BUS NETWORK REDESIGNS:

A 21ST CENTURY ATTEMPT TO SAVE MASS TRANSIT

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Abstract

This thesis project is focused on the practice of bus network redesigns in the United States between 2014 and 2023. After introducing the concept of bus network redesigns in Chapter I, in Chapter II I summarize the existing academic, historical, and gray literature on bus network redesigns. I observe that network redesigns are used to adapt transit networks to changes in urban development and travel patterns. I also find that academic literature on bus network redesigns has focused primarily on modeling their accessibility impacts, including for the ways redesigns can improve riders' access to jobs and health care services. Following, I consider the robust gray literature on bus network redesigns, including writing on individual blogs, reports by advocacy groups, and policy case studies. I conclude that there has been no comprehensive study on the quantitative impacts of bus network redesigns, and also observe that much of the work being done to shape network redesigns comes from the professional, not academic side of the field. In Chapter III I summarize my key findings from a series of interviews conducted with active transit planners who have worked on bus network redesigns. Those planners observe that bus network redesigns distinguished themselves from existing transit planning methods in the mid-2010s. They also demonstrate how bus network redesigns are spread in a variety of ways, oftentimes proposed by one of a few prolific consulting firms, but also developed internally by transit agencies, or municipal governments. Finally, I detail the way that community engagement has become an increasingly robust component in bus network redesign projects, especially as redesigns have grown in scale. In Chapter IV, I establish a framework for measuring the effects of bus network redesigns that can be added to as more data becomes available for treated networks. I use National Transit Database data to measure changes in yearly ridership and vehicle operating hours at transit agencies. I cluster agencies with their peers using a k-means clustering technique and assess treatment effects via an OLS linear regression, first with time as a binary variable, then with time as a panel variable. I find no statistical differences between treated and untreated networks, although I do observe weak positive associations with operational performance metrics over time in treated networks. I also calculate difference in difference effects for treated networks from their peers. I find slight associations with operational efficiencies, albeit with large standard errors that suggest diverging trends among treated networks. To conclude the thesis, I suggest that, regardless of their quantitative effects, bus network redesigns are intrinsically valuable for transit agencies because of how they facilitate wholistic, network-scale thinking about how transit can serve our cities.

Key words: bus network redesigns, transit planning, accessibility modeling, transit operations

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Chapter I: the rediscovery of the bus

Mass transit in the United States is in crisis, and it's not because of Covid. Between 2012 and 2018, bus ridership across the nation declined by 18%, before plummeting in 2020 (Erhardt et al. 2022). Any efforts to make our cities more sustainable need to entail switching trips back to mass transit. Despite the decline in transit ridership, few transit planning interventions purport to reverse the last decade's systemic losses. This is why bus network redesigns hold so much promise.

Bus network redesigns are a transit planning technique where planners treat a city's bus network as a blank slate and attempt to maximize the performance of the system by reallocating service hours spatially and temporally. The technique has become wildly popular, with dozens completed since 2014 and several currently in planning stages, including those for Washington, DC, Philadelphia, and for Boston.

As Scudder Wagg, Principal Associate at Jarrett Walker + Associates, explained to me during an interview for this project, in the 2010s there was a "rediscovery of the bus" as a tool for transit planning (Wagg 2024). Buses were embraced as the infinitely adaptable tool for building robust networks that maximize the efficiency of existing transit resources.

On relatively quick timelines and for much less money than transportation megaprojects, bus network redesigns allow transit planners to offer real change to riders. In one redesign process, an agency can implement large scale changes including new routes and network structures, while simultaneously adjusting the small details that hold back bus routes -- avoiding problematic turns, cutting underutilized portions of alignments, and fine-tuning transfers.

The recent ascendance of network redesigns means that there has been a limited amount of study on their effects. Changing bus routes is a significant intervention that can shape travel patterns and livelihoods across regions. Many bus routes follow the path of historic trolleys and have served their communities for generations. That so many cities have taken on the challenge of redesigning their bus networks indicates both the dire need for intervention in our transit systems and of the influence of the technique's popularity.

This thesis is the product of curiosity about the history and effects of bus network redesigns. My driving questions include: how did bus network redesigns take their current form and how can we measure their effects on transit networks? I hope that my work contributes to historical and empirical knowledge on bus network redesigns. As the technique proliferates across the country, it is imperative that planners study its implementation to ensure that redesigns are practiced in an effective and equitable manner.

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My introduction to bus network redesigns came with the release of the Philadelphia's 2020 Transit Plan, and subsequent presentations by SEPTA staff to 5th Square, a Philadelphia urbanist political action committee. Like many who came before me, I was enthralled by the possibility that SEPTA's precious operational resources could be used more effectively. Planners spoke about how Bus Revolution would address SEPTA's gradually declining ridership and would make the system more user friendly. It also didn't hurt that I saw a chance for the simplification of my least favorite circuitous bus routes. I was soon helping Transit Forward Philly, another advocacy group, with canvassing to collect rider feedback for Bus Revolution, and eagerly awaited the release of SEPTA's first Bus Revolution Draft Network in fall 2022.

My excitement for change was tempered by a cascade of delays, revised network drafts, and political fights over the new network. At the time of this thesis, Bus Revolution has not been implemented, and is tentatively scheduled for some time in 2025. Despite my disappointment, in the last three years I have witnessed a city negotiate the shape of a bus network redesign in real time. The experience of watching Bus Revolution in action encouraged me to study how other cities completed similar projects and to determine how researchers have measured the effects of bus network redesigns across the country.

My early reading on bus network redesigns left me with many questions, especially on the techniques and effects of the projects – how did planners implement these projects and how successful were they? I found little but anecdotal evidence that backed up the promises I heard planner make about the anticipated effects of projects like Bus Revolution.

I undertook this thesis project to continue asking questions about bus network redesigns and to try and share some of my findings. I hope this work provides insight on how bus network redesigns came into being, how they affect the performance of bus networks, and how transit planners have shaped their development.

My research questions are split into three sections, with corresponding chapters. First. I want to consider how academic literature has engaged with the rapid rise in popularity of bus network redesigns. Next, I look to summarize the state of the professional practice of bus networks among professional planners at transit agencies, cities, and consulting firms. Finally, I aim to quantify the effects that bus network redesigns have on our cities.

In Chapter II, I summarize the available literature on bus network redesigns, both from academic journals and from blogs and trade publications. I find that there has been robust study on optimization techniques for planning bus network redesigns and for equity modeling relating to bus network redesigns. However, I observe that there is comparatively less writing that assesses the real-world effects of implemented bus network redesigns on transit network performance. I also find a significant body of informal, or gray, literature about bus network redesigns that has been published by research institutes, on personal blogs, and by consultants who are active in the field. These publications often concern the socio-political practice of bus network redesigns, including how they are implemented and how stakeholders interact with them. In my review of both academic and gray literature, I am to bridge the gap between the two camps and frame bus network redesigns as a transit planning tool that is actively being shaped by a wide range of transportation planners. Ultimately, I conclude that bus network redesigns' promise to improve the efficiency of transit networks can be wielded both as a tool for improving the social and environmental effects of our transit networks, and as a cost cutting tool for the managed decline of those same systems. Under the right circumstances, those conflicting intentions can be balanced in tension with one another to produce positive effects, regardless of the quantitative impacts that bus network redesigns have on bus networks.

Chapter III focuses on the professional practice of bus network redesigns, as characterized by a series of interviews I conducted with American transit planners. Those discussions provide an invaluable companion to the academic literature summarized in Chapter II. The professionals I spoke with are part of an active network of transit planners at transit agencies, government offices, and consulting firms who shape the practice of bus network redesigns. I divide their insights into four subcategories: first, I contextualize the history of bus network redesigns as emerging from transit planning techniques that were honed during post WII transit decline, and that reemerged in late 20th Century transit expansion. Second, I summarize the mechanics of starting the bus network redesigns process via political and stakeholder buy-in from a mixture of advocacy from transit agencies, cities, and consultancies. Third, I characterize the use of bus network redesigns for helping transit agencies articulate the value of their own services, then helping them shape their network to meet those goals. Finally, I cover the increased prominence of community outreach as a part of the bus network redesign process, which is sure to characterize the future professional practice of bus network redesign planning. Overall, these interviews show the way that the basic tools of bus network redesigns are adapted to work across different scales and agency priorities, from small cities trying to eke out more service across a handful of lines to the country's biggest transit networks, who look to right decades of unaddressed network inefficiencies with one overhaul. No matter the differences between bus network redesign processes in various cities, the practice provides a fruitful ground for planners to think critically about how to adapt networks to the demands of their ridership and allows agencies to push for ambitious goals towards becoming lifestyle networks that provide affordable, sustainable transit trips for all kinds of urban trips.

In Chapter IV, I measure the effects of 14 bus network redesigns that were completed in American cities between 2014 and 2021. To observe the effects of bus network redesigns, I pair treated agencies with their national peers based on a k-means clustering analysis and with regional peers based on proximity. I then compile agencies' unlinked passenger trips (UPT), UPT / vehicle revenue hours (UPT/VRH), passenger miles traveled (PMT) and PMT/VRH as measures of the overall performance of their bus networks. Finally, I estimate the treatment effects of bus network redesigns using a difference-in-difference approach to show how much agencies changed completing bus network redesigns for three years after implementation, relative to their untreated peers. I observe that, despite statistically significant decreases in key metrics across all networks over my treatment periods, redesigned networks show a slight, non-statistically significant association with increases in UPT and UPT/VRH after treatment. Further, in the third year after a redesign, treated networks showed a statistically significant gain of 3.1 UPT/VRH. These findings suggest that, while bus network redesigns may offer only mild performance improvements to transit networks, they may be an invaluable tool for stemming the tide of ridership and efficiency declines that characterized bus network performance in the 2010s and were exacerbated during in the recovery from the Covid-19 Pandemic.

This is an exciting time to study bus network redesigns. After rising to prominence in the 2010s, almost every major transit agency will have completed a bus network redesign by the mid-2020s, and dozens of medium and smaller networks have already done so. Bus network redesigns push transit agencies to clearly articulate the value of their systems and help them strive to be better. I hope that this work will build a foundation for future study of the technique as it matures. Every year in the near future will provide further opportunity for study of recently implemented bus network redesigns (Cleveland, Dallas, Hampton Roads, Madison, Miami, Milwaukee), and impending redesigns (Alameda County, Boston, Philadelphia, Washington). My research shows that the true value of bus network redesigns may lie in the space they make for agencies to articulate their values, connect with their riders, and establish strategic change as a regular part of the experience of using their system. Bus network redesigns may not skyrocket the efficiency and ridership performance of networks, but they give agencies a foundation for making future interventions, from bus speed and reliability improvements to customer experience and accessibility enhancements.

Bus network redesigns explained: the blank slate approach

Bus network redesigns are not an entirely novel transit planning technique. However, they use previously developed transit planning techniques on a scale and with a regularity that has not been seen before. It is notable that, between 2015 and 2025, and almost all major US transit agencies will have redesigned their bus networks.

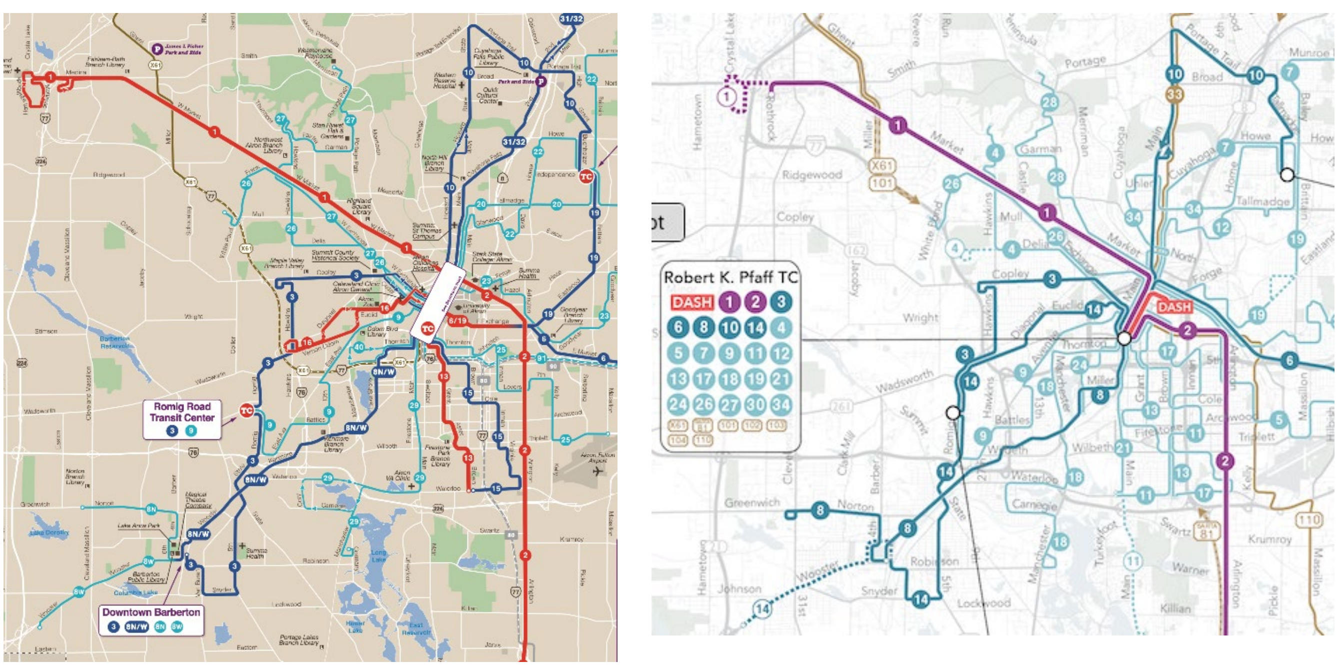
Jarrett Walker explains that “not all bus networks are designed. Many developed haphazardly,” as cities and political structures changed around them. “Over the decades, that process [led] to service that is more complex, less frequent, and thus measurably less useful” (Walker 2024, pp 177). Bus network redesigns are a tool for undoing those decades of accumulated inefficiencies at once. One of the defining traits of bus network redesigns as I define them is the practice of changing all of an agency’s routes in one day to match a new, “designed” network to improve on the proceeding haphazard layout of routes. This is a technique that marks the modern emergence of bus network redesigns, with Tallahassee’s StarMetro changing all of its routes at once in 2011 (Bhattacharya et al. 2014). However, I mark the beginning of the modern bus network redesign as Jacksonville’s 2014 redesign, which was quickly followed by Houston’s landmark 2015 redesign. Those two redesigns were also critical projects for Jarrett Walker + Associates (JWA), who are indelibly linked with the practice of bus network redesigns across the US.

Jarrett Walker, founder of JWA, has been one of the most influential voices on bus network redesigns in the transit planning world. Through the work of his consulting firm, his 2013 book *Human Transit* (revised in 2024), and his accompanying *Human Transit* blog, Walker has spread the techniques and theories behind bus network redesigns. Walker often seems to be connected to every large-scale bus network redesign in some way or other, either as direct participant in the planning process, as a contact through conferences and workshops, or a as source of inspiration for transit planners across the country.

The strength of Walkers' approach rests in its adaptability. His writing stresses the way that bus network redesigns consist of a series of discussions and tradeoffs meant to help transit agencies align their service with their values. One of the essential through lines of Walker's style is an adherence to a blank slate approach to network planning, where an entirely new network can be driven from scratch. Even when most of a network will remain the same, the mere idea of a blank slate redesigns helps agencies overcome the difficultly of pursuing ambitions changes to the way they allocate service across their networks.

A typical announcement of a completed bus network redesign contains many of these tropes. Take the following blog post on Walker's Blog, *Human Transit*, titled "Akron: Welcome to Your New Network." The post explains that Akron's "Reimagined Network was designed to provide

Figure 1 Akron's new network (left) and old network (right)
Source: Jarrett Walker + Associates



frequent and convenient service in busy places where many people need to travel to, while continuing to offer lifeline service in places where and for people whom transit is essential" (Landman 2023). The post's claims about the "new" network are not corroborated by the explanation. While some routes were added or eliminated, most routes stayed the same, but were tweaked in ways that adjust the service frequency, span, and legibility. See in Figure 1 how Akron's "new" network (left) looks very similar to its old network (right). This comparison does not serve to claim that bus network redesigns are misrepresented, but rather to show how the "newness" of a network does not always rely on its total redesign. Rather, small changes to frequency, connectivity, and even branding on a map can have significant effects on the feel of using a network and on the performance of that network.

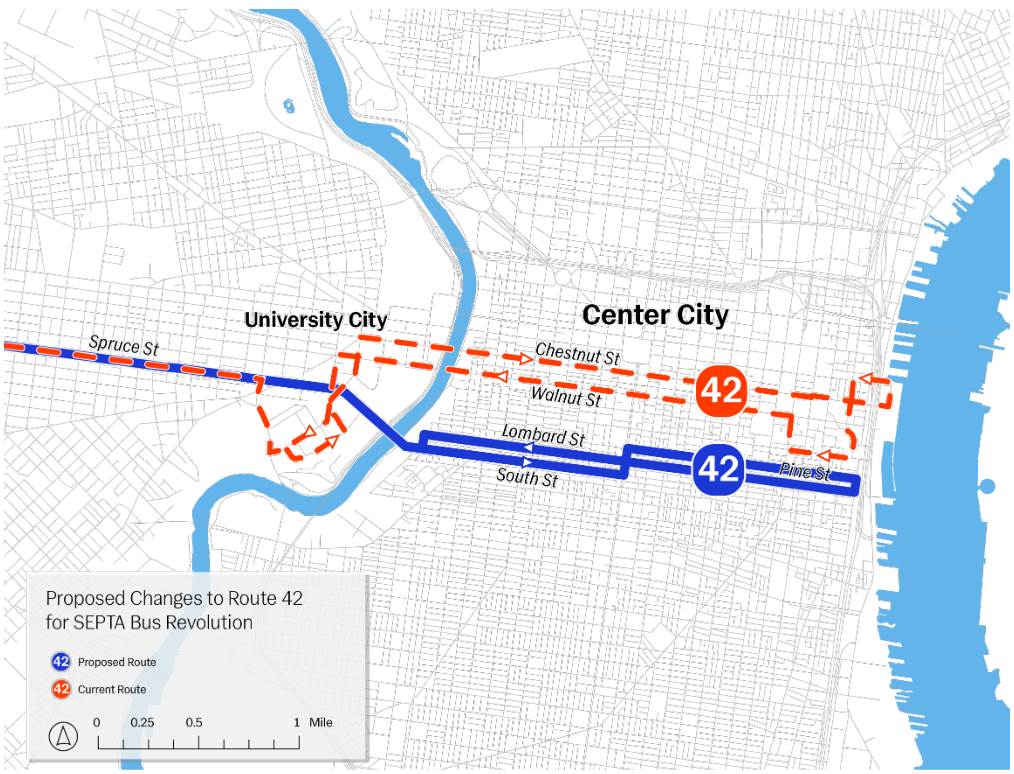
In Table 1, I map out some of the objectives and techniques that are commonly a part of bus network redesign processes. Despite the emphasis on the network "design" process of bus network redesigns, many of the techniques used in them are unrelated to the layout of the routes themselves. Restructuring bus routes is certainly the main technique in network redesign planning, but it is supported by non-spatial techniques as well, including by redistributing service hours and increasing the legibility of routes. For example, many small-scale redesigns include the introduction of weekend or later night service (Gamez 2024). Many redesigns are also used to identify bus routes based on frequency, so riders understand the functional differences of the routes they see on maps (see Figure 1). Finally, redesigns can also be paired with improvements to bus shelters, payment systems and stop signage (Byala et al. 2019). Notably, the backbones of transit networks are the routes that are least likely to change in a redesign but are also the routes that will be most legible on a redesigned map. See how Akron's routes 1 and 2 continue to serve a similar northwest to south arc across the region after the redesign. However, subtle tweaks to the routes' approaches to the urban core could result in significant time savings, without impacting the rest of the routes' services.

Table 1 Overview of bus network redesign objectives and implementation strategies

Objective	Implementation
Restructure network	Redraw bus routes to serve specific trip generators and to provide opportunities for strategic transfers with other transit services
Redistribute service hours	Adjust service span and frequency to provide more service on off peak times, on weekends, and on routes in the highest demand
Increase legibility	Rebrand routes based on their service frequency (red for 15 max routes, blues for 30 max, etc.)
Reduce conflicts	Eliminate chokepoints in the network by tweaking routes around problematic intersections and keeping routes on arterials as much as possible
Improve customer experience	Improve amenities for passengers, including new bus stop infrastructure or locations. Can include bus stop consolidation.

Figure 2 Proposed changes to Routes 40 and 42 in SEPTA Bus Revolution

Source: SEPTA Bus Revolution 2023



I look towards SEPTA's Bus Revolution redesign process as an example of how the various techniques are combined in a bus network redesign process. Figure 2 shows the proposed changes to SEPTA's Route 42, which is being partially combined with Route 40. The major changes to the route include the elimination of service to the south side of the University City Hospital complex and the shifting of Center City service from along Walnut and Chestnut streets to Lombard and Spruce Streets, five blocks to the south. Overall, the shape of the route and the major trip generators along it stay the same, however, small tweaks produce significant changes to the run time of the route and the number of jobs it serves.

By moving the route away from the most congested parts of its current alignment, around the hospital complex and in the heart of Center City, SEPTA could save upwards of 15 minutes on every trip. Figure 3 shows how, by comparing the schedule of Route 42 to the schedule of Route 40, we can see that the route could cut 30% of its overall run time at AM peak through Bus Revolution adjustments. This means that, where the current routes around 14 buses to maintain 10 min headways along the route, the proposed alignment would need as few as 8 buses to maintain the same frequency (SEPTA 2024). Meanwhile, by skirting around the edge of the region's largest employment centers, the proposed routes would provide quarter-mile access to over 80,000 fewer jobs than the previous route (Figure 4).

While these tradeoffs seem difficult to balance for even one route, bus network redesigns ask transit agencies to perform the same calculations for every route in their system. Though resulting networks oftentimes look quite similar to the precursors, the small changes made to each route can add up to transform the overall utility of a network for its riders. If SEPTA gains six extra buses and operators by adjusting Route 42, they can reinvest those resources elsewhere in the system to spread high quality, frequent transit options around the city.

Figure 3 Adjustments to SEPTA's Route 42 as part of Bus Revolution

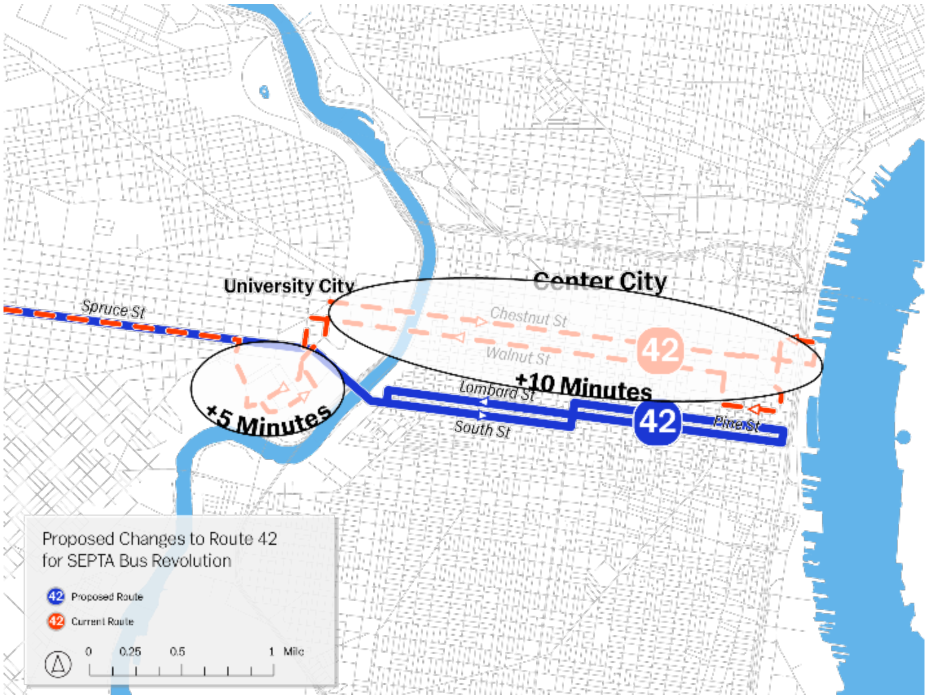
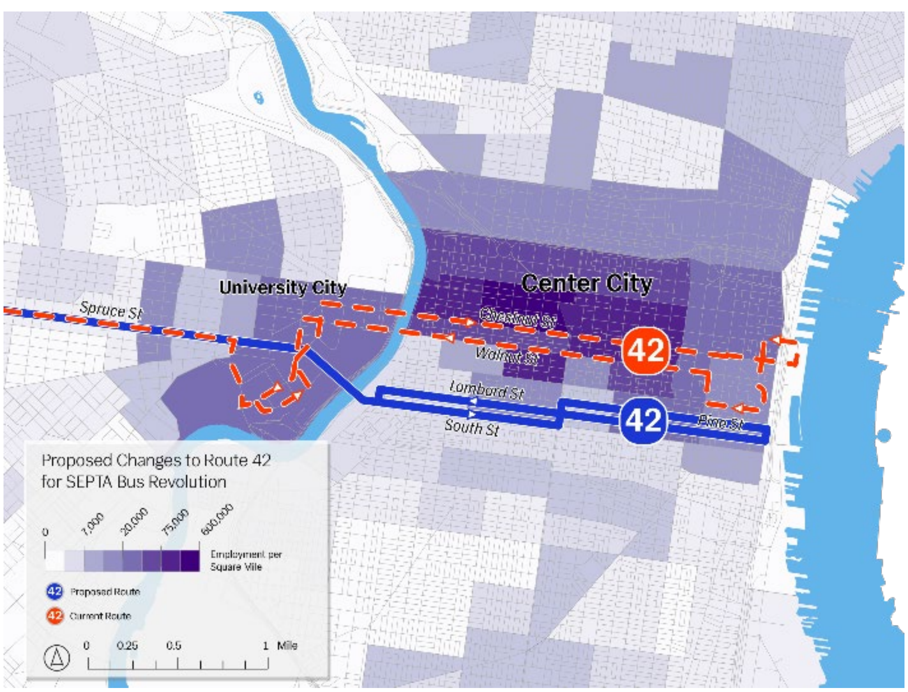


Figure 4 Employment density overlay on SEPTA's Route 42



Chapter II: History and Literature Review

In this chapter I summarize the history of bus network redesigns, characterize the methodology used in their contemporary implementation, highlight the access modeling used to justify many bus network redesigns, summarize some of the gray literature than has been written about bus network redesigns, and end on a discussion of critiques of bus network redesigns as manage decline of American bus networks. This literature review focuses on a subset of writing on comprehensive bus network planning. Specifically, I exclude a robust literature on algorithmic bus network optimization, which I find has had a limited impact on the implementation of bus network redesigns on existing bus networks. The literature I summarize focuses more on the challenges of implementing bus network redesigns in American cities, including in Richmond, Columbus, and Houston, among others. Among my sources, Transit Cooperative Research Program (TCRP) reports 140 and 221 provide particularly comprehensive information on the way that agencies have approached their bus network redesign processes. Those reports are unique among academic literature for their capture of the professional planning strategies used in recent bus network redesigns. I also engage with several works of non-academic, gray, writing and research that have been influential in codifying bus network redesign practices in the United States. These pieces include reports from The Transit Center and NYU's Marron Institute of Urban Management, as well as writing by self-publishing urbanist thinkers Jarrett Walker and Alon Levy.

My key findings from this literature review include that there has been no standard review process for the successfulness of bus network redesigns, and that bus network redesigns have been implemented in a variety of manners that make them difficult to compare directly to one another. I also observe that there are a significant number of bus network redesigns currently being planned or implemented, which heightens the importance of building a framework for evaluating their successes and to capitalize on their momentum as a transit planning method. Further, it appears that there are conflicting views on the purposes of bus network redesigns in the United States, with some parties seeing them as a reliable strategy for improving the overall quality of transit services and others seeing them as a means for managing the steady decline of transit service. Ultimately, I argue that, despite growing academic engagement with bus network redesigns, much of the engagement with the technique has been in planning offices around the country. Future study on bus network redesigns needs to take into account the way transportation consulting firms and other planning offices have shaped the practice.

The need for bus network redesigns: How cities outgrew their bus networks

As transit systems made the technological evolution from trolley car networks to bus networks in the mid-20th century, their management strategies did not always capitalize on the operational flexibility of being freed from rails. While the shift to buses allowed for more flexible scheduling, routing, and street maintenance practices, the routes that buses traveled generally followed similar, if not identical, patterns to the trolley routes they succeeded. After all, those trolley routes had been integral to shaping the built environments that surrounded the (Warner 1978).

In the decades that followed the transition to buses, urban forms shifted to meet the demands of an auto-driven society, as they once had for trolleys. As urban regions changed, bus routes continued to follow the paths of the trolley forebears – though they were no longer on rails, their routes were treated as immutable. Transit agencies failed to take advantage of the main competitive advantage of buses – their route flexibility.

By the 1980s, many urban cores were unrecognizable from how they looked when trolleys dictated the pace of city life, with downtowns a landscape of high rises and parking lots, sometimes punctuated with modern rail transit systems that whisked commuters across inner cities and back to the suburbs (Bloom 2023). Bus routes, meanwhile, were still the vestiges of early trolley routes and had not changed to meet the new regional travel patterns.

Despite the pace of regional urban change, transit planners remained hesitant to adjust routes to meet the new demands of their cities. The majority of system-wide bus network adjustments were set on adjusting route scheduling and frequency adjustments (Puchalsky 2007). While potentially impactful, these strategies did little to address systemic issues caused by the circuitous routing and unintuitive layouts of many networks. By the late 20th Century, the "planning of bus routes [was] the single important element of the bus planning process not to have seen serious research results carried into practice" (Ceder and Wilson 1980).

Ceder and Wilson's early assessment bus network redesigns highlight the likely downsides in disruption of regular travel patterns and confusion to riders:

> "One would certainly expect that this kind of major rethinking of the whole network would be appropriate very infrequently, if at all, for any property because of the major effort involved in the analysis as well as the disruption imposed on passengers if wholesale changes are made to the system. For many North American properties, however, which have not been through such a reappraisal since 1940, it is high time to consider such an undertaking."

Due to the expected side effects of shifting an entire city or region's mass transit network, few cities conducted bus network redesigns before the 2010s, with Madison Wisconsin's 1998 redesign an early outlier (Murphy 2023). However, transportation trends in the 2010s led to a notable decline in bus ridership across North America that may have been a nurturing ingredient for the proliferation of bus network redesigns between 2015 and the present.

By 2000, the long decline of public transit, especially in the use of bus networks, left planners with few paths forward to build the share of the public using sustainable, equitable travel modes. In their 2003 review of literature on factors influencing transit ridership, Brian Taylor and Camille Fink concluded that "transit ridership is largely, though not completely, a product of factors outside the control of transit managers" (Taylor and Finke 2003). Their review indicates that transit agencies will be ineffective at shifting trips to transit as long as the United States pours untold resources in interstate construction and accommodates the convenient storage or personal vehicles around all urban cores.

From 2012 to 2018, bus ridership in the United States decreased by 15% across all bus networks, with especially steep declines from 2014 – 2018 (Erhardt et al. 2022). These decreases can be explained by various developments, including the rise of ridesharing, robust increases in car ownership in America, and the increasing divergence between historic bus networks and contemporary urban travel patterns (Dong 2020; Klein and Smart 2017).

These decreases in ridership were the encouragement many transit agencies needed to redesign their bus networks to try to reverse ridership losses and better meet the needs of service populations. In Table 2, I identify twelve bus network redesigns completed in major American cities between 2014 and 2019, and a further nine that were implemented between 2020 and 2023. There are fourteen bus network redesigns currently planned for implementation in the next several years.

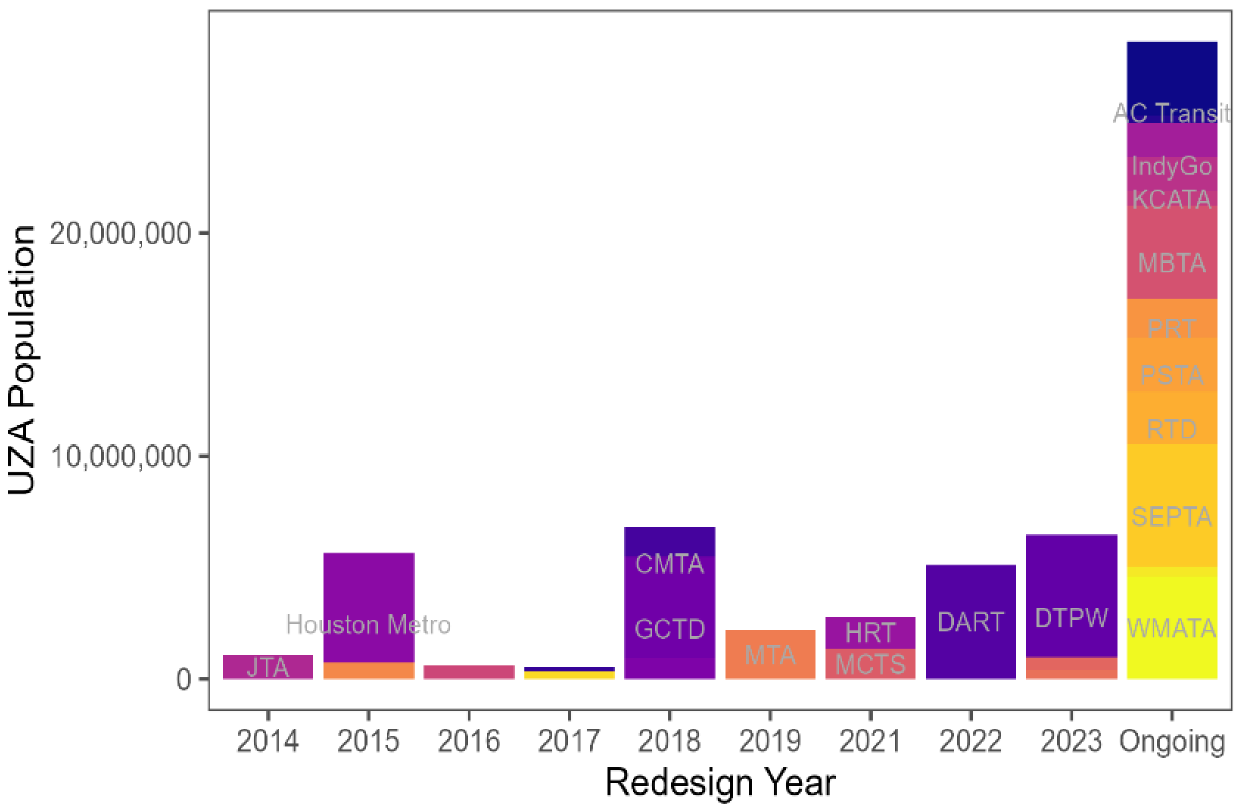
Bus network redesigns have emerged out of a nadir in American transit planning, and among all policy ideas and capital projects that planners can throw at transit agencies, no project comes close to bus network redesigns' promise for molding transit networks to the needs of riders. The promise of the bus network redesign is alluring, and it's not surprising that so many cities have pursued them.

TCRP reports 140 and 221 serve as landmark studies on the arrival of bus network redesigns to American transit planning. These reports pay more attention to transit agencies' relationship to bus network redesigns than other academic literature. 2019's TCRP 140: *Comprehensive Bus Network Redesigns* includes the invaluable survey results of 38 transit agencies that help define the burgeoning bus network redesign trend through the perspective of practitioners. The report confirms the utility of bus network redesigns for improving, rather than cutting transit services, noting that "bus network redesigns are usually conducted to focus on the needs of the riders and potential riders and on the agencies' need to operate efficiently" (Byala et al. 2019, pp 3). The report also indicates that the rise in bus network redesigns has not been shaped entirely from within transit agencies' planning offices, as "agencies [who complete bus network redesigns] rely on consultants to conduct a lot of the heavy lifting on planning transit network redesigns" (Byala et al. 2019, pp 4). Overall, the report does a comprehensive job of tracking the rise of bus network redesigns, but acknowledges that ways that the practice is continuing to be shaped by national consultancies.

2021's TCRP 221: *Redesigning Transit Networks for the New Mobility Future*, supplements TCRP 140 by focusing on the intricacies of bus network redesign implementation across the country. Figure 5 shows how, between 2019 and 2021, large scales bus network redesigns continued to be implemented across the country, and how there remains a large cohort of agencies, including many of the nation's largest, that are in the process of planning bus network redesigns. TCRP 221 reflects this acceleration of bus network redesign planning by focusing its recommendations on improving communications for and implementation of bus network redesigns. The report's key recommendations for bus network redesign planning stress how "equity considerations are integral to bus network redesign planning, and concludes that that, "the importance of frequent and meaningful engagement with stakeholders and the public cannot be overstated; there is no such thing as too much outreach, engagement, and communication when planning and implementing a bus network redesign" (Byala et al. 2021, pp 3).

TCRP 221's recommendations for further study were especially influential on my work. Specifically, the report recommends study of the "benefits and outcomes" of bus network redesigns after sufficient time (they recommend at least 18 months) has elapsed since implementation (Byala et al. 2021, pp 78). This recommendation underscores the way that the rapid proliferation of bus network redesigns has hampered researchers' ability to study post-implementation effects. While the promise of bus network redesigns has been proven through equity modeling, through short-term observation of effects, and via anecdotal evidence, many of the largest tests of the technique will be implemented without large-scale studies of its efficacy. Likewise, the report also recommends comparison of bus network redesign effects based on style of implementation – full overnight redesigns, phased redesigns, etc. While that classification is not in the purview of my work, it should be an important part of any future analysis of bus network redesign effects (Byala et al. 2021).

Figure 5 Plot of population of redesigned agencies, including 14 planned redesigns



Completed Bus Network Redesigns

CITY	AGENCY	YEAR
Jacksonville	JTA	2014
Houston	Houston Metro	2015
Omaha	Omaha Metro	2015
Livermore	LAVTA	2016
Columbus	COTA	2017
Orange County	OCTA	2017
San Bernadino	VVTA	2017
Salem	Cherriots	2017
Richmond	GRTC	2018
Austin	CMTA	2018
Gwinnett County, GA	GCTD	2018
Baltimore	MTA	2019
San Jose	VTA	2020
Milwaukee	MCTS	2021
Los Angeles	LA Metro	2021
Hampton Roads	HRT	2021
Cleveland	GCRTA	2021
Dallas	DART	2022
Madison	metro transit	2023
Miami-Dade	DTPW	2023
Akron	METRO	2023
Suffolk County	SCT	2023

Table 3 Completed and bus network redesigns the United States

Source: Agency websites, TCRP 144, Human Transit Blog

Table 2 Planned bus network redesigns

Source: Agency websites

Planned Bus Network Redesigns

CITY	AGENCY
Alameda County, CA	AC Transit
Allentown	LANTA
Boston	MBTA
Chattanooga	CARTA
Denver	RTD
Indianapolis	IndyGo
Kansas City	KCATA
Knoxville	KAT
New York City	NYC MTA
Philadelphia	SEPTA
Pinellas County, FL	PSTA
Pittsburgh	PRT
Washington, DC	WMATA
Wichita	Wichita Transit

Equity modeling: measuring bus network redesigns before implementation

Since the full emergence of bus network redesigns in the mid-2010s, academic literature on the method has been outpaced by a stream of transit agency publications, blog posts, and consulting recommendations that have largely shaped the practice. Among this diverse set of planners, a literature has emerged that largely serves to predict the outcomes of bus network redesigns, but has not yet blossomed into assessing the real impacts of them.

In this section I summarize instances where literature is devoted to predicting the equity and ridership implications of proposed bus network redesigns. I focus specifically on work performed on bus network redesigns for Columbus, Ohio and for Richmond Virginia, which provide a survey of the methodology used by transit agencies, private consulting firms, and academics to anticipate the effects of large-scale interventions on bus network routing.

A key observation from these papers is that there is no consensus on how to adequately model the equity or ridership impacts of bus network redesigns. Transit agencies often claim that their newly designed networks will increase ridership and increase access for specific underserved or under resourced groups, yet the models they use to come to these conclusions are not always replicable (Houston METRO 2014).

Dueling Equity Models in Richmond, VA

A specific instantiation of the difficulties surrounding equity modeling occurred during Richmond, Virginia's redesign process. In 2019, the Greater Richmond Transit Company (GRTC) hired Jarrett Walker + Associates (JWA) to redesign their network to maximize core frequency and eliminate low ridership routes on the edges of the downtown core (Walker 2018). As partner to the redesign process, researchers at Virginia Commonwealth University (VCU) completed their own model, which showed that JWA's proposed network would reduce service to low-income residents by 22% (Fasulo 2018). Despite GRTC' desire to pursue a ridership focused redesign, such a drastic decrease in service to low-income residents would have been untenable. In response to VCU's model, JWA conducted their own model of transit access for vulnerable populations and concluded that the proposed redesign would decrease service to low-income residents by just 2%, despite a significant decrease in network coverage (presumably, the decrease in service to higher income residents would have been much higher).

The discrepancies between VCU and JWA's respective models underscores how professional redesigns are often conducted based on subjective modeling and are not extensively backed by evidence of successful increases in ridership, operational efficiencies, or equitable access to transit.

Liu et al. conducted their own modeling of the proposed bus network in order to examine what caused the disparities between JWA and VCU's respective models (Liu et al 2022). They determined that VCU's model failed to account for the frequency of routes, and that their access model was run on a simplified street grid that lacked important pedestrian access points to bus stops.

The controversy caused by VCU's model captures the dialectical nature of redesign planning – agencies must make tradeoffs between service coverage and service frequency, and going too far in one direction or another could jeopardize the utility of their entire systems. In Richmond's case, planners and residents may have been comfortable with a 2% drop-in service to low-income residents in exchange for more frequent core service, but they would not have accepted a 22% drop. GRTC likely had no threshold set for acceptable drops in service to vulnerable communities, yet they knew that a 22% loss in service to underserved populations was unacceptable.

Difficult Assessments of Transit Accessibility

One of the only tools that planners have for guiding bus network redesigns is comparative accessibility modeling, where access to transit is measured before and after proposed changes. This is an invaluable tool for route simplification and frequency enhancements but may elide over socioeconomic complexities when deployed at scale. For several decades, transportation researchers have advocated for including non-spatial measures of personal accessibility on top of general geographic and financial constraints in accessibility models. However, non-spatial metrics have not been widely deployed in modeling used in bus network redesigns (Wachs and Kumagai 1973).

To improve on accessibility models based on generalized geographic impedance, researchers suggest incorporating individual-level constraints into accessibility models, layering factors including household size, vehicle access, and median income on top of conventional metrics of distance from and frequency of transit services (Geurs and van Wee 2004; Ryerson et al. 2022). These socioeconomic inputs can more realistically predict the way that riders will interact with similar transit services, given differing socioeconomic factors.

The widespread rollout of bus network redesign planning methods may complicate agencies' ability to build socioeconomically sensitive variables into their planning and communications process. Planners at SEPTA note how, during their bus network redesign process, their most important tool for communicating the effects of route changes to politicians and riders was Remix's *Jane* isochrone tool (Remix 2020). The tool allows a user to drop a rider, "Jane," anywhere they want on the map and see how far she could travel by transit and how many jobs she could reach from that spot, under different proposed service patterns. The tool's prominence across recent bus network redesigns highlights the continuing utility and allure of basic impedance accessibility models that fail to take into account accessibility models. Spatially derived accessibility models are both easier to build and share than models with non-spatial components. The critical importance of public communications in the bus network redesign process could cause complications for the rollout of those more complex models.

If planners were to build accessibility models that accounted for propensity to travel among socioeconomic clusters, an isochrone tool like *Jane* might indicate unexpected changes in accessibility that follow non-spatial parameters. Just because more of a region might be able to theoretically access more jobs from their home after a redesign, this doesn't mean riders will be likely to take advantage of those options if they have high rates of car ownership, wealth, and /or lack of interest in traveling to the newly accessible areas of the city.

Building complex accessibility models allows planners to equitably deliver transit service to communities across a region, given limited resources. There may be a reason to work towards maximizing physical accessibility across a region, especially in terms of ensuring that the most riders possible are offered frequent service, but is a luxury that inequitable, sprawling cities rarely have.

Firms working on bus network redesigns may be on the cusp of developing the kinds of accessibility models that would account for non-spatial determinants of accessibility. In an interview with Bethany Whitaker, Senior Principal and Nelson\Nygaard consulting associates, she explained how her firm develops “composite transit demand” maps or “transit propensity indexes” to share with clients (Whitaker 2024). These maps serve as additions to composite maps of employment and job density, and are labeled either with tiers of demand intensity, or even with theoretical transit service frequencies that areas can support. Though the variables that go into these maps are project – dependent, they often include poverty rate, zero-car households, and the rate of youth and elderly residents, among others. When overlaid with transit coverage, these maps highlight where areas with high demand are served by existing transit and where new investments

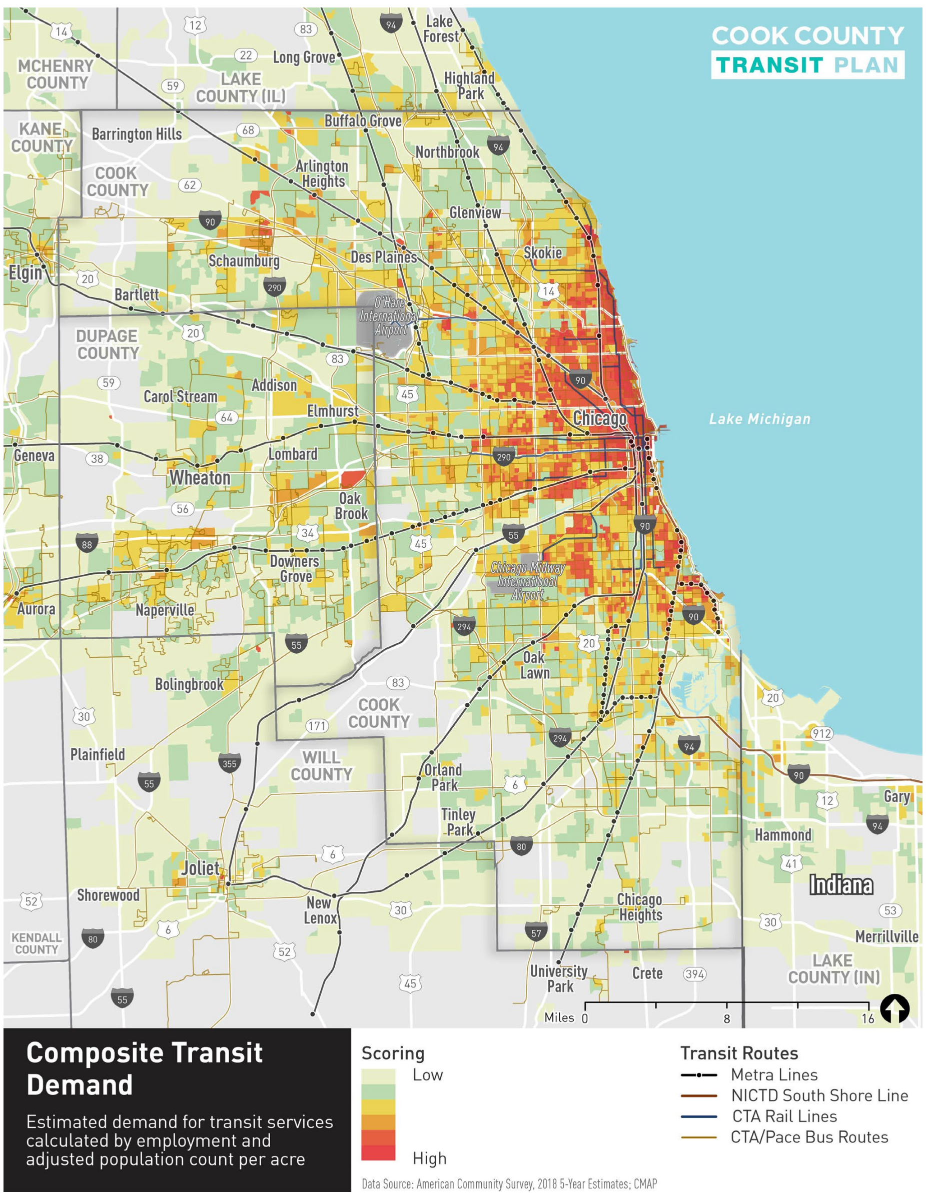


Figure 6 Example of non-spatial transit demand map

Source: Nelson/Nygaard and Associates for the 2023 Cook County Transportation Plan would be prudent. See Figure 5 for an example of these graphics. While this technique does not engage directly with residents' access to transit, it does show the way that non-spatial determinants of accessibility are used by professional planners in everyday practice. This may be a long-awaited realization of the vision that Wachs and Kumagai set forth decades ago.

Questionable Access Modeling in Columbus' Redesign

The Central Ohio Transit Authority's (COTA) 2017 bus network redesign and implementation of a bus rapid transit lines presents another opportunity for studying the way varied accessibility modeling can complicate the bus network redesign planning process. In a follow up to COTA's internal access modeling for the bus network redesign, Lee and Miller assess the proposed changes' specific effect on workers' access to both healthcare jobs and medical appointments in northeast Colombus. They conclude that "new public transit services do not always have intuitive outcomes," and that transit agencies need to perform "scientific investigation and planning… to avoid unintended consequences" when redesigning their systems (Lee and Miller 2018, pp 63).

To assess the impacts of COTA's redesign, Lee and Miller use a space-time model that takes into account route geography, timetables, access, and cost. This comprehensive approach likely exceeded the complexity of the geographic model used by COTA's consulting team (COTA 2017) and concluded that the redesign had an ambiguous impact on improvements to the service population's access to jobs and healthcare services.

By increasing the complexity of an analytical framework of transit, Lee and Miller devalued some of the key assumptions of transit planning, including that frequency and adjacency to large trip generators are some of the most important parts of transit planning. COTA's attempt to realign high-trafficked bus routes towards more commercial areas and away from preexisting travel patterns may have devalued their redesign under a space-time model.

Lee and Miller's study pays critical attention to the travel dynamics of existing underserved and carless population, but their methodology has some limitations that should be considered in future research. Their study only measures changes in the physical limits on accessibility; it does not take into account the possible behavioral changes that come along with bus routes running on simpler routes at higher frequency, even if those routes do not serve all job centers with the same coverage as before. In fact, one potential benefit of COTA's bus network redesign is to make the bus network more legible and reliable, hopefully leading to greater ridership. Weighting transit travel patterns that have been shaped by circuitous, unreliable routes will disfavor streamlining and increasing the frequency of those same routes.

Large institutions with homogenous land use, including medical facilities and schools, can appear underserved when routes are simplified so as to not go far out of their way to loop around campuses. This may have been the cause of Lee and Miller's observation that, "although [COTA's bus network redesign] intended to increase accessibility by providing frequent as well as consistent service, it was not clear that [it] offers better accessibility than the former bus system in the Linden neighborhood" (Lee and Miller 2018, p.62). This observation comes despite the slight tweak of the route and significant increase in frequency across off-peak and weekend service. Their model may weigh direct accessibility over frequency and service hour span. The dilemma of measuring the effectiveness of bus network redesigns evident in the COTA examples frames one of the essential dilemmas of the bus network redesign process: the ridership versus coverage debate.

Bus network redesign Essentials: Ridership versus Coverage

The coverage versus ridership debate may be the essential animating question of the contemporary practice of bus network redesign planning. The debate pits transit agencies' twin imperatives against each other: with the same fixed resources, agencies hope to serve as many riders as possible (ridership), while equitably providing public transit options across a region (coverage). Any given agency's answer to this question will dictate the shape, frequency, and spread of its network. Fortunately, the bus network redesign process provides space for agencies to tackle the issue head-on like no other transit planning method can.

Over the course of his book and blog, *Human Transit*, Jarrett Walker centers the ridership versus coverage debate to highlight the promise and contradictions inherent in the bus network redesign process. Walker details how US transit agencies must explicitly address the contradictory expectations for them to serve entire regions and high ridership numbers without increasing their budget. Walker explains how agencies will often "adopt both goals in some form but will never resolve the conflict between them," inadvertently "[hurling] their staff in opposite directions at once" (Walker 2024, pp. 121).

Walker suggests that transit agencies must delineate their respective commitments to coverage and ridership in order to exercise effective transportation planning. Using San Jose as an example, Walker shows how an agency might separate their systems into separate zones that with focuses on either ridership or coverage. During San Jose's bus network redesign process, Walker observed that, the Valley Transit Authority (VTA) dedicated 70% of their resources to routes in the system that focused on ridership and 30% of their resources on less frequent routes designed to bolster their regional coverage (Walker 2024, pp 129).

Though the ridership versus coverage debate is an overly simplified model for the trade-offs involved in the bus network redesign process, it lays out a satisfying equation for transit agencies to calculate as they move forward with their redesigns.

Walker's intuitive reduction of the main challenges in the bus network redesign process are corroborated by research into the effect of environmental factors on transit ridership. Several papers indicate that, among factors that have the greatest impact on transit ridership, only service provision is under the control of transit agencies (Lyons et al. 2017). This implies that, despite gas prices and density of trip generation laying outside the sphere of influence of transportation planners, service layout and service frequency still have significant impacts on transit ridership and must be actively managed if agencies hope to increase ridership and efficiency.

Transit ridership modeling on a national level indicates that route density is an essential third metric needed to bridge the gap between Walker's coverage and ridership models. Lyons et al., route density is a better indicator of increased systemwide ridership than route frequency (Lyons et al. 2017). This finding suggests that, if an agency were to lean too far into a focus on ridership, they would risk lowering the density of routes and negatively affecting ridership. Even the most frequent spine of transit needs to be supported by moderately frequent feeder routes to be a part of an effective transit network.

The ridership versus coverage debate is also a provide grounds for communicating transit planning considerations to ridership and other stakeholders. A stated preference survey of riders' desires for bus network interventions in Chattanooga, Tennessee indicated that "existing bus riders prefer the coverage scenario that provides access to more places but with lower frequency service and longer passenger waiting times. Non-riders usually prefer the ridership scenario with more frequent service" (Zeidan et al. 2021, pp 839). The ridership versus coverage debate is fruitful in part because groups across a transit network will perceive in many ways, based on their travel patterns, physical mobility, and preexisting relationship to transit. Bus routes can't provide perfect service to everyone, so highlighting riders' differing expectations for transit is essential for making informed, transparent decisions about how to allocate service within the constraints of limited operational budgets.

Critiques of bus network redesigns: optimistic transit planning or managed decline?

Some of the most robust engagement with bus network redesigns has been published in non-academic settings, including in lengthy newsletter posts, policy papers, and blogs. These documents oftentimes cast a critical gaze on bus network redesigns in a way that their academic equivalents do not. In a 2021 post on their personal blog, Alon Levy, a fellow at NYU's Marron Institute of Urban Management, framed bus network redesigns as "bus decline management," only months after publishing an official case study on Brooklyn's bus network redesign process called "Rebuilding Bus Ridership in America" (Levy 2021; Levy and Goldwyn 2020). Likewise, after Jarrett Walker + Associates' landmark work on Houston's 2015 bus network redesign, Walker addressed the system's 8% drop in weekday local bus service in a blog post where he explained the network's shift to higher weekend service and its integration with new rail services (Walker 2015).

Non-academic publications have been integral in shaping the professional discourse on bus network redesigns, and thus have made a direct impact on how bus network redesigns are implemented. At the same time, these publications allow for frank discussion of bus network redesigns that put their efficacy in perspective. These works often note that bus network redesigns are implemented out of necessity, due to falling ridership and limited operational budgets. Such writing often implies that bus network redesigns are a sign of ineffective institutions: where successful transit networks would be able to add service to meet demand and tweak routes to optimize for efficiency, floundering agencies throw the whole kitchen sink at the problems by resorting to a technique as drastic as a bus network redesign. Resorting to a bus network redesign implies that decades of prior transit planning was ineffective. Unfortunately, bus network redesigns change routes, but they do not necessarily change the role of transit for communities.

Bus network redesigns have the potential to save agencies money via improvements to operational efficiency. The question remains of what agencies will do with that money. They can reinvest in the system to further improve service, or they can use bus network redesigns purely as austerity measures. For example, AC Transit's ongoing *Realign* plan is designed to cut and redistribute service hours in the wake of Covid-19 induce travel pattern changes (Der 2024). Portrayed as a “cost-neutral plan,” the reality of inflation means that AC Transit’s bus network redesign will likely include significant cuts to service span and frequency. In this case, the optimistic techniques used in mid-2010s bus network redesigns are utilized for a plan that holds less promise for increase in transit ridership. There is a significant risk that agencies who are in desperate need of greater operational funds begin to turn to bus network redesigns for their cost-cutting potential. Just as the precursor techniques to bus network redesigns were used to trim networks in the last century, bus network redesigns can be used for that intention again.

Whatever an agency’s motivation or implementing a bus network redesign, it is unavoidable that bus networks are simultaneously the backbones and least efficient modes in our transit networks. While still wildly more efficient than cars, there is a chance that bus network redesigns treat bus networks as the panacea for our urban transit woes when, in reality, they are just one treatment. As Alon Levy explains, “all of these bus reforms – network redesigns, dedicated lanes, bus shelter, real-time information, signal priority – push back the decline, but they do not halt it. Eventually, something other than labor-intensive buses will be required, most likely some kind of light rail and subway combination as with the railstitutions happening here in Berlin or in Paris” (Levy 2021).

Chapter III: Summarizing the state of professional practice

Professional knowledge on bus network redesigns is spread across a network of planners who have been designing and implementing redesigns across the country. Much of this information is not included in academic or professional publications yet has been integral in shaping the way bus network redesigns are practiced. In this chapter, I compile my observations from interviews with planners who are actively working on bus network redesigns at consulting firms and cities. Their articulation of the history, methodology, and realities of working on bus network redesigns add political and social considerations to the literature review and quantitative analysis I completed in the preceding chapters. While these planners also work with equity modeling network performance analysis, their work is equally shaped by the relationships that cities have with their bus networks and by the political forces that affect them.

The transit planning community seems to generally cooperate in sharing ideas and techniques, but the necessarily competitive nature of the public contracting process may have contributed to a segmentation of transit planning knowledge across consulting firms. I hope that this work can bridge some of those divides by highlighting the techniques and theories shared by a variety of bus network redesign practitioners.

This chapter is divided into four themes that arose in my interviews. The first is that bus network redesigns exist in a continuum of transit planning processes. While bus network redesigns have been effectively branded as a separate technique in and of themselves, they emerged out of an existing transit planning practice that included pre-established long-range and strategic transit planning processes. Bus network redesigns also drew much of their methodology from previous disruptive periods in transit planning, including post WWII transit network collapses and restructuring surrounding the rollout of Great Society subways.

Second, I consider the insights that my interview subjects provided on the professional and political requirements for planning and implementing bus network redesigns. Bus network redesigns can be proposed and championed in numerous configurations, including as recommendations from a regular transit planning process, or as an initiative in and of themselves. Likewise, the impetus for bus network redesigns can come from cities, agencies, or consultancies. I summarize several of these processes, including for CapMetro in Austin, where a consultancy proposed a bus network redesign as a recommendation in a long-range transit plan, and in Philadelphia, where transit planners at the City first proposed a bus network redesign, before handing it off to SEPTA, the transit agency.

Third, I focus on the value of bus network redesigns for nurturing conversations about the value of transit services in American cities. My interviewees all emphasized how bus network redesigns are a powerful tool for helping transit agencies articulate why transit is important for their communities. Bus network redesign planning processes require transit agencies to make trade-offs that reflect their relative prioritization of ridership and coverage, along with equity and sustainability concerns. Transit agencies are seldom given the opportunity to simultaneously articulate and act upon their values. Bus network redesigns provide a space where that can happen. Jarrett Walker + Associates, who have completed dozens of bus network redesigns in the United States and abroad, make transit agencies' values articulation an essential part of their bus network redesign process. This technique ensures that transit agencies have clear, guiding principles to help with their redesigns. However, other planners who I spoke with discussed the difficulty of sticking to agency values when it comes time to draw the new bus lines. While bus network redesigns may be invaluable for pushing transit agencies to articulate their values, those values may not always find a clear manifestation in the resulting redesigned networks.

Finally, I summarize how the scale of community outreach for bus network redesign projects has increased dramatically in the recent past and will likely continue to increase in the future. There are several reasons why this could be the case. First, transit planners have an increased sensitivity to the effects of transportation planning on marginalized populations. Second, the increasing scale of bus network redesigns mean that changes are being made to larger networks that affect greater numbers of ridership and involve well-organized advocacy groups. This can result in drastically different sociopolitical conditions, compared to early bus network redesigns conducted in smaller transit markets. Regardless of the cause, the increased community outreach for recent bus network redesigns provides a platform for transit planners to restructure the way they interact with riders and stakeholders. In Philadelphia, for example, planners completed more than 200 community meetings between 2021 and 2024 for Bus Revolution, and my interview subjects reported their firms' increased emphasis on developing new, participatory planning exercises. These changes show how planners view bus network redesigns as collaborative projects, rather than as top-down exercises in maximizing the quantitative performance of their systems. Again, bus network redesigns show themselves to be critical tools for fostering discussions about transit, but do not always result in the specific changes that could affect broad-scale changes to local and regional mobility.

My interviews provide insight to the state of professional practice of bus network redesigns across the country. As the technique has gained purchase, more cities, firms, and planners have been involved in shaping the how bus network redesigns are implemented. The practice will continue to evolve in the future, as travel patterns and the built environment continue to change around our bus networks. Fortunately, bus network redesigns provide transit planners with a tool to be active participants and responders to those changes.

Interview methodology

I conducted four official interviews for this project among active transit planners with experience working on bus network redesign projects. Each of these interviews focused on topics that pertained to the interviewees' professional roles and all took place between February and April of 2024. Though I include several direct quotes from these interviews, this chapter focuses more on the general themes that the interviews revealed, rather than on the specific projects that the planners worked on.

Details on each interview are included in Table 4. Additionally, I have worked as an intern for both the City of Philadelphia's Office of Complete Streets and for Nelson\Nygaard Consulting Associates. These experiences gave me prior exposure to my interview subjects. While I hope future work on this topic will interact with a wider variety of experts, my connection to several of these interview subjects is one of the preconditions for this project. As an intern, I saw some of the work that went into bus network redesign projects, especially for SEPTA's Bus Revolution project through Philadelphia's Office of Complete Streets. Those experiences led me to this choice of subject matter, but also shaped by access to interview subjects.

Table 4 List of interview subjects

Participant	Affiliation	Title	Experience	Themes
James Gamez	Nelson\Nygaard, Seattle	Principal, Transit Sector Co-Lead	West and Midwest bus network redesigns, Cap Metro redesigns	COAs, TDPs and other adjacent transit plans; community outreach
Bethany Whitaker	Nelson\Nygaard, Boston	Senior Principal	East coast bus network redesigns, SEPTA Bus Revolution	Large-system bus network redesigns
Scudder Wagg	Jarrett Walker + Associates	Principal Associate	East coast redesigns, Richmond bus network redesign	Communicating values through transit planning, evaluating network performance
Chris Puchalsky	City of Philadelphia	Director of Policy and Strategic Initiatives, OTiS	Bus optimization, public policy, SEPTA Bus Revolution	Knowledge sharing, public outreach, political coordination
Andrew Simpson	City of Philadelphia	Complete Streets District Manager, Office of Complete Streets	City of Philadelphia Connects and 2020 Transportation Plan	Interview shared with Chris Puchalsky

Finding bus network redesigns' precursors

One of the questions I asked my interview subjects was, "are bus network redesigns a *new* planning technique?" I knew this was a loaded question. Of course, no technique is entirely new, but much of the popular presentation of bus network redesigns presents them as a novel approach to transit planning (Olin 2020). Consultancies and cities may have limited incentive to dispel the newness of bus network redesigns, as this can be helpful in framing their planning as innovative. In response to my question, interview subjects responded with insightful observations of how bus network redesigns emerged from previous planning techniques by utilizing preexisting methodology to achieve different results. Specifically, they explained that the route planning techniques they use in bus network redesigns were developed by management consultants and route planners tasked with cutting service during the long decline of public transit after WWII. However, those same techniques that were once used to identify which services to cut have recently been used to reinvigorate bus networks in our cities. Bus network redesigns are the appropriation of reimagined, if not new transit planning techniques for use in 21st century cities.

Contemporary transit network planning emerged in the 20th century, as urban mass transit systems morphed from agglomerations of competing private transit services to interconnected, publicly run networks. For the first time, urban mass transit could be operated as a strategic service, rather than as a cut-throat business. Unfortunately, the reason for this change was the rapid rise of car culture and de-urbanization after WWII. So, despite the benefits associated with the centralized transit planning, newly minted agencies were generally only in positions to cut lines, to reduce frequency, and to remove rail operations from city streets.

These lean years for transit required agencies and consultants to develop network-wide planning tools to make the most out of declining funding. First Transit, a transportation planning and operations firm founded in 1955, was one of the most influential shapers of these new transit management techniques. First Transit pioneered the comprehensive operational analysis (COA) technique, which approached transit planning from the network scale (Wittmann 2024). To some practitioners, COAs remain synonymous with bus network redesigns. First Transit would go on to run over 300 transit services in the United States, including many city transit networks, yellow school bus systems, and Coach buses. The company was bought by the French conglomerate TransDev in 2023, and the brand was retired (First Transit 2022; Mass Transit 2023).

While there is no direct through-line from First Transit to bus network redesigns, First Transit is an important example of the kinds of companies and consultants that came to influence mid-century transit planning. These companies were tasked with turning the rapid decline of American mass transit into profitable, or at least stable, entities. This shift pushed agencies to evaluate transit services based on a new paradigm, where state and federal subsidies could support lifeline sources instead of mandating profitability (Bloom 2023).

After the long decline of transit, there were some rumblings of a Great Society renaissance, with new funds going to urban rail across the country. The broad success of these rail projects, including in the Bay Area, Washington, DC, Atlanta, and Baltimore were met with bus restructuring that was designed to complement the new rail services. While these efforts were often insufficient to take full advantage of modern rail services, they helped agencies think wholistically about the purpose of the extant transit networks (Bloom 2023). New rail services cast extant bus lines in relief as integral cogs of the regional transit network.

One of these Great Society induced redesigns was Miami's Network '86 plan. The plan was designed to adapt the Miami region's bus network to an expanding rail transit system, which saw the opening of the first line of the Miami Metro in 1984 and the Miami people mover in 1986 (Krishnaiyer 2016). For the first time in a generation, Miami and other cities were expanding bus transit options, and their bus networks had to change in kind. Techniques honed for austerity planning were useful for redistributing networks to serve newly opened rail services.

Similar processes were influential in developing the necessary transit planning tools for bus network redesigns, including the restructuring of bus networks to serve a boom in light rail construction, which saw systems open in San Deigo (1980), Portland (1986), and Dallas (1996), among many other cities over the next several decades. The regular expansion of Portland's MAX system over the 1990s and 2000s resulted in a cluster of bus network realignments. For example, the fall 2015 opening of the MAX Orange Line over the transit only Tilikum Crossing bridge resulted in realignment of several bus routes serving Downton Portland from Southeast and Milwaukee (MacKinnon 2012). Though Portland's light rail restructurings are not full bus network redesigns on the scale of what I measure in this project, they are evidence of the contemporaneous venues where transit planners developed and exhibited the network planning skills that would be used across the country in short order.

Scudder Wagg, of Jarrett Walker + Associates, explained to me that his firm cites both Miami's Network '86 and Portland's light-rail induced redesigns as precursors to their bus network redesign process (Wagg 2024). However, when JWA worked on Houston's 2015, bus network redesign, they portrayed their techniques as a novel discovery in transit planning that proved how inefficiencies in bus networks were keeping cities from reaching their full transit potential. In the lead up to the project's approval, Jarrett Walker characterized his firm's work in a way that emphasized the novelty of the technique and aimed at expansion to new markets. In a blog post titled "houston (sic) transit: reimagined," Walker wrote, "if you suspect that transit could be doing more in your city, read all about the Houston plan. You'll be amazed, as we were, about how much is sometimes possible" (Walker 2014). JWA's approach to network planning may have utilized pre-established transit planning techniques, but its results showed that techniques designed for transit's decline could be used for its resurgence. The Houston redesigned cut underperforming routes, concentrated service on the densest corridors, and encouraged transfers between bus routes and between bus and light rail. JWA saw that their redesigned allowed Houston METRO to run more useful service without increasing their number of service hours (Walker 2014). The excitement that followed this realization may have been the critical spark for the ensuing proliferation of bus network redesigns across the country.

If current bus network redesigns remain closely linked to previous network restructurings, then question remains of when to start counting large network restructurings as bus network redesigns. One candidate could be Madison, Wisconsin's 1998 change to a radial, transfer-based network (Madison Metro Transit 2019). However, every planner I spoke with cited Houston's 2015 redesign as a watershed moment for the practice, even though it was not the first to be implemented. For my purposes, I don't include Madison's 1998 redesign (although I do note their 2023 redesign), and don't start with Houston either. Instead, I use Jacksonville's 2014 redesign as a starting point, as it was a complete network restructuring the took place in the same era as Houston's, even if it received less media and professional attention. What is more important is that all the planers I spoke with noted how, on or about the time of Houston's redesign, transit network planning changed.

The importance of state transit planning requirements

Through this work, it became evident that bus network redesigns cluster in certain areas of the country, including among medium sized cities in California, in Wisconsin, and across the great plains. While agencies who undertake bus network redesigns may be influenced by regional peers, my interview subjects noted that many of these bus network redesign clusters are the result of state transit reporting policies.

States generally require transit agencies to complete strategic transit planning processes in order to receive state funding, much as transit agencies also report to the FTA as a prerequisite for receiving federal money. However, the scale of required planning processes in some states may lend them towards undertaking bus network redesigns. Wisconsin's State Code includes a section that clearly articulates "administrative policies and procedures for implementing [an] urban mass transit operating assistance program" (Wisconsin § 4.01). This guidance includes the mandated completion of a Transit Development Program (TDP) every four-years by all of the state's publicly supported transit operators (Wisconsin § 4.09). The code goes so far as to clarify that all TDPs need to include measures and goals for:

(a) The ratio of passengers, as expressed in unlinked trips to service area population.

(b) The ratio of operating expenses to passengers, as expressed in unlinked trips.
(c) The ratio of operating expenses to revenue hours.
(d) The ratio of revenues to operating expenses.
(e) The ratio of passengers, as expressed in unlinked trips, to revenue hours.
(f) The ratio of revenue hours to service area population.

This clear guidance may have been influential in establishing Wisconsin as a prime candidate for bus network redesigns. Madison, Wisconsin completed one of the first modern incarnations of a bus network redesign in 1998, and then completed a second bus network redesign in 2023. Milwaukee completed a bus network redesign in 2024.

Wisconsin's state mandated TDP requirements are fertile grounds for bus network redesigns both because they give agencies regular opportunities to assess the state of their systems and because they ask that agencies specifically assess the kind of metrics that bus network redesigns can be effective at addressing, including, as I measure in Chapter IV, unlinked passenger trips per vehicle revenue hours.

By comparison, a state like New York, where I have observed no completed bus network redesigns outside of New York City, has no clear state level guidance about what should be included in a transportation plan, or how often such a plan should be updated. While the capitol region's CDTA published a Transportation Development plan roughly once a decade (CDTA 2024), Buffalo's NFTA has no standardized strategic planning process (NFTA 2024), and New York's outsized MTA releases a variety of non-standardized strategic plans across its myriad transit operators (MTA 2024).

These varied regional practices and state reporting requirements result in a spectrum of terms with locally specific meanings. I clarify some of these distinction in Table 5. Some existing literature uses my preferred "BNR" acronym, but many planners talk about "bus network redesigns" or "comprehensive bus network redesigns" (Liu et al. 2023, Byala et al. 2019). One competing acronym for the process is "transit system redesign," or "TSR," but I opted for the BNR moniker to indicate the importance of bus networks to the practice (Lee and Miller 2018). Another significant trend in bus network redesigns nomenclature is the usage of specific branded names for bus network redesign projects. Not all agencies develop these brands, usage usually stresses the newness and transformation of the bus network redesign process – SEPTA's "Bus Revolution," Cap Metros "Cap Remap," Cleveland's "Next Gen," etc. Other similar processes include Transit First's

"Comprehensive Operational Analysis" (commonly used by firm Nelson/Nygaard), and the various transit plans mandated by state statutes.

Table 5 bus network redesign equivalent terminology

Term	Era	Purpose	Notes
Bus Network Redesign (BNR)	Early 2000s – present	Blank slate redesign of transit network. General term.	Promoted by Jarrett Walker + Associates
City specific brandings: Bus Revolution (SEPTA), Cap Remap (Cap Metro), Next Gen (GCRTA)	Mid 2010s - present	Locally specific project name to brand network redesign initiatives	Not used in all BNR projects. Often accompanied by project specific websites and other branded materials.
Comprehensive Operational Analysis (COA)	Mid-century - present	Wholistic assessment of transit services, can include BNR-like elements	Term currently used by Nelson\Nygaard Consulting Associates
Regional Transportation Plan/ Transit development program	Mid-century - present	Standardize planning processes for state tax-payer support transit services	See California § 65080 and Wisconsin § 4.09.4a

How bus network redesigns come into being: city, agency, consultancy

Transit agencies do not always take the initiative to pursue bus network redesigns on their own. Often, and especially in the earlier years of the practice, consultants and regional partners encouraged agencies to pursue the projects. This relationship has increased the influence of consultants on the spread of bus network redesigns and has allowed other planning entities including city governments, MPOs, and advocacy groups to become involved in the practice of bus network redesigns.

As articulated by one of my interview participants, "it's hard for a transit agency to come to the realization on their own that their service is broken because they spend most of their professional time making the sorts of adaptations to their network and optimizations [that made it dysfunctional] in the first place" (2024). Transit agencies' skewed perceptions of their own networks can make interactions with external planners especially transformative. Bus networks are the manifestations of myriad social, political, and logistical decisions that build something which may not serve the best interests of its users. Two examples of this process include that of an early bus network redesign-like process undertaken by Cap Metro in Austin, which was instigated by an outside consultancy, and of SEPTA's Bus Revolution in Philadelphia, which started as an internal suggestion made by the City of Philadelphia.

In the case of Cap Metro, the outside firm Perteet Inc was contracted to complete a COA (see Table 5) for Austin's bus routes (Nichols 2010). I do not count this restructuring as a complete bus network redesign, as it only affected a subset of the agency's routes, but the process introduced Cap Metro to a new way of thinking about their network (Olivieri 2013). James Gamez, now a principal at Nelson\Nygaard Consulting Associates, was the Principal Planner for Cap Metro at the time. He explained to me that the consultant who completed their COA opened the agency up to a new way of thinking about their bus network. Gamez recalled that, before their COA process, Cap Metro's "focus had been how to refine schedules, how to adjust routes to meet things like new developments or requests for new service, but less so just taking a blank slate approach. The COA gave [Cap Metro] the understanding to take a step back and examine a lot of additional subjects and think about how the network should look and how it should evolve over time" (Gamez 2024).

Cap Metro's 2013 restructuring is perhaps more indicative of the early stages of the bus network redesign boom. Before Houston's high-profile redesign, few agencies knew that they could think of the structure of their entire bus networks as malleable. This way of thinking was more common in consulting spaces, where planners and management analysts were comfortable assessing the high-level performance of transit networks. However, only five years after their 2013 restructuring, Cap Metro implemented *Cap Remap*, their "most significant bus network overhaul ever," according to then CEO Randy Clarke (Pritchard 2018). After being introduced to methods of thinking wholistically about their network by Perteet, Cap Metro soon joined the movement of large agencies completing full bus network redesigns.

In contrast to Cap Metro's redesign, SEPTA's ongoing Bus Revolution process was initiated by planners at the City of Philadelphia, who were working on two transit plans in the late 2010s, the short term *Connect*, and the long-range *Philadelphia Transportation Plan*. The two plans gave transit planners at the City's Office of Transportation, Infrastructure, and Sustainability (OTiS) the chance to put national best practices in front of SEPTA, a transit agency that had made few changes to its bus network for decades. Chris Puchalsky, Director of Policy and Strategic Initiatives at OTiS, explains how planners at the City were excited to join ranks of national peers who were using bus network redesigns to improve their bus networks. The planners at OTiS were "sold on this idea that yes, there's big problems and we think we can fix it. Houston had done it. It worked in other places. And so we did a lot of in selling here at the city, got past people's nervousness and then we talked to SEPTA" (Puchalsky 2024).

Where Cap Metro was led to a bus network redesign after hiring a consultant to complete a more standard COA process, SEPTA had the idea brought to them by their own public sector partners. This difference underscores the way that information about bus network redesigns was disseminated over the 2010s. By the Covid-19 Pandemic, "Houston's redesign" was a household name among transit planners and the impetus for network-scale wholistic planning processes could be initiated from the public sector, from activists, or from consultants.

Puchalsky and Andrew Simpson, a Complete Streets District Manager at OTiS, stressed that, after their introduction of a bus network redesign for SEPTA in a strategic transportation plan for the City, it took significant buy-in from SEPTA to implement the project. Puchalsky and Simpson credit Leslie Richards' appointment as General Manager and CEO of SEPTA in 2020 as a pivotal moment for the project. In the early stages of her tenure, Richards saw Bus Revolution as a signature project she could "grab onto" to jump start her administration (Puchalsky 2024). Richards replaced Jeffery Knueppel, a 30-year SEPTA employee who was trained as an engineer and focused his administration on system state of good repair and engineering concerns (Laughlin 2019). Richards' comparative outside perspective and training as a planner were a convenient match for the City's bus network redesign plan.

Despite the differences between Philadelphia and Austin's respective approaches to their bus network redesigns, they share a through-line of consultant influence in shaping the spread of knowledge on the practice. Incidentally, planners at OTiS began to develop their proposal for SEPTA after seeing Jarrett Walker give a lecture at the University of Pennsylvania in 2016. Walker spoke about his approach to transit planning, and assessed Philadelphia's need for more robust circumferential routes, to complement their established grid network (Saksa 2016). Jarrett Walker's predictable appearance at the instigation of a bus network redesign highlights the way that a national ecosystem of planners and firms enabled bus network redesigns to crop up in a variety of settings.

Bus network redesigns for communicating and acting on agency values

Aside from the economic and efficiencies that come along with successfully implementing bus network redesigns, the process allows transit agencies to carve out space for discussions about the value of mass transit in their communities. Establishing normative expectations for transit service is an essential part of the bus network redesign process.

In my conversation with Scudder Wagg, Principal Associate at Jarrett Walker + Associates (JWA), Wagg described how his firm's bus network redesign process was built off a concern that "value choices were hidden in transportation planning processes" (Wagg 2024). JWA's approach to bus network redesign planning is designed to break transit agencies out of long-held expectations for transit operations, to "very intentionally try to raise the value choices that are independent of the technical issues in [bus network redesign] processes" (Wagg 2024). Their approach treats transit service as much as a practice of social theory as of engineering. JWA's unique approach may be influenced by Jarrett Walker, the firm's Founder and CEO, who completed a PhD in drama and wrote his dissertation on Shakespeare's *Coriolanus* (Walker 1996). Walker's background in the humanities may be a critical grounding force in JWA's ability to guide firms towards humanist, theoretical discussions that are not always at the forefront of transit planning.

One of the benefits of the values-based transit planning articulated by JWA's Scudder Wagg is that such conversations can often make clear values that transportation agencies already had. The associated benefits of this process include that agencies can avoid being judged based on metrics that they never set out to meet. No agencies in the United States attempt to maximize ridership on all their lines, yet nearly all agencies are maligned for having "underperforming" routes that fail to move a nebulous expectation for critical mass. Wagg explained that "the worst thing in the world is when an agency is constantly being judged on its ridership when we all know implicitly half the service isn't really oriented towards ridership, but no one has explicitly written that down in policy" (Wagg 2024).

JWA's careful attention to agencies' values was not unique among the bus network redesign practitioners I spoke with. James Gamez, of Nelson/Nygaard spoke about how clarifying goals and communicating them is a key part of bus network redesigns. Gamez explained that, "during the kickoff, we're already talking about, how do we want to message this? What do we see come out of it? What are the key goals from the board and staff, and how do we make sure that that fits into that project name and brand?” (Gamez 2024) This emphasis on establishing goals from the outset and integrating them into the communications about the projects dovetails with increases in community engagement, the final key theme that came out of my interviews.

Despite planners’ laudable push to help agencies articulate their values, translating those values into tangible network interventions does not always come smoothly. Bethany Whitaker, who worked on several bus network redesigns on the east coast, explained that agencies’ goals are often out of sync with their financial constraints. Whitaker notes that it can even feel like an “unforced error” when agencies are unable to meet the goals they set due to cost-neutral redesigns processes (Whitaker 2024). In the case of SEPTA’s Bus Revolution, planners recalled the overwhelming difficulty of working within cost-neutral budget constraints meant that questions of service hours and route feasibility dominated planning discussions, rather than the original aims of the Bus Revolution project (Puchalsky 2024; Simpson 2024). SEPTA’s Bus Revolution proposal was also shaped by three successive revisions that left their proposed network looking progressively more similar to their original network. While bus network redesigns provide strong foundations for agencies to reflect on and articulate their service values, actually acting on those values remains as difficult as always, especially with budgetary restrictions.

Bus network redesigns and community outreach

The final theme I discuss in this chapter is the increased volume of community engagement being performed in the bus network redesign process. This change may be the result of contemporaneous shifts in the city planning field generally, and in the increasing scale of bus network redesign projects more specifically. First, period from the mid-2010s to early 2020s is characterized by an increased focus on racial and social justice, first in response to national political trends, then to the Black Lives Matter protests of 2020. Second, as the scale of bus network redesigns has increased, so has the intensity of communities’ relationships with their transit services. Even Houston, one of the biggest cities to have completed a bus network redesign so far, sees just one-third of the daily ridership of SEPTA of the MBTA, which are currently completing bus network redesigns. This increased scale has pushed consultants and cities to intensify their outreach for bus network redesigns and has stretched the timeline of projects from a few months to a few years.

The increased scale of bus network redesigns has added several complexities to the planning and implementation process. With cities like Houston and Boston as pioneers, planners developed strategies for scaling-up bus network changes, from peel-off signage to education campaigns. At the foundation of these strategies is a scaled-up version of the community outreach used for earlier systems.

The growing scale of bus network redesigns has also complicated the existing dynamic between consultancies and transit agencies. Whereas the contemporary practice of bus network redesigns was forged through consultants suggesting bus network redesigns as a component of strategic transit plans, large cities behave differently. For a city like Philadelphia, where there are dozens of public sector transit planners between SEPTA and the City's Office of Transportation, Infrastructure, and Sustainability, consultants were used for their experience, but not for their guidance in the same way.

Likewise, larger cities see that outside consultants are less capable of developing the kind of local knowledge needed to propose plausible network solutions. For example, the first draft recommendation for SEPTA's Bus Revolution in fall 2022 included the elimination of SEPTA's Route 49, a bus route that had only been added to the system three years earlier (SEPTA 2024). Route 49 connects neighborhoods on the fringe of Center City to academic and medical jobs centers in University City and was the first route added to SEPTA's bus network in over decade (Penn PPSA 2019). When consultants Nelson/Nygaard approached a redesign of SEPTA's bus network, the 49 was an easy cut – its termini are already connected to the city's integral rail lines by frequent bus service and the 49 has a penchant for getting stuck in traffic as it meanders past 30th St Station and the University City hospitals (Whitaker 2024). Outside consultants had a limited appreciation or the warren of rail yards, highways, and riverfront that isolates University City from surrounding neighborhoods and of the crisis of antisocial behavior that plagued SEPTA's Market Frankford Line (El) in the post-Pandemic recovery (Torrejón et al. 2023). It was affront to University City employees that their access to a one-seat rider to work would have been so short lived, and that their commutes would now involve unreliable transfers to the much maligned, tobacco smoke infused El. The 49 was added back into the network by the second draft network, released in spring 2023 (SEPTA 2024).

The uproar over Route 49 was only one of a handful of proposed changes that caused an uproar in SEPTA's bus network redesign process. The public outreach that followed underscores the trend towards increased public outreach as a feature of bus network redesigns for larger transit agencies. In the two years after SEPTA released their first draft network, SEPTA staff and outreach consultants completed 178 individual public events and collected over 20,000 online surveys (SEPTA 2024). The scale of their public outreach dwarfed that completed for any prior project. However, in February 2024, when the SEPTA Board moved towards approving the Bus Revolution, they were met by a barrage of criticism from City Councilmembers who accused them of completing inadequate outreach (Zisk 2024; Gilmore Richardson 2024). At the time of this thesis, SEPTA is in the process of completing further outreach sessions, two years after their first proposed implementation date.

Public outreach for bus network redesigns has also been bolstered by the development of key mapping tools that have improved planners' ability to communicate changes to riders. First and foremost, the software Remix has allowed planners to incorporate interactive maps of alternatives into outreach materials in ways that would not have been possible over five years ago. Remix has transformed the bus network planning field, where, according to their own promotional materials, "before Remix, [route planning] required a bunch of different tools. You might use an Excel model to figure out costs, then physically draw things out on graph paper. Drafting a complex route could take a week of work. Remix lets planners do the same thing in a matter of minutes" (Remix 2024). Now owned by Via ("the world's most powerful digital infrastructure for public transportation"), Remix has become a ubiquitous tool both in transit planning and communications (Via 2024; Korosec 2021). Their interactive isochrone tool, "Jane," allows users to drop a figure onto maps to see changes in spatial accessibility in different network scenarios.

The authors of TCRP 221 conclude that, "there is no such thing as too much outreach, engagement, and communication when planning and implementing a bus network redesign" (Byala et al. 2021). However, SEPTA's extensive public outreach process shows the way that the high expectations for community outreach have caused perpetual delays for the project, preventing riders from accessing otherwise attainable service benefits. As Chirs Puchalsky, who was involved in Bus Revolution for the City of Philadelphia notes, the project "had more public engagement than any public works project in Philadelphia ever … I can't think of one [project] that's had more public discussion, more meetings, more survey results … more deliberation." However, Bus Revolution continues to be plagued by criticism that riders and their city council members didn't know about the routes. In April 2024, when SEPTA shared its latest final draft network for Bus Revolution, council member's districts were included on the map, perhaps in a nod to the extent that jockeying over Bus Revolution had become an active arena for Philadelphia politicians (SEPTA 2024). Changing bus routes is a disruptive event in the lives of transit riders and others in a city. Bus network redesigns ask that planners and riders take on this challenge, the likes of which no amount of community engagement can fully prepare for.

Chapter IV. Data Review

I find no statistical difference in performance between agencies that completed bus network redesigns treatments and their untreated peers. However, my analysis provides a framework for measuring the effects of bus network redesigns as more redesigns are completed and more years of data are made available.

In this chapter, I discuss my methodology for measuring the treatment effect of bus network redesigns, including my use of National Transit Database (NTD) metrics, peer city selection via k-means clustering, and treatment effect analysis using a difference-in-difference methodology. I find that there are weak positive associations between bus network redesigns and increases in yearly unlinked passenger trips (UPT) and UPT per vehicle revenue hours (UPT/VRH). These associations have high standard errors that suggest significant variance in treatment effects between treated agencies. My only statistically significant finding is of a 3.1 increase in UPT/VRH for treated agencies after three years. This individual significant finding indicates that the efficiency benefits of bus network redesigns may be delayed for several years after implementation.

To complement my linear models, I generate difference-and-difference estimations for UPT and for UPT/VRH. I find slight average increases in network performance after redesigns, again with large standard errors that suggest diverging trends in treatment effects. When disaggregated, I find that some agencies stand out for their performance relative to peers, including Richmond, Austin, and Cleveland who gained UPT and Orange County and Omaha, who lost UPT. Surprisingly, I observe that, while Richmond and Austin were among those that gained the most UPT/VRH compared to peers, Orange County was as well. This suggests that Orange County's redesign may have included a reduction in total service hours, which should be accounted for in future models.

My findings may be a key resource for evaluating the ability of bus network redesigns to improve the overall performance of bus networks. While the irregular implementation of bus network redesigns makes it unwise to directly compare treatments to one another, the relative improvement of select redesigned networks to untreated peers can be a guiding motivation for future bus network redesigns and for further study of the technique. This methodology can also be used to trace the effects of the more than one dozen bus network redesigns that are slated for implementation in the near future. Whether or not it is prudent to evaluate bus network redesigns quantitatively, network redesigns are touted as a tool for righting ridership losses and improving operational efficiencies. It is important that they be evaluated on those metrics.

To conclude the chapter, I consider how variables for the scale of change in bus route miles, change in concentration of vehicle revenue hours per route, and change in average speed across all routes should be important metrics for characterizing the types of interventions made in each bus network redesign.

NTD Data and Evaluation Metrics

The data I use for the project comes from the National Transit Database (NTD), the primary compiler of transportation data for the Federal Transportation Administration (FTA). Over 850 transportation providers report their data directly to the NTD, which makes the data readily available to the public (FTA 2015). Transit agency data is an essential tool for the FTA to apportion billions of dollars of annual federal funds to agencies and is thus a regular and reliable source of data to use for broadly assessing the performance of transit system in the United States.

For my data analysis, I use the "Service Data and Operating Expenses Time Series by Mode" data set from the NTD's 2021 Time Series data (FTA 2022). This dataset includes key operating metrics for every transit agency in the United States from 1991 to 2021, including their operating expenses, fare collection, passengers served, and vehicle miles operated. Together, these data points allow for coarse time series analysis of United States transit agencies based on yearly changes.

I extensively utilize the unliked passenger trip (UPT), passenger miles traveled (PMT), and vehicle revenue hours (VRH) metrics from the NTD Time series data to gauge the performance of transit agencies. I also combine these metrics to evaluate unliked passenger trips per vehicle revenue mile (UPT/VRH and PMT/VRH) as a metric of transit agencies' operational efficiencies. These metrics provide a proscribed view of what makes a transit agency more or less successful, but they are invaluable tools for making generalizations about agencies' trends in ridership and operational practices.

I decided to use these metrics after discussions with transit planners, including those interviewed in Chapter III. Their guidance helped me select metrics that are the most generalizable across transit agencies. I decided to avoid including any metrics related to operating costs due to the variable wages and reporting methods between agencies and to avoid any measures of distance traveled (either in passenger miles or vehicle miles), as these metrics vary widely depending on the built environment in agencies' service areas. Compared to vehicle or passenger miles, I found that measuring vehicle hours was a more reliable comparison between agencies, as it remains constant between services, regardless of how far a vehicle ran or how expensive it was to operate. Likewise, I recognize the utility of UPT as a base measurement of service but am wary of its downsides. Unlinked passenger trips are the easiest way to measure ridership, but it does a poor job of capturing transfers between services, which can be a key design feature of redesigned networks. Unfortunately, data for linked passenger trips does not exist on a broad enough scale for use in this project.

Elevated values for UPT and UPT/VRH do not mean that one transit agency is more successful than another. For example, transit systems that are designed to encourage rider transfers between modes will necessarily generate higher UPT figures than a system that is designed to provide more one-seat-rides across its service areas (Grisé et al. 2021). Likewise, if an ambitious transit agency were to expand its coverage or provide more express bus service across a region, it is likely that its UPT/VRH could decrease, despite an increase in accessibility by other metrics. Both of these scenarios play out regularly in every transit service planning. Nevertheless, my interest in pursuing this study of bus network redesigns is grounded in a curiosity for whether or not such a transit planning method can *improve* a transit system. There are many ways to observe improvement, some qualitative and some quantitative, and assessing changes in UPT, PMT, and VRH are just one strategy.

The reason why I center my quantitative analysis around those values, despite their downsides, is that, relative to peers, successful transit agencies should see positive trends in total ridership, ridership miles, and efficiency when they run a system that is useful, appealing, and convenient to riders (Taylor and Fink 2013). Despite the negative relationship between expanding service coverage and UPT/VRH, if that expanded service improved the overall utility of a transit system, then the consequential increases in UPT should outweigh the downsides of expanded coverage. Likewise, measures of PMT should increase in those scenarios, so the effect should be visible within my analysis.

Aggregating Modes from the NTD Time Series Data

This project is focused on studying bus networks, yet NTD time series data contains metrics for several different kinds of bus service, rail service, and microtransit. In my analysis, I only consider metrics for bus modes, despite knowing the limitations of this decision. Over my study period, several transit agencies introduced rail services that supplemented and supplanted existing bus services. Likewise, transit agencies often reclassify bus service when they introduce new commuter, rapid, or express bus routes. It is impossible to isolate bus ridership dynamics alone when they are intertwined with other modes of transit service. When I refer to bus network metrics in this project, I refer to the aggregation of the following NTD modes classifications: “Motorbus,” “Rapid Bus,” “Commuter Bus,” and “Trolley Bus.” I filter out “Demand Response,” “Heavy Rail,” “Light Rail,” and “Commuter Rail.”

My decision to only measure bus ridership precludes my ability to measure the symbiotic effects of rail and bus systems. However, since this project focuses on bus network redesigns, it seems most prudent to avoid measures of rail ridership. An instance where this causes problems is with Houston’s 2015 bus network redesign. Despite widespread acclaim for Houston’s bus network planning, few discuss the relevant light rail extensions that opened on Houston’s Purple and Green lines in 2015 (Houston METRO 2014). Those light rail openings both drove existing bus riders and new transit riders to rail services and coordinated with newly designed routes from the bus network redesign. From 2015 to 2016, bus ridership in Houston went up by just 1.2%, from 66.5 million UPT to 67.3 million UPT. Meanwhile, total ridership, including bus and rail, went up by 4.5%, from 86.1 million UPT to 89.0 million UPT. Isolating Houston’s bus network from its rail network diminishes the NTD data’s ability to characterize transit ridership in the city but is necessary for this project. Figure 7 and Figure 8 show how, when Houston METRO’s UPT is measured for buses alone, it exhibits only a slight increase after the 2015 bus network redesign (marked with a dashed line). Meanwhile, when UPT is viewed for all modes combined, Houston’s post bus network redesign performance stands out among peers, most of whom exhibit declining UPT in the late 2010s. Despite the positive overall ridership trends Houston exhibited over the same era, my analysis ultimately only considers the bus network trends, which are still positive, although not as dramatic.

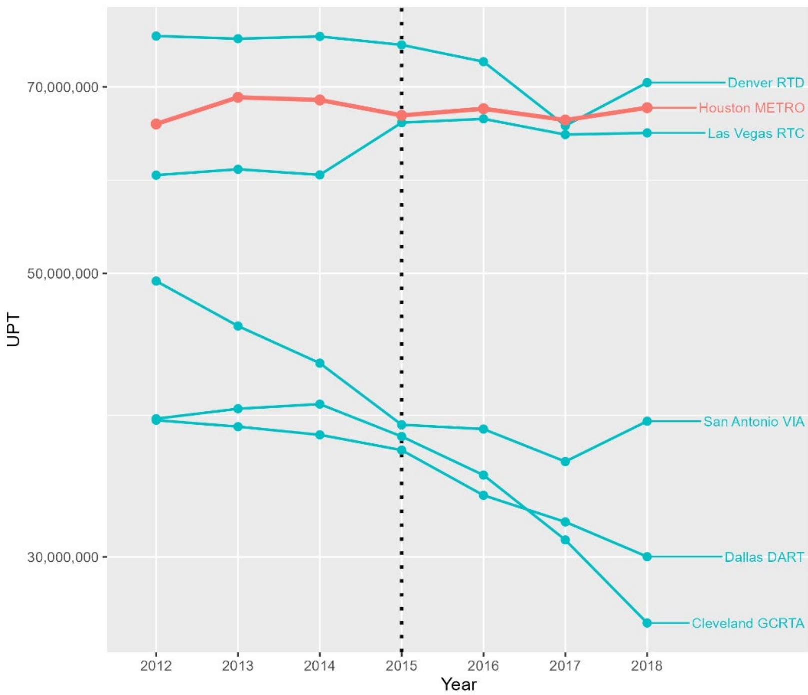


Figure 8 Change in UPT for bus modes only modes, Houston and peers

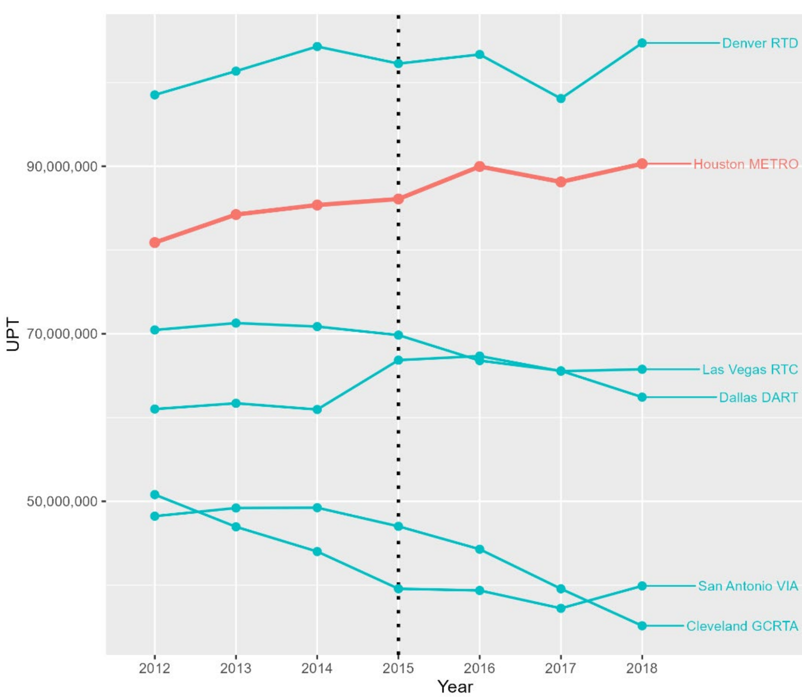


Figure 8 Change in UPT for all modes for Houston and peers

Clustering Transit Agencies for Analysis

To assess the treatment effects of bus network redesigns, I pair treated networks with peer agencies. I used a two-fold approach to assign peers seven peer networks to each redesigned system. First, I selected five quantitative peers using a k-means clustering technique, then I assigned two regional peers, regardless of agency characteristics. Through these methods, I attempted to build an unbiased pool of peers to compare against while still capturing the regional dynamics of travel via public transit. See Appendix for a list of agencies and matched peers.

I use an unsupervised k-means clustering analysis to identify clusters of transit agencies based on their 2019 values for unlinked passenger trips, vehicle revenue miles, total operating

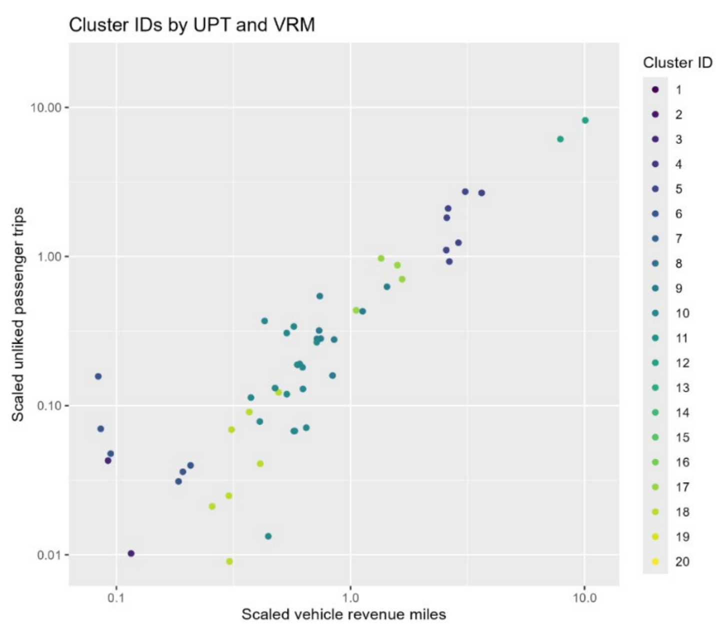
Table 6 K-means clustering group summary statistics

K-Means Cluster Characteristics

Source: NTD

		2019 Mean		
CLUSTER ID	N	UPT (X10,000)	VRH	TOTAL OP. EXP.
1	60	132	74,384	6,869,864
2	1	224,545	31,166,743	4,144,330,477
3	17	1,295	740,881	88,995,576
4	22	611	387,216	53,325,536
5	7	23,444	6,389,580	1,075,543,362
6	15	1,686	778,593	138,253,514
7	33	275	195,856	19,720,463
8	10	849	315,817	35,949,854
9	8	6,195	2,375,027	309,791,872
10	16	3,786	1,655,176	251,594,215
11	36	227	140,214	18,043,262
12	2	87,958	18,905,533	3,829,799,128
13	8	650	168,291	15,221,595
14	75	62	43,658	4,153,736
15	42	181	106,569	11,366,670
16	18	996	512,267	70,528,838
17	4	10,797	3,431,795	775,739,687
18	8	2,288	1,237,791	143,187,361
19	28	373	244,919	29,129,959
20	76	12	14,615	1,361,124

Figure 9 Transit agency clusters, displayed by scaled UPT and VRM



expenses, and their metropolitan statistical area population size. I select for 20 different clusters in order to maximize the amount of specificity I could achieve between clusters. See summary statistics for the clusters in Table 6. Figure 9 shows these clusters, visualized by their scaled values for only their vehicles revenue miles and unlinked passenger trips. Though these were only half of the clustering criteria, the resulting clusters are fairly correlated along the axis.

Linear Model for UPT and UPT/VRH

I use an ordinary least squares (OLS) linear model to estimate the effects that bus network redesigns have on UPT and VRH for bus networks. I decided to use an OLS model because of the relatively normal distribution of my two responsive variables, UPT/VRH and the log of UPT. Taking the log of UPT allows for the skewed tail of UPT metrics, which contain several high outliers, notably big transit agencies like the NY MTA.

I incorporate dummy variables for treatment and for treatment time into my model. Treatment indicates whether or not an agency completed a bus network redesign at any time and treatment time indicates whether an agency already completed a bus network redesign. In order to adapt to the variety of treatment years when agencies completed bus network redesigns, I normalized the times periods so that I look at a five year stretch for each agency, within bus network redesign completion in year two. This means that all effects are measured from the year before treatment, through three years after treatment.

The equation for my OLS model is as follows:

$$Y = \beta_0 + \beta_1 * treated + \beta_2 * time + \beta_3 * (treated{:}\, time)$$

where *treated* and *time* are binary variables and *(treated:time)* is the interaction between them.

See the result of my model in Table 7: The regression output shows how my model is more effective at accounting for changes in efficiency than for raw values alone, with UPT/VRH and PMT/VRH's an order of magnitude higher than for UPT and PMT alone. However, none of the coefficients for the interaction between time and treated show statistically significant differences between treated and non-treated agencies. At the same time, the model shows that there was a statistically significant decline in UPT/VRH and PMT/VRH for all networks in the model. This is evidence of the nationwide decline in transit ridership that I discuss in Chapter I.

In this model, all pre and post redesign years are grouped together. While this increases sample size for each statistical measurement, it also may cover up the way bus network redesigns effects evolve over time. To remedy this loss, I developed another model where time is declared as panel data, so each year is treated as a different linear model. See Table 8 for the results.

The only statistically significant value for treated networks is for UPT/VRH three years after treatment, which shows a statistically significant correlation of an increase in UPT/VRH by 3.1. This compares to a statistically significant decrease in UPT/VRH among all networks by 7.7 at the same time period. While a change of 3 UPT/VRH seems small, it could have significant impacts over an entire transit network. For example, between 2019 and 2023, SEPTA's city bus division experienced a decrease in UPT/VRH of 8.4, from 40.6 to 32.2. A change of 3 UPT/VRH is therefore in the same range of changes experienced by transit agency as a result of the Covid-19 Pandemic. While a change of 3 UPT/VRH likely wouldn't transform an agency's operations, it could be a critical boost a the margins of farebox recovery targets and route utilization. An increase of a few UPT/VRH can certainly help and agency, but it would likely not feel like a revolutionary change.

Table 7 OLS model for UPT, UPT/VRH, PMT, and PMT/VRH with binary time variable

	Dependent variable:			
	UPT	UPT_VRH	PMT	PMT_VRH
	(1)	(2)	(3)	(4)
time	-573.817	-4.318^{***}	-2,334.362	-25.209^{***}
	(533.932)	(1.371)	(2,753.079)	(7.988)
treated	-304.415	-3.690^{**}	1,442.450	-1.714
	(581.579)	(1.493)	(2,998.760)	(8.701)
time:treated	196.662	1.293	56.170	2.868
	(755.094)	(1.939)	(3,893.442)	(11.297)
Constant	$2,416.300^{***}$	22.654^{***}	$9,669.432^{***}$	104.281^{***}
	(411.239)	(1.056)	(2,120.443)	(6.153)
Observations	118	118	118	118
R^2	0.016	0.175	0.017	0.135
Adjusted R^2	-0.009	0.153	-0.009	0.112
Residual Std. Error (df = 114)	2,014.650	5.172	10,388.010	30.142
F Statistic (df = 3; 114)	0.637	8.069^{***}	0.666	5.927^{***}
Note:		*p<0.1; **p<0.05; ***p<0.01		

Table 8 OLS model for UPT and UPT/VRH with treatment and time effects

	Dependent variable:			
	UPT	UPT_VRH	PMT	PMT_VRH
	(1)	(2)	(3)	(4)
time2	-57.990	-1.405*	-257.091	-15.683**
	(194.488)	(0.736)	(884.707)	(6.545)
time3	-227.957	-2.655***	-1,039.315	-21.748***
	(194.488)	(0.736)	(884.707)	(6.545)
time4	-583.052***	-4.935***	-2,356.568***	-32.742***
	(194.488)	(0.736)	(884.707)	(6.545)
time5	-762.123***	-7.745***	-3,370.845***	-45.363***
	(199.936)	(0.756)	(909.493)	(6.729)
time2:treated	0.371	0.345	-230.497	7.645
	(275.047)	(1.040)	(1,251.164)	(9.257)
time3:treated	120.919	0.800	-104.435	6.806
	(275.047)	(1.040)	(1,251.164)	(9.257)
time4:treated	197.063	1.574	-141.161	4.925
	(275.047)	(1.040)	(1,251.164)	(9.257)
time5:treated	346.835	3.118***	905.969	12.227
	(282.753)	(1.070)	(1,286.217)	(9.516)
Observations	118	118	118	118
R^2	0.259	0.674	0.276	0.501
Adjusted R^2	-0.008	0.557	0.015	0.321
F Statistic (df = 8; 86)	3.759***	22.255***	4.095***	10.797***
Note:				*p<0.1; **p<0.05; ***p<0.01

Interestingly, my time panel regression shows that there may be a delayed improvement effect of bus network redesigns on metrics of UPT. For both UPT and UPT/VRH, coefficients rise steadily over the three years after redesigns. While variance remains large, this trend could be corroborated when more redesigns are added to the results. In contrast, trends for PMT and PMT/VRH, have no clear trend in their association with bus network redesigns, and have similarly high standard errors as values for UPT.

Overall, while I do not feel comfortable concluding that bus network redesigns cause positive effects on transit agencies' operating metrics, many of the treated agencies I observed outperformed their peer agencies in the three years after implementing a bus network redesign. I hope to gather more data and include variables that could control for this high variance to clarify these relationships in the future. However, the uncertain polarity and high amount of variance in treatment effects indicates that a difference in difference measurement could be a useful way of studying the effects in the meantime.

I use the DiD package in R to calculate and visualize the treatment effects of networks who completed bus network redesigns (Callaway and Sant'Anna 2022). The DiD packages calculates difference-in-difference (DiD) estimators that indicate the expected difference in response variable for treated and untreated groups. This estimate shows the relative effects of bus network redesigns, compared to untreated agencies, and is a critical tool for contextualizing the effects of bus network redesigns in an era of otherwise decreasing transit network performance.

DiD for UPT: slight, steady increases

Figure 7 shows the calculated DiD estimators, with confidence intervals in blue. Year 0 indicates the bus network redesign year, and each subsequent year shows one year after. While there is no statistically significant difference between UPT trends for treated and untreated

Figure 10 Difference and difference plot for unlinked passenger trips, aggregated at national scale

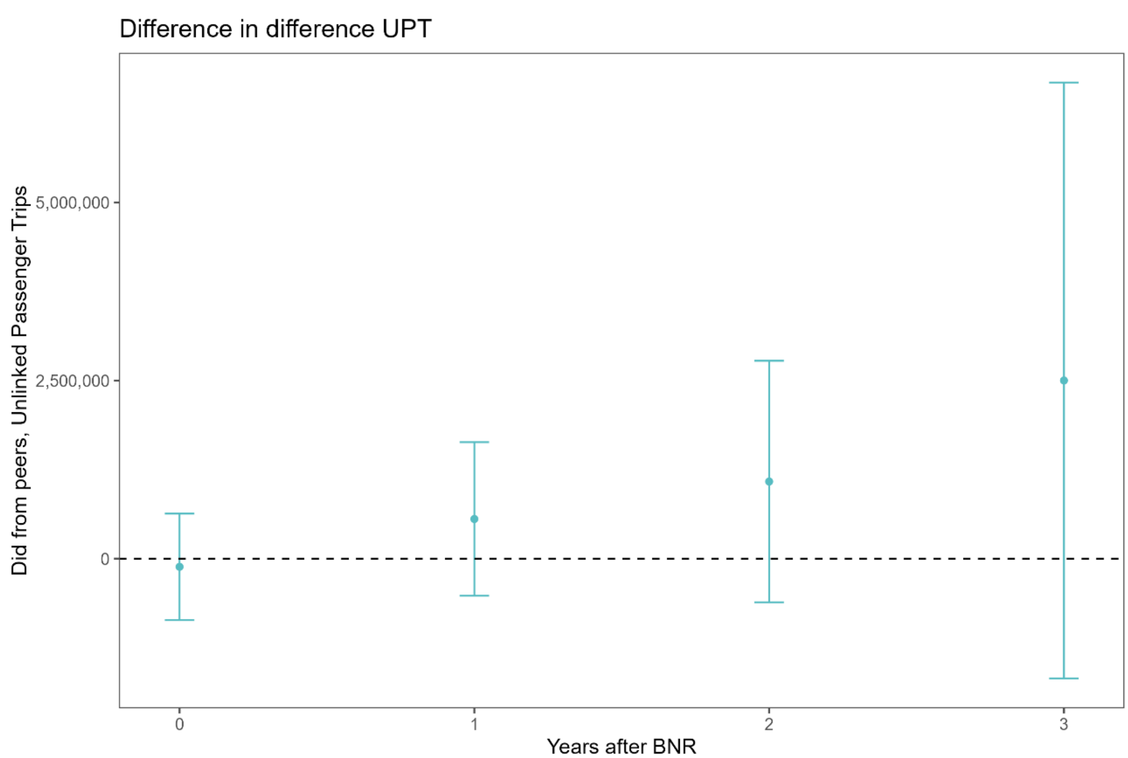


Table 9 Difference in difference estimators for UPT

YEARS SINCE REDESIGN	Unlinked Passenger Trips DID ESTIMATE	STD. ERROR
0	−114,516	353,737
1	557,165	495,463
2	1,082,968	805,657
3	2,501,827	1,953,509

networks, the DiD estimators show how there is a gradual divergence between them. I did not look for effects of bus network redesigns beyond three years. If these trends were to continue, there would be even stronger associations between increased UPT and treated networks. Likewise, the large margins of error may also be the result of my small sample size, with just 12 pairs of treated networks and their peers in the data set.

Table 9 shows how, despite significant increases in the DiD estimator each year after a bus network redesign, the standard error of the estimate keeps pace. This indicates that whatever positive effects are associated with some treated networks, others in the data set experience comparatively less improvement.

Overall, these results indicate that bus network redesigns have a slightly positive correlation with UPT across all implementations. While UPT can have slightly different implications depending on the transit system, it always means some form of increased ridership, whether via more trips altogether or more trips with transfers in them. Bus network redesigns should be seen as a reliable tool for agencies looking to boost their overall ridership, whether to improve fare recovery ratios, for quality of life improvements, or to induce mode shift to transit.

DiD for UPT/VRH: promising increases with delayed effects

The same tables, made for UPT/VRH show similar, but more pronounced positive trends. These results show how the treatment effect of bus network redesigns may not be linear, and may even have a delayed onset in transit networks. This trend has been observed anecdotally, as riders can take months or years to grow accustomed to network changes (Walker 2015). However, Figure 11indicates that, across all treated agencies, UPT/VRH stayed relatively flat in the two years after bus network redesign before increasing more significantly three years after treatment.

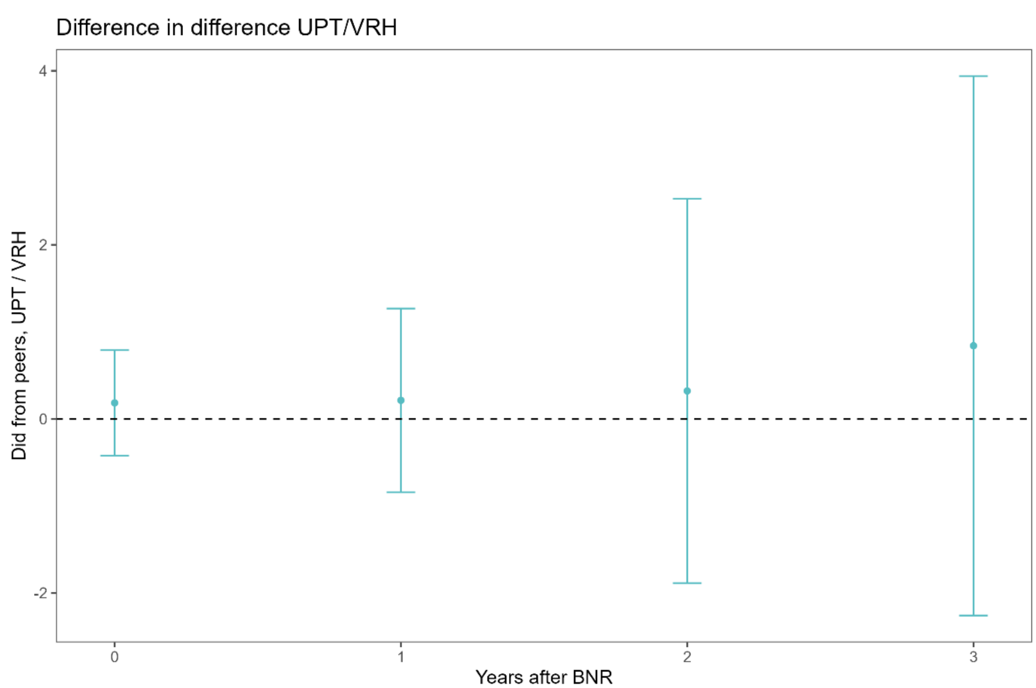
Table 10 shows how DiD estimators for UPT/VRH compared to peers jumped by .52 from year two to three, after increases of just .1 or less in the previous years. This means that relative VRH growth may actually outpace UPT growth in the first year after a redesign. For example, if an agency begins running greater service hours on day one of a bus network redesign, their UPT/VRH may reduce as ridership grows to utilize the full network.

This model for UPT/VRH shows two things. First, it indicates with a similarly healthy dose of uncertainty that bus network redesigns reduce the effects of chronic transit ridership losses, as were seen in the 2010s and in the recovery from Covid-19. Second, the model indicates that agencies should not expect immediate efficiency gains after implementing their new networks. Bus network redesign implementors should not expect to see the full effects of changes to service patterns for several years after a redesign.

Table 10 Difference in difference estimators for UPT/VRH

	Unlinked Passenger Trips per Vehicle Revenue Hour	
YEARS SINCE REDESIGN	DID ESTIMATE	STD. ERROR
0	0.184	0.262
1	0.213	0.490
2	0.321	1.022
3	0.840	1.331

Figure 11 Difference and difference plot for unlinked passenger trips per vehicle revenue hour, aggregated at national



Variability City to City

Table 8 shows how the extreme variability of treatment between my subject cities results in wide margins of error for DiD and make it difficult to predict the effects on any one specific bus network redesign treatment. The table shows the percent change in treated networks and their peers, paired with the percentage point DiD for one year and three years after a bus network redesign. Baltimore only has data for year one, due to the recency of their bus network redesigns. However, where Houston and Jacksonville show consistently positive results, Columbus shows dramatic growth after year one, but by year three slightly underperforms its peer networks. Omaha, meanwhile, exhibits consistently negative change compared to its peer networks.

This variability of DiD indicates the need for more complex measures of the difference between bus network redesign treatments. For example, is there something about the priorities in Colombus or Omaha's redesigns that made them unsuited to UPT growth. If not, is this a factor of

Table 11 City by city DiD for UPT and UPT/VRH

Difference in difference for complete BNRs with peer agenices

	Unlinked Passenger Trips (1000s)			Unlinked Passenger Trips per Vehicle Revenue Hour		
LOCATION	YEAR 1	YEAR 2	YEAR 3	YEAR 1	YEAR 2	YEAR 3
Houston	433	2,084	1,113	−0.54	1.02	0.94
Jacksonville	1,023	2,023	2,536	2.08	3.50	4.15
Omaha	−298	−292	−431	0.02	0.11	−0.27
Columbus	4,111	5,067	1,092	2.62	3.39	3.48
Richmond	1,204	6,165	14,191	1.18	2.73	5.87
Baltimore	7,755	7,982	—	2.41	4.94	—
Livermore	16	139	495	1.58	3.03	5.55
OCTA	−2,604	−4,345	−2,795	1.23	0.45	4.70
VVTA	−267	−162	621	−3.47	−3.49	−1.05
Salem	584	624	2,606	1.93	1.86	3.23
Austin	996	412	8,435	−0.82	−0.15	3.99
GCTD	1,434	3,862	7,030	0.46	1.08	3.20

difficulties in implementation, or in local exogenous factors the require more research? The difference within my treatment groups shows how my model may effectively generalize across bus network redesigns, but that it is not a useful tool for predicting the effects that a bus network redesign may have on any one network.

A curious phenomenon occurs, where OCTA (Orange County) was the worst performing treated agency by raw UPT, but performed robustly by UPT/VRH, with a gained of 4.70 after three years. This indicates that, despite losing total trips compared to its peers, OCTA improved in efficiency. This could happen in several ways, including by through its peers showing dramatic swings in ridership or efficiency themselves, or more significantly, by OCTA running less service after their redesign than before.

This leaves me with two important points. First, when moving forward with this project, I will try to control for unusual performances in peer groups, so that treated agencies aren't punished or flattered by unusual trends elsewhere. Second, I will incorporate raw measures of operating hours or operating expenses into my model to make sure that my analysis accounts for agencies' overall expenditures or service level changes.

Takeaways for future analysis

The inconsistencies noted above require in-depth characterizations of distinct bus network redesigns to resolve. My current analysis uses only a dummy variable to assess bus network redesign treatment, while bus network redesigns exist on a spectrum of changes, from the complete network overhauls to slight tweaks in existing routes. For this reason, I suggest that future analysis attempt to incorporate both the physical elements and operational results of bus network redesigns to assess their effectiveness. These metrics could include measures of percent of route miles changes in a bus network redesign, change in overall average speed of the bus network, and rate of concentration of service hours among routes. Variables like these could give a better sense for how bus network redesigns affected networks, including whether changes were focused more on actual route alignments or in the distribution of service across existing routes.

As a starting point though, the analysis in this chapter can be expanded to include bus network redesigns completed since 2020. When paired with metrics on the styles of interventions made in individual bus network redesigns, this data can be used to inform the planning processes of other agencies. Where agencies are only able to complete operationally cost-neutral redesigns or are unable to include capital improvements in their bus network redesigns, this data mya help them decide whether pursuing a bus network redesign is right for them. Finally, as transit ridership continues to dynamical adjust with post-Pandemic travel patterns, this data should be used to contextualize the difference in difference between agencies who completed bus network redesigns and those that did not or who made other interventions in their systems.

Conclusion

TCRP 140 concludes that "some of the agencies that have already implemented bus network redesigns are implementing robust performance measurement programs to track their progress. Future research on the results of these evaluations – cross-referenced with how they were planned and implemented – will be useful for agencies that are still earlier in the process" (Byala et al. 2019, pp 77). When I searched for agencies' self-evaluations of their redesigns, I was unable to find any significant reports, documentation, or dashboards that tracked the effects of bus network redesigns. In contrast, analysis of bus network redesigns stayed strictly in the speculative, pre-implementation realm. This gap in analysis was the main motivation for this project, where I assessed the effects of bus network redesigns on high-level network performance metrics. While I found no statistical improvements in operating performance among agencies that completed redesigns, my modeling was affected by limited sample sizes and significant variance between treated subjects. Fortunately, there are many more agencies who have recently completed redesigns or who are planning redesigns right now. With the addition of descriptive variables, including total operating expenses and spatial indicators of redesign scale, my model can serve as platform for further investigation on the effects of network redesigns.

Regardless of the quantitative effects of bus network redesigns, my research indicates that the practice holds significant benefits for transit agencies. By approaching bus route planning in the framework of a bus network redesign, transit planners can ask essential questions about how well a transit network serves the people, communities, and cultures that interact with it. The findings from such a process can easily be turned into material changes in bus routes and schedules, but they can also be shelved for later use, incorporated into the operating ethos of an agency, or change the long-term relationship that a city has with its transit network.

In her work of urban theory, *A City is Not a Computer*, Shannon Mattern explores the role of maintenance in caring for and building complex relationships with our urban system. She writes that, when we maintain our cities, "we should always ask: What, exactly, is being maintained? 'Is it the thing itself,' … 'or the negotiated order that surrounds it'" (Mattern 2021, pp 116). Mattern shows how the act of studying and improving a bus network is about much more than the redesigned routes themselves – it will always also be about the relationship between a city and its public services, riders and their options for mobility, transit operators and their capacity to run reliable services.

Every bus network redesign process produces a plethora of route profiles, unrealized draft networks, and unarticulated observations from the planners, riders, and consultants who assemble them. In the case of SEPTA's bus network redesign, early drafts of the redesigned network eliminated freeway-based routes in Northwest Philadelphia due to their poor reliability and poor efficiency due to limited stops. SEPTA planners observed that the routes also provided redundant service to Regional Rail. However, the relatively high frequency and low fare of those bus routes proved much more important to riders, who balked at the alternative for taking Regional Rail, which comes every 45 minutes at peak and costs over $4 each way (Batchis 2021). Alongside Bus Revolution, SEPTA is also undergoing a long-range planning process called Reimagining Regional Rail, which could bring more frequent and reliable rail service to Northwest Philadelphia in the next decades. Although SEPTA reintroduced the freeway routes in later revisions of the Bus Revolution plan, their planning department already has a blueprint for future adjustments to the bus network that can be made when Regional Rail service is improved in the area.

Careful observation of our transportation systems lays fertile ground for future project work and shifts institutional relationships with transit in ways that will continue to improve our bus networks. The process of planning bus network redesigns provides transit agencies with expanded metrics and perspectives on where secondary interventions including all-door boarding, headway-based scheduling, transit signal priority, and transit priority lanes can be used to enhance average speeds and operational ease. Whether bus network redesigns alone are reliable tools for improving efficiency and shifting trips to transit, they may be a critical first step in working towards those goals.

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Appendix

Table 1. Selected peer cities for DID tests

City	Agency	Redesign Year	Peer 1	Peer 2	Peer 3	Peer 4	Peer 5	Regional Peer 1	Regional Peer 2
Jacksonville	JTA	2014	Rhode Island Public Transit Authority (RIPTA)	Sacramento Regional Transit District	Transit Authority of River City (TARC)	Indianapolis and Marion County Public Transportation (IndyGo)	Pinellas Suncoast Transit Authority (PSTA)	Hillsborough Area Regional Transit Authority (HART)	Central Florida Regional Transportation Authority (LYNX)
Houston	Houston Metro	2015	Utah Transit Authority (UTA)	The Greater Cleveland Regional Transit Authority (GCRTA)	Regional Transportation Commission of Southern Nevada (RTC)	Denver Regional Transportation District (RTD)	MTA Bus Company (MTABUS)	Dallas Area Rapid Transit (DART)	VIA Metropolitan Transit (VIA) (San Antonio)
Omaha	Omaha Metro	2015	Capital Area Transit System (CATS)	Toledo Area Regional Transit Authority (TARTA)	Sarasota County (SCAT)	Lower Rio Grande Valley Development Council (LRGVDC)	Community Transit, Inc. (Community Transit)	Kansas City Area Transportation Authority (KCATA)	Metropolitan Tulsa Transit Authority (MTTA)
Livermore	LAVTA	2016	City of Colorado Springs (MMT)	City of Durham	City of Knoxville (KAT)	Kitsap Transit	Salem Area Mass Transit District (SAMTD or SKT)	City of Modesto (MAX)	City of Visalia (VT)
Columbus	COTA	2017	Broward County Board of County Commissioner s (BCT)	City of Charlotte North Carolina (CATS)	Fort Worth Transportation Authority (FWTA)	Milwaukee County (MCTS)	Montgomery County, Maryland	Transit Authority of River City (TARC)	Greater Dayton Regional Transit Authority (GDRTA)
Orange County	OCTA	2017	Capital Metropolitan Transportation Authority (CMTA)	City and County of Honolulu (DTS)	City of Phoenix Public Transit Department (Valley Metro)	Pace - Suburban Bus Division (PACE)	Snohomish County Public Transportation Benefit Area Corporation (Community Transit)	City of Los Angeles (LADOT)	Santa Clara Valley Transportation Authority (VTA)
San Bernadino	VVTA	2017	Toledo Area Regional Transit Authority (TARTA)	Sarasota County (SCAT)	Lower Rio Grande Valley Development Council (LRGVDC)	Community Transit, Inc. (Community Transit)	Kansas City Area Transportation Authority (KCATA)	Santa Barbara Metropolitan Transit District (SBMTD)	Golden Empire Transit District (GET)
Salem	Cherriots	2017	Marin County Transit District	City of Colorado Springs (MMT)	City of Shreveport (SporTran)	City of Waukesha	City of Greensboro (GTA)	Tri-County Metropolitan Transportation District of Oregon (TriMet)	Lane Transit District (LTD)

City	Agency	Redesign Year	Peer 1	Peer 2	Peer 3	Peer 4	Peer 5	Regional Peer 1	Regional Peer 2
Richmond	GRTC	2018	Rhode Island Public Transit Authority (RIPTA)	Capital District Transportation Authority (CDTA)	Sacramento Regional Transit District	Southwest Ohio Regional Transit Authority (SORTA/ Metro / Access)	Pinellas Suncoast Transit Authority (PSTA)	Fairfax County, VA (Fairfax Connector)	Transportation District Commission of Hampton Roads (HRT)
Austin	CMTA	2018	Tri-County Metropolitan Transportation District of Oregon (TriMet)	Port Authority of Allegheny County (Port Authority)	Santa Clara Valley Transportation Authority (VTA)	Regional Transportation Commission of Southern Nevada (RTC)	City of Los Angeles (LADOT)	VIA Metropolitan Transit (VIA) (San Antonio)	Fort Worth Transportation Authority (FWTA)
Gwinnett County, GA	GCTD	2018	Spokane Transit Authority (STA)	Suffolk County (ST)	Ann Arbor Area Transportation Authority (AAATA)	Antelope Valley Transit Authority (AVTA)	City of El Paso (Mass Transit Department)	Piedmont Authority for Regional Transportation (PART)	Metropolitan Atlanta Rapid Transit Authority (MARTA)
Baltimore	MTA	2019	North County Transit District (NCTD)	Alameda-Contra Costa Transit District (AC Transit)	Connecticut Department of Transportation (CDOT)	Hudson Transit Lines, Inc. (Short Line)	Metro Transit (Minneapolis)	Washington Metropolitan Area Transit Authority (WMATA)	Southeastern Pennsylvania Transportation Authority (SEPTA)