,696	564	564
Number of groups	568	568	571	571	570	570	575	575	558	558

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.12: Worry of COVID-19 infection in public transit by gender

	No Compliance		Partial Compliance		Full Compliance		Empty Transit		Empty Park	
VARIABLES	1	2	3	4	5	6	7	8	9	10
Male (baseline)										
Female	0.79***	0.80***	0.70***	0.68***	0.62***	0.51***	0.34	0.22	-0.11	-0.22
	(0.20)	(0.21)	(0.19)	(0.20)	(0.19)	(0.19)	(0.22)	(0.22)	(0.23)	(0.23)
Other	2.67*	2.83*	1.51	1.30	2.42**	0.93	2.63**	0.60	3.91***	2.78**
	(1.42)	(1.53)	(1.18)	(1.23)	(1.11)	(1.17)	(1.32)	(1.36)	(1.34)	(1.42)
Controls	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Constant	6.28***	5.58***	6.10***	5.46***	5.22***	5.55***	3.06***	5.99***	2.10***	4.46***
	(0.23)	(1.08)	(0.23)	(0.99)	(0.21)	(0.92)	(0.24)	(1.09)	(0.21)	(1.15)
Observations	2,652	2,652	2,665	2,665	2,706	2,706	2,696	2,696	564	564
Number of groups	568	568	571	571	570	570	575	575	558	558

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.13: Worry of COVID-19 infection by self-declared use of face mask in public transit

	No Compliance		Partial Compliance		Full Compliance		Empty Space		Empty Park	
VARIABLES	1	2	3	4	5	6	7	8	9	10
Never/Sometimes wearers (baseline)										
Always wearers	1.41***	1.48***	0.78**	0.93**	-0.62*	-0.42	-0.89**	-0.92**	-1.49***	-1.02**
	(0.37)	(0.38)	(0.35)	(0.37)	(0.36)	(0.38)	(0.40)	(0.43)	(0.51)	(0.48)
Controls	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Constant	5.37***	5.78***	5.75***	6.38***	6.16***	6.48***	4.12***	6.25***	3.50***	3.65***
	(0.41)	(0.85)	(0.39)	(0.79)	(0.39)	(0.77)	(0.43)	(0.88)	(0.52)	(1.02)
Observations	2,617	2,617	2,643	2,643	2,673	2,673	2,653	2,653	557	557
Number of groups	561	561	564	564	563	563	568	568	551	551

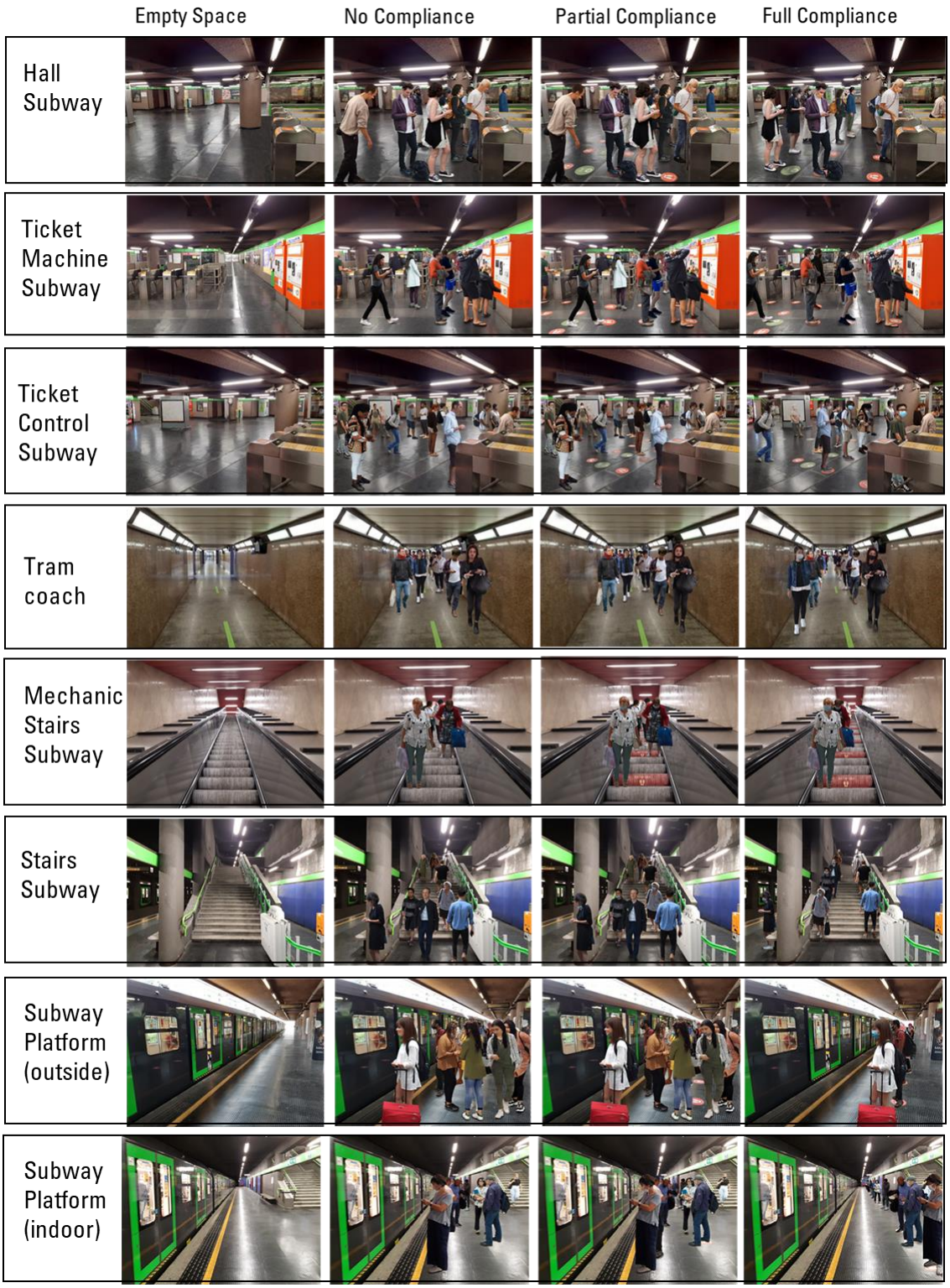
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

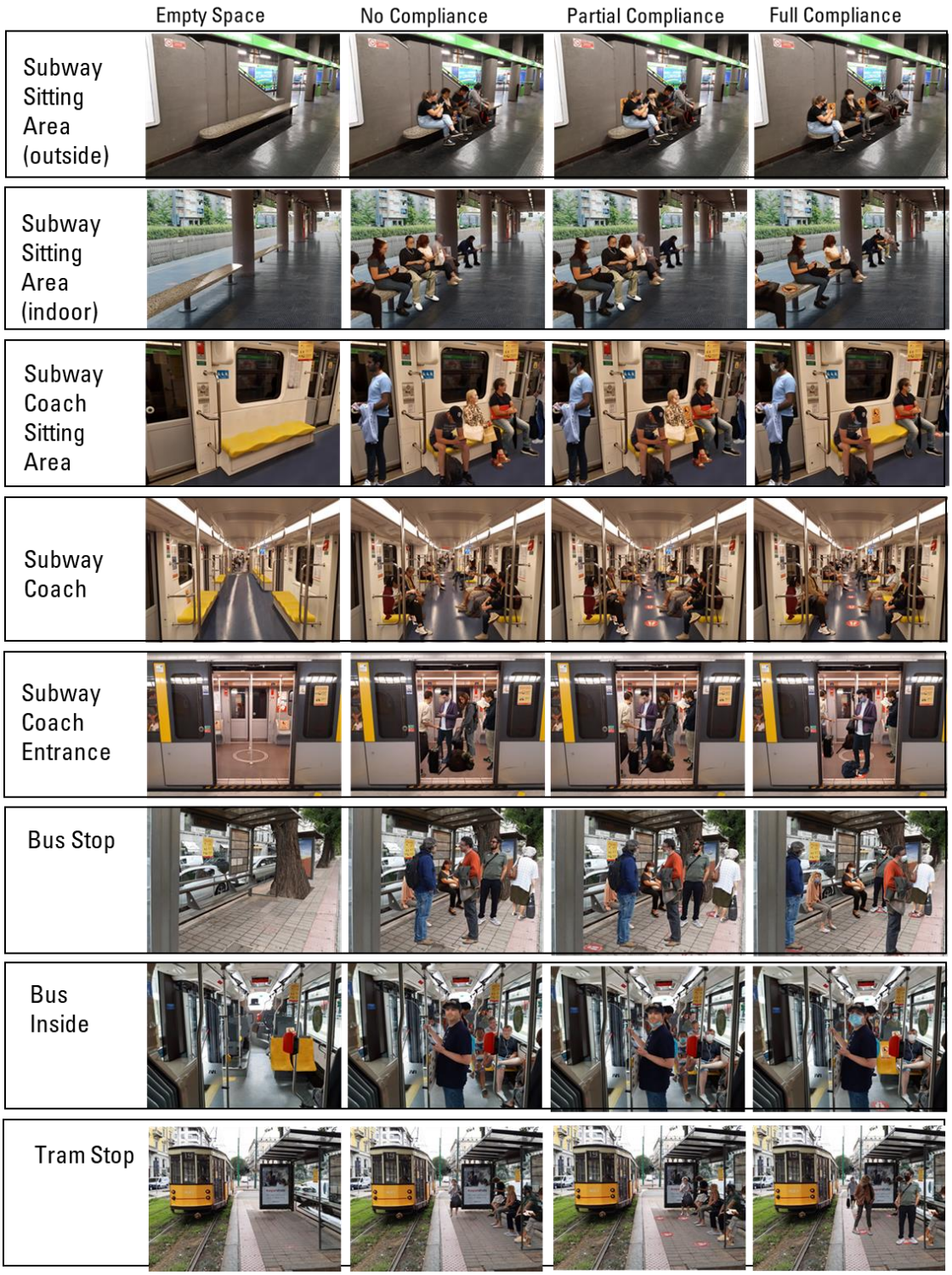
Table A.14: Worry of COVID-19 infection in public transit by age

	No Compliance		Partial Compliance		Full Compliance		Empty Transit		Empty Park	
VARIABLES	1	2	3	4	5	6	7	8	9	10
Under 30 year (baseline)										
31-45 years	0.21	0.16	0.09	0.01	0.19	0.23	0.02	0.06	-0.20	-0.20
	(0.27)	(0.27)	(0.25)	(0.26)	(0.24)	(0.24)	(0.28)	(0.28)	(0.29)	(0.30)
36-59 years	-0.02	-0.13	-0.08	-0.24	0.09	0.02	0.48	0.62**	0.41	0.48
	(0.28)	(0.29)	(0.27)	(0.28)	(0.25)	(0.26)	(0.30)	(0.30)	(0.31)	(0.32)
Over 60 years	0.12	-0.22	0.24	-0.06	0.36	0.17	0.20	0.30	0.31	0.49
	(0.32)	(0.36)	(0.30)	(0.34)	(0.29)	(0.32)	(0.34)	(0.37)	(0.35)	(0.39)
Controls	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Constant	6.69***	5.59***	6.47***	5.46***	5.45***	5.56***	3.09***	6.06***	1.91***	4.58***
	(0.26)	(1.08)	(0.26)	(0.99)	(0.24)	(0.92)	(0.27)	(1.09)	(0.25)	(1.15)
Observations	2,652	2,652	2,665	2,665	2,706	2,706	2,696	2,696	564	564
Number of groups	568	568	571	571	570	570	575	575	558	558

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Image 2. A: Photographic Simulations used in the experiment




Empty Space
No Compliance
Partial Compliance
Full Compliance
Subway Sitting Area (outside)
Subway Sitting Area (indoor)
Subway Coach Sitting Area
Subway Coach
Subway Coach Entrance
Bus Stop
Bus Inside
Tram Stop

	Empty Space	No Compliance	Partial Compliance	Full Compliance
Tram Inside				
Train Coach Entrance				
Train Inside				
Empty Park				

CHAPTER 4: Paper III

Perceptions of Surveillance: Exploring Feelings Held by Black Community Leaders in Boston Toward Camera Enforcement of Roadway Infraction

Published in Cities in 2023

4.1 INTRODUCTION

Cameras are used around the world to enforce traffic laws and regulations, improve roadway safety conditions, and cultivate behavior change. Camera enforcement programs collect photographic data via combined radar and image capturing technology mounted either on roadway and sidewalk infrastructure or on-board vehicles (e.g. buses, squad cars) (Rodier and Shaheen, 2007; Tang et al., 2022). This data can be used to determine speed, to serve as visual evidence of a violation, or to discern – either through license plate imaging or both plate and driver imaging – whom to cite with a corresponding infraction.

Much effort has gone into evaluating the impact of camera enforcement (CE) programs on roadway behavior and safety outcomes. A San Jose, California study found a 15% reduction in the share of speeding 10mph or more over the speed limit following the introduction of speed-enforcement cameras (Davis, 2001). Paradise Valley, Arizona and National City, California saw 40% (Institute of Transportation Engineers, 1999) and 51% (Berkuti and Osbuen, 1998) reductions in crashes, respectively, after camera introduction. Pulling from 35 studies across 11 non-US countries, the Cochrone Collaboration's report – widely acknowledged as a leading effort in international review of roadway CE systems – found camera implementation corresponded with an overall reduction in instances of speeding over the posted speed limit ranging from 8% to 70%, reductions in accounts of crashes in the vicinity of cameras of 8% to 49%, and decrease in the proportion of crashes resulting in fatalities or serious injuries ranging from 11% to 44% (Wilson et al., 2010).

Single occupancy vehicles are not the only travel mode with roadway CE applications. Bus-only lanes, which have "the potential to significantly improve bus speeds and reliability (Cesme et al., 2018)," are highly dependent on adherence to space use regulations to deliver their full benefit. Additionally, perception and/or awareness of lacking bus lane enforcement has been found to increase violation rates, further diminishing the effectiveness of the lane (Gavanas et al., 2013; Kepaptsoglou et al., 2011). A New York City-based assessment found that in the absence of CE, between 30% and 50% of buses traveling in bus lanes face some sort of significant obstruction, negatively impacting trip times (Safran et al., 2014). However, since implementing CE, NYC bus speeds along routes featuring bus-only infrastructure have increased 34% (Frost, 2019). Observing similar service benefits, Birmingham, UK found a decrease in observed bus lane offences of 60% and a decrease in average bus trip times of 32% after switching from in-person to camera enforcement (Wiggins, 1998).

Despite a wealth of success statistics for car-based safety and transit performance alike, uptake of camera enforcement in the US has been comparatively slow. With fewer than half of the country's states hosting CE programs of any kind, the US lags far behind nations generally thought of as its infrastructural peers (European Road Safety Observatory, 2018). As of July 2021, just 19 states and Washington D.C. have speed CE programs in operation, while D.C. and 22 states use red-light cameras (National Conference of State Legislatures, 2021). San Francisco and New York stand as the only two municipalities running system-wide CE programs for their bus lanes (Goffman, 2018; Fox, 2020), with fewer than a handful of cities – such as Los Angeles (Linton, 2021), Seattle (Trumm, 2020), and Philadelphia (Murphy, 2020) – preparing to pilot the approach on a select few of their bus-only roadway segments.

Somewhat counterintuitively, this straggling posture has increased over time. Roadway CE programs were once far more widespread in the US then they are today. In 2012, the number of municipalities hosting CE of speeding violations, red-light running, or both peaked at 533 (IIHJS-HLDI, 2022). As of January 2022, that number dropped by 37% totaling just 338 municipalities (ibid). While this decrease in application has been attributed, in part, to difficulty of program management and several cases of fraud (Morain et al., 2016; Albanese, 2018), by far the dominant opposing force to the expansion of CE programs has been

negative public opinion (Turner and Polk, 1998; Ralph et al., 2022a). The perceived strength of public disapproval has even motivated legislators in some states to go so far as to ban camera use for roadway enforcement entirely (Morain et al., 2016; Short, 2019).

Despite this decommissioning trend over the last decade, interest in CE is on the rise. Discussion of its potential is active in legislative halls across the country (Romaine, 2022). This swell in CE conversation has two primary sources of fuel. Firstly, the country is in the midst of a movement of police reform garnering significant attention at the national level. 2022 was a record breaking year with respect to police violence. Police killed 1,192 people, nearly 100 a month, making it the deadliest year on record since data began being tracked nationwide in 2013 (Mapping Police Violence, 2023). Additionally, awareness of, and outrage at, the starkly disproportionate share of these deaths represented by Black people – 26% compared to the 13% of the national population that they comprise – has increased. This exists against the backdrop of the highly visible justice work conducted by Black Lives Matter Movement participants and other racial equity advocates in recent years. Combined, these factors have resulted in a surge in financial, legal, and policy resources for enforcement reform (Romaine, 2022; Department of Justice, 2022; Eder et al., 2021; Levin, 2023; Aspinwall and Weichselbaum, 2020).

Secondly, roadway safety is worsening. Deaths on US roads reached a record high in 2021, with 42,915 people losing their lives in collisions that year (Laris, 2022). Cyclist and pedestrian deaths in particular have soared as compared to pre-COVID rates (Snider, 2022). While the pandemic-driven changes to travel behavior have undoubtedly contributed to the worsening of these numbers, pre-pandemic roadway safety was similarly in a consistent state of decline since the 1980s (Zipper, 2022). Conditions are presently so dangerous that Transportation Secretary Pete Buttigieg has declared the country in a state of roadway safety crisis (Yen, 2022).

With this alignment of timeliness and urgency comes opportunity for policymakers committed to improving roadway safety and behavior. Before them stands the chance to gain significant ground in support for alternatives to in-person officer enforcement. As the appropriateness of roadway camera enforcement stands as more of a political, even emotional question than a technical one – given that opposition persists against copious positive performance evaluations – an enrichened understanding of public perception may be what is needed for this strategy to achieve more extensive viability. They are further faced with the opportunity to improve upon persistent race-based injustices. Key to that is learning directly from those communities thus far most harmed by enforcement practices. This work seeks to facilitate exactly that.

The following section explores existing literature on public opinion toward CE, and closes by posing a research question that target key gaps. Section 3 discusses the motivation behind the choice of Boston as a case study, then details data collection and analysis methodologies. Section 4 delivers findings, while section 5 concludes with a collection of recommendations and discussion of study limitations.

4.2 LITERATIURE REVIEW

Several studies have attempted to gauge public opinion of CE of traffic violations in the US. The majority of these focus on red-light running and speeding violations, and collected their data via random sample phone surveys (e.g. Freedman et al., 1990; Retting et al., 1999; Maccubbin et al., 2001; Retting et al., 2008; Hu and McCartt, 2016). One of the most extensive nationwide surveys found that 69% of participants supported CE of traffic violations, 15% disapproved of it, and 16% had undecided feelings on the subject (NHTSA, 1998). This particular national survey further strove to understand views held by those opposed

by presenting participants with an optional selection of potential concerns to self-align with. Primary objections found were:

- Violation of (data) privacy rights / government infringement
- Revenue generating system; government money-grab
- Camera systems feel intentionally deceptive
- Potential for camera error

These specific concerns have been widely corroborated by other studies from across the country.

From Chicago (Kidwell and Richards, 2014) to Los Angeles (Price, 2019), San Mateo, California (ibid) to Washington DC (Cicchino et al., 2014), nearly all examinations of public opinion highlight perceived privacy violation as a hurdle for CE program implementation. Turner and Polk (1998) suggest that making minor adjustments to CE processes could help dampen feelings of privacy infringement. They recommend that rear license plate imaging be used exclusively, as opposed to front-of-vehicle imaging that can capture faces, and that the imagine captured not be mailed to the public along with the citation as seeing the image may serve to alarm. The research team of Fries et al. (2012) suggest that some privacy concerns may stem from the fact that there are no nation-wide data privacy and protection standards that police departments or transportation agencies have to adhere to. They recommend establishing Federal regulations to combat this. Studies from Freedman et al. (1990) and Retting et al., (1999) speak to factors that impact this concern. Their respective studies find that familiarity with CE is associated with fewer privacy worries, and that privacy concerns lessen significantly from a pre-implementation to post-implementation phase of a CE program. These findings host implications for the value of awareness campaigns and proof-of-concept demonstrations.

Much like privacy worries, concerns that camera enforcement is first and foremost a revenue generation tool are rampant across the public opinion literature. Several factors feed this perception of government money-grabbing. Ralph et al. (2022b) note that news media stokes this fire with sensationalist headlines that often cast the government against the public. Phrasing of CE-related fines 'lining government pockets' or 'filling government coffers' is not uncommon. Other research uncovered that the fact that private camera operating companies, in some cases, get a sizable cut of CE-related revenue contributes to the public feeling like cameras are being used for profit under the guise of safety (Rodier and Shaheen, 2007). Additionally, the literature highlights claims from the public of feeling that information in public space (i.e. signage alerting roadway users of nearby cameras) was being intentionally limited, and that CE was covert by design so as to catch as many offenders as possible and drive up revenue, not to encourage safer driving behavior (Freedman et al., 1990; McCartt and Eichelberger, 2012).

These feelings cannot be separated from the matter of widespread mistrust of governing bodies. Trust in government is nearing historic lows in the US (Pew research Center, 2022). Logically, this influences public opinion of camera enforcement as government agencies most typically serve as program administrators. Ralph et al. (2022b) examine this relationship. They find that those with higher levels of trust in local government were more supportive of camera enforcement than those with low levels. This work goes on to suggest that the directness of this relationship may actually be a blessing for government, as enforcement reform, camera or otherwise, could be a prime opportunity to rebuild trust; an effort that would have positive externalities well beyond the realm of enforcement. Agreeing with the potential power of this relationship but looking at the other side of the coin, McKenna (2007) warns that if mismanaged, CE could have the unintended consequence of further undermining trust. Finally, Fries et al., (2012) speak to the connection between trust and sustainability. They argue that without increased trust in government, the

longevity of CE programming is in question; even for programs currently up and running and with track records of public approval.

The public opinion literature does not exclusively identify negative feelings toward CE. There is a considerable amount of alignment on findings related to the benefits that camera enforcement has over in-person enforcement. Much of the public agree that CE host the potential for increased capacity and consistency of enforcement (Ralph et al., 2022a; Fox, 2020), and is effective at decreasing roadway injuries and fatalities (Hu et al., 2011; Turner and Polk, 1998; Cicchino et al., 2014).

The interactions that gender (Retting et al., 1999; Blincoe et al., 2006; Shaaban, 2017; Corbett and Caramlau, 2006), age (Soole et al., 2008; Shaaban, 2017; Rodier and Shaheen, 2007), and location (IAM, 2014; Passetti, 1997; Soole et al., 2008) have with support for camera-based enforcement strategies have also been explored. Literature on these topics features general consensus on the following findings: those who identify as men are less in favor of CE than persons of all other genders, the young – most commonly defined as under 35 within the literature – are less in favor of CE than the old, and those in rural and suburban environments view CE far less favorably than those in urban environments.

One notable interaction between identity and opinion, however, has not been thoroughly examined. Existing research fails to reflect perspectives of communities who historically have had a uniquely negative relationship with law enforcement. It is extensively documented that police interaction with communities of color in the US – Black communities in particular – is disproportionately frequent, intrusive, traumatic, and deadly (Butler, 2017; Engel et al., 2012; Gelman at al., 2007; Hayes, 2017; Johnson et al., 2017; Rosenbaum, 2006; Taylor, 2006; Tyler et al., 2015; Wietzer, 2000). This would logically suggest that people of color may have strong or otherwise unique feelings toward camera technology as a law enforcement strategy.

Scholars of identity, policing, and power have explored the interplay between surveillance and racial oppression. Unsurprisingly, they express grave concerns about what implications for non-white, hyper-policed communities might be within an increasingly 'Big Brothering' society. In his 1998 *article Surveilling the City: Whiteness, the Black Man, and Democratic Totalitarianism*, John Fiske argues that "surveillance is a technology of whiteness that racially zones city space by drawing lines that Blacks cannot cross and Whites cannot see." Here, surveillance as a segregationist tool applies not only to physical 'city space', but to non-physical space as well – social, economic, psychological, the list goes on. Similarly, literature documenting the history of how camera surveillance technologies have been used in the US to uphold the social norms of inequity, division, oppression, and exclusion is devastatingly bleak. Acutely, it highlights how violating these norms so often results in loss: of life, of freedoms, of power and agency, of community, of personal wellness, of humanity (Browne, 2015; Arnett, 2020; Roberts, 2010; Sewell et al., 2016). Though these works do not focus specifically on traffic infractions, they bear a warning of what increased surveillance of any type may bring about.

Vice journalist Aaron Gordon relates race and roadway enforcement more acutely by calling to attention that, "Any effort to eliminate racism in American policing must figure out what to do about traffic enforcement, which is the leading cause of interactions between police and the public, according to the Department of Justice (2020)." While there is a wealth of literature exposing the existence of disproportionate targeting of motorists of color – particularly Black motorists – by law enforcement (Baumgartner et al., 2021; Pierson et al., 2020; Seo, 2019; Shoub et al., 2020; Grogger and Ridgeway, 2006), such cannot be said of literature centering Black opinions on the matter. Within the same passage Gordon goes on to emphasize that, "… by law, it is almost entirely up to the officer whether to let the person go with a warning, give them a ticket, to search their vehicle, or escalate the situation even further. It is an

interaction intentionally designed to let the officer do virtually whatever he or she wants, reflecting the inherent biases of our legal system (2020)." As the role of transportation in American systems of racial oppression cannot be overstated and must not be overlooked, research attention should be paid to understanding feelings toward roadway-related CE specifically held by those who have been most marginalized by 'biases of our legal system.'

While multiple studies have explored how traffic cameras *perform* with respect to racial profiling – consistently finding that cameras exhibit far less racial bias in administering tickets than police officers do (Eger et al., 2015; Quintanar, 2017) – only one study, to my knowledge and at time of writing, specifically weds the subjects of roadway CE, race, and public opinion. Via survey, the team of Ralph et al. (2022a) ask what effect can be expected from applying a racial justice framing to pro-camera enforcement campaigning. What is meant by 'racial justice framing' in this work is a shift in advocacy technique from a focus on race-blind safety to one that explores "the role cameras could play in reducing racial-profiling (ibid)." They find that applying such a framing technique does increase support for traffic camera use among individuals who believe that racial profiling exists and who disapprove of the practice. The work also assesses whether or not a racial justice framing would incur backlash, resulting in decreased support for CE. No evidence of backlash among respondents of any race was found. This type of research, that which focuses on the racialized politics of CE, is an essential component to any hope of achieving not only functional and safe roadways, but just ones as well.

Finally, despite there being many applications of roadway CE currently in practice (e.g. enforcement of stop signs, prohibited turns, toll payment, pedestrian-only zones, high-occupancy vehicle lanes, and parking regulations) the conversation surrounding CE has been hyper-focused on red-light and speed limit programs. Nuance can be added to our understanding of the topic by widening this lens. With interest and investment in bus-priority roadway design presently sweeping the globe (GlobalBRTdata, 2022; Duncan, 2021), exploration of camera enforcement's applications for transit infrastructure warrants increased attention.

This research attempts to narrow some of the gaps in the literature by centering Black thought and expanding discussion of CE beyond its most conventional applications by answering the following question: How do Black community leaders in Boston understand the potential use of camera enforcement for traffic and transit roadway violations? Exactly who is meant by 'community leaders' as well as a discussion of why this group was selected as the focus of this research is offered in the next section.

4.3 METHODOLOGY

4.3.1 Boston as Case Study

For several reasons, Boston serves as a well suited case study for policy makers to gain insight from. Firstly, this site hosts relevance for the subject. Massachusetts state-level representatives have proposed legislation that would allow for CE of certain traffic violations several times within the last decade. The most recent proposal was put forth as a part of a 2021 Road Safety Bill. Despite a historical lack of support, many of the state's elected officials feel that appetite for CE of traffic violations is growing as it gains a new champion in newly elected Governor Maura Healey (Young, 2020; DeCosta-Klipa, 2021; Mintz, 2023).

Secondly, trends in Boston are representative of metropolitan areas across the country desperately struggling with safety conditions on their streets. The city has consistently averaged just over 3000 motorist incidents a year between 2015 and 2020 (City of Boston, 2020). After dropping by 1000 incidences in the first year of the COVID-19 pandemic, annual motorist incidences for 2021 spiked back up over 3300

incidences despite decreased peak period traffic and decreased total vehicular trips per capita as compared to pre-pandemic levels (City of Boston, 2022).

Thirdly, Bostonians are not green to camera technology in roadway spaces. In 2016, Massachusetts began the removal of all of its highway tollbooths in exchange for an "all-electronic tolling system using E-Z pass transponders (AP, 2017)." While this is the only form of roadway camera enforcement allowed in the state under the existing legal structure, this now five-year-old system has increased state-wide familiarity with how a camera-based enforcement program operates. A foundation of familiarity may facilitate greater depth of participant engagement.

Additionally, the Massachusetts State House is already being intentional about wedding racial justice and traffic-related administration. Two bill proposals – one regarding the establishment of a taskforce to assess the extent of racial profiling in traffic stops, another requiring police departments to report on racial data from both traffic and pedestrian stops to support the efforts of this taskforce – have recently been made to the Joint Committee on Transportation. Both of these proposals could have implications related to the design and applicability of CE programming (MilNeil, 2021).

Finally, the question of what role CE will come to play in the world of transit is particularly interesting for the Greater Boston Area. Capitalizing on the bus renaissance of the last decade (Duncan, 2021), in 2018 the Massachusetts Bay Transit Authority (MBTA) committed $8 billion to a 5-year capital investment plan, a focal piece of which was bus service projects (MBTA Bus Transit Priority). Multiple evaluations suggest that the in-person enforcement currently applied to these projects is not the most effective way to maximize benefits to transit riders nor return on investment for the MBTA (Goffman, 2018; Frost, 2019). Because of this, the MBTA and related parties may be willing to be more creative than other agencies might in their approach to improvement strategies.

4.3.2 Data Collection

4.3.2.1 Focus Groups

Many have expressed their dissatisfaction with surveys as the methodology most commonly used in efforts to gain nuanced insight into the debate over camera enforcement (Wissinger et al., 2000; Soole et al., 2008; Blincoe et al., 2006). Here, I conducted virtual focus groups to complement and enrich previous survey findings. In addition to having the benefits of being comparatively inexpensive, flexible, and quick to set up when conducted virtually (Robson and McCartan, 2016), focus groups have proven particularly useful in situations where the topic of interest was awkward, taboo, or highly politicized (Hopkins, 2007).

I convened six virtual focus groups each ranging from 90 to 115 minutes long, dependent on participant schedules. These groups were comprised of community leaders who all racially self-identified as Black. In this case, 'community leaders' refers specifically to individuals who serve in an elected, unpaid capacity on the boards of Boston neighborhood associations. These individuals are entrusted with acting on behalf of their constituents and neighbors. They host community meetings, are tasked with information dissemination, and are entrusted to collect concerns held by their constituents. Knowing that these individuals are accustomed to thinking beyond themselves, sharing collectively held views, and prioritizing community wellbeing, I hoped that featuring them would allow amplification of many more Black voices, a sort of multiplier effect.

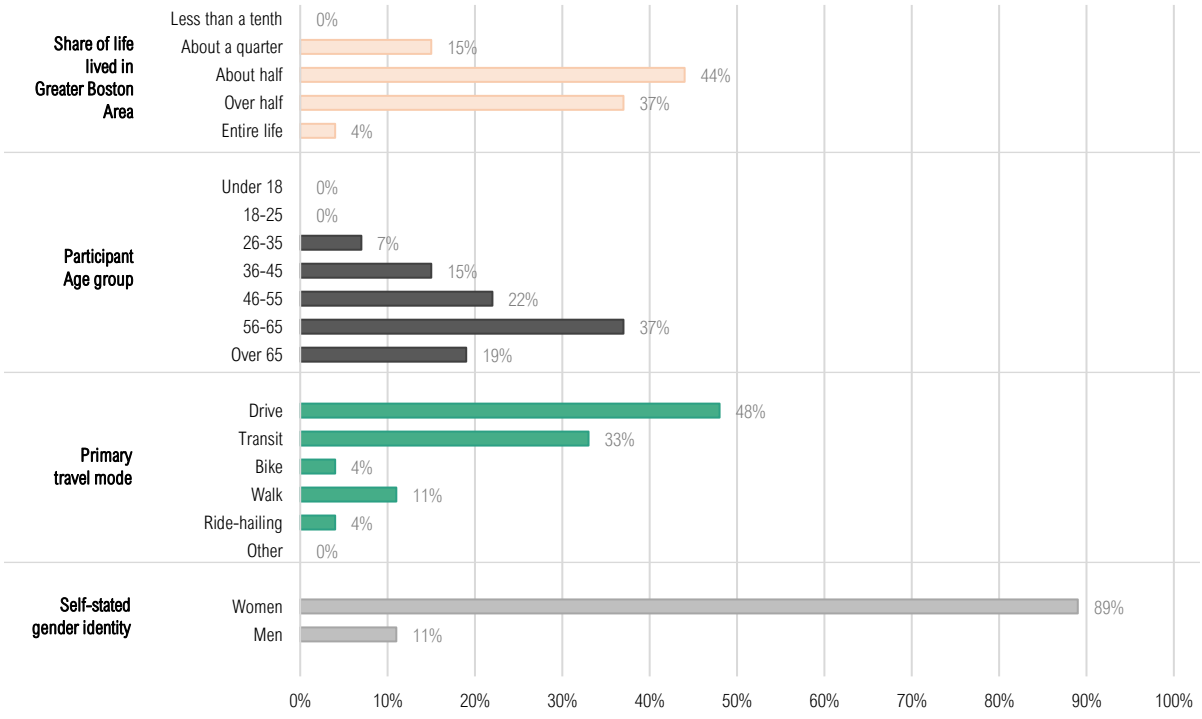
Allow me to state emphatically that the 'Black Community' is not monolithic in its experiences, feelings, and opinions. I would never claim that by including this particular cohort of participants that I have fully captured all, or even a comprehensive sample of the perceptions held by members of this diverse

community. As such, it is important to keep in mind that comprehensiveness was not the goal; existing survey research may accomplish that better. Depth of understanding was this work's focus.

Recruitment was conducted via email. 103 neighborhood associations were sent an email invitation to participate in this research pending their eligibility: having at least one elected board member who identifies as Black. As of November 1st, 2021, when invitations to participate were drafted, this list of 103 encompassed all active neighborhood associations in Boston with a public-facing web-presence of any kind: website, Facebook page, mention on City's neighborhood-specific information web pages.

Having been a transportation planner in Boston myself for a number of years, I have worked directly with several Black board members of neighborhood associations in the past. As a result, some of the participants were known to me. Additionally, as civic projects often cross the borders of different neighborhood associations, several participants and had worked together previously. Though focus groups of strangers are generally preferred (Smith, 1972), given that the Black community accounts for just 19% of the city's total population and is highly geographically concentrated, it would have been a near impossible task to recruit an entire participant cohort of Black, elected, neighborhood association board members who were complete strangers.

Chart 1. Pre-participation survey responses

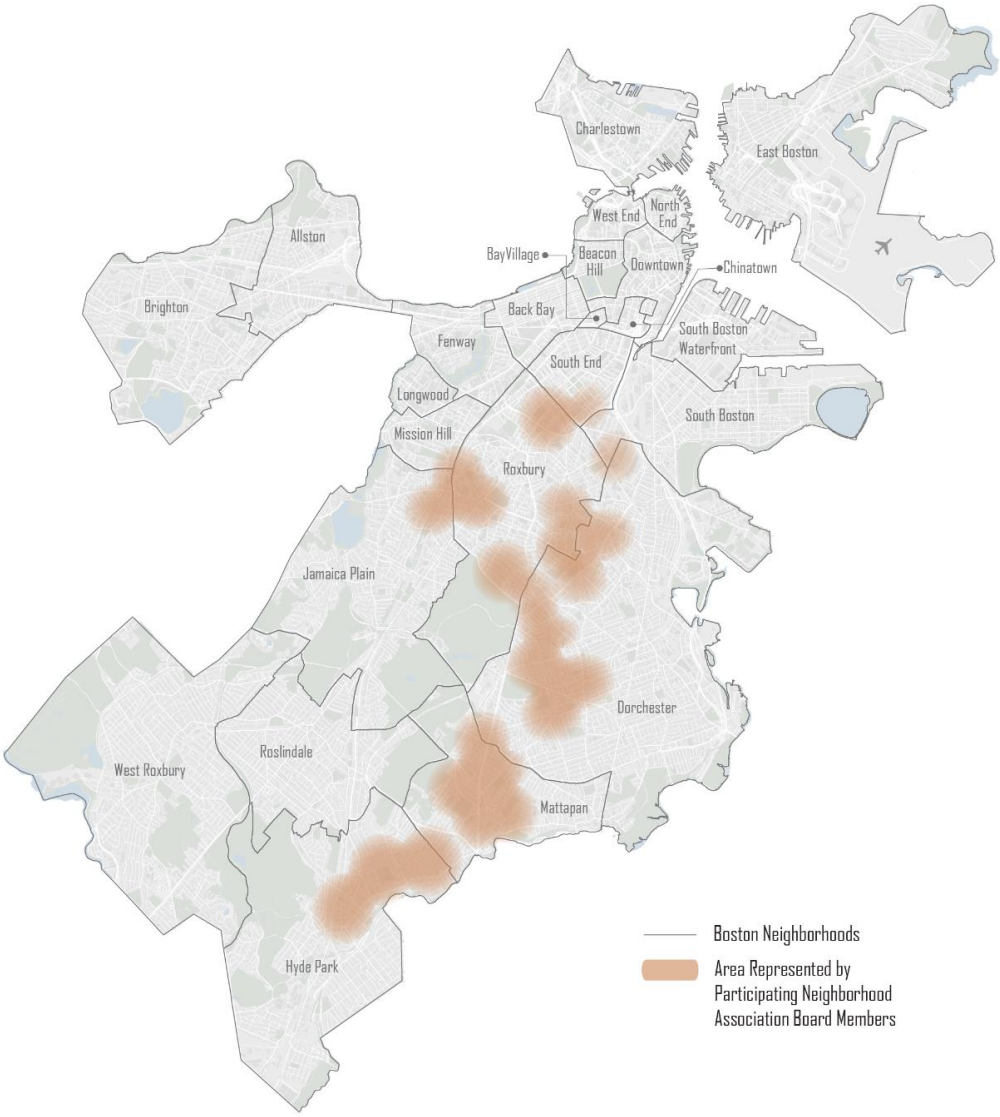


That said, there are unique research benefits to having a focus group comprised of acquaintances. Focus groups can suffer from being a type of performance (Grandclement and Gaglio, 2011; Fletcher, 1992; Bhopal, 1995; Bocholtz, 2000) in which participants tend to "act as if speaking to a gallery governed by the norms of public discourse (Gamson, 1992)." Featuring participants known to one another may help minimize this behavior. Several research teams have found an increased accountability applied between focus group members in cases of pre-existing relationships. In these studies, group members challenged each other on contradictions between what they were 'professing' to believe inside of the group and how

they actually behaved outside of the group (Kitzinger, 1994; Robson and McCartan, 2016). Similarly, some researchers contend that assembling groups of people known to one another and with whom members might 'naturally' have these types of discussions – i.e. discussions of race, transportation, enforcement – results in richer, freer-flowing sessions (Kitzinger, 1994; Fern, 1982). Discussion of how these dynamics played out as well as engagement with researcher reflexivity can be found in the Appendix.

The logistical design elements of these focus groups were shaped both by advised best practices and operational practicality. Scholars of qualitative methods most commonly cite between five and eight participants as preferable for a fruitful focus group (Fern, 1982; Osborn, 1953; Krueger, 2002; Merton et al., 1956). Schedule alignment among participants was such that I was able to run five groups of five community leaders each, and one group of two. This totaled 27 participants representing 22 different neighborhood associations. The geographies that these leaders represent is depicted in Figure 1, while their summarized responses to a demography-focused pre-participation survey are shown in Chart 1. It is important to note that the exact areas that the associations cover have been slightly distorted within the figure to better protect the anonymity of participants.

Figure 1. City area represented by collection of neighborhood association participants.



4.3.2.2 Informational One-Pager

During the latter half of each focus group, I introduced a one-page information sheet (see Figure 2). The sheet highlighted Boston's current roadway enforcement system as well as an infographic depicting the process of how camera enforcement works conceptually. This information was introduced via the screenshare feature on Zoom, and had two objectives. Firstly, I wanted to explore how, if at all, views toward CE change when distinction is made between which enforcing body – municipal police force, Boston Transportation Department officers, MBTA Transit Cops – might be involved. Secondly, reduction of the status imbalance between the researcher and the participants or among participants themselves is important (Mikecz, 2012). The literature suggests that this potential power imbalance can be mitigated by the introduction of a prompt (ibid). The prompt levels the pre-existing knowledge playing field by providing a transparent, shared, and confined set of information for participants to reflect on.

Figure 2. Single slide informational prompt.
Information Sourced from: City of Boston Parking Clerk's Office and the MBTA Safety and Violations Guidance.

4.3.3 Data Analysis

I chose to utilize a thematic analysis methodology. Thematic analysis is a highly iterative process that "seeks to unearth the themes salient in a text at different levels (Attride-Stirling, 2001)" through the creation of a set of thematic networks. These networks are links between ideas that build upon one another, traveling toward the identification of primary themes central to the description of the phenomenon of interest (Daly et al., 1997; Nowell et al., 2017). Within the thematic framework, an inductive analytical approach was taken. This entailed the application of a data-driven interpretation by which the raw transcripts were read many times over to allow themes to emerge (Boyatzis, 1998). Inductive analysis was selected because it takes on an exploratory orientation and is often applied when attempting to decipher meaning-making and understanding (Crabtree and Miller, 1999; Guest et al., 2014). Additionally, thematic analysis' demonstrated rooting in excerpts from the raw data "ensures that interpretation remains directly linked to the words of participants (Patton, 1990)"; a principle central not only to the establishment of rigor and credibility, but also central to the respecting of research participants (ibid; Thomas and Harden, 2008).

4.4 FINDINGS

4.4.1 Stage 1 - Establishing a Baseline

Before asking community leaders to explore the possibility of something that does not currently exist – a roadway camera enforcement program in the Boston Area – I first asked them to reflect on present conditions out on Boston streets. The following theme emerged from this initial line of questioning: Boston's current enforcement system is not effective at inciting safe, healthful roadway behavior.

This theme had two primary contributing factors. The first being that behavior on Boston roadways is concerning. In building a foundation for this claim, participants emphasized the emotional distress that they feel as roadway users of all transportation modes. One focus group participant said, "I feel really frustrated when I see reckless driving behavior." Other group members used the words "tense," "scared," "pissed-off," and "anxious" to illuminate their feelings when out on Boston streets:

> *"I'm getting older. I don't move as fast as I used to, and crossing the streets scares the hell out of me. People drive into the crosswalk while you are in it if they decide you are taking too long."*

> *"I'm even considering not letting my 16-year old get her license for a few more years. She is going to be furious, but it's just too dangerous out there."*

Participants compared behaviors to what they had experienced elsewhere to highlight the magnitude of the problem. One proclaimed, "I have never seen as much red-light running and jaywalking anywhere as I have seen in Boston. And I've traveled a ton!" Similarly floored, a fellow group member expressed, "The amount of double-parking blows my mind. I have never seen that happen anywhere else as much as here. We even have triple parking. Not kidding."

The second contributing factor to this theme is that the current system does not serve well to remedy this concerning behavior. There was much agreement that enforcement barely happens at all, and that when it does happen, ticketing, or verbal chastising in the absence of ticketing, are not resulting in noticeable change. Many expressed feeling that the reason behind this ineffectiveness was two-fold. On the one hand, police lack the capacity to enforce roadways comprehensively: "We have thousands of bus stops. Trying to get officers to prevent people from parking in all of them is extremely unrealistic." On the other hand, police are choosing not to enforce: "You can double-park right in front of a police officer, make eye contact, and not get a ticket. They really can't be bothered."

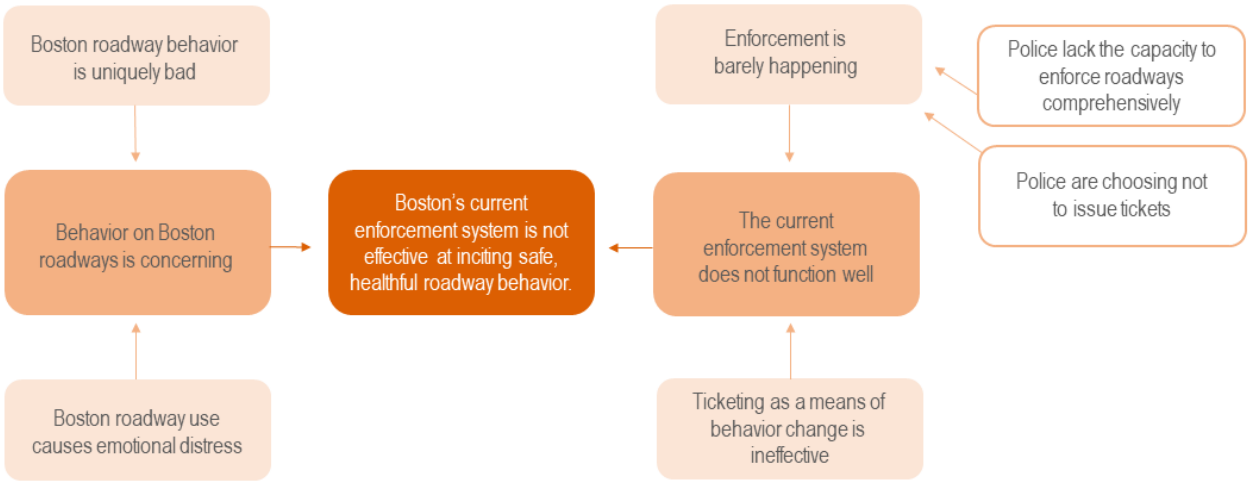
The degree of consensus around these two points – that current roadway use induces negative feelings, and that the current enforcement system is not mitigating those negative feelings through resultant behavior change – was striking. At no point did any participant from any focus group take an opposing stand or even a neutral position on the matter. Expressions of dissatisfaction were impassioned and uniform across persons of different neighborhoods, ages, and amount of time lived in Boston. Statements similar to the following were commonplace:

> *"Traffic enforcement has been an embarrassment in Boston for decades. Don't get me wrong, there are some things that Boston is great at and should be proud of… but traffic, roadway management, safety, street things… nah."*

> *"At this point, it's a joke. A horrific joke. People dying regularly in accidents is just something that I guess has been decided is fine in this city. No one in a position to do anything about it seems to give a damn. Nothing is done, and nothing changes. Actually that's not true. It does change. Every year it gets worse."*

The thematic network for this first stage of analysis can be seen in Figure 3 and serves as the foundation upon which the second stage of exploration was built.

Figure 3. – Stage 1 Thematic network



4.4.2 Stage 2 - Camera Enforcement: Not a Panacea

4.4.2.1 Camera vs. In-Person Enforcement

The second stage of analysis, whose thematic network can be seen in Figure 4, similarly rendered two dominant themes. The first is that as a means of bringing about favorable roadway behavior, camera enforcement is not a silver bullet, but may be better than in-person enforcement. Greater consistency and wider coverage were two commonly cited superiorities over the current system:

> *"If you're going to do enforcement it should be automated so that everyone on the road has the same expectations. It should be consistent and everywhere. It's about expecting to get caught when you do something you shouldn't rather than what we have now which is that I expect to get away with it."*

Participants also reflected that in their experience elsewhere, CE systems were successful at changing their own roadway behavior, though not without aggravation. Respondents mentioned how financially cumbersome the processes had been, stressing the size of the fines. Anecdotes often featured individual fines of between $200 and $300 dollars, and the experience was even referred to as financially "painful". Still, in all cases, participants noted that the result of these processes was their lasting behavior change:

> *"Years ago I was caught by speeding cameras in DC. I still remember which intersections I need to slow down on, and that was years ago. It wasn't even a crazy fine: $50 or $75 I believe. I think I just drive slower when I'm in DC in general. You never know if new cameras have been put up someplace."*

Camera enforcement's potential to facilitate the removal of the police department from the roadway enforcement system was deemed particularly attractive. "I'm not saying cameras are perfect. It's not like they are race-neutral. There are still people involved behind the camera and they have their own prejudices that would impact that system as well. But nothing can be as bad as police officers. They have too much power to do whatever they want. The law allows them to not be accountable." Complaints of lacking impartiality and grossly imbalanced power dynamics in the in-person system were echoed in all sessions through statements like, "If you're going to do enforcement, might as well make it camera-issued rather than up to the whims of some ego-pumped person in uniform who can act without rules."

Views on what the role of police officers should then be within a CE system were by no means unanimous. Some participants felt police should be available for some situations, like tending to crashes, while others felt the force should be entirely disbanded. Still, most agreed that largely due to their carrying of firearms, police should be removed from any tasks that required they patrol the streets; particularly for the safety of Black roadway users. The two statements below capture the widespread sentiment well.

> *"If we have to have this necessary evil of enforcement, then it shouldn't be done by the police. It shouldn't be done by anyone carrying a gun. It should be impossible to have a situation escalate from a double-parked car or a ran stop sign to a death at the hands of law enforcement."*

> *"Think about Sandra Bland and Philando Castile and other people who ultimately got killed at what should have been a pretty routine traffic stop. Like… if that violation was enforced by a camera would they still be alive? Of course we can't know, but I think it's likely."*

Many participants emphasized that CE was not void of significant shortcomings. In particular, some mentioned feeling that CE was "intentionally cryptic" in an effort to catch as many offenders as possible and raise revenue for the enforcing agency. Additional concern was expressed at the potential for CE programs to be privatized, and for any data collected via roadway cameras to be acquired for other, prejudicial uses. Many were adamant in stressing that they felt neither the City nor the MBTA had in place the responsible data management infrastructure and privacy agreement expertise necessary to avoid the potential for such data abuse. Additionally, fears that CE would likely be subject to inequitable application across racial lines were expressed regularly: "As a person of color, specifically as a Black man, I can't just believe that a new, powerful surveillance tool won't be used nefariously and systematically against me."

In determining whether the benefits offered by camera enforcement outweighed these potential shortcomings, there was a notable difference of opinion across age groups. Despite agreeing that current in-person enforcement was barely happening and was fairly useless at improving roadway behavior, there were a few who felt that the negatives of CE were too significant, and that in-person enforcement was preferable to a CE program. Those who held this stance were almost all over the age of 55. The under age 46 cohort accounted for those most open to CE programming. This same age group also felt most strongly in favor of a new enforcement system, camera or otherwise, completely void of police presence.

This disparity could be explained by several factors. Older participants more often offered anecdotes in which they experienced positive interactions with cops. They would cite instances of being pulled over and having the exchange end in a "smile," "a shared joke," "a pleasant bit of small talk about the neighborhood or something like that." Though this group did not paint their experiences with Boston police as exclusively positive, their mixed set of experiences stood noticeably oppositional to the exclusively negative traffic-stop experiences that younger participants shared. A portion of this disparity could be the result of changed – directionally negative – police behavior over time.

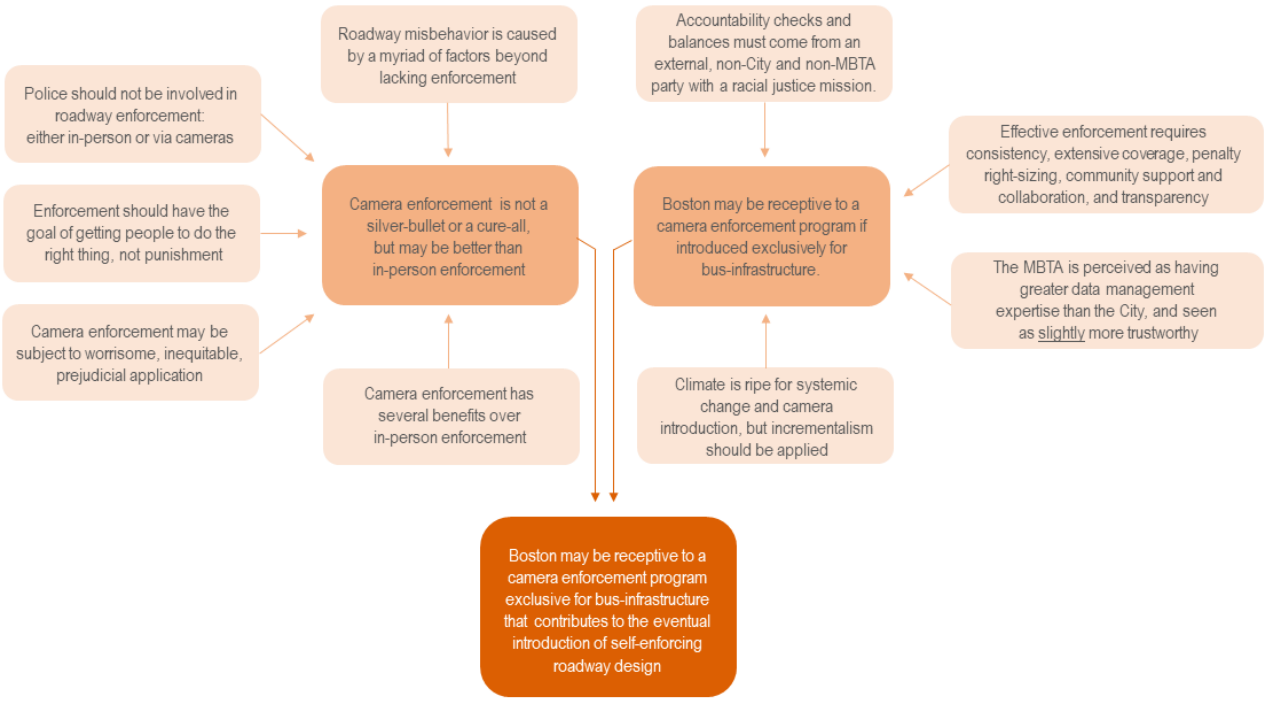
Another potential temporal explanation comes by way of evolving school curriculum. Older participants in three focus groups directed the conversation toward changes that they have noticed in civics education in Boston between their time as school children and their children's time within the same school system.

> *"I swear Boston Public Schools do not teach Civics anymore. There is a complete lack of understanding of how basic local government works. Or should work. And because of that, the only understanding that young folk have is extremely negative. They only see social media. They haven't had the experience, many of them, of police officers coming to their schools and explaining who they are and what their responsibilities are. They don't have the experience of meetings police officers positively. Whereas, when I grew up, they came, they talked about safe street crossings, about signage and what it means, about ways to be a good driver, and stuff like that. I'm not saying we need to flood schools with cops. Hell no! I'm just*

saying it feels like my children and their children have absolutely no positive examples or understanding of governing agents, cops included."

Irrespective of the age disparity in strength of opinion, overall, the majority of participants felt that camera enforcement would likely be more effective at making Boston streets safer for Black and non-Black roadway users alike than the current in-person method.

Figure 4. – Stage 2 Thematic Network



4.4.2.2 Enforcement is not the Be-all End-all

Participants stressed that even if CE was preferable to in-person enforcement, it should not be treated as the end of the enforcement-reform road. Lacking enforcement is not the sole cause of roadway misbehavior, making improved enforcement just one component of achieving high-functioning, safe, non-distressing roadways.

Community leaders were well attuned to the interconnectedness of roadway behavior, traffic volumes, housing scarcity, unaffordability, and displacement:

Participant A: "The amount of traffic is somewhat… amazing. Boston is not a huge city, yet it generates huge city congestion. It's traffic that is coming from outside the city into the city. The streets along the city limits headed inward are full to the brim as early as 6am. I know this because I see it."

Participant B: "I think much of it could be from previous Boston residents who have been displaced and now live outside of the city. I can't even tell you how many friends I have that used to live in Roxbury and have been forced to Brockton or Randolph and how many of them are caretakers to their older parents who live in public housing here in Boston. So they are having to drive back and forth between things like multiple jobs, family, services, that used to be concentrated in one place for them."

Participant A: "You talk to young people hanging out around Franklin Park, and they tell you they actually live in New Bedford or Lawrence, but they feel like their lives, their schools, the places they like to eat and hangout, are all here in Boston. It's because of costs. These kids' parents have either been priced out, or want to buy, but can only do that way outside of Boston. It's a major problem on so many levels, and for sure one of those levels is traffic and congestion and street safety."

This conversation segment suggests that taking a comprehensive approach to tackling roadway safety – explicitly addressing topics of mode-share, gentrification and displacement, property prices, and land-use – may offer the best chance for gaining public support, at least among communities negatively impacted by these factors.

Inconsistent roadway laws across jurisdictions, lack of care and compassion for one's fellow roadway user, faulty or failing infrastructure (i.e. potholes, missing crosswalk countdown clocks, poor street lighting), and excess demand for roadway space were cited as additional causes of roadway misbehavior that would likely not be solved by the introduction of a camera program.

The ultimate objective of enforcement programming was discussed. Many felt that any enforcement program should have the explicit goal of getting people to do the *right* – in this case most often meaning the *safe* – thing, rather than inflicting punishment or raising revenue. Community leaders therefore proposed that self-enforcing systems where punishment is not needed because misbehavior is virtually impossible should be the true aim. In four of the six focus groups, participants proposed an alternative to the models of in-person and camera enforcement. They argued that what is called for is a focus on street-design as an enforcing entity: "You design the street well and there is no need for additional enforcement; it self-enforces." They offered that a CE program may be a good midway point between the current system and a self-enforcing, design-led system:

"I think I could stomach it if it were something temporary. If it were meticulously evaluated and monitored, and if the data collected, you know like the locations of the worst and most frequent offenses, was used to inform design changes that replace the cameras entirely. I still have major reservations; surveillance capitalism and all that. But at this point, something has to change. I've had too many friends and neighbors die or get seriously hurt in crashes on Boston streets."

4.4.2.3 Camera Enforcement: Transit First

The second dominant theme postured is that the members of Boston's Black communities may be receptive to a CE program if it were introduced exclusively to enforce bus lane and bus stop violations. Support for this theme fell into distinct categories: why such a program should be MBTA-led, and what elements were critical to ensure acceptability.

Several participants proposed that the initial introduction of any CE program to Boston streets should focus on bus-infrastructure. This was in part because of the clearly visible ineffectiveness of unenforced bus lanes and the ableist injustices associated with rampant parking and idling in bus stops. A community leader from a neighborhood hosting one of the City's new bus lanes expressed, "I'm sold on the bus lane thing. In New York, the buses are flying. And it's all because they have bus lanes, and the bus lanes are empty of cars. We don't have that. We have a few bus lanes sure, but they are not respected by drivers at all. So we {the public} feel like they don't work at speeding up the bus." Other related statements included:

"It makes me sick to see our elders having to dismount the bus in the middle of the street. They should be dismounting directly onto the sidewalk, but the buses can never get there because the stops are parked up. It's unsafe. And that huge step down off the bus and the step up the curb to get back to safety… it's a big deal for some. Especially our aging population. And you know that our Black neighborhoods account for a large portion of Boston's aging population."

Acknowledgement of the issues associated with unenforced bus infrastructure was coupled with the identification of several attributes of the MBTA that positioned it as preferable to the City to manage a CE program. One such attribute is the authority's very nature as a cross-jurisdictional entity. Having regulations apply to MBTA-affiliated roadway space region-wide might get around town-to-town legal inconsistency – an issue that participants identified as negatively impacting roadway behavior presently.

Another attribute revealed itself once the informational one-pager (see Figure 2) was introduced during each session. The different camera placement options that exist in CE programs elsewhere was discussed. Participants were resistant to any scenario in which the camera could take an image of the faces of those inside the vehicle. This resistance made placement options in which facial imaging was impossible comparatively attractive. Because this would be the case with bus-specific CE – where a camera is positioned low on the front of the bus exclusively to capture license plate details – this model received greater support.

Additionally, there is a growing level of familiarity with the MBTA running proof-of-concept, temporary projects: "It would go over best if the T ran it. That way it can feel like 'the T is implementing a new pilot' which is language that we are getting used to these days." Even some who expressed equal levels of mistrust with the City as with the MBTA showed interest in the idea of a pilot: "I feel very mixed about it. I'm worried it will be used against *us*. But, the current situation is just so bad… I think I need to see it. To experience it in some way." With an existing internal team dedicated to the management and evaluation of pilot programs (Transit Pilot Policy, 2017), the MBTA may be best suited to execute such a program. Furthermore, participants hypothesized that by hosting an in-house system, the MBTA may be well positioned to ensure that the proceeds from the punishment of the misbehavior be funneled directly to the primary victim of that misbehavior. This would be accomplished by having fines go directly toward bus service improvement. The idea that any revenue collected from a roadway infraction should be dedicated to making further infractions of that same kind less frequent was strongly supported. Statements like, "You park in a bus stop, you screw bus riders. So, your penalty payment should go to improving the experience of bus riders," were met with broad approval.

4.4.2.4 Trust is Paramount

Finally, every focus group session revealed major, deep-seated trust issues between Boston's Black community and governing authorities. Leaders stressed that while community trust in the MBTA was not particularly strong, it was stronger than trust in the Police Department, in the Boston Transportation Department, and in the City in general.

> *"Let me be clear. I don't trust any of them. I don't like any of them. But at least I feel like the T {MBTA} has been making visible efforts at being more transparent. I feel like the City could release a 'Transparency Plan' tomorrow and it would make me trust them even less somehow. I would think, 'Nope. What is this? Why now? They are up to something. This is a front for something sinister.' There is zero trust there."*

Further illustrating this suspicion, groups consistently featured heavy us-versus-them sentiment. Interestingly, for older participants – roughly over 50 years of age – *us* was Black Boston and *them* seemed to specifically refer to Boston government while for younger participants, *us* was Black Boston and *them* was law enforcement in the specific form of police officers. Despite the variation in classification, the feelings of wariness were shared with similar strength. If at least some of this mistrust cannot be healed, then it is not hard to envision a scenario in which public support for not only an enforcement reform plan, but any roadway policy, design, or programming change is an impossibility; a condition warned about in the public opinion literature on CE (McKenna, 2007; Ralph et al., 2022b).

4.4.2.5 Buy-in, Participation, and Review

On the topic of what is needed for a transit-focused camera enforcement program to be successful, a couple key elements revealed themselves as non-negotiables: community buy-in and on-going collaboration, and a transparent, publicly accessible data privacy policy and accountability framework. To ensure these elements, participants saw an opportunity for a beneficial partnership between the MBTA and racial-justice-driven community organizations, as well as the formation of an external program overseeing body.

In one focus group, the following was said of collaboration and buy-in:

> *"If a group like Black Lives Matter (BLM), or Urban League, or the NAACP, or a well-respected local group used the T's analytical capacity and outreach funds, and the T used their community legitimacy, and they both did an education campaign on exactly how cameras would be used and how they benefit rather than harm Black folk… that would probably go a long way toward getting both groups what they want. Unobstructed bus lanes for the T and a defunded police department for BLM. Or more of a voice, a true seat at the table for on-the-ground organizations already doing engagement work."*

It is worth noting that occasions of collaboration between transit agencies, the MBTA included, and organizations involved in race-centered justice work are not uncommon. Most often, these collaborations take the form of community advisory committees (National Academies of Science, Engineering, and Medicine, 2013). Unfortunately, these committees tend to be unidirectionally beneficial. Community organizations lend their expertise and clout, but are rarely offered any decision-making power (Lynn and Kartez, 1995; Litman and Burwell, 2006; Matthews et al., 2018; Cronley et al., 2021). It is hard to argue that this format supports true partnership: a relationship in which leadership and decision-making authority are shared. Through statements like the quote above, it is clear that what is called for to achieve community buy-in of a CE program is a mutually beneficial relationship that serves to distribute power across partnering stakeholders rather than further concentrate it within enforcement agencies.

On the topic of accountability, one community leader offered the following:

> *"I believe that Boston missed a key opportunity back when then-Councilor Andrea Campbell put forth the proposal for the city to have an Inspector General or something similar. Because you need to have a completely independent entity to gather and protect data. Unless that information is protected and that privacy agreement is vetted by the public, then I don't feel comfortable with any of these three {MBTA, Boston Transportation Department, Boston Police Department} running a camera enforcement program. If there is no accountability system, then any enforcement system is a failure. So who will check the MBTA? Who will check the City? Without an independent office, nobody."*

Community leaders demonstrate much wisdom in their emphasis of this need as the value of oversight by external parties is largely supported across scholarship of policing. Be it a civilian oversight model (Finn, 2001) or a professional auditing model (Attard, 2009), the benefits of consistent oversight have been found to be penetrating in cases where oversight committees have power of review which is then paired with disciplinary consequences (Clarke, 2009). These benefits include a decrease in incidences of police brutality and use of deadly force (Prenzler and Ronken, 2001), an increase in accessibility of the formal complaint process (Hope, 2021), a decreased use of disrespectful language toward civilians by law enforcement agents (ibid), and an increase in civic trust (Ferdik et al., 2013). While oversight committees have most commonly been applied to police departments, there is no reason to think that the principles of such bodies could not be applied to other enforcement programs; for example, those hosted by transit agencies.

4.4.2.6 Getting the 'Penalty' Right

Right-sizing infraction penalties was also described as fundamental to an appropriate camera enforcement program. Community leaders stressed that the size of a fine could be the difference between behavior change and behavior stasis, but could also be the difference between a pipeline to prison and an equity-rich program. No concrete plan for a fining scale was offered. Focus groups discussed whether a fine was even the correct format to bring about desired behavior: "A warning might honestly be just as useful as a ticket. I'm not sold on the idea that a financial payment is most effective way to change behavior. I think it just makes people angry at the government." The idea of having the mail-received penalty for a first-time offense be a warning rather than a fine was presented in all groups. Statements of support like, "That would be good so people could learn and get used to the system rather than feel immediately blindsided," were made. All groups concluded that this element of right-sizing the penalty needed much further discussion before any program got implemented, but that the ethos of an 'educate first' approach felt appropriate.

Beyond camera-specific enforcement, the sentiment that traffic penalty structures need close attention, if not complete overhaul, is shared on the national stage. Several major policy and research engines – the likes of the Fines and Fees Justice Center, the Vera Institute of Justice, Vision Zero Network, the Brookings Institute, and the Urban Institute – are actively working on alternatives to regressive fine systems that regularly subject communities of color and low income communities to the possibility of being trapped in a cycle of poverty and punishment (Hanak, 2021). Some of their recommendations include removal of late fees, implementation of an income-adjusted fine structure, and the ability to pay fines in monthly installments (ibid). Because of work by these organizations and others, several cities – e.g. San Francisco and Chicago – have implemented low-income ticket cost reductions ranging from 25% to 80%. While more and more municipalities adopting fine reduction schemes is surely progress, none are being so bold as to do away with fines as the primary penalty format of their traffic enforcement systems. The non-financial penalty structure suggested here by community leaders would make any municipality willing to adopt it a true pioneer in enforcement reformation.

4.5 DISCUSSION AND CONCLUSION

By way of virtual focus groups, this work complements field-dominating survey research on public opinion toward roadway camera enforcement, and expands the literature by exploring transit applications and centering the voices of those most marginalized by existing enforcement practices. Two stages of thematic analysis combined to shed light on feelings held by Black community leaders regarding the potential use of CE for traffic and transit roadway violations using Boston, Massachusetts as case study. Ultimately, the following was revealed: Though lukewarm on camera enforcement in general, Black community leaders feel that Boston may be receptive to a CE program if it were applied exclusively to bus-infrastructure (i.e. bus lanes and bus stops), were operated solely by the MBTA (i.e. transit providing agency), were overseen by an independent oversight committee with consequence administering capabilities, and were intended to serve as an interim measure en-route to the installation of self-enforcing roadway design. This conclusion was informed by discussions of concerns toward CE, benefits of cameras over in-person practices, deep-seated mistrust of governing agencies, and equity-supporting program design elements.

Many of the concerns contributing to the overall lukewarm feelings and mild trepidation toward CE found here are echoed in the public opinion literature as being felt by white and non-white persons alike. Namely, these include concerns of privacy and data abuse, lack of oversight and mistrust in governing and policing authorities, and perceived government money-grabbing. Beyond this list of non-racially delineated worries, Black community leaders expressed concern that by way of algorithmic racism (Patty and Penn, 2023;

Crockford, 2020), CE programs have the potential to continue the enforcement practice of inequitably targeting communities of color.

Despite these concerns, Black community leaders identified several key benefits that CE has over in-person practices that ultimately make it an attractive enforcement alternative. Some of these elements align with findings from the wider literature, while others offer insight on which the literature is scant. Leaders agreed that, if not disproportionately deployed in neighborhoods of color, CE could offer increased enforcement capacity and consistency. They also emphasized believing camera enforcement to causally contribute to lasting behavior change and significant safety improvements overall. These feelings align with those found in much of the CE literature. Black community leaders warmed most intensely to CE's potential to be an entirely gun-free system, and to be operated without any police involvement. The degree to which leaders stated that these conditions would be crucial to the gaining of their support serves as a significant contribution to the public opinion knowledge base.

This Boston-specific context offers lessons that can be applied more broadly. Policy makers seeking to gain support for camera-based enforcement alternatives and wanting to advance racial equity in the process may benefit from being open to the following Black community leader-informed program design recommendations: 1) introduce camera enforcement through a pilot project with a finite duration and evaluation process; 2) divide CE programming into individual parts each specific to a single application, (e.g. red-light separate from speeding separate from bus application); 3) establish an external oversight committee with decision-making authority; 4) lead with the objective of education and behavior change rather than punishment; 5) have specialists in behavior, justice advocates, members of the public and leaders from the most enforcement-marginalized communities help determine the nature of the program's penalty structure; 6) explicitly disallow an increase in police funding or an increase in on-street officer presence as part of any CE programming; 7) channel funds collected via CE directly into street infrastructure projects that target safety through design as eventual replacement for cameras; 8) couple enforcement policy with attempts at targeting systemic contributors to unsafe roadway behavior beyond individual behavior (e.g. displacement and mode-share); 9) require inclusion of justice organizations as well as other enforcement-marginalized members of the public on the oversight committee; 10) house CE programming in whichever non-police, governing authority the public has the greatest trust; 11) put in place protections such that no police agencies may be granted access to camera collected data.

As Figure 5 shows, recommendations one through five are well established in the CE literature and are featured in currently operational programs. Six through eight call for modifications to recommendations previously made on the subject. These modifications, as can be seen the comments column of Figure 5, relate to explicit restrictions on expansion of the police machine, eventual phasing out of cameras, and taking a multi-pronged, urban planning, preventative approach to enforcement policy.

Recommendations nine through eleven offer new ideas to the CE policy design landscape and directly address several concerns previously identified as major influencers over public opinion. Recommendation nine tackles fears of perpetuated targeting of particular communities. Recommendation ten speaks to issues of government mistrust. No municipality, at time of writing, hosts their CE program in anything other than a Transportation Department, Transit Authority, Police Department, or Traffic Authority. While these agencies are the default, they do not have to be the only options. The pervasive hinderance to successful enforcement policy posed by mistrust in particular authorities may best be tackled by considering other agencies as CE program hosts; or, at the very least, studying which of the default agencies the public is most open to engaging with. Recommendation 11 speaks to worries surrounding privacy and data protections by encouraging policy designers to be specific in their limitations of who is barred from tapping into this powerful tool of surveillance.

Figure 5. – Black community leader-inform camera enforcement program design recommendations

		Recommendation	US Example	Non-US Example	Literature with Similar Recommendation	Comments
1	E	Introduce roadway camera enforcement as a pilot program with finite duration & evaluation process.	Scottsdale, AZ – 2006 Beaverton, OR – 2018 Charlotte, NC – 2004	Çerkezköy, Turkey - 2013 Nicosia, Cyprus - 2021 Cairo, Egypt - 2020	Allsop, 2010 Cebryk & Bell, 2004 Leduc, 2008	none
2	E	Divide CE into smaller, distinct pieces. Consider beginning with bus-related applications.	New York, NY – 2010 San Francisco, CA – 2008 Seattle, WA – 2021	Melbourne, Australia – 2013 Paris, France – 2017 Seoul, South Korea – 2005	McKenna, 2007 Carnis, 2007 Mulligan, 2008	Compartmentalization may increase perceived legitimacy. Not all applications incite the same response from the public.
3	E	Establish an external oversight committee, with consequence administering power, to monitor and evaluate the program.	Oakland, CA New Orleans, LA Knoxville, TN	Colombo, Sri Lanka Wadsworth Borough, UK Johannesburg, South Africa	Fries et al., 2012 Osse, 2016 Mokoena, 2019 Kiesling & Ridgway, 2006	none
4	E	Lead with the objective of education and behavior change rather than punishment.	New York, NY Seattle, WA Fairfax, VA	Dublin, Ireland Stockholm, Sweden South Wales, UK	McCartt & Eichelberger, 2012 Delaney et al., 2005 Fleiter & Watson, 2012	none
5	E	Have specialists in behavior, justice advocates, members of the public & leaders from the most enforcement-marginalized communities help determine the nature, magnitude, and form of the program's non-regressive penalty structure.	San Francisco, CA – penalty reformation; advocate informed Albuquerque, NM - optional community service in place of fine; advocate informed	Germany - points toward loss of license; research informed Mexico City - mandatory community service after a certain number of points; advocate informed	Hanak, 2021 Dixon & Alexander, 2005 Mohammed & Labuschagne, 2008	none
6	M	Disallow for any increase in police funding or any increase in on-street officer presence as part of any camera enforcement programming.	Portland, OR Colorado Springs, CO	Bristol, United Kingdom Lower Saxony, Germany	Ralph et al., 2022 Woods, 2021 Bliss, 2020	Examples here have a police divestment initiative, or no practice of using CE to increase police funding/presence. None explicitly disallow, nor does the literature.
7	M	Channel CE-collected funds directly into street infrastructure projects that target safety through design as eventual replacement for cameras.	Seattle, WA Washington DC Staten Island, NYC Baltimore, MD	Vancouver, Canada Rio de Janeiro, Brazil Milan, Italy Queensland, Australia	Ralph et al., 2022 Greenfield, 2022 Turner & Polk, 1998 Ralph et al., 2022	None of the programs nor literature specify the goal of camera replacement, but do focus on infrastructure investment.
8	M	Couple enforcement policy with attempts at targeting systemic contributors to unsafe roadway behavior beyond individual behavior.	Chicago, IL – funds from CE earmarked for after-school, job creation, and anti-violence programs.	London, United Kingdom - funds from CE used for free transit passes for elderly and young people (Hackney Council)	Ralph et al., 2022** Greenfield, 2022** Marshall, 2018 Vera Institute of Justice, 2021	No programs directly connect housing/settlement patterns and changes (e.g. displacement) with CE policies.
9	N	Require inclusion of justice organizations as well as other enforcement-marginalized members of the public on the oversight committee.	none	none	Rodier et al., 2007^ Woods, 2021^ Vera Institute of Justice, 2021	No CE program oversight bodies have explicit or mandated inclusion of justice organizations, institutions, advocates, etc.
10	N	House CE program in whichever governing authority the public has the greatest trust.	-	-	-	Identification of trust as an issue is present in the literature, but solutions are under-explored.
11	N	Establish protections such that police may not be granted access to camera collected data.	none	none	Fries et al., 2012 Woods, 2021 Ralph et al., 2022*	No programs outright disable police data access.

E = reiteration of a well-established recommendation; M = modification of an established recommendation; N = presentation of a new recommendation to CE policy design landscape

**Speaks to protections against data seizing and misuse, though not specific to police; **Acknowledges these factors and their connection to race, but does not make explicit recommendations on the subject*

^Recommends giving groups and members of the general public with a 'special interest' a greater role in the oversight and review process, but does not specify those with heightened condition of vulnerability

This work adds to the policy maker toolkit for shaping civilian-informed enforcement systems, and, hopefully, will contribute to the simultaneous improvement of roadway safety, decrease in racially unjust policing, and rebuilding of civic trust so desperately needed in so many places.

4.5.1 Limitations and Topics for Further Study

No work is without its limitations. The pre-participation survey unearthed a demographic imbalance between the participant sample and the broader reality of the subject of enforcement with respect to gender. The gross majority of participants identified as women (89%). Women are generally more in favor of camera enforcement as well as far less likely to violate roadway regulations than those who identify as men (Retting et al., 1999; Corbett and Caramlau, 2006). It is reasonable to assume that men, being statistically more likely to be engaged in the enforcement process, may have notably different perceptions of the appropriateness of camera-based enforcement alternatives. While this assumption does not degrade the value of the largely women-led findings here, it does suggest that extending this work might entail seeking viewpoints from a more gender-diverse group of community leaders with an eye to comparison.

Because each participant was only engaged with in a single focus group session, it was not possible to assess how their views toward camera enforcement may have changed over time or directly in response to having participated in this work. This information would be useful in that it could speak to the mixed findings on the subject of a possible familiarity effect found in the CE literature (Freedman et al., 1990; Blincoe et al., 2006). This work also does not explore the specifics of what it would take – structurally, financially, etc. – to implement a program that meets all of its resultant policy design recommendations. How might budgetary responsiveness change with decreased revenue brought about by increased compliance with roadway regulations? What might staffing needs look like to host a CE program entirely outside of an existing enforcement agency? What sources of revenue should be pursued to enable a program of this type? These ideas require further examination.

Additionally, this work does not explore how acting on any of the Black community leader-informed recommendations made here may result in backlash. Backlash can take many forms. For example: further worsened trust in government among certain groups; increased tensions across racial lines if non-Black members of the public feel that a CE program of this design affords the Black community undue preferential treatment; or even retaliatory action from police departments for being sidelined from the roadway enforcement process. Any such backlash would undermine the intensions of roadway enforcement reform. Therefore, to avoid such outcomes, these possibilities should be further studied.

Finally, while one could argue that Black America has the most to gain from camera-forward enforcement reform – not only because of racially disproportionate practices of police brutality, but because decades of inequitable investment in infrastructure has resulted in Black neighborhoods hosting disproportionately unsafe roadways (Haddad et al., 2023; Greenfield, 2022; Barajas, 2021; Rennert, 2016; Golub et al., 2013) – we must ask ourselves: 'Who has the most to lose with CE?' Persons with prior offenses as well as undocumented and non-citizen individuals may be positioned to be most taken advantage of, perhaps even targeted, via an enforcement system so dependent on automation and the on-file information of members of the public. Voices from these communities similarly need amplification regarding the acceptability of roadway CE programs, and enforcement alternatives more generally, if meaningful steps toward equity in both policing and roadway safety are to be made.

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ACKNOWLEDGEMENT OF ETHICAL CONSIDERATIONS

All research design elements of this work were approved by the London School of Economics and Political Science Research Ethics Committee on November 13th, 2020.

APPENDIX: Paper 3

A.1 Participant Protections, Researcher Reflexivity, and Reflections on Methodology

Researchers face ethical challenges in all stages of a study, from designing through to reporting. "These include anonymity, confidentiality, informed consent, researchers' potential impact on the participants and vice versa (Sanjari et al., 2014)." These matters, as well as the ideas of power and protection, were considered at length. I reflected on ways in which participating in this research might cause harm to those involved, arriving at two categories of potential participant vulnerability. Firstly, serving in their elected roles, participants were all semi-public figures. What these people say on record has the potential to impact their board position or future election favorability. As a result, I decided to include neither the name of participants' associations, nor any personal identifying information.

Secondly, it was not lost on me that this work called for Black individuals to discuss, among other things, the relationship between their communities and law enforcement entities. By asking participants to engage in this conversation, I introduced the potential to inadvertently surface distressing thoughts or past experiences that they or loved ones have had with the police. In an attempt to avoid inducing this type of stress, I was sure to frame my more delicate questions as requests for reflection upon *either* personal experiences *or* general perceptions.

No research can call itself robust without engaging with reflexivity, "the recognition that the product of research inevitably reflects some of the background, milieu and predilections of the researcher (Gibbs, 2007)." This 'inevitability' makes it futile to try to eliminate the effects of the researcher; rather, it is necessary to understand these effects and monitor and report them (Brewer, 2000). In this spirit, I now make an effort to shed light on aspects of myself that intersect with this work, and reveal instances in which I was able to identify how these aspects shaped the research process.

Professionally, I am tied to both transit and racial equity advocacy in Boston. In my past role as a Transit Planner with the Boston Transportation Department, my projects called for regular collaboration between myself, community associations, organizers, and the Massachusetts Bay Transportation Authority (MBTA). It was through my work in this capacity that some focus group members were familiar acquaintances of mine. By using this existing familiarity, placing at least one such acquaintance in each group, I hoped to create a comfortable, informal environment in which people felt safe to speak plainly on a sensitive topic.

Furthermore, it is vital to note that I am a Black woman, and that that fact was discernible to anyone participating in these Zoom meetings. Given that discussion of enforcement cannot, and should not, be parted from discussion of race relations, it is possible that respondents censored, played-up, or played-down their views in an attempt to appear a certain way to me – the researcher – rather than accurately represent their own beliefs. Past studies have cited issues of researcher appeasement as a sizable hurdle in attempting to discern meaning-making and internalized understanding (Blee and Taylor, 2002).

However, what I experienced in this work was a readiness to share personal anecdotes, frequent praise from one participant to the next for either past work within the City or a particularly poignant enforcement-related idea, and groups that regularly ended in participants expressing interest in working together further, both on matters concerning roadway enforcement and other civic issues impacting Boston neighborhoods. This is likely due in part to the virtual format. Walston and Lissitz (2000) suggest that the computer-based environment may lessen participants' concern for what the moderator thinks of them, discouraging the withholding of seemingly unsavory information. Such was the case here. Participants playfully used profanity and divulged personal experiences that occasionally cast themselves in a somewhat negative

light; often playing the traffic fugitive. It may also largely in part be due to the fact that these groups were composed entirely of Black individuals. Robson and McCartan (2016) support this claim via their suggestion that demographically homogenous groups may create a 'safe-space effect' allowing for a freer flowing of ideas.

Further support is offered by Browne (2016): "Laughter and humor are emphasized within focus groups as a way of overcoming social awkwardness, particularly within marginalized groups." Laughter, an influencer of conversation tone, is more readily forthcoming when participants feel that they share perceivable commonality (ibid; Robinson, 2009; Wilkinson et al., 2007); which also explains why groups of all women and groups in which all participants appeared to be near to one another in age featured the most jovial atmosphere and comradery-laden language. I feel strongly that this research is richer for having featured spaces exclusive to Black voices and Black reactions. In this exclusivity, groups were well-primed to host moments of shared suffering, were open to disagreement, and were welcoming to playfulness and informality. Though I am not alone in the belief that minority-exclusively research is a uniquely valuable knowledge-shaping tool (Kitzinger, 1994; Morgan, 1996; Stanley, 2016), our current national social climate is such that emphasis of this value, and any influence that such emphasis may have over research design and funding decisions, cannot be overstated.

Finally, I find that the following statement rang true for my data collection process: "In-depth knowledge of the research topic and familiarity with the interviewees' culture and norms of behavior facilitated gaining their trust and establishing rapport, which proved invaluable in obtaining the interviewees' own perception of events (Mikecz, 2012)." My being Black, having called Boston home for ten years, and being a transportation professional all unquestionably contributed to the success of the data gathering process. Statements like "… well *you've* seen it" and "…as *we* know *they* will" were made frequently, suggesting shared positioning between myself and participants likely fostering openness.

A2. Black Women Leading the Charge

With each focus group it became more and more apparent that Black women are, and for so very long have been, at the core of much civic activation, participation, movement, progress, and stability in Boston. Beyond the facts that nearly all of this work's participants – 24 out of 27 community leaders – were women, many of them shared stories of community-led enforcement, engagement, and education efforts that they have personally participated in:

> *"Back in the day I was a member of _____ (name omitted for participant anonymity). It was kind of a neighborhood watch. In the 80s and 90s, we did traffic work. Prompted by the death of an older lady – somebody hit her going 75mph – we did a heck of a safety campaign about it. Eventually we got speed bumps put in down there. Originally we were promised more comprehensive traffic calming, but we never got it. I guess they figured speed bumps were good enough. Typical. 'Thanks for the crumbs, City Hall.'"*
>
> *"The issue is that we don't have ongoing productive dialogue with our elected officials or with City Hall department staff. There is no ongoing educational discussion of outcomes of these {planning} elements saying, "You know… look… lives have been saved!" Now, there is starting to be more dialogue in my neighborhood. Now that the City is paying community groups to do it. Ha. In other words paying sistas that were already doing it at neighborhood association meetings and in line at the grocery store, or whatever. That's progress. I think it is increasing the support for things like road diets and stuff like that."*

Continuing to promote, learn from, and financially support the work and expertise demonstrated by Black women community leaders can only be beneficial to any government agency, both in and outside of Boston, both in and outside of enforcement.

A.3 Participation Consent Email

Participants were invited to focus groups via direct email. Participants were asked to respond to their invitation with the following text copy and pasted into their acceptance email with their names typed into the blank space provided:

"I, _____ consent to participating in this research under the agreement that my name and professional position shall not be included in any associated published works, and shall not be known at any point in the research process to anyone but Lindiwe Rennert, and my fellow focus group participants. I also consent to preserving the confidentiality of the group by refraining from any discussion of group comments or membership outside of the session."

Additionally, at the beginning of the session, participants were reminded of their agreement to a 'four-walls' policy – that no discussion of what was said by whom was in attendance should take place outside of the virtual focus group.

A.4 Focus Group Question Guide

I developed this guide to add some structure to the focus groups, and to anchor them around different topics. Use of this guide, however, was not rigid, and discuss was allowed to flow where participants directed it. Still, all focus groups engaged with all anchor topics in the guide, if not every sub-question.

Introductions

Remind participant of their agreement to a 'four-walls' policy – that no discussion of what was said and who was in attendance should take place outside of the virtual focus group.

- Appreciation + Disclosure
    - Hi everyone. Thank you for making the time and being open to sharing your thoughts.
    - Just want to remind you all that this meeting will be audio recorded, that you can leave this meeting at any time, should you feel uncomfortable, that the recording will only be accessed by me, and it is strictly going to be used for the transcribing process. Upon publication of this work, both the anonymized - by me – written transcripts and the audio recording from this meeting will be deleted.
    - Additionally, everything you say here is confidential; neither your name nor your association's name shall appear anywhere in this research.

- Explanation of Research Purpose
    - Center Black voices. Gain understanding of perceptions of enforcement as they are today, have been in the past, as well as ideas about what they could be in the future.

- Introductions
    - There is no need to share your names in this space if you would rather not, but let's go around the room and share the gender pronouns we use so that we can engage with each other respectfully.

Traffic Infractions

Objective: To establish a shared understanding of what is meant by 'traffic violations' within the group, to get a sense of sentiment toward violation behavior, and to open the group up to thinking about the punitive system as something not set in stone.

- Framing the Magnitude of, and Firsthand Exposure to, the Issue
    - Can you describe the types of traffic-related behavior you see a lot of that is technically a violation of traffic laws, and how seeing these behaviors make you feel?
    - What is the most common punitive system (response) you encounter for these infractions?
    - How do you feel about the effectiveness of the current punitive system in bringing about behavior change? What elements work and what doesn't; please be specific.
    - Are there other concerns about the current system that you have heard from your community members?

Camera Enforcement – General

Objective: To explore the group's level of familiarity with, comfort with, and exposure to camera enforcement.

- Can you describe the different types of camera enforcement that you are familiar with?
- When you hear the phrase 'automated camera enforcement', what feelings first come to mind?
- What types of concerns do you have related to automated camera enforcement that are specific to your community?
- Can you expand on some of the feeling members of your community/organization have expressed related to camera enforcement?
- Have you ever personally been penalized for a traffic violation via camera enforcement?
- Can you describe how that experience made you feel and how, if at all, it affected your behavior afterwards?

Camera Enforcement – Transit Specific

Objective: To gain the group's views not on camera enforcement in general, but on camera enforcement as it relates to transit; specifically after being shown the data-visualization 1-pager on how camera enforcement can be done.

- Redirecting from General to Specific Lens
    - Let's reframe our scale here, and think of automated camera enforcement specifically for transit-related traffic infractions. Bus lane and bus stop violations, for example.

- Introduce Prompt: 1-pager shared via a link in the virtual chat platform
    - Can you describe your initial reactions to this information? Does anything surprise you?

- Transit-specific Enforcement Logistics
    - (Briefly describe that the MBTA is currently lobbying legislators to push for bus-facility enforcement with the T has administrative agency. Describe the logistics proposed by the T) How do your comfort levels differ between on-board cameras versus on-street cameras?
    - How does the distinction in keeper of violation data between MBTA, BTD, and Boston Police make you feel?
    - How does your comfort level differ with the T vs BPD vs BTD as enforcing agency?
    - Is there another agency that you would be the most comfortable with as the enforcing agency, and why?
    - If transit-specific automated camera enforcement were implemented, who do you think should receive the revenue from fees and what should be done with it?

Police Reform

Objective: To explore what links and relationships the group feels could exist between the current race-centered justice work and the implementation of camera enforcement.

- Defunding/Abolishing the Police
    - Given calls for defunding and further abolition of police departments present today, fueled by the Black Lives Matter Movement, is police reform/transformation something your community is interested in supporting in general?
    - What role you think automated camera enforcement might play in advancing that objective?

- Wrapping Up
    - Do you think your community would be in favor of some sort of camera enforcement? And if so, what sort? And why that sort?
    - Are there any pieces of camera enforcement that we have talked about that you think members of your community would be interested in? Which ones and why?.
    - How do you feel about the idea of pilot testing camera enforcement?
    - Can you describe the types of practices or policies you think might bring about behavior change from the current way streets functions to a safer way? This can be related to what we have discussed here or something entirely different.

Concluding

- Appreciation
    - Thank you all for your time, honesty, and expertise.

- Explanation of Next Steps in the Research
    - Next steps with this work entail additional focus groups.
    - The goal for this work is to result in a journal article published in an academic journal, as well as a shorter memo design for a political audience.
    - I will share the finalized version of my research with you once it is published via email. You are welcome to share both the full research article and brief memo with your representatives, your communities, anyone you wish.
    - Please remember that if at any point between now and January 28th you wish to retract your consent to having your comments included, you are at full liberty to do so. Just reach out to me directly.

- Space for Any Remaining Comments
    - Do you have any questions for me or comments that you would like to add before we wrap up?

CHAPTER 5: Paper IV

Changing Travel Behavior in a Rapidly Gentrifying City: Evolving Transit Mode Choice in the Washington DC Metropolitan Area

5.1 INTRODUCTION

The desirability of urbanity among the US populace has come in waves. The White flight and en masse suburbanization that typified much of the 1950s through 90s was the trough of the most recent of these waves (Nicholaides and Wiese, 2017). That period gave way to an urban resurgence which accelerated over the two decades leading up to the onset of the COVID-19 pandemic. Between 2000 and 2020, many urban centers – particularly those rich in existing mobility infrastructure, available sites of employment in the financial, tech, and creative industries, and concentrations of higher education institutions – experienced a significant influx of new residents (Wiltse-Ahmad, 2019; Bereitschaft, 2020).

Proponents of this urban renaissance argue that there is much to gain from the current wave of settlement preferences: increased population density may afford commercial enterprises new customers (Meltzer, 2016); once vacant or blighted properties gain tenants and, therein, caretakers to maintain and upgrade them (Shaw, 2004); and cities increase their tax bases, strengthening their ability to provide for their residents through the provision of public goods and social programs (Vigdor et al., 2002). However, stark disparities in just who has benefited in this return to the city and for whom the process has been dominated by experiences of loss, trauma, and exclusion (Shaw and Hagemans, 2015; DiGregorio, 2020; Howland, 2021) have aptly led to a collective framing of this moment in person-movement (i.e. settlement) history as an era of widespread gentrification (Richardson et al., 2019).

Gentrification has no singular definition, and therefore has been associated with a range of characteristics (Williams, 2015). This range is further expanded by the fact that what gentrification looks and feels like is deeply contextually dependent on place-based elements of history, markets, and power structures, as well as personhood elements of identity (Zuk et al., 2018; Kirkland, 2008; Hwang and Sampson, 2014). Nonetheless, most definitions specify present US gentrification as spatially involving, at a minimum, changes in neighborhood composition related to age, race, and income that take the following forms: younger average age and fewer intergenerational households, as well as increased Whiteness and increased average incomes among resident cohorts (Finio, 2022). Stated perhaps more simply, those doing the bulk of the moving from outside the city into it – and from utility lite to utility laden areas within cities – have been younger, whiter, and wealthier than the existing populations of the neighborhoods they are moving into (Kirkland, 2008).

In cases where this in-migration has exceeded housing supply or has inflated housing prices beyond the affordability limits of the existing rental community, the result has largely been displacement of low income, of color, older, and multigenerational households (Cortright, 2019). For many being removed from their homes by market forces, the only option has been to relocate to less amenity rich, lower density, peripheral urban neighborhoods and suburban areas (Kneebone and Berube, 2013).

Undoubtedly, changes in who lives where have mobility implications. Thus, the question is begged of what this means relevant to transportation. To some degree, one might expect from these gentrification-related realities a comparative degradation of trip quality for older, lower income, and of color travelers entailing longer, more expensive trips (Zhao, 2015; Bereitschaft, 2020). One might also expect a drop in walking mode share for these groups, which would have implications for worsening physical and mental health (Kelly et al., 2017). This is to say nothing of the injustice in resource distribution associated with society's means and power majority groups gaining comparatively ever-greater access to the highest level of service (e.g. best frequencies and largest number of routes) of the comparatively affordable, highly subsidized travel mode that is transit (Revington, 2015).

Against this backdrop, this study tackles the following question: How have the gentrification-associated elements of race, age, and income changed as predictors of transit mode choice in the Washington DC metropolitan area during the last two decades of rapid gentrification? A greater understanding of changing travel behavior amidst these settlement conditions could help practitioners and policymakers better maximize transit ridership, minimize service distribution inequities and inefficiencies, and better connect those reliant on transit services to the places, things, and people that make up their lives.

5.2 LITERATURE REVIEW

5.2.1 Mode Choice Determinants

The body of literature dedicated to understanding the determinants of mode choice is extensive. Most work has found that factors influencing mode selection fall into six categories: individual characteristics, household characteristics, season and weather factors, trip characteristics, work conditions and policies, and elements of the built environment. To a lesser extent, a few scholars have looked at the mode determining role played by societal norms, attitudes, and beliefs. The most extensively studied factors that make up these categories are shown in Table 1.

Table 1. Travel mode choice determinant factors

Individual Characteristics	Trip Characteristics
Gender and Sex	Departure time
Education level	Trip purpose
Race/Ethnicity	Number of individuals in travel group
Language (as compared to location's official language)	Travel cost (time and monetary)
Payment subscription (access to monthly pass)	Number and complexity of trips needing to be made in a day
Occupation and employment status	
Driver's license	**Season & Weather**
Body mass index	Level of precipitation
Age	Outdoor temperature
Mode used for attending grade school	Level of humidity
Built Environment	**Household Characteristics**
Urbanization level (density)	Household size
Level of greenery and water features along trip route	Number of children in household
Street furniture conditions	Household income
Topography	Availability of vehicles
Features associated with traffic safety/calming along route	Availability of bicycles
Street connectivity	
Amenity composition along trip route	**Work Conditions + Policies**
Parking availability at destination	Time of start and stop to workday
Expanse and level of service of mode network	Travel compensation package and support facilities/storage

Illustrative of some of the ways that individual characteristics affect mode choice less frequently highlighted in the literature, Ton et al. (2019) find that having a part-time job is more positively associated with cycling than having a full-time job. Polk (2004) finds that those who identify as women have greater intention to reduce car use than those who identify as men, and that that intention contributes to their higher propensity to select sustainable modes. Building on this, Scheiner and Holz-Rau (2012) find that such gendered mode choice influencers hold even in household with as many cars as drivers. Limited proficiency in the dominant language of one's locale has sway over mode choice as well. Bursa et al. (2022) find that, for tourists in particular, limited language proficiency significantly decreases transit mode selection likelihood. Lastly, McCarthy et al., (2017) find that mode choice habits are formed during grade school ages and that those habits largely prove lasting over one's lifetime.

A great many built environment factors play heavily into mode selection decision-making. To highlight just a few, the presence and quality of cycling infrastructure dictates bike mode choice significantly (Khan et al., 2014; Masoumi, 2019). Greater intersection density and mix of land-uses increase the likelihood of choosing to walk (Buehler, 2011; Khan et al., 2014). Buehler (2011) finds that level of seamlessness in multi-agency and multi-modal transit network integration impacts the likelihood of transit mode selection. Further on the topic of network quality, frequency of service, system cleanliness, average wait times, and reliability all influence modal preference for transit rendering higher quality service associated with higher transit selection likelihood (Paulley et al., 2006; Chakrabarti, 2017). Finally, Ramezani et al. (2018) find that mode choice sensitivity to built environment changes is higher for discretionary trips than for compulsory ones, a finding that speaks to the connection between impact factors in the category of built environment and those in the category of trip characteristics.

Adding to our understanding of how trip characteristics relate to mode choice, Limtanakool et al. (2006) look at medium- and long-distance trips and find, unsurprisingly, that car mode selection gains likelihood as the car gains travel time advantage over transit. They also find that leisure trips are less sensitive to travel time influences over mode selection than work trips. Ha et al., (2020) find that preference for transit significantly decreases when one or more transfer is required to complete a trip, and walking distances from site of transit egress to destinations have greater transit selection disinclination impact than walking distances from trip origin site to transit access point. Several studies have also found, as one would suspect, that an increase in baggage or cargo needs significantly increases likelihood of car mode choice (Tam et al., 2008; Tam et al., 2011; Alhussein, 2011; Akar, 2013).

Seasonality and weather have a particularly strong influence over use of the most sustainable modes. Inclement weather and extreme temperatures typically decrease the likelihood of walk and bike mode selection in favor of vehicular modes (Ton et al., 2019; Faber et al., 2022). They have also been found to decrease propensity for transit in favor of car selection (Hyland et al., 2018). Some studies have taken to looking forward, attempting to predict the impacts that continued climate change will have on mode choice (Böcker et al., 2013; Böcker et al., 2016). They find that climate change, in some parts of the world, is likely to flatten out seasonal variation in mode choice.

Household characteristics have received a sizable amount of research attention in the realm of mode choice determinant factors. Having household-level access to a vehicle greatly increases the likelihood of car mode selection (Buehler, 2011; Ding et al., 2017), as does the presence of children within the household (Rubin et al., 2014; Du et al., 2020). Similarly, bike ownership – as opposed to access to temporary bike use via bikeshare, for example – has proven an important determinant of bike mode choice, especially among students (Moniruzzaman and Farber, 2017).

Work conditions and policies have been less extensively examined than other mode choice determinant categories. Still, findings from the sub-topic are significant. Moniruzzaman and Faber (2017) find that having access to a lengthy – for example a weekly, monthly, or annual – fare pass, commonly provided through one's employer or academic institution, has significant impact over the selection of transit, especially for short trips that could, for many, reasonably be made on foot. Employer-provided rewards programs that compensate you for sustainable mode selection – typically walking, biking, and transit use – have been found to significantly increase likelihood of selection of those respective modes (Bueno et al., 2017; Shin 2020). Finally, we generally feel safer in more brightly lit places and in places where other people are visibly present (Peña-García et al., 2015; Jorgensen et al., 2013). These conditions are somewhat time-of-day sensitive, and in such, the likelihood that we find ourselves in situations we perceive as 'safe' in part relates to when our work time spans. In particular, perceived public unsafety negatively

effects transit and walking mode choice likelihood in many places (Lee, 2013; Ramezani et al., 2018; Madhuwanthi et al., 2016; Masoumi, 2019; Rennert, 2023).

Speaking to the relationship between mode choice and social norms, Klinger (2017) finds that the social norms of a place have significant influence over the mode selection of new residents. Phrased differently, mode choice is susceptible, at least in part, to heard behavior. Lanzini and Khan (2017) add nuance to this line of exploration, finding that attitudes and social norms have a greater effect on intended mode selection behavior than actualized behavior. McCarthy et al., (2017) further contribute, finding that social norms associated with role expectation – for example, what is 'good parenting' understood to be in a particular place – influence mode choice as well.

More detailed discussion of the temporally fixed mode choice determinant literature can be found in the following meta-analyses (Ewing and Cervero, 2010; Lanzini and Khan, 2017) and reviews (Paulley et al., 2006; Buehler, 2011; Van Leirop et al., 2018; Ton et al., 2019; Colovic et al., 2022). As mode choice is geographically, economically, socially, and evenly politically content-sensitive, engagement with these more extensive reviews and meta-analyses can help explain where the relationships highlighted above hold true, where they prove insignificant or directionally oppositional, and what explains these variations.

5.2.2 Gentrification and Evolutions in Mode Choice Determinants

Most research on the topic of mode choice determinants has been static, looking at a single moment. A significantly smaller subset of work focuses on how travel behavior has changed over time. Even less emphasis has been placed on exploring the intersection of gentrification elements and the evolution of mode choice determining factors. The pool shrinks further still – down to a handful of studies – when discussing a specific geographical context; the US in this case. This section engages with these works.

Education, rail proximity, and race.

Bereitschaft (2020) takes up this mantle in a study of 101 US metropolitan area urban cores. Looking at changes in mode choice predictive factors for work trips between 2000 and 2015, this work hones in on the gentrification-related elements of income, college degree attainment, Whiteness, and young adulthood (defined as being age 18 to 39, specifically). It finds that education attainment is closely associated with increased walking and cycling mode selection. Relatedly, due to where the young, wealthy, and educated are increasingly choosing to residentially cluster – namely in urban cores concentrated near rail stations (Zuk et al., 2018; Grube-Cavers and Patterson, 2015; Chapple et al., 2016; Rennert, 2022) – the predictive strength over transit mode selection offered by the factor of proximity to rail stations remains positive between 2000 and 2015, but decreases in degree of strength. In other words, gentrifiers are choosing to live near rail, but have a greater behavioral preference for walking and cycling than the previous rail-proximate tenants they are replacing (Moos et al. 2017; Izadi, 2022). Bereitschaft unearths further impact to transit mode choice related to race finding that increase in the proportion of White residents in an urban core is negatively associated with transit mode choice.

Other works similarly find race related to significant changes in mode choice determination over the last three decades. With respect to intra-group comparisons, Black and Latinx travelers in particular are increasingly significantly less likely to mode select transit as time passes and gentrification-related settlement patterns persist (Klein et al., 2018; Pucher and Renne, 2003). Cross-group comparisons reveal that though significant differences in mode choice likelihood remain across racial groups, mode selection behavior of minority groups is more closely matching White behavior over time (Polzin et al., 1999). An example interpretation of this finding is as follows: though Black travelers remain statistically more likely than White travels to conduct their journey via transit, the degree to which this likelihood holds is

decreasing. Blumenberg and Shiki (2007) find that this is, in part, because transit use is decreasing across all races – controlling for income – and car use is increasing among non-White groups in particular.

Howland (2021), by way of qualitative research in a field heavily dominated by quantitative modelling, adds an additional layer of understanding to the race-gentrification-mode selection relationship. In its examination of displaced Black households in Portland, Oregon, this works finds that even in cases where transit mode choice is preserved by travelers pre- and post-relocation, *desired* mode choice changes. Interviews reveal that displaced Black residents continue to remain dependent on their social support networks in the neighborhoods from which they were displaced. Interviewees cited drastically lengthened travel times as the primary motivation for wanting to change travel modes. Ultimately, it is important to note that even in cases where mode selection may not be impacted by gentrification-related settlement pattern changes, satisfaction with that mode selection very well may be.

Attitudinal contradictions, and variation by gentrifier type.

Broadening the lens beyond race, most work relating travel behavior and gentrification render unfavorable findings for transit agencies. Danyluk and Ley's (2007) research is no different. They find that compared to non-gentrifying neighborhoods, gentrifying neighborhoods in metropolitan areas, particularly within urban cores, are increasingly hosting an "underutilization of public transit." They take this analysis a step further and introduce a discussion of how this behavior stands in opposition to the stated attitudes – which they define as pro-transit and transit-seeking – of gentrifiers; namely of Millennial gentrifiers. Contributing further nuance, they also find that first-wave gentrifier, a group defined as being more similar to existing resident communities with respect to income and education level (Duque et al., 2013; Bartz and Douglas, 2012; Benton, 2014; McFarlane, 2021), are more likely to use transit than second-wave gentrifiers, and that gentrifiers living in "new-build units" are the least likely of all gentrifiers to use transit.

Powerful habits.

Explanation for this 'underutilization' of transit associated with gentrifying neighborhoods, at least in part, is offered by the work of Srinivasan and Bhargavi (2007). Looking at mode selection for work trips from 1999 to 2004, they find that past choices influence present choices: mode choice is habitual even after we change our environment. This suggests that urban core in-movers – potentially from suburban, less transit-rich environments – who didn't use transit prior to relocating will likely continue not to, while displaced urban core out-movers who previously used transit will likely continue to once forced outward. Blumenberg and Shiki (2007) similarly conclude that mode choice habits are persistent after relocation. However, they find that these habits tend to dissipate with time and an assimilation effect occurs in which the relocated individual takes on mode choice more closely aligned with the geographical norm they find themselves in. This holds particularly true for out-movers, who Blumberg and Shiki find increase their likelihood of car mode selection significantly after 5 years post-relocation.

Age and income.

Regarding the gentrification element of age, findings from the mode choice determinants literature are varied. Some work finds no significant change in mode choice predictive power associated with age (Klein et al., 2018), while other research finds that older young adults and middle aged individuals are becoming increasing likely to use transit (Srinivasan and Bhargavi, 2007; Godfrey et al., 2019). On the gentrification element of income, there is general consensus across the literature. Studies largely align in finding that being a low-income earner has weakened as a likelihood predictor of car-free travel (Srinivasan and Bhargavi, 2007; Swanstrom and Ploger, 2022; Klein et al., 2018; Pucher and Renne, 2003). This means that low-income earners are either willing or having, increasingly so, to move toward private vehicle selection and away from walking, cycling, and transit selection (Blumenberg and Thomas, 2014; Cournoyer, 2018).

5.2.3 Gaps in the Literature

This research aims to contribute to our understanding of evolving, gentrification-related mode choice determinants by targeting three primary gaps in scholarship. Firstly, work trips dominate the literature. While there exists some exploration of other trip purposes – tourism (Hsieh et al., 1993), education (Ewing et al., 2004), family visits (Rubin et al., 2014), shopping (Wang et al., 2010) – examples are few and far between, and largely contextually situated outside of the US. This work both adds additional trip types beyond existing studies and allows for within-study, cross-type comparison. The value of this is two-fold. For one thing, work trips, in their very nature as generally mandatory and locationally fixed, are hypothesized to be less subject to condition or environment changes than discretionary trips (Ewing et al., 2004) and may therefore be underestimating the impact of gentrification-related settlement patterns on mode choice determination. For another, as the COVID-19 pandemic has shifted a sizable share of trips away from work toward other purposes, knowledge of non-work-related travel behavior is of increasing importance to practitioners in the planning and transportation fields.

Secondly, there has been little focus paid to rapidly gentrifying cities. Much of the US-specific work has looked at post-industrial cities with comparatively low housing demand pressures (e.g. Philadelphia, PA and St. Louis, MO). Swanstrom and Ploger (2002) suggest that gentrification in these types of cities may be significantly less disruptive an experience than in "strong-market, global, magnet cities;" of which Washington DC is a prime example. They, and others (e.g. Wyly and Hammel, 2004; Zuk et al., 2018), hypothesize that in strong-market cities, elements of loss and of forced behavior change may be particularly pronounced, especially for housing insecure, low-income, and of color communities.

Finally, the literature's treatment of 'transit' is distinctly rail-centric. Most work on mode choice determinants only controls for proximity to rail stations and ignores access to bus services. This study gives the bus its moment in the sun exploring how different degrees of bus service access might impact mode choice. Additionally, few works include paratransit in their analysis. With the cohort of persons across the US anticipated to rely on paratransit increasing (Wang et al. 2022), this particular subset of transit trips needs to see increased inclusion in transit research at large. This study acts in accordance with this need for inclusion.

5.3 METHODOLOGY

5.3.1 Why Washington DC

For several reasons, the Washington DC metropolitan area is the ideal context in which to situate this work. The District of Columbia has had the highest percentage of gentrifying census tracts among the 100 largest US cities for several consecutive years over the last decade earning it the title of 'most intensely' or 'fastest' gentrifying city in the country across a number of studies (e.g. Balk, 2019; Richardson et al., 2019). In this sense, DC serves as a comparatively extreme case of gentrification, potentially allowing for more seismic, more capturable trends in associated travel behavior change.

The region has also been the poster child for the White-Black tensions so central to US-based discussions of gentrification (Golash-Boza et al., 2023). DC was the first large city – 500,000 residents or more – to have a majority Black population. In 1957, this earned it the moniker 'Chocolate City'. At its peak, the city's Black population reached 71% of total residents. However, since 2011, DC no longer has a majority Black population. According to the American Community Survey 1-year estimates for 2023, the current Black share of DC residents sits at 45%. Relatedly, a study conducted by the National Community Reinvestment Coalition determined that over 20,000 Black residents were displaced from the District between 2000 and 2013 by market pressures (Richardson et al., 2019). At the same time, the city's

surrounding areas have increased in racial diversity, getting less White overall (Kurzius, 2020). Taken in concert, these conditions well-exemplify in-out urban core flows aligned with settlement patterns of gentrification.

Finally, transit networks serving the DC metropolitan area have remained relatively unchanged since 2006. This holds particularly true for the region's rail network. This consistency across the full period of analysis lessens the chances that observed changes in transit mode choice selection likelihood are heavily influenced by changes in quality or expanse of transit service.

5.3.2 Regional Household Travel Survey and Travel Diary Data

Recent years have seen an increased use of travel diary data to analyze travel behavior and mode selection (Klein et al., 2018; Chang et al., 2019; Ton et al., 2019; Ha et al., 2020; Aderibigbe and Gumbo, 2022). This gain in favor is fueled by the richness in per-trip information that travel diaries offer, as well as a travel diary's ability to log travel behavior of participants over several days, allowing for the capture of day-to-day variability as well as longer-run – week to week – patterns of stability (Schlich and Axhausen, 2003). Because of this, travel diaries are able to speak to "travel behavior on a typical weekday (Klein et al., 2018)."

The National Capital Region Transportation Planning Board and the Metropolitan Washington Council of Governments have conducted a random-selection regional household travel survey approximately every ten years since 1968. The two most recent of these pertain to 2007 and 2017 and include personal travel diary logging as well. Additionally, this decade spans the period of fastest rate of gentrification for the DC region (Richardson et al., 2019), making these years of travel data particularly apt for this analysis.

This two-part data collection process, which covers 22 jurisdictions across the states of Virginia and Maryland and the District of Columbia, renders a dataset that captures demographic and journey information at the household, person, and individual trip levels. A household travel survey – part 1 – and personal weekday travel diary – part 2 – combine to paint a comprehensive picture of how people in the DC Metropolitan Area are making trips of every type. An example of what types of information each of these two parts provides is as follows: the household travel survey gives information on household size, number of vehicles available, whether or not a household has children in it; the personal travel diary gives information about age, race, travel mode, workplace- and school-offered transportation subsidies, trip time of day, and trip purpose at the level of the individual and geography of the census tract. Unique identification numbers allow for the linking of trip, personal, and household level data across the two data collection instruments.

In preparing the data, certain exclusion criteria were employed to minimize the effect of outliers and to ensure that all inputs used were appropriately comparable across the two data collection years. Trips were excluded in the following cases: (1) if any part of their household survey or travel diary was filled out incompletely or was missing geo-spatial information; (2) if a trip was made as part of professional driving (e.g. truck or ride-hailing drivers; note that the ride-hailing trip would be counted, but in the passenger's trip log not the drivers); (3) if a trip origin was located outside of the DC Metro Area (defined by the 22 jurisdictions served by the MPO); (4) if travel was logged for someone under the age of 5; (5) if a trip lasted over 3 hours; (6) if a trip destination purpose was defined as 'return home'. This inclusion determination process resulted in 81,949 trips across 10,718 households in 2007 and 117,965 trips across 16,855 households in 2017.

Justifications for most of the exclusionary choices listed above are self-explanatory. However, a few call for elaboration. Criteria number (4) was established under the assumption that essentially all trips made by

someone under the age of 5 are also made by someone else within the household also logging a travel diary. In this sense, this creates a double-counting effect if included. The majority of other mode choice determinant studies avoid having to account for this by focusing on trips made by those aged 18 and older. Some that include school-related trips bring their lower extreme for age down to about 12 years (Ton et al., 2019; Zwerts and Wets, 2006). However there is enough evidence of children younger than age 12, especially those attending school close to home, making trips alone – typically on foot, by bicycle, school bus, or local bus – to warrant inclusion.

The cut-off point of 3-hour long trips, criteria number (5) from above, was selected for two reasons. Firstly, after 3 hours for a single, uninterrupted trip, one has likely exceeded a geography that could be considered DC Metro Area travel if traveling by car or train, and therefore there is significant likelihood that such a trip was subject to an error in data recording. Secondly, this approach mirrors the cut-off used by other regional travel research in this part – the Mid-Atlantic Region – of the country (Klein et al., 2018). Finally, regarding criteria number (6), trips with a destination of 'home' were excluded due to their dependence on previously selected mode-choice for the leaving of one's home. Similar treatment was deployed by Ton et al., (2019) in their modelling of travel behavior determinants.

5.3.3 Exploring and Categorizing the Data

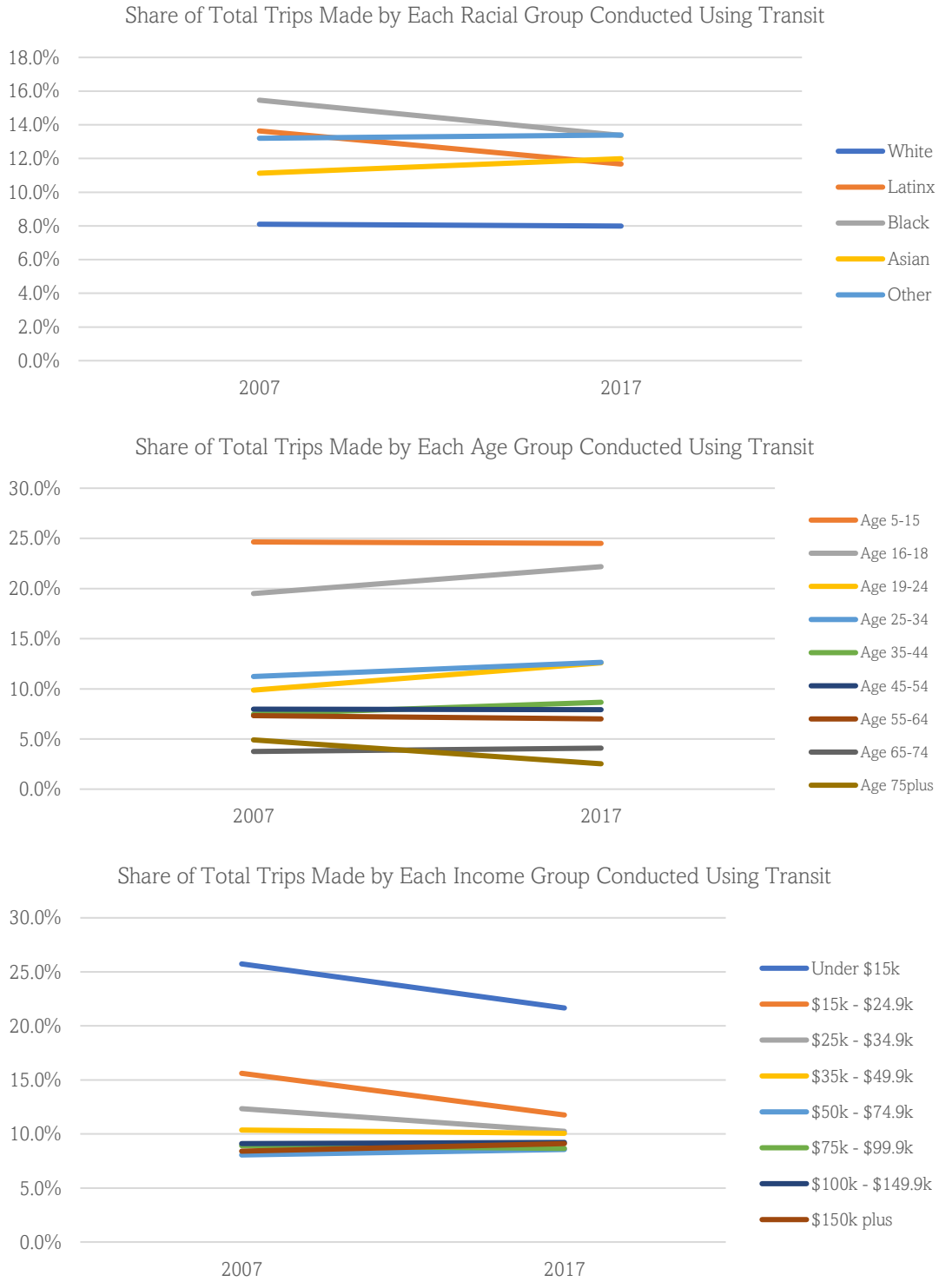
Before delineating by trip type, changes in transit use between the 2007 and 2017 datasets across all trips were graphically explored (see Figure 1). Any trip made using rail, bus, or paratransit services was defined as a transit trip. The share of total trips made using transit was slightly less in 2017 than in 2007, sitting at 9.3% and 9.8% of total trips respectively.

As mentioned in the introduction section, age, race, and income are three elements commonly used to describe, define, and typify gentrification. The pervasiveness of these elements across the literature motivated their centering in this analysis. Education attainment is also frequently included in gentrification indices (Finio, 2022), but that information was not available for both the 2007 and 2017 travel datasets, and therefore could not be featured. Similarly, arguments in favor of using displacement as the key-most piece of gentrification-related research have been eloquently made (Brown-Saracino, 2017). However, data limitations, such as an inability to track specific individuals over time, placed major barriers on the feasibility of that approach.

This initial examination revealed that between 2007 and 2017, the share of trips made by Black and Latinx riders that were conducted using transit decreased. Asian riders made an increased share of their total trips via transit, and the share of total trips made by White riders that featured transit largely remained constant. Travelers aged 16 to 34 grew the share of trips they made using transit. Those between the ages of 35 and 74 generally maintained their transit mode share, while those 75 and older decreased theirs. Finally, transit use as a share of total trips lessened among DC-area travelers from households earning below $35,000 a year between '07 and '17, remained constant among those earning between $35,000 and $50,000 as well as between $75,000 and $150,000. Transit use as a share of total trips increased, however, among households earning between $50,000 and $75,000 as well as among those earning over $150,000 annually.

These trends in changing DC-area travel behavior over time begin to suggest alignment with gentrification narratives of transit rich areas – proxied here by transit mode share – becoming increasingly comparatively young, comparatively wealthy, and less Black and Latinx.

Figure 1. Change in transit use by traveler characteristics



Trips were then categorized by destination purpose. Activity definitions used by the MPO changed slightly between the two years. Table 2 details those differences and specifies how grouping was handled in this analysis to make the two years comparable, and states transit mode share by trip type across both data collection years.

Table 2. Change in transit use among travel survey respondents by trip purpose at destination.

Trip type	Year	Definition from survey data dictionary. Trip activity at destination logged as:	Transit mode share
Work + School	2007	"work", "volunteer", "education", "study", or "school"	18.73%
	2017	"work", "volunteer", or "school"	18.96%
Errands	2007	"shop", "quick stop", "personal business at establishment", or "drop off/pick-up"	4.09%
	2017	"shopping", "getting gas", "non-shopping errand", or "drop off/pick-up"	3.26%
Leisure + Dining	2007	"eat", "visit/socialize", "exercise", "recreation", "entertainment"	9.10%
	2017	"meal", "meal (quick-stop)", "socialize", "exercise", "recreation", or "entertainment"	4.36%
All Other Trips	2007	"health care", "civic/religious", or "other"	9.17%
	2017	"health care", "civic/religious", or "other"	10.31%

Work and school trips were isolated both because they are unique in nature (e.g. highly regular in pattern, subject to distinct service quality – traffic, delays, better transit frequency, crowded vehicles – due to herding, highly time-inflexible) and so that this work can be put in conversation with existing mode choice literature, which is heavily dominated by study of work trips. Given sustained COVID-19-induced remote work affordances, errand trips have increased as a share of total trips made in the US. Wanting to be able to offer insights relevant to this to as great a degree as possible without having post-COVID travel survey data, this trip type too was centered. Similarly, leisure and dining trips have also increased as a share of total trips. Beyond that fact, these trips, more so than other trip types, can have an alcohol element to them that may disincentive or legally disallow use of certain modes such as driving single occupancy vehicles or riding a bike. This contributed to the choice to isolate trips of these types.

It is worth noting that while interest has been expressed in the literature as well as in policymaking spaces for specific attention to healthcare-related trips, there were not enough observations in the 2007 and 2017 datasets to isolate this classification. As a result, healthcare trips were housed within 'All Other Trips'.

5.3.4 Logit Model

A binomial logit model was selected for this analysis. Logistic modelling is a particularly widely applied method among works studying travel behavior and mode choice (e.g. Ton et al., 2019; Ko et al., 2019; Ha et al., 2020; Shin, 2020; Dong et al., 2022). Here, the basic logistic regression form for choice of transit to conduct a trip (=1) is given by:

$$\ln \frac{P(transit = 1)}{1 - P(transit = 1)} = \beta_0 + \beta_i X_i + \varepsilon$$

where β_0 is the coefficient of the constant term, β_i represents the coefficients for the explanatory variables X_i, and ε is the error term. A 'transit trip' was defined as involving use of a bus, train, or paratransit service.

Beyond the travel information provided by the regional household survey and travel diaries from 2007 and 2017, built environment information related to accessibility was added to the model. This included bus stop and train station location data associated with each of the relevant years of analysis across all municipalities served by the MPO. It also included calculation of intersection density for every census tract in the metro-area. The number of jobs reachable within 30 minutes of transit travel from each census tract was calculated for both 2007 and 2017 and also included in the set of mode choice influencing variables. All walk- or travel-sheds, as defined in Table 3, were calculated in ArcGIS using Network Analyst and were applied to the origin locations of trips. Data sources for each of these variables are listed in the Appendix.

Table 3. Variable descriptions

Variable	Definition	N – Work + School		N – Errands		N – Leisure + Dining		N – All other trips	
		2007	2017	2007	2017	2007	2017	2007	2017
Gentrification Elements									
Under $50k	1 if traveler's household income is below $50,000, 0 otherwise	2,240	2,324	4,071	3,757	3,164	2,046	3,181	5,783
$50k – $99.9k	1 if traveler's household income is between $50,000 and $99,999, 0 otherwise	6,067	6,573	8,099	7,585	6,717	4,872	6,876	12,687
$100k – $149.9k	1 if traveler's household income is between $100,000 and $149,999, 0 otherwise	6,163	6,935	7,105	6,855	6,563	4,816	6,463	12,634
	Reference: traveler's household income is $150,000 or more	3,891	9,830	3,744	8,803	3,809	5,954	3,796	16,511
Age 5 – 17	1 if traveler is age 5 to 17 years; 0 otherwise	3,165	3,639	1,642	1,619	3,378	1,547	2,715	5,559
Age 18 – 24	1 if traveler is age 18 to 24 years; 0 otherwise	978	1,389	675	608	947	767	925	1,947
Age 25 – 34	1 if traveler is age 25 to 34 years; 0 otherwise	2,770	5,336	2,557	3,325	2,427	3,065	2,442	7,144
Age 35 – 54	1 if traveler is age 35 to 54 years; 0 otherwise	7,579	9,513	8,727	9,349	6,786	5,265	7,671	14,601
	Reference: traveler is over the age of 54 years	3,869	5,785	9,418	12,099	6,715	7,044	6,563	18,364
Black	1 if traveler racially identifies as Black, 0 otherwise	2,577	3,382	3,385	4,021	2,476	2,117	2,822	6,194
Latinx	1 if traveler racially identifies as Latinx, 0 otherwise	753	1,417	616	1,112	635	716	692	2,106
Asian	1 if traveler racially identifies as Asian, 0 otherwise	817	2,146	792	1,821	768	1,177	779	3,581
Race – other	1 if traveler identifies as race other than Black, Latinx, Asian, or White, 0 otherwise	455	1,122	463	924	472	610	477	1,765
	Reference: traveler racially identifies as White	13,759	17,595	17,763	19,122	15,902	13,068	15,546	33,969
Personhood Elements									
Female	1 if traveler identifies as female, 0 if not	8,822	12,508	13,638	15,712	10,831	9,579	11,041	25,355
	Reference: travel does not identify as female	9,539	13,154	9,381	11,288	9,422	8,109	9,275	22,260
Mobility disability	1 if traveler has a mobility-related disability, 0 if not	758	383	2,011	982	1,313	514	1,319	1,595
	Reference: traveler does not have a mobility-related disability	17,603	25,279	21,008	26,018	18,940	17,174	18,997	46,020
Household Elements									
Within DC	1 if traveler's household is located within DC, 0 otherwise	2,894	4,035	3,140	2,835	3,466	2,993	3,385	6,930
	Reference: traveler's household is located outside of DC	15,467	21,627	19,879	24,165	16,787	14,695	16,931	40,685
Household size	# of people in traveler's household	–	–	–	–	–	–	–	–
Household vehicles	# of motor vehicles owned by traveler's household	–	–	–	–	–	–	–	–
Household bicycles	# of bicycles owned by traveler's household	–	–	–	–	–	–	–	–
Access Elements									
1 bus service	1 if 5-min walkshed of trip origin census tract centroid provided access to 1 bus route, 0 if otherwise	787	845	803	880	830	653	837	1,588
2 bus services	1 if 5-min walkshed of trip origin census tract centroid provided access to 2 bus routes, 0 if otherwise	1,433	2,115	1,895	2,501	1,592	1,601	1,666	4,779
3 bus services	1 if 5-min walkshed of trip origin census tract centroid provided access to 3 bus routes, 0 if otherwise	618	898	874	800	654	518	692	1,499
4+ bus services	1 if 5-min walkshed of trip origin census tract centroid provided access to 4 or more bus routes, 0 if otherwise	3,168	5,016	3,698	4,162	3,904	3,556	3,847	8,935
	Reference: 0 bus routes in 5-min walkshed of origin tract centroid	12,355	16,788	15,749	18,657	13,273	11,360	13,274	30,814
Train stations	# of stations providing rail service within a 10-min walkshed of trip origin census tract centroid	–	–	–	–	–	–	–	–
Intersection density	# of street intersections within trip origin census tract divided by square area (miles) of tract.	–	–	–	–	–	–	–	–
Trip Condition Elements									
Trip time – early	1 if trip begins between midnight and 6am, 0 otherwise	1,294	2,072	193	243	199	398	357	625
Trip time – late	1 if trip begins between 9:01pm and 11:59pm, 0 otherwise	80	79	296	389	602	308	1,937	2,963
	Reference: trip begins between 6:01am and 9:00pm	16,987	23,511	22,530	26,368	19,452	16,982	18,022	44,027
Work | School Elements									
Student under 16	1 if traveler is a student under age 16, 0 if otherwise	2,576	4,801						
Student 16+	1 if traveler is a student aged 16 or older, 0 otherwise	647	894						
	Reference: travel is not a student	15,138	19,967						
Jobs held	Total # of jobs traveler has as either full or part time employment	–	–						
Benefits – free parking	1 if traveler's work/school provides free parking, 0 otherwise	7,330	11,716						
Benefits – parking help	1 if traveler's work/school subsidizes parking costs, 0 otherwise	373	2,193						
Benefits – transit help	1 if traveler's work/school subsidizes transit costs, 0 otherwise	2,738	6,107						
Benefits – walk or bike	1 if traveler's work/school financially incentivizes walking or biking, 0 otherwise	1,614	558						
Benefits – bike parking	1 if traveler's work/school provides free bike parking, 0 otherwise	5,305	3,336						
	Reference: traveler has no work/school transportation benefits	3,256	3,241						
Jobs reachable	Total # of jobs reachable within a 30-min of travel by transit from trip origin census tract centroid	–	–						

5.4 RESULTS AND DISCUSSSION

The results of modelling predicted transit use for four different types of trips by characteristics related to traveler household and personhood, infrastructure access, trip conditions, work and school-related circumstances, and, focally, the gentrification elements of income, age, and race are presented in Table 4.

Table 4. Binomial logit model results for transit mode choice change over time by trip purpose

	Work + School		Errands		Leisure + Dining		All Other Trips	
	2007	2017	2007	2017	2007	2017	2007	2017
GENTRIFICATION								
UNDER $50K	0.321***	0.0294	0.194	0.215	0.242*	0.332*	0.469***	0.260***
$50K - $99.9K	0.0646	-0.117*	-0.438***	-0.0662	0.0786	-0.0355	0.106	-0.0124
$100K - $149.9K	0.119	-0.0262	-0.0833	-0.101	0.245**	0.0401	0.200*	0.114*
AGE 5 - 17	0.998***	1.174***	0.946***	1.263***	1.775***	0.332	2.437***	2.464***
AGE 18 - 24	0.436***	0.516***	0.472*	0.459	0.654***	0.338	0.930***	1.033***
AGE 25 - 34	0.0540	0.113	0.255*	0.0861	0.368***	0.0306	0.346***	0.319***
AGE 35 - 54	-0.0499	-0.0888	0.239**	0.0540	0.277***	0.0595	0.198*	0.160**
BLACK	0.288***	0.120*	0.446***	0.358***	0.205**	0.200*	0.189*	0.336***
LATINX	0.129	0.0801	0.240	-0.431*	0.309*	-0.0722	0.207	0.217**
ASIAN	0.188	0.118*	0.172	0.0707	-0.0110	0.279*	0.0497	0.340***
RACE – OTHER	0.352**	0.223**	0.251	0.346	0.0969	0.450*	0.384**	0.198*
PERSONHOOD								
FEMALE	-0.108*	-0.0331	-0.0208	-0.0204	-0.183***	0.0633	-0.154**	-0.152***
MOBILITY DISABILITY	0.184	0.257	0.437***	0.831***	0.441***	0.349*	0.341**	0.754***
HOUSEHOLD								
WITHIN DC	0.0120	-0.586***	1.622***	1.716***	1.524***	0.597***	1.874***	1.654***
HOUSEHOLD SIZE	0.0649**	0.0560**	0.0331	0.0333	0.0673*	-0.0350	0.0375	-0.00167
HOUSEHOLD VEHICLES	-0.344***	-0.491***	-0.915***	-0.933***	-0.392***	-0.673***	-0.513***	-0.491***
HOUSEHOLD BICYCLES	-0.0407**	-0.0268*	-0.0120	-0.0422	-0.0329	0.0577	-0.0598**	-0.0102
ACCESS								
1 BUS SERVICE	-0.0045	-0.0315	0.0587	0.727***	0.310**	0.297	-0.0556	-0.0886
2 BUS SERVICES	-0.0538	0.0482	0.159	0.333*	0.0496	0.483***	-0.511***	-0.124
3 BUS SERVICES	-0.105	0.263**	0.270	0.598**	-0.548**	0.360	-0.372*	-0.156
4+ BUS SERVICES	0.0267	0.0259	0.542***	0.665***	0.297***	0.503***	0.167*	0.219***
TRAIN STATIONS	-0.247***	-0.208***	0.226***	0.491***	0.302***	0.155***	0.483***	0.536***
INTERSECTION DENSITY	0.000301	0.00144***	-0.001***	-0.002***	-0.001***	0.001	-0.002***	-0.002***
TRIP CONDITIONS								
TRIP TIME – EARLY	0.468***	0.553***	0.0872	-1.123	-0.550	0.0980	-1.335***	-1.486***
TRIP TIME – LATE	-1.404*	-1.351*	-0.829*	-0.609	-0.718***	-0.545	-0.792***	-1.120***
WORK | SCHOOL								
STUDENT UNDER 16	0.487*	0.138						
STUDENT 16+	0.346	0.225						
JOBS HELD	-0.356**	-0.207**						
BENEFITS – FREE PARKING	-1.710***	-1.800***						
BENEFITS – PARKING HELP	-0.640***	-0.638***						
BENEFITS – TRANSIT HELP	2.115***	2.065***						
BENEFITS – WALK OR BIKE	-0.0293	-0.0948						
BENEFITS – BIKE PARKING	0.0644	-0.293***						
JOBS REACHABLE	0.169**	0.167**						
CONSTANT	-1.212***	-0.946***	-2.657***	-3.158***	-2.880***	-2.954***	-2.711***	-2.651***
OBSERVATIONS	18,361	25,662	23,019	27,000	20,253	17,688	20,316	47,615
LOG LIKELIHOOD	-6562.1	-9240.7	-2981.1	-2715.6	-5155.7	-2736.7	-4658.8	-11441.9
PSEUDO R-SQUARE	0.26	0.26	0.24	0.30	0.16	0.14	0.25	0.28

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In interpreting the coefficients in the table, it is important to note that the values associated with each modelled characteristic are log units. To convert these into information about likelihood these values must first be exponentiated. The process of exponentiation results in an odds ratio that compares the effect of each modelled variable on the dependent variable – in this case transit use to complete a trip – as compared to each modelled variable's reference case, if a categorical variable, or to one additional unit, if numerical (see Table 3 for variable descriptions). In the presentation of results that make up the remainder of this section, the process of exponentiation and odds determination has already been carried out, and stated findings should be understood as conditional on 'all else equal'.

5.4.1 Work and School Trips

In 2007, travelers from households earning below $50,000 annually had 37.8% greater odds of making their work or school trips using transit than those from households earning $150,000 or more. By 2017, members of those two earning pools were no more or less likely than one another to commute via transit. Additionally, lower-middle income travelers ($50,000 to $99,999 annually) were not significantly more or less likely than high income travelers ($150,000 and up annually) to commute via transit in 2007, but by 2017, they were significantly less likely to do so (11.0% lower odds). Both of those changes speak to the general trends associate with gentrification and transit access: high income travelers are increasingly settling in transit-rich neighborhoods, low-income travelers eligible for affordable housing (i.e. government subsidized) remain place-beholden to existing housing stock of that particular type, middle-income travelers whose housing options are subject to the competitive market are being displaced to peripheral, less transit rich areas (Finio, 2022). These results may well be reflecting that reality.

Influences on transit mode selection related to age generally remained consistent across the two years. In both cases, travelers below age 25 were more likely to make work and school trips using transit than travelers aged 55 and older. The magnitude of this likelihood slightly increased between 2007 and 2017. Specifically, the odds of using transit to get to work or school were 54.7% greater in 2007 and 67.5% greater in 2017 for travelers aged 18 through 25 than for travelers over age 55. This aligns with trends of growing 'youthification' of higher density, amenity and transportation infrastructure rich areas that comprise a part of gentrification settlement patterns (Moos, 2016).

Black travelers had a significantly higher likelihood (33.4% greater odds) of using transit to get to work or school than White travelers in 2007. While Black travelers remained significantly more likely to commute via transit in 2017, this likelihood dropped to just 12.7% greater odds than White travelers. Being Asian went from not significantly impacting the likelihood, as compared to being White, that one would travel via transit to work or school in 2007 to significantly making one more likely to use this mode for this trip type (12.5% greater odds). This could be because centrally located neighborhoods dominated by Asian communities in 2007, for example DC's Chinatown, that supported walk trips well, became increasingly inhabited by White residents over the ten-year span (Xie and Batunova, 2019). This may have contributed to Asian residents being pushed from conditions that lent themselves to walk-to-work and walk-to-school travel behavior to locations where walking was not competitively advantageous over transit. This would align with documented gentrification and minority suburbanization trends, especially those specific to Black (Smith and Greer, 2018) and Asian communities (Fong, 2010).

Outside of the gentrification elements of the model, several findings prove interesting and warrant attention. In 2007, having one's work or school trip originate within DC, as opposed to outside of DC, did not make the trip any more or less likely to be made using transit. In 2017, however, work or school trips originating in DC were significantly less likely (44.3% lower odds) to be conducted via transit than those originating outside of DC. This change could be for several reasons. One possibility is that the walking environment within DC improved between 2007 and 2017 to a strong enough degree as to incite mode-

shift from transit to walking (Rodríguez and Joo, 2004; Ewing, 2013). Another possibility is that transit-using workers and students who lived within DC in 2007 remained transit-using, but as of 2017, lived outside of DC; this would align with previously discussed flows of in-city out-city settlement patterns and pressures associated with gentrification. A third justification comes down to worsening traffic within DC over this time period. This worsening (Weber, 2015) would have decreased the mode-competitive value of the bus and increased that of rail. The DC rail network is largely designed to funnel riders from outside the city into its central business district, while the bus network is intended to best serve local trips. A pattern of worsening traffic would encourage use of rail for lengthy trips and walking or biking for local trips, while discouraging bus use.

The relationship between gender and transit mode selection likelihood also changed over the decade. In 2007, the odds of making a work or school trip using transit as someone who identifies as female were 10.2% lower than for someone who identifies differently. By 2017, female commuters were not significantly any less likely to commute via transit than non-female identifying commuters. This aligns with findings from scholarship exploring gendered travel behavior over that period (Tokey, 2021). Similarly, while being a student under age 16 made the odds of using transit for school trips 62.7% greater than those of an employed adult using transit for work trips, that was no longer the case ten years later. 2017 saw no significant difference is transit use likelihood between students under age 16 and employed adults for their respective school and work trips. This speaks to the general US trend of a decrease in independent youth use of transit as a means of getting to and from school (McDonald et al., 2011; Lidbe et al., 2020).

Somewhat counterintuitively, an increase in the number of train stations within 10 minutes walking distance of one's trip origin site is associated with a significant decrease in likelihood that one commutes via transit. This holds true for both 2007 and 2017; 21.9% and 18.8% lower odds with each additional train station in each year, respectively. This is likely because the higher concentrations of transit stations tend to be co-located with higher concentrations of points of interest, jobs in particular. This co-location would likely encourage one to walk or bike, as the trip would be comparatively short.

Finally, results speak to the power of work and school transportation demand management (TDM) benefit programs. Specifically, workers and students with access to transit assistance benefits had 8 times greater odds of commuting via transit than workers and students without in both 2007 and 2017. Conversely, the odds of commuting via transit for those with access to free parking were 81.9% lower in 2007 and 83.5% lower in 2017 than for those who had no travel assistance program benefits. Those with partial financial assistance for parking were also less likely to commuter via transit (47% lower odds) than those without any travel benefits program support in both years. Results additionally suggest that providing access to bike parking is a stronger mode choice incentive than payment for bike use or subsidized bikeshare, which render no significant impact in either 2007's or 2017's model. This is useful for transportation planners focusing on mode shift, and generally aligns with findings from policy evaluation literature as well (Hamre and Buehler, 2014; Heinen and Buehler, 2019).

5.4.2 Errand Trips

With respect to the gentrification element of income, the model finds no significant difference in the likelihood of transit use for errand running between travelers from households earning either low (under $50,000) or upper-middle ($100,000 to $149,999) incomes as compared to those earning high incomes ($150,000 or more) in either 2007 or 2017. However, in 2007, the odds of using transit for errand trips were 35.5% lower for travelers from lower-middle income households ($50,000 to $99,999) than for those from high income households. By 2017, this relationship no longer held statistical significance as no traveler income group – not low, lower-middle, or upper-middle – was any more or less likely than high income travelers to use transit to run errands.

In 2007, all age groups younger than 55 were more likely than those over 55 to run errands using transit. In 2017, only youth – those aged 5 through 17 – were significantly more likely to run errands via transit than those 55 and older (3.5 times greater odds). Travelers ages 5 through 17 have significantly less access to alternative travel modes than older travelers. For example, their guardians may feel they are too young to cycle for errand trips, or they may not have a driver's license. As this holds true in 2017 just as it does in 2007, this finding of generally maintain likelihood as compared to older travelers meets expectation. The changes across the other age groups, as well as the changes associated with income, suggests that the spatial elements dictating mode choice for errands – as they relate to age and income – have become more similar between 2007 and 2017. In other words, these are results one would expect if age and income groups are becoming less geographically segregated, which is a measured outcome of US gentrification patterns in general at the metro-area level (Christafore and Leguizamon, 2019).

At both ends of the decade, being Black had a significant impact on the likelihood that one ran errands using transit as compared to being White. However, just as with work and school trips, the magnitude of that likelihood decreased over time, going from 56.2% greater odds in 2007 to 43.0% greater odds in 2017. Likelihood of using transit for errands was not significantly different between Latinx and White travelers in 2007. That, too, changed in 2017. At which time, the odds of errand running via transit were 35.0% lower for Latinx travelers as compared to White travelers. With these findings, alignment with the previously discussed gentrification narrative persists, especially as errands tend to be run somewhat locally, and Latinx communities are experiencing suburbanization more acutely than any other racial minority group (Massey and Tannen, 2018). With the suburbs of the DC metro area offering far less extensive transit service than its urban centers, these findings, too, meet expectations as transit is likely becoming a less and less suitable or attractive option for this group.

Again looking beyond the gentrification-related variables, the model reveals that in 2007, having access to a greater number of rail stations or to four or more bus routes proximate to your trip origin site – more specifically, within 10-minutes walking distance for rail and 5-minute for bus – made you significantly more likely to use transit for errands than having access to no bus service or fewer train stations. While this held true in 2017, access not only to a wealth of transit services but to any services at all made one more likely to use transit for errands than having a dearth of access. Where only access to four or more bus services significantly increased transit use likelihood for errand trips in 2007, access to as little as a single bus route increased odds of transit use as compared to no access within a 5-minute walk or trip origin site in 2017. This could be a reflection of increased transit dependence, potentially spurred on by heightened living costs (Reed, 2012; Desmond, 2022), or increased transit favorability, perhaps shaped by ground gained in pro-sustainability social values (Clark and Carlisle, 2020) or lessened stigmatization of bus-use (Collins, 2013). It also may be reflecting a relocation of transit reliant travelers away from areas lush with transit options (e.g. 4 or more bus routes) to places where options are sparse (e.g. a single bus route), or mode shift of displacement-made transit reliant communities that were previously walkers.

While in 2007, the odds of conducting an errand trip late in the evening via transit were 56.4% lower than doing so between the hours of 6am and 9pm, time of day had no significant impact of transit-use likelihood for errand-related trips in 2017. This could in part be explained by lengthened hours of transit service; DC-area bus services slightly extended hours of operation for a few routes between 2007 and 2017.

5.4.3 Leisure and Dining Trips

In 2007, travelers from households earning under $50,000 annually were significantly more likely than those from households earning $150,000 or more to take transit for trips related to leisure and dining (27.4% greater odds). This continued to be true in 2017, but to an even greater extent (39.4% greater odds). Similarly, the odds of taking transit for this trip type were 27.8% greater for someone from a household

earning between $100,000 and $149,999 than for someone from a household earning $150,000 or more in 2007. However, by 2017, this was no longer the case. Neither group was significantly more or less likely than the other to modally select transit for their leisure and dining journeys. A reasonable assumption as to the forces behind these results would be that in 2007, the high income travelers were more likely to take a taxi or drive themselves for these trips, but by 2017, ride-hailing – a mode whose pervasiveness in the travel market significantly increased between the two comparison years – may have gained competitive advantage over transit for upper-middle income travelers for this trip type. Another explanation could be that upper-middle income travelers may have moved into more centralized neighborhoods allowing them to walk to their leisure and dining venues more so than their potentially suburban clustering sites of 2007.

All age groups below 55 were significantly more likely to use transit for leisure and dining trips than those age 55 and over in 2007. By 2017, however, no age group was significantly more or less likely than the 55 and over group to take transit for this trip type. This aligns with several observed patterns over that time period. Firstly, youth (age 5-17) were less likely to travel alone on transit in 2017 than they were in 2007, especially for non-school trips (Marzi and Reimers, 2018; Desjardins et al., 2022). Secondly, as previously emphasized, the influence on transit use that the post-2014 surge in popularity that ride-hailing platforms like Uber and Lyft underwent cannot be overstated. These results may be capturing the turn away from transit toward ride-hailing demonstrated across age groups for this particular type of trip making propensity for transit more uniform across age cohorts.

Being Latinx changed from rendering one significantly more likely to take transit for leisure and dining trips than someone White in 2007 (36.2% greater odds), to no significantly more or less likely in 2017. Conversely, being Asian went from not significantly impacting transit use likelihood as compared to being White in 2007 to positively and significantly impacting that likelihood in 2017 (32.2% greater odds). Again common narratives of gentrification patterns are reflected. Just as with work and school trips, given their residential concentration in 2007, Asian residents may have been more likely to walk for this trip type than they were in 2017 having been displaced to less central neighborhoods, though ones still well served by transit.

Changes in transit use likelihood related to gender identity for leisure and dining trips directionally matched those of work and school trips. Female travels had 16.7% lower odds of using transit than non-female identifying travelers in 2007. However, in 2017, there was no significant difference in the likelihood of transit use between these two groups. Regarding trips taken in the evening, just as with errand trips, traveling at night went from making the trip less likely to be conducted via transit than a daytime trip in 2007 (51.2% lower odds) to no significantly more or less likely in 2017. In this case, the role that DC's extension of nighttime hours of operation on a number of their transit services makes for a particularly well-suited explanation of findings as the extension in service better matched closing times at bars and nightlife entertainment programming in 2017 than in 2007. This could have lessened transit's competitive disadvantage for this trip type at this time of day.

5.4.4 All Other Trips

Low and upper-middle income travelers were more likely than high income travelers to use transit for trips types defined as 'all other trips' in 2007; 59.8% and 22.1% greater odds, respectively. This remained the case in 2017, however, to a lessened magnitude: 29.7% greater odds for low income travelers and 12.1% greater odds for upper-middle income travelers. Similarly consistent, all other age groups remained more likely than travelers over age 55 to use transit across the decade span. There was a slight increase in this comparative likelihood among youth and young adults, and a slight decrease in it among adults aged 25 through 54. These trends align with expectations and well as with gentrification narratives previously discussed of wealth and youth influxes into areas better served by transit.

The likelihood of taking transit for 'all other trips' for Black, Latinx, and Asian travelers increased significantly as compared to that of White travelers from 2007 to 2017. Black travelers went from having 20.1% to 39.9% greater odds of transit use for these types of trips than White travelers. Latinx and Asian travelers were no more or less likely to use transit than White travelers in 2007 but had 24.2% and 40.5% great odds, respectively, of doing so in 2017 than their White counterparts. Explanation for the intensity of this racialized heightening in transit use likelihood may come down to the nature of the trips in this category. 'All other trips' includes healthcare, civic, and religious trips. These are trip purposes that are not readily geographically transferable; one grows attachment/loyalty to one's doctor, church group, etc. So, though these communities may have relocated, their health providers, churches, community centers, and the likes may have remained in place. If these trips were largely made locally in 2007 – and therein more likely conducted on foot – gentrification-induced relocation of communities of color may have translated into the need for transit use to sustain patronage to these places among these groups in 2017.

5.5 CONCLUSION

This work examines how transit use has changed over time in a rapidly gentrifying US metropolitan area. Using a binomial logit model informed by regional household survey and personal travel diary data, specific focus was placed on the mode choice predictive strength of several gentrification-related elements of personhood: race, age, and income. The extent to which each of these elements rendered one more or less likely to use transit to complete a trip throughout the Washington DC metro-area was determined for 2007 and for 2017. Analysis was carried out specifically for work and school trips, errand trips, leisure and dining trips, as well as for an amalgamated grouping of 'all other trip' types.

Findings related to race align with the literature on several distinct points. Past work has found that Whiteness is less positively associated with transit mode selection than are other races (Bereitschaft, 2020). Results from this analysis generally support that finding for both 2007 and 2017 across all trip types. Previous studies have also concluded that Black and Latinx transit mode likelihood – compared to that of White travelers – is decreasing over time (Pucher and Renne, 2003; Klein et al., 2018). That, too, is found here across three of the four trip types studied: work and school trips, errands, and leisure and dining. Finally, trending convergence of transit mode choice likelihood across racial groups – a flattening of variation – has been identified in the literature (Polzin et al., 1999; Blumenberg and Shiki, 2007). This model's findings echo that theme: where in 2007, only Black travelers were consistently significantly more likely than White travelers to use transit, that consistency extended to nearly all groups of color for nearly all types of trips by 2017 suggesting increased similarity of travel mode selection among these groups.

On the topic of age, findings between this study and others are slightly less in lockstep. Some who've explored travel behavior and mode preference found no significant change over time across age groups (Klein et al., 2018). Here that only holds true for work and school trips and for trips in the 'all other trips' category. In those cases, age-related likelihood to use transit generally remained consistent between 2007 and 2017 with younger travelers, particularly those below age 25, having greater odds of transit use than older travelers, namely those aged 55 and up. Scholars have also found the highest transit selection likelihood to consistently be among older young adults – aged 18 to 25 – as compared to older travelers (Godfrey et al., 2019). If one excludes children, as does the gross majority of previous research, that finding – which reflects gentrification-related trends of urban youthification (Moos, 2016) – is mirrored in this work.

Literature on the final focal gentrification element has found that being of low income has decreased in transit mode choice predictive strength over time (Blumenberg and Thomas, 2014; Cournoyer, 2018). As compared to high income travelers, results from the model align with this finding for work and school trips

and for 'all other trips'. This finding is not supported, however, for errand trips, where no change in comparative transit use likelihood over time is revealed for this income group, nor for leisure and dining trips where the inverse – an increased transit use likelihood among low compared to high income travelers – is found. Additionally, this work finds that in general, transit use likelihood among middle income travelers lessened as compared to high income earners over the analyzed decade.

Overall, findings from this study, namely those specific to race and income, align with common gentrification narratives of changed neighborhood composition in comparatively transit-rich areas. The changes one would expect from these areas experiencing increased Whiteness and heightened average incomes among their residential populations are largely reflected here.

These results host implications related to equitability of subsidy distribution. Transit is a significantly subsidized travel mode, supported – to varied degrees across state lines as well as from one agency to the next – by public funds (Hudspeth and Wellman, 2018). If the benefits of that subsidy are disproportionately increasing being distributed to the wealthy, the degree to which transportation systems harbor injustice and inequity grows. Relatedly, what these findings are capturing may relate to a worsening poverty tax (Karger, 2007) if the observed decreased likelihood of low income travelers to take transit as compared to high income travelers is associated with an increase in their car mode share; single occupancies vehicles being the more expensive of the two modes. One way to avoid contributing to that tax would be to expand identity-based fare structures, as opposed to, for example, exclusively distance-based structures. Finally, the continued dominance in transit mode selection by Black travelers exhibited in this analysis has policy implication for those in search of an avenue through which to operationalized reparations efforts. It suggests, as has other research (Rennert, 2016), that transit may be an area well-suited to that work.

5.5.1 Limitation and Further Study

This work is not without its limitations. The slight differences in data definitions between the 2007 and 2017 datasets occasionally forced broader-than-ideal categorizing of information. For example, this motivated the overly simplified racial groupings used. Data limitations also motivated the use of intersection density as a proxy for walkability. Walkscore data would have been preferable as it takes into account a wider range of features that influence walkability, but that information was not collected at the tract level in 2007 and was cost-prohibitive to acquire from the provider. Additionally, the most detailed geography at which trip origin data was available was the census tract. This informed the use of census tract centroid as the spatial grounding for all accessibility calculations. In the absence of exact location information, an unsurprising impossibility due to privacy restrictions, block group-level data would have been better, allowing for greater accuracy in these calculations. Furthermore, this model does not account for the role that bike infrastructure accessibility may have over transit mode choice. Unfortunately bike infrastructure network information across the entire region was not available for either year of interest.

Further work on this topic could include continued exploration of travel behavior changes over time across varied trip types, but center different modes (e.g. cycling, bus-specific transit, walking). It could also include increased attention paid to the beliefs, attitudes, and self-prescribed identity elements (e.g. environmentalist) known to shape mode choice. The information collected via the 2007 and 2017 travel diaries does not allow for such an analysis, but the addition of a few questions to the upcoming 2027 data collection instruments could change that. Regional household surveys and travel diaries of the types used in this study are hugely useful research tools. Their continue and expanded administration paired with ongoing finetuning are worthy of celebration and support.

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APPENDIX: Paper 4

Transit provider data was provided at researcher request directly from provider agencies for desired years.

Table A.1. Data list of non-household survey and travel diary data

Data Type	Data Source	Year
Jobs Data		
US Census	Longitudinal Employer-Household Dynamics (LEHD): Work Area Profile | All jobs	2007 | 2017
Tract Data		
US Census	Census tract shapefiles	2000 | 2017
Road Network Data		
US Census	TIGER/Line shapefiles	2007 | 2017
Transit Network Data	**Routes, GTFS, and Access Points** (i.e. stops and station sites)	
Washington DC	DC Circulator	2007 | 2017
	Washington Metropolitan Area Transit Authority (Metro)	2007 | 2017
	Amtrak	2007 | 2017
	DC Streetcar	2017
Virginia	Arlington County Transit (ART)	2007 | 2017
	City of Alexandria Transit Company (DASH)	2007 | 2017
	City of Fairfax transit (CUE)	2007 | 2017
	Virginia Regional Transit (VRT)	2007 | 2017
	Virginia Railway Express (VRE)	2007 | 2017
	Loudon County Transit (LC Transit)	2007 | 2017
	Fairfax County Connector	2007 | 2017
	Prince William County (OmniRide)	2007 | 2017
Maryland	Maryland Transit Administration (MTA)	2007 | 2017
	Montgomery County Transit Services (Ride On)	2007 | 2017
	Prince Georges County (TheBus)	2007 | 2017
	Charles County Transit (VanGO)	2007 | 2017
	Frederick County (TransIT)	2007 | 2017
	City of College Park (Shuttle-UM)	2007 | 2017
	Greenbelt Connection	2007 | 2017
	Central Maryland Regional Transit (RTA)	2007 | 2017

Table A.2. Transit use for work and school trips: 2007

	Mode Used_Transit	t-stat
WithinDC	0.0120	(0.14)
HHSIZE	0.0649**	(2.88)
HHVEHICLES	-0.344***	(-12.30)
HHBICYCLES	-0.0407**	(-2.63)
Under50k	0.321***	(3.75)
50-99.9k	0.0646	(0.99)
100-149.9k	0.119	(1.90)
Age5_17	0.998***	(5.96)
Age18_24	0.436***	(3.58)
Age25_34	0.0540	(0.64)
Age35_54	-0.0499	(-0.70)
FEMALE	-0.108*	(-2.43)
BLACK	0.288***	(4.52)
LATINX	0.129	(1.20)
ASIAN	0.188	(1.83)
RACE_other	0.352**	(2.82)
DISABLED	0.184	(1.57)
1bus_5mins	-0.00454	(-0.04)
2buses_5mins	-0.0538	(-0.64)
3buses_5mins	-0.105	(-0.85)
4plusBuses_5mins	0.0267	(0.39)
TrainStations_10mins	-0.247***	(-7.73)
Intersection_density	0.000301	(1.59)
Depature_Early	0.468***	(5.12)
Depature_Late	-1.404*	(-2.28)
STUDENTS_Under16	0.487*	(2.44)
STUDENT_Age16plus	0.346	(1.86)
JOBS_Held	-0.356**	(-3.29)
BENEFITS_ParkFree	-1.710***	(-24.30)
BENEFITS_ParkHelp	-0.640***	(-3.98)
BENEFITS_Transit	2.115***	(34.28)
BENEFITS_WalkBike	-0.0293	(-0.33)
BENEFITS_BikePark	0.0644	(1.08)
JOBS_Reachable30mins	0.169**	(3.04)
cons	-1.212***	(-7.49)
N	18361	

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.3. Transit use for errand trips: 2007

	Mode Used_Transit	t-stat
WithinDC	1.622***	(15.10)
HHSIZE	0.0331	(0.81)
HHVEHICLES	-0.915***	(-15.74)
HHBICYCLES	-0.0120	(-0.38)
Under50k	0.194	(1.38)
50-99.9k	-0.438***	(-3.35)
100-149.9k	-0.0833	(-0.66)
Age5_17	0.946***	(5.70)
Age18_24	0.472*	(2.21)
Age25_34	0.255*	(2.13)
Age35_54	0.239**	(2.64)
FEMALE	-0.0208	(-0.28)
BLACK	0.446***	(4.95)
LATINX	0.240	(1.17)
ASIAN	0.172	(0.86)
RACE_other	0.251	(1.06)
DISABLED	0.437***	(4.01)
1bus_5mins	0.0587	(0.32)
2buses_5mins	0.159	(1.20)
3buses_5mins	0.270	(1.46)
4plusBuses_5mins	0.542***	(5.67)
TrainStations_10mins	0.226***	(6.68)
Intersection_density	-0.00108***	(-4.49)
Depature_Early	0.0872	(0.22)
Depature_Late	-0.829*	(-2.06)
cons	-2.657***	(-14.45)
N	23019	

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.4. Transit use for leisure and dining trips: 2007

	Mode Used_Transit	t-stat
WithinDC	1.524***	(18.49)
HHSIZE	0.0673*	(2.44)
HHVEHICLES	-0.392***	(-11.38)
HHBICYCLES	-0.0329	(-1.68)
Under50k	0.242*	(2.39)
50-99.9k	0.0786	(0.94)
100-149.9k	0.245**	(3.06)
Age5_17	1.775***	(18.79)
Age18_24	0.654***	(4.63)
Age25_34	0.368***	(3.94)
Age35_54	0.277***	(3.58)
FEMALE	-0.183***	(-3.45)
BLACK	0.205**	(2.62)
LATINX	0.309*	(2.32)
ASIAN	-0.0110	(-0.08)
RACE_other	0.0969	(0.62)
DISABLED	0.441***	(4.21)
1bus_5mins	0.310**	(2.58)
2buses_5mins	0.0496	(0.48)
3buses_5mins	-0.548**	(-2.82)
4plusBuses_5mins	0.297***	(3.89)
TrainStations_10mins	0.302***	(11.24)
Intersection_density	-0.00113***	(-5.77)
Depature_Early	-0.550	(-1.54)
Depature_Late	-0.718***	(-3.68)
cons	-2.880***	(-22.29)
N	20253	

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.5. Transit use for 'all other' trips: 2007

	Mode Used_Transit	t-stat
WithinDC	1.874***	(22.33)
HHSIZE	0.0375	(1.29)
HHVEHICLES	-0.513***	(-13.68)
HHBICYCLES	-0.0598**	(-2.88)
Under50k	0.469***	(4.46)
50-99.9k	0.106	(1.20)
100-149.9k	0.200*	(2.33)
Age5_17	2.437***	(24.27)
Age18_24	0.930***	(6.42)
Age25_34	0.346***	(3.57)
Age35_54	0.198*	(2.43)
FEMALE	-0.154**	(-2.77)
BLACK	0.189*	(2.49)
LATINX	0.207	(1.57)
ASIAN	0.0497	(0.36)
RACE_other	0.384**	(2.66)
DISABLED	0.341**	(3.05)
1bus_5mins	-0.0556	(-0.42)
2buses_5mins	-0.511***	(-4.25)
3buses_5mins	-0.372*	(-2.04)
4plusBuses_5mins	0.167*	(2.09)
TrainStations_10mins	0.483***	(17.27)
Intersection_density	-0.00168***	(-8.10)
Depature_Early	-1.335***	(-4.10)
Depature_Late	-0.792***	(-6.93)
cons	-2.711***	(-19.57)
N	20316	

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.6. Transit use for work and school trips: 2017

	Mode Used_Transit	t-stat
WithinDC	-0.586***	(-8.54)
HHSIZE	0.0560**	(3.13)
HHVEHICLES	-0.491***	(-19.30)
HHBICYCLES	-0.0268	(-1.64)
Under50k	0.0294	(0.41)
50-99.9k	-0.117*	(-2.27)
100-149.9k	-0.0262	(-0.55)
Age5_17	1.174***	(7.89)
Age18_24	0.516***	(5.01)
Age25_34	0.113	(1.75)
Age35_54	-0.0888	(-1.49)
FEMALE	-0.0331	(-0.89)
BLACK	0.120*	(2.16)
LATINX	0.0801	(1.01)
ASIAN	0.118*	(1.98)
RACE_other	0.223**	(2.64)
DISABLED	0.257	(1.81)
1bus_5mins	-0.0315	(-0.30)
2buses_5mins	0.0482	(0.70)
3buses_5mins	0.263**	(2.73)
4plusBuses_5mins	0.0259	(0.47)
TrainStations_10mins	-0.208***	(-9.29)
Intersection_density	0.00144***	(5.70)
Depature_Early	0.553***	(7.54)
Depature_Late	-1.351*	(-2.15)
STUDENTS_Under16	0.138	(0.83)
STUDENT_Age16plus	0.225	(1.57)
JOBS_Held	-0.207**	(-2.92)
BENEFITS_ParkFree	-1.800***	(-32.63)
BENEFITS_ParkHelp	-0.638***	(-10.13)
BENEFITS_Transit	2.065***	(39.71)
BENEFITS_WalkBike	-0.0948	(-0.83)
BENEFITS_BikePark	-0.293***	(-4.80)
JOBS_Reachable30mins	0.167**	(2.82)
cons	-0.946***	(-7.99)
N	25662	

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.7. Transit use for errand trips: 2017

	Mode Used_Transit	t-stat
WithinDC	1.716***	(14.93)
HHSIZE	0.0333	(0.88)
HHVEHICLES	-0.933***	(-15.76)
HHBICYCLES	-0.0422	(-1.08)
Under50k	0.215	(1.68)
50-99.9k	-0.0662	(-0.58)
100-149.9k	-0.101	(-0.88)
Age5_17	1.263***	(7.40)
Age18_24	0.459	(1.92)
Age25_34	0.0861	(0.72)
Age35_54	0.0540	(0.52)
FEMALE	-0.0204	(-0.26)
BLACK	0.358***	(3.68)
LATINX	-0.431*	(-2.08)
ASIAN	0.0707	(0.45)
RACE_other	0.346	(1.86)
DISABLED	0.831***	(5.22)
1bus_5mins	0.727***	(3.63)
2buses_5mins	0.333*	(2.51)
3buses_5mins	0.598**	(2.61)
4plusBuses_5mins	0.665***	(6.19)
TrainStations_10mins	0.491***	(14.60)
Intersection_density	-0.00242***	(-5.24)
Depature_Early	-1.123	(-1.54)
Depature_Late	-0.609	(-1.59)
cons	-3.158***	(-18.17)
N	27000	

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.8. Transit use for leisure and dining trips: 2017

	Mode Used_Transit	t-stat
WithinDC	0.597***	(4.95)
HHSIZE	-0.0350	(-0.81)
HHVEHICLES	-0.673***	(-11.79)
HHBICYCLES	0.0577	(1.60)
Under50k	0.332*	(2.50)
50-99.9k	-0.0355	(-0.32)
100-149.9k	0.0401	(0.38)
Age5_17	0.332	(1.74)
Age18_24	0.338	(1.79)
Age25_34	0.0306	(0.27)
Age35_54	0.0595	(0.57)
FEMALE	0.0633	(0.81)
BLACK	0.200*	(2.42)
LATINX	-0.0722	(-0.38)
ASIAN	0.279*	(2.00)
RACE_other	0.450*	(2.46)
DISABLED	0.349	(1.72)
1bus_5mins	0.297	(1.46)
2buses_5mins	0.483***	(3.75)
3buses_5mins	0.360	(1.55)
4plusBuses_5mins	0.503***	(4.59)
TrainStations_10mins	0.155***	(4.44)
Intersection_density	0.000675	(1.53)
Depature_Early	0.0980	(0.36)
Depature_Late	-0.545	(-1.71)
cons	-2.954***	(-17.14)
N	17688	

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.9. Transit use for 'all other' trips: 2017

	Mode Used_Transit	t-stat
WithinDC	1.654***	(29.59)
HHSIZE	-0.00167	(-0.10)
HHVEHICLES	-0.491***	(-20.73)
HHBICYCLES	-0.0102	(-0.66)
Under50k	0.260***	(4.24)
50-99.9k	-0.0124	(-0.25)
100-149.9k	0.114*	(2.46)
Age5_17	2.464***	(39.24)
Age18_24	1.033***	(11.41)
Age25_34	0.319***	(5.53)
Age35_54	0.160**	(3.03)
FEMALE	-0.152***	(-4.33)
BLACK	0.336***	(6.73)
LATINX	0.217**	(2.81)
ASIAN	0.340***	(5.47)
RACE_other	0.198*	(2.47)
DISABLED	0.754***	(8.73)
1bus_5mins	-0.0886	(-0.79)
2buses_5mins	-0.124	(-1.94)
3buses_5mins	-0.156	(-1.30)
4plusBuses_5mins	0.219***	(4.26)
TrainStations_10mins	0.536***	(30.36)
Intersection_density	-0.00198***	(-8.65)
Depature_Early	-1.486***	(-6.47)
Depature_Late	-1.120***	(-12.32)
cons	-2.651***	(-33.97)
N	47615	

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

CHAPTER 6: Conclusion

This US-centric – though not US-exclusive – work set out with the objective of providing transit practitioners with insights and resources that will help them confidently advance both transit and social equity, particularly as they relate to race. In pursuit of that aim, four distinct research questions were explored. They were: 1) What factors explain the wide variation found across transit proximity premiums on residential property values, what role do levels of transit service play in the magnitudes of those premiums, and how can past premiums research be utilized as a predictor of yet un-studied premiums?; 2) How do COVID-19 safety measures (CSM) in transit spaces affect travelers' worry of COVID-19 infection, and how do the conditions of transit spaces themselves influence this effect?; 3) How do Black community leaders in Boston understand the potential use of camera enforcement for traffic and transit roadway violations?; and 4) How have the gentrification-associated elements of race, age, and income changed as predictors of transit mode choice in the Washington DC metropolitan area during the last two decades of rapid gentrification?

Below, the ways that these questions were tackled is summarized, and their findings and equity implications detailed. This detailing is done primarily with respect to the concepts of justice-through-acts-of-repair – which include the components of reckoning, acknowledgement, accountability, and redress – and Reparative Maximization proposed in Chapter 1 Section 3 as fundamental to achieving a state of transit equity. This concluding chapter comes to a close with a discussion of what this research, taken collectively, has contributed to the world of transportation equity scholarship, its weaknesses, and offers reflections for future research and practice.

6.1 CONCLUSION AND DISCUSSION

Access to transit infrastructure is valuable. In areas surrounding rail stations, some of that value gets absorbed by property markets. Since 1970, over 200 case studies (published in English) have explored the extent to which transit access impacts property value uplift. However, findings from this body of research vary widely (Debrezion et al., 2007; Mohammad et al., 2013). In an attempt to explain this variation, previous meta-analytic studies have focused on testing the roles that built environment elements, temporal factors, and modelling techniques play in shaping the observed relationship between proximate positioning from rail stations and property pricing.

The first of the four studies comprising this dissertation expands on these meta-analyses by introducing the first examination of how transit service elements – e.g. frequency, fare, reliability – impact rail-induced residential property value uplift. It further contributes to the literature by expanding the range of geo-comparability of uplift findings across four continents, examining the potential effects of the Global Financial Crisis of the late 2000s, and adding 10 new variables of potential influence not only under the banner of 'transit service', but pertaining to neighborhood socio-demographics and housing policy as well. Findings reveal that factors of geography, housing data type, race and ethnicity, rent control policies, rail type, transit cost, and transit network expanse all significantly affect rail access uplift magnitude ranging from depreciating effects of 7.4 percentage points to appreciating effects of 9.6 percentage points.

The findings from this study most acutely relevant to the overall research problematic of this dissertation are those specific to race and level of transit service. All else equal, premiums based on the inclusion of neighborhood racial or ethnic composition are lower than those that exclude area demographic information by 6.0 percentage points on average. This makes clear that accounting for race matters in the transit-access/property-market valuation puzzle. However, a greater understanding of exactly to what extent specific station-area racial composition is causal of property devaluation would allow policy makers to determine an even more precise percentage to which homes within minority-dominant, transit-

proximate areas are being lesser-valued; a realty that could be depriving homeowners of racial minority identities of some wealth. Such knowledge could ground a set of concrete, reparative actions.

This could, for example, take the form of appraisal correction practices via establishment of equity oversight entities for home sale processes, an approach proposed in parts of the US to course-correct for past, racially prejudicial wealth hoarding practices and policies such as redlining (Lee et al., 2024; PAVE, 2022; Taylor, 2019). In the four components of repair essential to achieving transit equity, findings from this study contribute to the process of *reckoning,* while reform such as appraisal correction would constitute an act of both *acknowledgement* and *redress*; though really only redress-lite in that such reform would exclusively impact future sales, doing nothing to account for past wealth denial.

This study further finds that on average, commuter rail premiums and heavy rail premiums are 9.6 and 4.0 percentage points higher than light rail premiums, respectively. It also finds that, with every one percentage point increase in annual expenditure share on transit (which is a function of transit fare price), premiums decrease an average of 1.4 percentage points, and for every 10 additional stations within a network, premiums are 0.21 percentage points higher. Beyond helping to explain variation across the literature and offering clear levers of impact (mode, fare, network size) for transit planners relevant to station-area premiums, these significant findings demonstrate that transit planners should not be sidelined in matters pertaining to housing security and stability as the choices they make affect housing prices. Rather, those in the field of housing and field of transit should collaborate in their efforts to support equitable housing and transit access landscapes by combatting trends of increasing unaffordability and market-driven displacement pressures in transit-rich areas; a call echoed by many throughout the transportation equity literature as well (Healey, 2003; Thomas and Bertolini, 2015; Paulsson et al., 2017).

On a final note, this work makes two additional contributions toward the overarching research aim. Firstly, the finding of no significant effect of changes to transit frequency on housing price premium should give transit service planners the confidence to provide the best, highest frequency possible to riders without fear of inducing unaffordability pressures across housing within station-surrounding areas. As frequency of service greatly affects accessibility (Merlin et al., 2021; Liu and Miller, 2024), this ought to provide both relief and license to equity conscious transit planners. Secondly, this study results in a fairly user-friendly model that any transit practitioners wanting to gain a sense of transit proximity premium in their own geographic context could use. This speaks directly to the part of this dissertation's objective focused on tool creation and resource expansion.

The second of this dissertation's studies focuses on feelings associated with transit use in a time of global health crisis. It's 2021 and the coronavirus has brought about major changes in travel behavior with transit ridership volumes in many places dropping to record lows. Transit providers have implemented several interventions aimed at both slowing the spread of the virus and retaining riders as travel restrictions of the pandemic's first year begin to lift. While the effectiveness of these measures has been evaluated with respect to spread rate reduction (Daghriri and Ozmen, 2021; Rao et al., 2021), little consideration has been given to their impact on riders' feelings of worry.

Using a photo-simulated randomized control trial, this study finds that safety measure type, level of compliance with those safety measures, and the conditions of transit spaces themselves significantly impact riders' levels of worry of COVID contraction. Specifically, hand sanitizer and health information provision prove not to assuage rider worry. Social distancing and face mask wearing do, however, only in cases of full compliance among all visible riders. These results hold consistent across all three cities studied – London, Milan, and Santiago – suggesting that full-compliance is required (at this point the evolution of

the pandemic) to reduce worry of infection across a diversity of cultural, social, and public health-specific contexts.

In line with results from existing literature (Zafri et al., 2022; Gnerre et al., 2022), this experiment finds that levels of perceived risk vary by gender. Travelers who identify as women experience significantly higher levels of worry in transit spaces than those who identify as men. Additional findings confirm results of past studies at the intersection of risk perception and health vulnerability (He et al., 2021), concluding that members of households in which an individual is immunocompromised or highly COVID-vulnerable are more worried about infection in transit spaces than members of otherwise lower-risk households. These disparities persist across different CSMs, different compliance levels, and different transit spaces. Unfortunately, a lack in sufficient degrees of freedom related to participant racial identities across the dataset prevented the possibility of directly assessing how race influences worry levels, and how those levels are impacted by CSM, compliance, or space conditions. However, several of the worry-reduction recommendations for transit planners and policymaker resultant of this study's findings have racialized equity implications. None more so, perhaps, then those related to enforcement of compliance with CSM.

In the absence of trust in other travelers to comply with all CSM regulations, enforcement, is likely necessary to effectively reduce traveler worry. Equity concerns related to law and regulation enforcement in and of transportation spaces is prevalent through the transportation equity scholarship landscape across the three countries featured in this study (Crawford, 2012; Charney et al., 2021; Ambrosini, 2021) as well as farther afoot. From Brazil (Alves, 2018) to South Africa (Kruger and Landman, 2007), Kenya (Nyamai, 2023) to Canada (Geldart, 2024), scholars have stressed that different forms of enforcement host different sources of risk of maltreatment and vulnerability to abuse for travelers from different marginalized groups. This body of research evinces the need for paying careful attention to exactly what form CSM enforcement in transit spaces takes so as not to exacerbate social inequities.

In many cases at this time in the pandemic (2021), police officers have been tasked with enforcing mask wearing in transit spaces. Commonly, the penalty for non-compliance is a fine and/or removal from the vehicle or transit station (Topham, 2021; Jacks, 2021). However, cases of that removal being violent and traumatic, especially for those with comparatively low levels of social power and privilege have not been rare (Rouhandeh, 2020; Duchamps, 2020). In addition to accounts of discomfort with increased police presence in public space associated with feared brutality and misconducted (Schultz and Bryon, 2021), low officer capacity and low willingness to actually enforce have been cited as contributary to particularly low compliance rates – often below 50% – in several municipalities using this enforcement approach (ibid.; Phillips, 2020). So, in the face of a need to keep riders safe from infection and safe from police brutality, as well as free from worry – a worry demonstrated to be dependent on compliance with CSM – what can equity-valuing transit practitioner do?

This study highlights the non-officer-based program deployed by the Southeastern Pennsylvania Transportation Authority (SEPTA), transit provider for the Greater Philadelphia Area, as a potentially more just approach to facilitating risk and worry reduction for riders. SEPTA calls their strategy a 'speak-softly-and-carry-a-box-of-masks' approach (Fitzgerald, 2021). In this strategy, 'enforcement' is replaced with encouragement and is handled by SEPTA employees from many departments. Some are planners, some are administrators, and some are social workers initially hired to connect those using SEPTA spaces for shelter with social services (Suzuki, 2020). None are law enforcement officers. None carry weapons, and none are permitted to forcibly handle any passengers (ibid). These workers distribute masks and offer COVID-safety educational materials to any people not wearing a face covering. They are assigned to zones spaced throughout stations to allow for a SEPTA employee to be visible from any enclosed transit

space not on-board a vehicle. There are no fines or removal penalties if passengers refuse to engage with workers or wear the free mask.

After the program's first 6 months, SEPTA conducted a 4,000-rider compliance audit across their service network. This audit concluded with a compliance rate of 90% reported (Fitzgerald, 2021), which outperformed the previous mentioned 50% compliance rate found across many officer-enforced systems.

Innovative strategies like this that activate individuals trained in de-escalation, customer assistance, consensus building, and education techniques (Suzuki, 2020; Kershner and Johnston, 2021) may be sustainable, effective, equitable ways forward in the future of behavior conditioning in transit spaces. In this sense, now in 2024, though the coronavirus spread rate has slowed, severity has lessened, and a sizable share of the global population has been vaccinated, this work holds relevance for ongoing sources of worry for riders (Koslowsky et al., 2013; Tran et al., 2023; Linovski et al., 2021; Conceição et al., 2023) as well as for transit practitioners wanting to be best prepared for any future potential public health crises or other enforcement-dependent situations.

It must be said, however, that reformed approaches to cultivating behavior change such as this – again, arguably *redress-lite* – still fall short of fostering repair en route to establishing true transit equity. In continuing to use the SEPTA example, at no point did the agency articulate that their approach was crafted as an intentional step away from previously dangerous and unacceptable practices by transit and city officers operating under SEPTA's purview. Had such been done, this would have constituted an act of *reckoning*, *acknowledgement*, and *accountability;* all necessary parts of the work that is justice. Still, approaches such as SEPTA's are indeed likely to decrease the subjectivity that disadvantages, marginalized, and socially underprivileged transit riders have to enforcement-related perils in transit spaces while hopefully allowing for some alleviation of feelings of worry related to other factors felt by those same riders in those same spaces.

The third study in this four-part collection, continues to explore matters of enforcement sparked by the previous work. Roadway camera enforcement (CE) programs have been found to effectively improve bus reliable, reduce private vehicle travel speeds, and decrease the number and severity of collisions. Despite a wealth of evaluative research confirming this enforcement approach's aptitude at promoting safer roadway behavior and improving transit service performance (Rodier and Shaheen, 2007; Wilson et al., 2010; Gavanas et al., 2013; Cesme et al., 2018), fewer than 50% of US states (at time of writing) host camera-based programs. Public opposition is frequently cited as the cause for the slow proliferation of this enforcement strategy (Ralph et al., 2022). However, with public demand for police reform, largely spurred by the successful proliferation of the Black Lives Matter Movement, having an increased presence on the national political stage (Romaine, 2022; Department of Justice, 2022; Eder et al., 2021; Levin, 2023; Aspinwall and Weichselbaum, 2020), wonder is raised at how feelings toward camera technology might currently stand among groups most marginalized by existing enforcement systems, and how those feelings might vary by type of camera enforcement application?

Through a series of virtual focus groups, this work centers Black voices on matters of surveillance and roadway enforcement by discussing feelings held toward camera programs with Black community leaders. This discussion is contextually situated in Boston, Massachusetts, where legislation that would allow for camera enforcement of roadway infractions is – at the time of this analysis – actively being deliberated in the State Senate. This work complements field-dominating survey research on public opinion toward roadway camera enforcement (Maccubbin et al., 2001; Cicchino et al., 2014; Ralph et al., 2022; Khojastehpour et al., 2022) and expands the literature by exploring feelings held regarding not only general traffic application but transit-specific applications as well.

Two stages of thematic analysis combine to form this study's findings. The first stage reveals that though lukewarm on camera enforcement in general, Black community leaders feel there is a need for enforcement change. Leaders feel that the roadways they engage with in Boston are unsafe, and that current enforcement practices both do little to improve that safety and, in their officer-dependency, disproportionately place members of the Black community at risk of negative life outcome and experiences resulting from interaction with law enforcement. Leaders stress the need for a better system.

The second part of this work concentrates on what that system change could look like. This stage finds that these leaders feel Boston may be receptive to a CE program if it were to be applied exclusively to bus-infrastructure (i.e. bus lanes and bus stops), were operated solely by the MBTA (i.e. transit providing agency), were overseen by an independent oversight committee with consequence administering capabilities, and were intended to serve as an interim measure en-route to the installation of self-enforcing roadway design that would eventually replace cameras entirely.

This work ultimately culminates in a recommended list of 11 program design elements. Policy makers seeking to gain support for camera-based enforcement alternatives and wanting to advance racial equity in the process may benefit from being open to the following Black community leader-informed program design recommendations: 1) introduce camera enforcement through a pilot project with a finite duration and evaluation process; 2) divide CE programming into individual parts each specific to a single application, (e.g. red-light separate from speeding separate from bus application); 3) establish an external oversight committee with consequence administering authority; 4) lead with the objective of education and behavior change rather than punishment; 5) have specialists in behavior, justice advocates, members of the public and leaders from the most enforcement-marginalized communities help determine the nature of the program's penalty structure; 6) explicitly disallow an increase in police funding or an increase in on-street officer presence as part of any CE programming; 7) channel funds collected via CE directly into street infrastructure projects that target safety through design as eventual replacement for cameras; 8) couple enforcement policy with attempts at targeting systemic contributors to unsafe roadway behavior beyond individual behavior (e.g. displacement and mode-share); 9) require inclusion of justice organizations as well as other enforcement-marginalized members of the public on the oversight committee; 10) house CE programming in whichever non-police, governing authority the public has the greatest trust; 11) put in place protections such that no police agencies may be granted access to camera collected data.

Regarding overarching framing for this dissertation, by having the appropriateness of programmatic elements determined by persons historically and ongoing disadvantaged by enforcement systems, this study aligns most clearly with the principles of procedural justice and decision-making power redistribution present in the Reparative Maximization approach to equity as well as across much of the wider transportation equity and justice literature (McAndrews and Marcus, 2015; Martens, 2016; Oluyede, 2022; Pereira et al., 2017; Karner et al., 2023). Across the 11 elements proposed, all four pieces of repair are present: *reckoning* in parts 1 and 4, *acknowledgement* in parts 3 and 9, *accountability* in part 6, 10, and 11, and *redress* through parts 5, 7 and 8. In this Black community leader designed structure, transit practitioners have at the very least, a starting-point blueprint for how to go about incorporating justice principles into their CE programming work.

The fourth and final of these studies explores changing travel behavior against a backdrop of rapid gentrification. Many cities across the US have experienced accelerated rates of gentrification over the last twenty years. The most prevalent narratives surrounding these settlement pattern changes involve amenity rich, urban core-proximate areas experiencing in- and out-flows of residents that results in wealthier, Whiter, younger neighborhood composition (Finio, 2022). Stated perhaps more simply, those doing the

bulk of the moving from outside the city into it – and from utility lite to utility laden areas within cities – have been younger, whiter, and wealthier than the existing populations of the neighborhoods they are moving into (Kirkland, 2008). In cases where this in-migration has exceeded housing supply or has inflated housing prices beyond the affordability limits of the existing rental community, the result has in part been displacement of low income, of color, older, and multigenerational households (Cortright, 2019). For many being removed from their homes by market forces, the only option has been to relocate to less amenity rich, lower density, peripheral urban neighborhoods and suburban areas (Kneebone and Berube, 2013).

Because mobility infrastructure is place-dependent, and many travel behavior preferences and practices are personhood-related, changes in who lives where have transportation implications. Using a binomial logit model informed by regional household survey and personal travel diary data, this work explores how transit use has changed between 2007 and 2017 in the rapidly gentrifying (Salazar, 2021) Washington DC metropolitan area.

Evolutions in the transit mode choice predictive strength of income, race, and age are determined for work and school trips, errand trips, leisure and dining trips, as well as for a single grouping of 'all other' trip types, contributing significantly to a body of literature heavily work-trip dominant (e.g. Klein et al., 2018; Chava et al., 2018; Bereitschaft, 2020; Osolen, 2023). Though variation across trip type exists, generalized takeaways include the following: transit selection likelihood has deceased among Black and Latinx travelers and increased among Asian travelers has compared to White travelers; young adults slightly increased their transit use likelihood over older adults; and low and middle income travelers' transit use likelihood has lessened compared to that of high income travelers. Supported by other studies with similar findings (Dominie, 2012; Klein et al., 2018; Nelson and Hibberd, 2023), these observations contribute to an overall narrative and understanding of how gentrification-specific settlement patterns relate to changed trends in travel behavior over time.

But what insights do these findings offer transit practitioners? These results have implications related to equitability of subsidy distribution. Transit is a comparatively highly affordable, significantly subsidized travel mode, supported – to varied degrees across state lines as well as from one agency to the next – by public funds (Hudspeth and Wellman, 2018). If the benefits of that subsidy are disproportionately increasing being distributed to the those with comparatively high incomes, the degree to which transportation systems harbor injustice and inequity grows. Relatedly, what these findings are capturing may relate to a worsening poverty tax (Karger, 2007) if the observed decreased likelihood of low income travelers to take transit as compared to high income travelers is associated with an increase in their car mode share; single occupancies vehicles being the more expensive of the two modes. One way to avoid contributing to that tax would be to expand identity-based fare structures (e.g. by age, race, or income), as opposed to, for example, exclusively distance-based (i.e. place-based) structures.

Support for this approach has been made by other transportation equity scholars concerned with the propensity of place-dependent service enhancement to perpetuate accessibility precarity for members of society with the least settlement staying power (Balboni et al., 2020); which often manifests as homeownership. Focusing service enhancement on personhood identity to a greater degree than is currently done – note that that is not to suggest that place-based improved be entirely nixed – could also arguably serve as an act of repair. Establishment of, say a low-income fare, is in a way a transit agency *acknowledging* that inequitable conditions or accessibility need hurdling. To create, for further example, a race-based fare to increase accessibility of racial groups whose access has been historically restricted, would similar be an act of *acknowledgement* as well as an act of *redress*. While ideas like this would require much closer examination to be feasibly operationalizable, they should not be quickly dismissed.

6.2 STATEMENT OF ORIGINALITY AND PRIMARY CONTRIBUTIONS

As a whole, key contributions of this dissertation to the landscape of transportation equity scholarship are perhaps best framed as responses to calls made by others in the field. Dozens of transportation equity scholars have noted the sorely lacking application of transportation equity/justice/social inclusion research findings and recommendations by transportation authorities and decision-makers. Several recent examples of those calling for a bridging of this cross-sectoral gap include Cantilina et al. (2021), Krapp et al. (2021), Bills (2022), as well as McCullough and Erasmus (2023). This work has – potentially – improved upon this with practice-centered research questions and implementation-focused recommendations.

There is also a push among scholars to feature the use of more varied, namely qualitative methods (Lucas, 2013; Jennings, 2015; Karner, 2016; Vecchio, 2020). By using focus groups, a meta-analysis, and a photo-simulated randomized control trial, this work has answered both the call for variation from the dominant norm of accessibility studies and for more qualitative analysis. Further on the subject of methodology, the last few years have seen a concentrated interest in amplifying the voices of those with lived experience of transportation disadvantage, transportation poverty, or transportation injustice in research, elevating their particular expertise rather than simply treating them as data points (Verlinghieri and Schwanen, 2020; Lowe et al., 2023). Parts of this work have done exactly that.

Some have called for further assessment of the impacts of new mobility technologies on disadvantaged and marginalized groups (Lucas, 2019; Guo et al., 2020; Bills, 2020; Pereira and Karner, 2021). This includes, but is not limited to, things like ride-hailing and sharing services, connected and autonomous vehicles, traffic and emission sensing, and automated camera enforcement. It is related to this particular technology application – camera enforcement – that this work contributes to the research landscape specific to impacts on, and reflections from, marginalized communities.

Finally, some have stressed the need for research to increasingly look at transportation equity, transportation justice, and mobility justice against the backdrop of gentrification trends (Sheller, 2015; Barajas and Braun, 2021; Agyeman and Doran, 2021; McCullough and Erasmus, 2023). This sits at the very core of much of this work. By placing wealth accumulation possibilities in concert with displacement pressures, policing with fears of exclusionary development and social network loss, mode choice with changing neighborhood sociodemographic composition, this dissertation contributes to meeting this need.

6.3 LIMITATIONS AND RELFECTIONS FOR FUTURE RESEARCH

In addition to the limitations and avenues of potential continued study specific to each individual research project that have been discussed in their respective chapters, there are some themes under both of these topics – weakness and future work – that warrant further attention.

Regrettably, the work within this dissertation contributes to the over-representation in this subject-area – that of transportation equity – of the West and the Global North. Due to information accessibility and my own language fluency limitations, this work undoubtedly has blind spots with respect to realities of transit inequities in and thought leadership from non-English publishing nations. This is a limitation that other scholars have posited is no minor barrier to innovation in this body of scholarship and the shrinking of knowledge gaps (Cidell, 2024).

Methodologically, details explaining my thematic analysis – the process of coding and organizing of themes – could have been more thorough, and more clearly systematized. I ran my thematic analysis manually. In

any future iterations of this work, I would use a software such as NVivo or Atlas.ti to aid in this effort. One of the significant benefits to these software is their capability to generate visualizations of the analysis process (Limna, 2023). Several of the decisions I made in describing my analysis were, in part, dictated by barriers of presentation format. Sharing a full code book, for example, in the absence of quality design, I felt added more confusion than it offered clarity. I may not have been correct in this determination. I acknowledge this weakness of the research, and plan not to let it prevent me from presenting a higher rigor of qualitative research in the future.

Additionally, though I was intentional in my framing of this work with a transportation practitioner audience in mind, I did not take my research, with respect to format, the step beyond literature toward user-tools to as high an extent as possible. For example, the property value premium model created in Paper 1 has the potential to be of great use to planners. However, it requires them to pull out paper and pad and execute the model in their desired contexts themselves. This leaves several capacity barriers in place, such as that of data literacy and time. An even more useful iteration of this model would be a wed-based platform that only requires users to enter their key datapoints before it automatically runs the model equation and generates the premium that users are looking for. This could theoretically happen in a matter of seconds. Aids like this can be the difference between a powerful idea, which lives on paper and gets used by a journal-reading few, and powerful tool, adopted into common practice. Falling short of the most user-friendly format was not exclusive to Paper 1. A greater number of maps in Papers 2 and 4, for example, would also have made those quantitative analyses more accessible to a broader audience.

Furthermore, structures of governance at transit-shaping agencies can be significant barriers to acts of justice and conditions of equity (Fischer et al., 2020; da Crus et al., 2023; Beyazit and Canitez, 2023). Unfortunately, despite begin aware of this, I fail to devote time to analyzing the specifics of those barriers, or to developing transformational alternatives to those structures that would better mobilize justice practices toward transit equity in the contexts that my work sits in. This is a mantle that I would like to see future research take up.

On that subject, this work opens several avenues for future research relevant to transit equity. Building on the local-level (i.e. city-level) focus taken in three of these four pieces, prioritizing wider generalizability going forward would be a significant contribution to practitioners. For example, future research might explore the degree to which the public – as defined by other geographies – might be accepting of the Black Boston community leader-informed camera enforcement program design that resulted from Paper 3. The 'public' in this continued line of research could refer to the populous of a single region, the entire nation, or residents of another country all together. A survey methodology, with its comparative ease of wide distribution (Braun et al., 2021), would better expand the geographical relevance of this work. Across the US specifically, there is also present demand for such work. The National Academies of Science, Engineering, and Medicine – the organization banner under which sits the US Transportation Research Board – has announced an upcoming request for proposal entitled 'The Future of Automated Traffic Enforcement and Public Acceptance' tentatively scheduled for release in 2025. Such as opportunity to directly connect research and practice, and to place racial and procedural equity at the core of this connection, as was attempted here in this research, must not go wasted.

Finally, there remains work to be done in operationalizing the equity threshold approach of Reparative Maximization proposed in the first chapter of this dissertation. Future research should strive to apply it concretely to examples of transportation practice and policies of many types and across different socio-political contexts. Concretization can only aid in the effort to convince transportation practitioners to take up this approach to grounding their work in a set of values capable of advancing collective wellbeing. In continuing to develop this idea, I plan to contribute to some such concretizing myself in the coming years.

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