Recent Decline in Public Transportation Ridership: Analysis, Causes, and Responses (2022)

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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP RESEARCH REPORT 231

Recent Decline in Public Transportation Ridership

ANALYSIS, CAUSES, AND RESPONSES

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2022

TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, adapt appropriate new technologies from other industries, and introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions,* published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), *Transportation 2000,* also recognized the need for local, problem-solving research. TCRP, modeled after the successful National Cooperative Highway Research Program (NCHRP), undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes various transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA; the National Academies of Sciences, Engineering, and Medicine, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Commission.

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TCRP provides a forum where transit agencies can cooperatively address common operational problems. TCRP results support and complement other ongoing transit research and training programs.

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FOREWORD

By Dianne S. Schwager
Staff Officer
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TCRP Research Report 231 and *TCRP Web-Only Document 74* present the research findings and conclusions from TCRP Project A-43, "Recent Decline in Public Transportation Ridership: Analysis, Causes, Responses." The research deliverables will serve public transit agencies; the communities they serve; and researchers striving to understand the recent decline in bus and rail transit ridership, the factors influencing the decline, and strategies that may enhance transit ridership and mitigate future ridership declines.

This research was undertaken to

- Understand the factors contributing to the pre-pandemic decline in transit ridership in the United States and quantify the relative contribution of each.
- Identify strategies for public transportation agencies to mitigate or reverse the ridership challenges they have faced, both pre- and post-pandemic, and to evaluate the effectiveness of those strategies.

The initial phase of the research considered traditional and emerging factors that affect transit ridership and are controllable by transit agencies as well as external factors not controllable by transit agencies. The second phase of the research used data that were more detailed from specific cities to conduct deep dives, including detailed route- and stop-level analyses of various critical factors regarding both the causes of ridership change and strategies to reverse declines. The results of these analyses, as well as simulation of future strategies, found that pre-COVID, peak-hour service was the most productive; transit priority, fare policies and discounts, and condensed service increase transit ridership; and micromobility has limited impacts on transit ridership. The research concluded that five strategies will lead to positive ridership outcomes: (1) Rethink mission, service standards, metrics, and service delivery; (2) rethink fare policy; (3) give transit priority; (4) consider partnerships with shared-use mobility providers carefully; and (5) encourage transit-oriented density.

In addition to *TCRP Research Report 231,* this research project produced *TCRP Web-Only Document 74*, which contains the appendices to the report, and a PowerPoint presentation that is available as a supplementary deliverable on the TRB site. The PowerPoint presentation is available at www.trb.org by searching for "TCRP Research Report 231."

CONTENTS

SUMMARY

Recent Decline in Public Transportation Ridership: Analysis, Causes, and Responses

Pre-pandemic Transit Ridership

The coronavirus disease 2019 (COVID-19) pandemic has dramatically affected all segments of economies across the globe, and mobility providers have been among the most affected by the stay-at-home mandates. Across cities, there have been significant declines in rail ridership compared to pre-pandemic levels, as rail modes are often used by workers who are more likely to have telework options. Bus ridership has also significantly decreased, though somewhat less than rail ridership since much of the lower-income and critical workforce populations that buses often serve continued riding transit out of necessity.

However, transit systems in the United States were already facing challenges prior to the pandemic with respect to ridership: Transit ridership declined 14% to 15% nationwide between 2012 and 2018. Buses were the most affected with the lowest ridership levels since at least the 1970s, and even heavy rail declined starting in 2015. As transit ridership declines, agencies lose fare revenue, which often results in reductions in service to meet budgets, which further results in losses in ridership—thus creating a downward spiral.

The causes of these pre-pandemic ridership losses were multiple and complex. As a result, TCRP initiated this research study to provide a deep-dive exploration of the ridership losses already being experienced by transit systems. This study was initiated before the pandemic and uses pre-pandemic data for its analyses. The objectives of the research are threefold:

1. To understand the factors contributing to the pre-pandemic decline in transit ridership in the United States and quantify the relative contribution of each factor,
2. To identify strategies to mitigate or reverse those declines and to evaluate the effectiveness of those strategies, and
3. To develop recommendations for how public transportation agencies can respond to the ridership challenges they have been facing both pre- and post-pandemic.

To accomplish these objectives, the researchers first conducted a thorough literature review and developed ridership change hypotheses. They then combined detailed data with robust statistical methods in a top-down approach that considered ridership changes at the system level, the route level, and the stop level. Finally, they conducted a future strategies analysis by simulating two transit networks. The combination of these methods has allowed the research team to both consider the diversity of transit systems in the United States and take advantage of more detailed data assembled for specific cities.

Explaining Transit Ridership Declines

Through the literature review shown in Chapter 2, four categories of factors and strategies for transit ridership change were identified, broken into the intersection of internal and external factors and traditional and emerging factors. Internal factors are those that transit agencies can control, while external factors are those that impact transit agencies but over which they have little control. Traditional factors are those that have long been shown to impact transit ridership, while emerging factors are more recent phenomena. Combining these two groups of factors gives us the following four categories:

- "Internal traditional" includes factors such as service quantity and quality, fares, and speed and reliability;
- "Internal emerging" includes factors such as restructuring transit networks, fare innovation and real-time technology, new on-demand services, and dedicated right-of-way;
- "External traditional" includes factors such as population and employment, demographics, car ownership, gas prices, and transportation demand management (TDM); and
- "External emerging" includes factors such as telework and teleshopping, gentrification, and new transportation services.

The existing literature identifies the important factors and the likely direction of each, but it is clear that a mix of factors are contributing to recent transit ridership trends, pushing transit ridership in competing directions. To separate the effects of each of these factors, Chapter 3 presents the multicity evaluation of ridership change, which developed longitudinal models of the change in system-level transit ridership by mode across many cities. This high-level analysis ensures that the trends being captured are broadly applicable across the nation. The models use National Transit Database (NTD) ridership data, U.S. Census Bureau data, and other data sources to test some of the hypotheses about ridership change for both bus and rail.

Overall, two sets of factors pushed to increase transit ridership from 2012 to 2018:

- **More service.** Transit operators are providing more bus and rail service. These service additions result in a net bus ridership increase ranging from 3% to 5% depending on the size of the metro area. Rail service increases are associated with ridership gains of 10% to 18%.
- **Land use.** Land use affects transit ridership in terms of total population and employment growth and in terms of how centralized that growth is. Metro areas have grown between 6% and 8% in population and employment, pushing up ridership. However, in many cases, that growth is becoming less centralized—pushing ridership down—so that the combined effect of land use changes is a less than 2% increase in ridership.

The causes of net transit ridership decline between 2012 and 2018 came from a combination of four main factors. Together, these factors more than offset the factors above that pushed ridership up over this period. These factors are the following:

- **Income and household characteristics.** Higher incomes, higher rates of car ownership, and an increase in the percent of people working at home contributed a net ridership decline of about 2% for bus and rail.
- **Bus and rail travel became more expensive.** Average bus fares increased across most metro area sizes. Average rail fares increased between 7% and 13%, depending on the size of the metro area. The result is net ridership declines of 0% to 4%.
- **Driving became less expensive.** Average gas prices decreased by about 30% over this period, contributing to about a 4% reduction in bus and rail ridership.
- **New modes compete with bus and rail.** The model results suggest that ride-hailing is the biggest contributor to dropping bus ridership between 2012 and 2018, resulting in net

decreases of between 10% and 14%. The effect of ride-hailing on rail ridership in larger metro areas is much smaller, but the effect in the mid-sized metro areas is similar to its effect on buses. Bike sharing and e-scooters have a much smaller impact, less than or about 1%.

Transit Agency Strategies and Ridership Factors

Although the system-level analysis has identified some important factors in ridership declines, many factors and strategies cannot be assessed at the national level due to inconsistencies in data from transit agency to transit agency or due to phenomena that are occurring at a more disaggregate level. The second phase of the research used more detailed data from specific cities to conduct deep dives into both the causes of ridership change and strategies to reverse declines. The results of this detailed route- and stop-level analysis of various critical factors and simulation of future strategies found several key things:

- **Transit priority can increase transit ridership.** The case studies in Minneapolis and St. Paul, Minnesota (Chapter 6), and Cleveland, Ohio (Chapter 9), showed that high-quality light rail transit (LRT) and bus rapid transit (BRT) can increase ridership substantially, even with limited service increases. The future strategies analysis showed that bus-only lanes can be even more effective than increases in service at increasing transit ridership.
- **Fare policies and discounts can increase transit ridership.** The case study in Topeka, Kansas (Chapter 8), showed that strategic fare discounts can increase transit ridership. Fare-free promotions for kids in the summer, seniors, and veterans can increase the use of transit.
- **Micromobility has limited impacts on transit ridership.** The case study in Louisville, Kentucky (Chapter 7), showed that e-scooters had limited—if any—impact on local bus ridership and may have even slightly increased express bus ridership. Transit agencies can consider micromobility partnerships to address first-mile/last-mile connectivity issues.
- **Condensing service can increase transit ridership.** The system-level analysis (Chapter 3) showed that transit ridership has been increased through not only added service but also bus network redesigns. This was reinforced though a future strategy analysis (Chapter 10), which showed the potential to increase transit ridership without major budget increases by reallocating existing service.
- **Pre-COVID, peak-hour service was the most productive.** Analysis across four agencies (Chapter 4) showed that a.m. and p.m. peak ridership was declining the least and nighttime ridership was declining the most. The most productive transit service (ridership per vehicle hour) was weekday peak hours. At the same time, nighttime ridership was found to be the most sensitive to changes in frequency.

Putting together both phases of the project led to the five recommended strategies presented in Chapter 11:

- **Rethink mission, service standards, metrics, and service delivery.** The research in this report has shown that prior to the COVID pandemic, transit ridership was peaking, with a.m. and p.m. peak ridership declining the least while weekday night and weekend night ridership declined the most; this was likely caused in part by the competition offered by ride-hailing services. How new COVID trends will interact with previous trends represents a major challenge for transit agencies as they try to plan for the future and reposition their mission and services. In light of this, transit agencies will need to rethink their mission, their service standards, the metrics they use to measure success, and their service delivery options.

- **Redesign fare policy.** Fare policy is typically within the control of the transit agency. The research in this report on pre-COVID trends confirms the positive impact on ridership that can be obtained from the implementation of fare discounts. At the same time, recent developments during the pandemic suggest that patterns may be significantly altered in the future with more teleworking and less regular commuting to downtown cores, which suggests that a review of fare policy may be required.
- **Give transit priority.** The research in this report has shown that giving transit priority can significantly increase transit ridership. Transit priority helps to increase average speeds, reduce travel times, and increase service reliability, which all contribute to making the transit service more attractive to potential riders. There is an array of increasingly complex methods and means to improve transit priority, including physical priority, transit signal priority (TSP), BRT, and LRT. Transit agencies can only implement physical priority measures and TSP in cooperation with the traffic engineers who manage traffic signals and the design and operation of streets, while the design and implementation of BRT and LRT systems are by their nature major, complex, and multiyear undertakings.
- **Consider partnerships with shared-use mobility providers carefully.** Many experts have suggested that transit agencies should develop partnerships with new, shared-use mobility providers, such as ride-hailing, microtransit, car-sharing, and micromobility (e.g., bike sharing, e-scooter) providers, in an effort to offer a broader array of services that might encourage people to not use their personal automobile. However, the research shows that transit agencies need to consider such partnerships with care since these new services can sometimes be competitors to transit, while others may serve a complementary role.
- **Encourage transit-oriented density.** The research in this report shows that regions where density increased in the areas accessible by transit experienced growth in transit ridership. The challenge is that density is defined by metropolitan and municipal planning policies and by the practical zoning regulations put in place by municipalities, none of which are under the control of transit agencies. Nonetheless, transit agencies can play an important role in encouraging transit-oriented density.

Future Impacts on Transit Ridership

As society moves to the "new normal" of a post-pandemic world, researchers are still trying to understand what longer-term impacts the pandemic might have on mobility, and public transit in particular. Although this research was based on pre-pandemic data, the findings from this detailed assessment of factors affecting transit ridership suggest a few key insights for the future:

- **Telecommuting impacts on transit will likely continue.** Even before the pandemic, telecommuting was impacting transit. During the pandemic, these impacts have been substantial and necessary. However, as the pandemic subsides, it is likely that many firms will retain some telecommuting practices; this will likely change expectations from the model of five days per week at the office and reduce the gap between peak hours and off-peak demand.
- **Population density may continue to decline.** As with telecommuting, even before the pandemic, population densities were decreasing; this has offset increases in transit ridership being seen from population increases. It remains to be seen how the public will react in the longer term, but with more flexibility in job locations comes more flexibility in living locations and a need for greater space in the home.
- **Low gas prices hurt transit ridership.** During the pandemic, oil producers could not give their product away. As traffic congestion has increased, gas prices have as well, but gas prices have generally stayed very low. If lower demand is sustained, it could continue

to keep gas prices low, making driving a much cheaper option and adversely impacting transit ridership.

- **Potential for higher transit fares.** Similarly, driving may stay cheap compared to transit if agencies are forced to raise fares to begin recovering their financial losses caused by the pandemic. The key to making transit affordable is high ridership on a per vehicle hour basis. With low ridership per vehicle hour, transit has to be subsidized to keep it affordable.
- **Impact on new modes is unknown.** Ride-hailing services also require sharing space, similar to transit. Although ride-hailing use was growing rapidly before the pandemic, its future trajectory and resulting impact on transit remains to be seen.

These future impacts point even more toward the successful strategies that agencies have been pursuing before the pandemic as well as new strategies presented here. This will allow the transit industry to continue to fulfill its twin mission—both to respectfully serve those who rely on transit on a day-to-day basis, through more emphasis on equity of accessibility and service, and to efficiently provide mobility in congested areas. Although the coming years may continue to be challenging, the transit industry is filled with champions who are eager to rise to the task of creating a more resilient and sustainable transportation system.

CHAPTER 1

Introduction

Even before the coronavirus disease 2019 (COVID-19) pandemic, transit ridership in the United States declined for the fifth consecutive year in 2019. In that year, every transit mode except commuter rail dropped in ridership. Buses were the most affected, with the lowest ridership levels since at least the 1970s. Even heavy rail ridership declined after an upward trend that began in 2009 (see Figure 1-1). As transit ridership declines, agencies lose fare revenue, which often results in reductions in service to meet budgets, which further results in ridership losses.

While these trends are consistent across U.S. cities, transit ridership in other countries has increased in the last several years. Canadian transit agencies have experienced a steady rise in transit ridership, which has closely followed increases in service since the mid-1990s (Miller et al., 2018). Freemark (2019) points out that French transit agencies have also increased in ridership during the same period when ridership at U.S. agencies has declined. According to the 2017 report by the International Association of Public Transport, or UITP, on urban public transport in the 21st century, 24 out of 39 countries in the study "experienced an increase or at least maintained a stable rate of public transport use (journeys per capita) over the past 15 years" (International Association of Public Transport, 2017). Switzerland, Austria, Luxembourg, Norway, Germany, United Kingdom, Sweden, Turkey, Belgium, China, New Zealand, Malta, Canada, Australia, Brazil, and France all saw mild or even large growth in transit ridership. The United States is not alone in its ridership losses, but most countries with similar losses have poor economic conditions or substantial changes in demographics.

1.1 Research Approach

The objectives of the research are threefold:

1. To understand the factors contributing to the recent decline in transit ridership in the United States and quantify the relative contribution of each factor,
2. To identify strategies to mitigate or reverse those declines and to evaluate the effectiveness of those strategies, and
3. To develop recommendations for how public transportation agencies can respond to the ridership challenges they have been facing.

A mix of factors is contributing to recent transit ridership trends, and several of these factors will push ridership in competing directions. Therefore, it is insufficient to address the topic with only an exploratory data analysis or through a qualitative assessment. Such exercises quickly become speculative, as can be found in much of the literature on the topic over the past few years. Instead, it is necessary to combine detailed data with robust statistical methods to separate out these competing factors, as was done for this project. This research was conducted in a two-phase, top-down approach that considered ridership changes first at the system level and then at

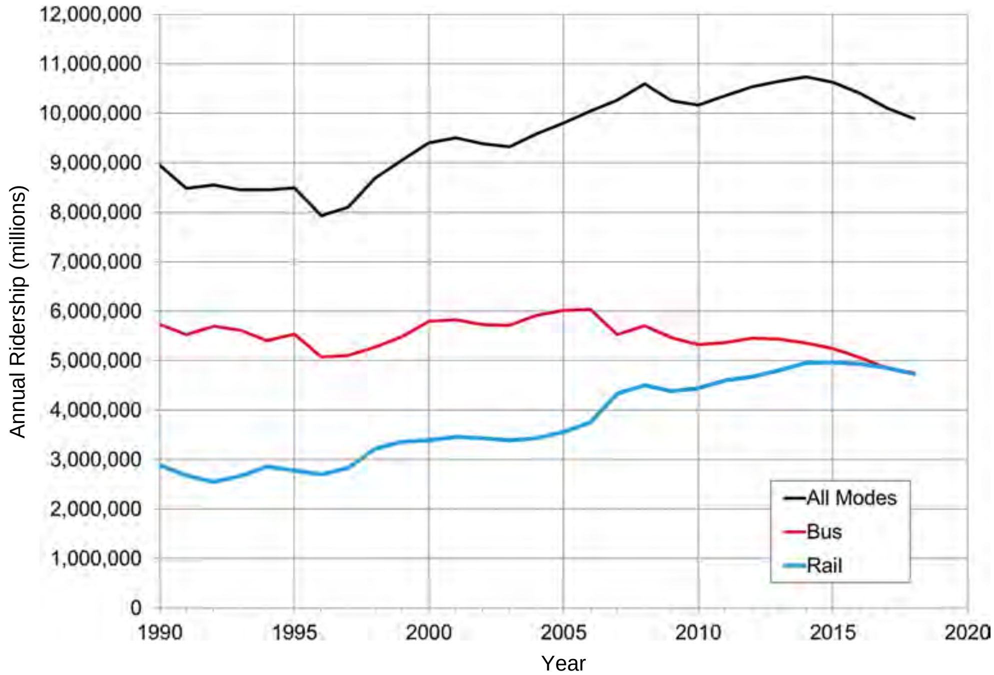


Figure 1-1. U.S. transit ridership by year.

the detailed route and stop levels. This allowed the research team to both consider the diversity of transit systems in the United States and take advantage of more detailed data assembled for specific cities. The research was divided into the various tasks shown in Figure 1-2. This project also builds on *TCRP Research Report 209: Analysis of Recent Public Transit Ridership Trends.*

1.2 Report Contents

Chapter 2 contains a review of the literature and current research regarding transit ridership change. Chapter 3 is a multicity evaluation of ridership change, in which longitudinal models of the change in system-level transit ridership by mode across many cities were developed. This high-level analysis ensures that the trends captured here are broadly applicable across the

Figure 1-2. Flow of tasks in Phase 1 and Phase 2 of research.

Table 1-1. Factors/strategies and cities for case studies.

Factor/Strategy	City	Transit Agency	Chapter
Hyper-Local (Stop-Level) Analysis			
Service changes	Portland, OR	TriMet	Chapter 4
	Miami, FL	Miami-Dade Transit	
	Minneapolis, MN	Metro Transit	
	Atlanta, GA	Metropolitan Atlanta Rapid Transit Authority	
Service disruptions	San Francisco, CA	Bay Area Rapid Transit	Chapter 5
Impacts of light rail transit and bus rapid transit	Minneapolis, MN	Metro Transit	Chapter 6
Route-Level Analysis			
Scooters	Louisville, KY	Transit Authority of River City	Chapter 7
Fare policies	Topeka, KS	Topeka Metropolitan Transit Authority	Chapter 8
Bus rapid transit	Cleveland, OH	Greater Cleveland Regional Transit Authority	Chapter 9
Future Strategies			
Multiple scenarios	Atlanta, GA	Metropolitan Atlanta Rapid Transit Authority	Chapter 10
	Oshkosh, WI	Go Transit	

nation. The analysis includes National Transit Database (NTD) ridership data, U.S. Census data, and other data sources that enabled some of the hypotheses developed about ridership change to be tested; these hypotheses are presented in additional detail in Appendix A of *TCRP Web-Only Document 74: Recent Decline in Public Transportation Ridership: Hypotheses, Methodologies, and Detailed City-by-City Results.*

Although the system-level analysis identified some important factors in transit ridership declines, as discussed in Chapter 3, many factors and strategies cannot be assessed at the national level due to inconsistencies in data from transit agency to transit agency or due to phenomena that are occurring at a more disaggregate level. The purpose of the second phase of the research is to use more detailed data from specific cities to conduct deep dives into both the causes of transit ridership change and strategies to reverse declines. As shown in Table 1-1, these results in Chapters 4 through 9 provide a more detailed route- and stop-level analysis. In addition, simulations were used to look at future strategies in Chapter 10.

Finally, Chapter 11 summarizes the research findings and identifies strategies to build ridership. Chapter 11 also describes the results of circling back to transit agencies to present preliminary results; this circle back allowed the research team to consider existing experience in order to identify key implementation considerations and valuable/practical resources that would aid in the pursuit of these strategies.

CHAPTER 2

Possible Causes of Ridership Decline Identified in the Literature

Any analysis of factors affecting transit ridership should begin with a review of the previous literature. In order to isolate the different factors that affect ridership, this review is segmented into internal factors, which are controlled by transit agencies, and external factors. Both internal and external factors are then further divided into traditional factors and emerging trends, creating four areas of possible ridership change that have been identified in the literature. An overview of the factors in each of these four areas is provided in Table 2-1. Although some broad themes are presented in the remaining sections of this chapter, a literature review by the research team is also available in *TCRP Research Report 209*: *Analysis of Recent Public Transit Ridership Trends,* which is the predecessor to this project.

The existing literature identifies the important factors and the likely direction of each, but it is clear that a mix of factors is contributing to recent transit ridership trends in the United States, pushing ridership in competing directions. Many of the factors listed in Table 2-1 are described in more detail in the following sections.

2.1 Internal Traditional Factors

The three primary areas under a transit agency's control that have traditionally impacted ridership are service quantity, fares, and service reliability.

2.1.1 Service Quantity

Service levels are the most important factor in ridership under control of the transit agency. There is a consensus in the literature that transit service levels—as measured in vehicle revenue hours (VRH) or vehicle revenue miles (VRM)—are the primordial factor affecting transit ridership (Dill et al., 2013; Kyte et al., 1988; Liu, 1993; Gomez-Ibanez, 1996; Kohn, 2000; Evans et al., 2004). VRH have been found to explain up to 95% of the variation in transit ridership (Taylor et al., 2009). More recently, a study by Boisjoly et al. (2018) identified vehicle revenue kilometers as the primary determinant of ridership in a panel regression study of 25 transit agencies from 2002 to 2015. By 2018, bus VRM had still not recovered their pre-2009 levels following the Great Recession service cuts. The relationship between ridership and service levels is not purely causal, however, as transit planners strive to plan service where they believe demand exists. *TCRP Research Report 209* found that although there is a clear relationship between VRH and unlinked passenger-trips (UPTs) in 2012, the relative change between the two variables between 2012 and 2016 was loosely correlated at the metropolitan area level (Watkins et al., 2019). At the route-segment level between 2012 and 2018, Berrebi et al. (2019) found that ridership is inelastic to frequency (i.e., a 1% increase in frequency generates less than a 1% increase in ridership). The elasticity is lowest on the most frequent routes.

Table 2-1. Factors affecting transit ridership.

	Internal	External
Traditional	• Service quantity • Fares • Speed and reliability • Service concentration • Access to transit • Security • Service quality	• Density • Population • Employment • Income • Gas prices • Commuting policies • Car ownership • Demographics
Emerging	• Restructuring transit networks • Demand-responsive services, flex route services, and microtransit pilots and partnerships • New fare media and fare integration • Real-time information • Maintenance issues • Dedicated transit right-of-way • School and employer partnerships • Fare discounts or elimination	• Gentrification • Aging population • Millennials • Telecommuters • Delivery services • Congestion and parking pricing • Shared mobility (ride-hailing, bike-sharing, car-sharing, scooters)

2.1.2 Fares

Overall, increases in fares will modestly decrease transit ridership. Although sensitivity to fares can vary widely within the customer base, modest changes in fares have been found to affect ridership greatly (Liu, 1993; Kohn, 2000). Kain and Liu (1999) evaluated the factors that contributed to increasing ridership in Houston, Texas, and San Diego, California, in the late 1990s while transit ridership was declining across the United States. The authors concluded that increases in service, reduction in fares, and growth in employment and population contributed the most to increasing ridership. In a time-series regression analysis of seven transit agencies, Wang and Skinner (1984) found that the elasticity of ridership fares ranges widely, from −0.042 to −0.62. Using a similar methodology, Chen and Chen (2011) found fare elasticities of −0.4 in the short term and −0.8 in the long term. In a cross-sectional study of transit agencies throughout the United States, Taylor et al. (2009) estimated that fare elasticity was −0.42. In a study of both bus and rail ridership between 1990 and 2017 in Vancouver, British Columbia, Mahmoud and Pickup (2019) found that ridership elasticity to fare is −0.3. Therefore, while studies vary in their estimates and while several studies point to differences between modes and time frames, ridership is generally considered to be inelastic to fares. In other words, a 1% increase in fares typically generates lower than a 1% decrease in ridership.

2.1.3 Speed and Reliability

Improved service reliability, including on-time performance, will increase transit ridership. Service reliability is a leading concern for both transit-dependent and choice riders (Krizek and El-Geneidy, 2007). Unlike other internal factors, which can be measured directly, the impact of reliability on ridership is driven by the experiences and perceptions of passengers. A clear measure of service reliability is schedule adherence. In a cross-sectional analysis of ridership at the route level in Los Angeles, California, Chakrabarti and Giuliano (2015) find that on-time performance is significantly correlated with bus ridership. In a similar study exploring ridership trends over time, researchers from the Massachusetts Bay Transportation Authority (MBTA) came to the same conclusion (Thistle and Zimmer, 2019).

2.2 Internal Emerging Factors

Three emerging areas under the control of transit agencies that can influence transit ridership are network design changes, technology, and demand-responsive service.

2.2.1 Bus Network Redesigns

Bus network redesigns increase ridership, but largely through increases in service and decreases in coverage. Several recent service-related efforts to increase transit ridership have consisted in restructuring bus networks to prioritize service concentration with higher frequency along specific corridors over geographic coverage (Houston; Omaha, Nebraska; Austin, Texas; and Columbus, Ohio). Called the "hottest trend in transit" by *Governing* magazine at the end of 2017, bus network restructuring is being considered by transit agencies across the nation. In 2020, LA Metro, Dallas Area Rapid Transit, Southeastern Pennsylvania Transportation Authority, and Washington Metropolitan Area Transit Authority (WMATA) were planning similar bus network redesigns (Hymon, 2017; Laughlin, 2017; Powers, 2017). In November 2017, *Streetsblog USA* wrote that "transit ridership is falling everywhere—but not in cities that redesigned their bus networks" (Schmitt, 2017). However, many of these bus network redesigns were accompanied by net increases in bus operating budgets, which may partly explain the ridership stabilization or increases (Byala et al., 2019). The network redesigns have also posed equity questions, as some have reported that low-income communities lost access while higher-income communities gained it (Flynn, 2015).

2.2.2 Technology

Passenger information can increase ridership, while the impact of mobile ticketing is still unknown. Technology changes can improve transit ridership as well. The provision of real-time information in Chicago, Illinois, was found to correlate with an increase in ridership when controlling for service levels, employment, and gas prices (Tang and Thakuriah, 2012). A study by Brakewood, Macfarlane, and Watkins (2015) examined bus ridership changes in New York City in response to the gradual availability of real-time bus information. The study revealed a median ridership increase of 2.3%, with higher increases on the largest routes. Additionally, many transit agencies are investing in new fare payment systems to improve payment convenience and the rider experience, particularly for tech-savvy riders who are already using their smartphones to pay for many other goods and services. While mobile ticketing and other new payment technologies are likely to have positive ridership impacts, there has been limited prior research specifically studying the effects of new payment systems.

2.2.3 Demand-Responsive Services

The impact of demand-responsive services on ridership is unknown. To provide greater transit access in low-density neighborhoods or in times of lower demand, there is increased interest in using demand-responsive transit services as an alternative to fixed route transit. Research has shown that in low-density areas, demand-responsive transit can service short trips faster (Qiu et al., 2015) and at a lower cost than fixed routes (Edwards and Watkins, 2013). Several transit agencies have implemented demand-responsive services either to reach the first mile/

last mile or to connect origins and destinations directly (Becker et al., 2013; Westervelt et al., 2018; Bliss, 2017a). However, quantitative research on the ridership implications of these programs is still lacking.

2.3 External Traditional Factors

The previous section considered factors that are internal, that is, under the control of a transit agency. The following sections consider factors that are external to the transit agency's immediate control: economic factors, gas prices, demographic trends, and employer-based commuting policies. It should be noted that although transit agencies can promote employer-based commuting policies—and TDM more generally—they do not control actual decisions made by employers.

2.3.1 Economic Factors

Rising employment levels have a positive impact on transit ridership overall. The level of employment has a mixed effect on transit ridership. While greater employment generates more trips from commuting and consuming, it also leads to private vehicle purchase (Hendrickson, 1986; Liu, 1993). The overall effect of the employment rate, however, has been found to be positive in several studies (Gomez-Ibanez, 1996; Taylor et al., 2009). *TCRP Research Results Digest 29: Continuing Examination of Successful Transit Ridership Initiatives* identifies the rise of employment rates as the leading cause for nationwide ridership increases between 1994 and 1996 (Stanley, 1998).

2.3.2 Gas Prices

Small changes in gas prices only moderately affect transit ridership. High gas prices, such as those in Europe, can have a much larger impact on encouraging transit ridership, but these prices are not found in the United States. There is limited evidence in the literature that gas prices substantially impact transit ridership (Sale, 1976; Dueker, 1998), though the value of the cross-elasticity of gas price to transit ridership has been found to vary substantially based on gas prices, urban form, mode, and time frame. In a time-series regression analysis of seven transit agencies, Wang and Skinner (1984) found that the cross-elasticity ranges widely, from 0.08 to 0.80. Maley and Weinberger (2009) found a cross-elasticity of 0.15–0.23 for city transit services and 0.27–0.38 for regional rail services. Yanmaz-Tuzel and Ozbay (2010) found a cross-elasticity of 0.12–0.22 in the short term, but this value drops to 0.03–0.18 in the long term. In a study of 11 Washington State counties over four years, Stover and Bae (2011) found a cross-elasticity of 0.17. Lee and Lee (2013) found that the cross-elasticity of ridership to frequency is 0.04 in sprawling metropolitan areas and 0.1 in compact regions. Nowak and Savage (2013) show that, as gas prices pass $3 or even $4, cross-elasticities increase to 0.28–0.38. Mahmoud and Pickup (2019) found a cross-elasticity of 0.08 in Vancouver. The general conclusion is that gas prices have relatively little impact on mode shift behavior, though they may cause some change in behavior in the short term when gas prices spike. A possible explanation for these generally low cross-elasticities is that persons with access to autos are relatively inelastic in their behavior, and gas prices are typically too low to motivate long-term vehicle purchases, which ultimately drives mode choice.

2.3.3 Demographic Trends

Traditionally, younger people use transit more. Millennials have potentially conflicting impacts on transit usage. Demographic trends may play a significant role in shaping the pool of potential riders who may use transit (Coogan et al., 2018). Traditionally, transit ridership differs by age, with younger members of the population using transit more; this is often related to their stage in family lifecycle and income. Following retirement, daily trip-making for commuting purposes drops dramatically, which would affect transit in particular since it relies on commuters for a significant proportion of its ridership. The current aging population is such that members of the huge baby boom generation bubble have already started reaching retirement age in great numbers (Driscoll et al., 2018). In addition, demographic trends may be changing. There is frequent discussion of differences in travel behavior among millennials (born 1980–2000). On the one hand, they tend to be less auto-oriented in their preferences and to exhibit a propensity to use shared-use modes (Grimsrud and El-Geneidy, 2013; Grimsrud and El-Geneidy, 2014). At the same time, they are often avid users of modes that can be in competition with transit, such as ride-sourcing (Alemi et al., 2018). Issues of housing affordability may already be encouraging a move to auto-oriented suburbs as they settle into family households.

2.3.4 Employer Commuting Policies (Transportation Demand Management)

Commuting policies and TDM programs encourage alternative modes, including transit. They can be successful in increasing ridership. Commuting policies, such as those included in TDM programs, are designed to create employer incentives that discourage the use of single-occupant vehicles for commuting by employees. Workplace policies have also been shown to alter employees' commuting habits in more general ways. A 2017 study by Bueno et al. used a multinomial logit model to show that parking and driver mileage benefits correlated with decreased transit use, while transit benefits and employer-discounted passes correlated with higher transit use. This study was limited to New York and New Jersey, states with historically high transit use per capita. Similar research was conducted by Dong et al. (2016) in Portland, Oregon, and Block-Schachter and Attanucci (2008) in Boston, Massachusetts, both with similar results. There is limited research on transit benefit programs in small urban areas with a lower transit mode share.

2.4 External Emerging Factors

As discussed repeatedly in the media and in the motivation for this TCRP study, there are many emerging external influences possibly impacting transit ridership. This section discusses six of the most significant factors: telecommuting and online shopping, gentrification, ride-hailing/ride-sourcing, car-sharing, bike-sharing, and dockless shared scooters.

2.4.1 Part-Time Employment, Telecommuting, and Online Shopping

Non-traditional commuters may have less incentive to use transit, while decreasing non-commuting trips may result from changing shopping patterns. Telework, part-time and flex work schedules, and online shopping are becoming more prevalent and impacting the demand for travel and the times when trips are undertaken. Employment trends have been steadily decreasing the number of workers with traditional five-day, nine-to-five jobs while increasing the number of part-time workers and the number of workers who telework. According to a Gallup poll, 43% of Americans reported working remotely at least sometimes, a 4% increase since 2012 (Gallup, 2017). Telecommuters also reported working remotely more often; 75% reported working from home more than once per week, up from 66% in 2012. These changes naturally decrease the number of commuter riders on transit. This trend may also affect commuters' decisions to purchase monthly passes in favor of more flexible options, thus reducing non-commuting trips (Habib, 2017). In addition, the increasing growth in online shopping not only has resulted in the demise of major retail chains and shopping malls, but also is likely to reduce the number of transit-based shopping trips. Delivery services such as Amazon and GrubHub have made shopping- and dining-delivery possible (Suel and Polak, 2018). Despite these trends, vehicle miles traveled are now at their highest point in history (Davis, 2017).

2.4.2 Gentrification

Gentrification in cities generally decreases transit ridership. A potential contributing factor to the decreasing transit ridership is the economic displacement of low-income earners from dense urban centers to the suburbs. Despite some trends that were temporarily going in the opposite direction, suburbs have outpaced urban cores in growth rate (Frey, 2018). While cities are becoming denser, they are also becoming less affordable, which has led to the economic displacement of low-income and minority residents who constitute the primary transit user base (Florida, 2017). A study from Berrebi and Watkins (2020) found that a drop in the proportion of minority residents explains part of the ridership decline in Miami, Florida, but not in Portland, Oregon; Minneapolis, Minnesota; and Atlanta, Georgia, over the short time frame analyzed.

2.4.3 Ride-Hailing/Ride-Sourcing/Transportation Network Companies

Early studies of ride-hailing impacts are mixed, therefore more research is needed. Since ride-hailing companies have started operating in U.S. cities, they have attained a 0.6% mode share in urban areas, which is substantial compared with the 1.7% and 1.1% mode shares of buses and passenger trains (Federal Highway Transit Administration, 2017). This trend, which coincides with the nationwide decline in ridership, has been investigated in multiple studies. In two surveys, respondents have reported that bus usage decreases while rail increases as a result of ride-hailing usage (Clewlow and Mishra, 2017) and that ride-hailing may replace or support transit differently for different trip purposes (Feigon and Murphy, 2016). Longitudinal studies conducted at the transit agency- or metropolitan area-level have come to diverging conclusions. Several studies using data up to 2015 have found that the entry date of Uber had either a positive relationship with transit ridership or no statistically significant relationship (Hall et al., 2018; Boisjoly et al., 2018). Using a similar methodology but more recent data, Graehler, Mucci, and Erhardt found that ride-hailing was correlated with a decline in transit ridership (2019). Erhardt et al. found that between 2010 and 2016, congestion as measured by vehicle hours of delay increased by 60% in San Francisco, California, with two-thirds of that increase attributable to ride-hailing (2019). While the evidence thus far seems to point toward ride-hailing as a potential cause of nationwide ridership decline, this relationship is still not well understood. There remain many research questions surrounding the competition or complementary dynamics between transit and ride-hailing.

2.4.4 Car-Sharing

Car-sharing has a complicated effect on ridership, possibly enabling a car-light lifestyle but sometimes substituting for transit use. The literature exploring the impacts of car-sharing on transit usage thus far has mixed results. Some studies reported that households that have access to car-sharing are using transit less than before (Martin and Shaheen, 2011; Sioui, Morency, and Trépanier, 2013). However, a report combining 15 studies found that car-sharing members' transit usage increased between 13.5% and 54% after becoming members (Shaheen et al., 2009). A study of car-sharing in San Francisco showed that car-share members use transit for 14.5% of their trips compared to 10.3% for non-members (Clewlow, 2016). *TCRP Report 108: Car-Sharing—Where and How It Succeeds* reported that 20% of car-sharing trips were accessed by transit (Millard-Ball et al., 2005). Other studies reported that some car-sharing users substitute transit trips with car-sharing, while others are using transit more since they either reduced car ownership or used transit to access car-sharing. These mixed effects were noticed in Philadelphia and San Francisco (Cervero et al., 2007; Lane, 2005).

2.4.5 Bike-Sharing

Bike-sharing can increase rail ridership at outlying stations, but it decreases bus ridership. Research in the literature has investigated the impact of bike-sharing on transit usage with surveys and empirical models. The main finding from surveys is that bike-sharing is both a competitor and complement to transit, as it replaces transit trips in dense areas and serves as a first-mile/last-mile connector in the suburbs (Buck et al., 2013; Fuller et al., 2013; Martin and Shaheen, 2014; Shaheen et al., 2013; Shaheen et al., 2014). Studies based on empirical models have quantified the impact of bike-sharing on transit ridership in New York City and Washington, District of Columbia. In New York City, it was found that every 1,000 bike-sharing docks along a bus route is associated with a 2.42% decrease in daily unlinked bus trips (Campbell and Brakewood, 2017). In Washington, an early study reported that a 10% increase of Capital Bikeshare ridership corresponds to a 2.8% increase in Metrorail ridership (Ma et al., 2015). Another study in Washington concluded that the impact of bike-sharing on Metrorail ridership was negative for stations located in core neighborhoods and positive for stations located in peripheral neighborhoods (Ma and Knaap, 2019). These findings indicate that bike-sharing both substitutes for and complements transit usage to varying degrees, depending on location.

2.4.6 Dockless Scooters

The magnitude of the impact of dockless scooters on transit ridership is unknown. Dockless scooters made their entry to U.S. cities in summer and fall 2017. Due to the recency of this phenomenon, the research so far is based on surveys. Respondents to these surveys see shared scooters as a complement to public transit. Populus (2018) reported that in 11 major U.S. cities, 70% of the sample surveyed see electric scooters as a complement to public transit. The National Association of City Transportation Officials (NACTO) reported that in 2018, 25% of scooter trips are connections to transit (2019). Although scooters may also be competing with transit, their impact in filling the first-mile/last-mile gap has been reported to be greater in magnitude. In San Francisco; Denver, Colorado; Arlington, Virginia; and Bloomington, Indiana, 34%, 20%, 9%, and 4% of survey respondents, respectively, reported using scooters as a connecting mode to/from transit; meanwhile, only 15%, 7%, 5%, and 2%, respectively, reported substituting transit trips (San Francisco Municipal Transportation Agency, 2019; Denver Public Works, 2019; DeMeester et al., 2019; Baltimore City Department of Transportation, 2019). These results indicate that scooters may be enabling more ridership than they substitute. These findings, however, are only based on surveys and may be impacted by selection bias.

2.5 Conclusion

Three internal traditional factors (those within a transit agency's control) have traditionally explained changes in transit ridership, and all three still impact ridership levels. Service levels are the most important factor in ridership under control of the transit agency—increasing service traditionally has increased ridership. Improved service reliability, including on-time performance, will increase ridership. Overall, increases in fares will modestly decrease transit ridership.

Similarly, there are four external factors that traditionally have impacted transit ridership. Rising employment levels have a positive impact on transit ridership overall. Small changes in gas prices only moderately affect transit ridership. Demographic trends, such as the aging and retirement of baby boomers, are decreasing the number of transit commuters, while the overall

Traditional factors, such as service levels and fares, can explain some recent changes in transit ridership, but emerging trends must be better explored to understand the current trends.

impact of millennials is unclear. TDM-related commuting policies to encourage transit usage and discourage auto usage can be successful at increasing ridership.

As will be discussed in the analysis presented in Chapter 3, although these traditional factors explain some of the recent ridership decline, they do not explain all of the changes being experienced by the industry. The impacts of emerging trends in technology, travel behavior, and transport policy are still not fully understood.

Three new trends are emerging within the control of the transit agency that may impact transit ridership. The literature has shown that bus network redesigns increase ridership, largely through increases in service. Passenger information can increase ridership, while mobile ticketing is yet unknown. The impact of demand-responsive services on ridership is unknown.

Finally, telecommuting, part-time employment, and online shopping will continue to decrease transit's potential market, as will gentrification trends in many cities. The impacts of new modes—such as ride-hailing, bike-sharing, and car-sharing—are unclear. These trends may require cities to try new techniques and/or new partnerships.

CHAPTER 3

Multicity Evaluation

As discussed in the previous chapter, a mix of factors is contributing to recent ridership trends, several of which will push ridership in competing directions. To separate the effects of each of these factors, this project conducted statistical analyses that correlate each factor with changes in transit ridership. The research team analyzed these factors in a two-phase, top-down approach that considered ridership changes first at the system level and then at the detailed route and stop levels. This let the team both consider the diversity of transit systems in the United States and take advantage of more detailed data assembled for specific cities. The analysis compared conditions from 2012, when bus ridership in the United States reached its post-Recession peak, to 2018.

The multicity analysis presented here includes estimated statistical models of the annual change in total bus ridership and rail ridership across 209 metropolitan statistical areas (MSAs) in the United States. (The data sources used in this chapter are outlined in Appendix D of *TCRP Web-Only Document 74*.) The system-level analysis allowed researchers to test many of the factors listed previously and laid the groundwork for the testing of other factors and strategies in Phase 2. The variation across both time and space allowed for better statistical estimates of the sensitivity to these variables because they may change at different rates in different MSAs. The resulting models give the percent change in ridership that would result from a 1% change in each descriptive variable, a relationship known as elasticity. These relationships are broad, and there will always be some portion of the real-world change that models cannot capture. For example, one might expect that changes in where and when service is scheduled affect ridership beyond changes in total VRM. Such details are difficult to capture at the system level and are instead explored in more detail at the route or stop level. The research team reported the results with a category labeled "unknown factors," which includes all the observed changes beyond what could be described by the models. Once these relationships were known, the researchers applied them to calculate the contribution of each factor to the change in bus and rail ridership for each MSA.

This chapter examines bus and rail ridership trends to understand better the similarities and differences across groups of MSAs. Second, the results of a statistical analysis that establishes the sensitivity of transit ridership with respect to changes in both internal and external factors are reported. Third, each factor's contribution to ridership change in each group is provided. Finally, conclusions are drawn about the overall reasons for transit ridership decline.

3.1 Transit Ridership Trends by Group

Before analyzing the reasons for transit ridership change, the research team first examined the patterns of how it has changed. The results in this chapter are grouped into three clusters of MSAs based on transit annual operating expenses per capita, as defined by APTA. The New York region is excluded from the main analysis because NY is an outlier in its historically high levels of transit ridership, which account for 40% of U.S. transit ridership overall. NY has witnessed moderate ridership gains over the past decade. Without data from the NY region, the long-term national transit ridership is decreasing. The three clusters of MSAs are as follows:

- The **high operating expenses group** (greater than $300 million annually) includes 19 MSAs with populations between 2 million and 13 million—such as Atlanta, Chicago, Philadelphia, and Houston—each with both bus and rail services.
- The **mid operating expenses group** (between $30 million and $300 million annually) includes 64 MSAs ranging with populations between 200,000 and 4.6 million, such as Bakersfield, California; Denver, Colorado; Indianapolis, Indiana; and New Haven, Connecticut. All MSAs with mid operating expenses have bus service, and 12 of them also have rail service.
- The **low operating expenses group** (below $30 million annually) includes 126 MSAs with populations ranging from 80,000 to 1 million—such as Athens, Georgia; Bridgetown, New Jersey; Morristown, Tennessee; and Yuma, Arizona—each with only bus service.

Appendix C of *TCRP Web-Only Document 74* shows the full list of MSAs by operating expenses group and results for each MSA, while this report includes the overall results for each group. Figure 3-1 shows the percent change in bus ridership relative to 2012 for each group, according to data from NTD. Bus ridership in the high and mid operating expenses groups peaked in 2008, then declined in the wake of the Great Recession, while bus ridership in the low operating expenses group continued to grow through the Recession. All three groups increased again before peaking in 2012, then declining steeply from 2014 to 2018. In 2018, bus ridership in all three groups was about 15% lower than its 2012 peak.

Transit ridership declines are not limited to buses. Figure 3-2 shows the change in rail ridership relative to 2012. In the high operating expenses group, rail ridership increased until 2014, then decreased, ending 6% below its 2014 peak and 3% lower than 2012. Rail ridership in the mid operating expenses group was more dynamic, with a higher peak in 2008 and a steeper post-Recession decline and recovery. Rail ridership growth in this group is driven in part by new

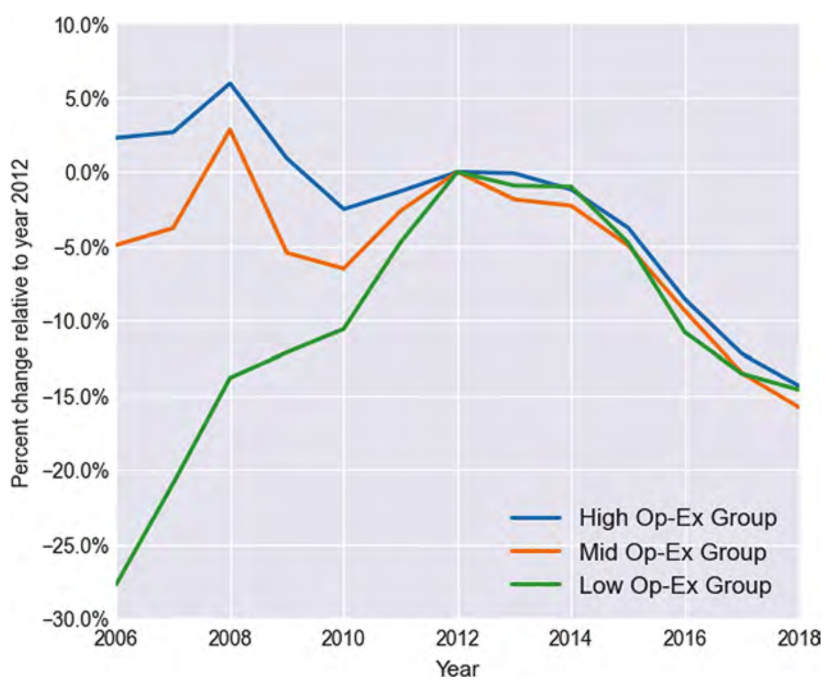


Figure 3-1. Percent change in bus ridership from 2012.

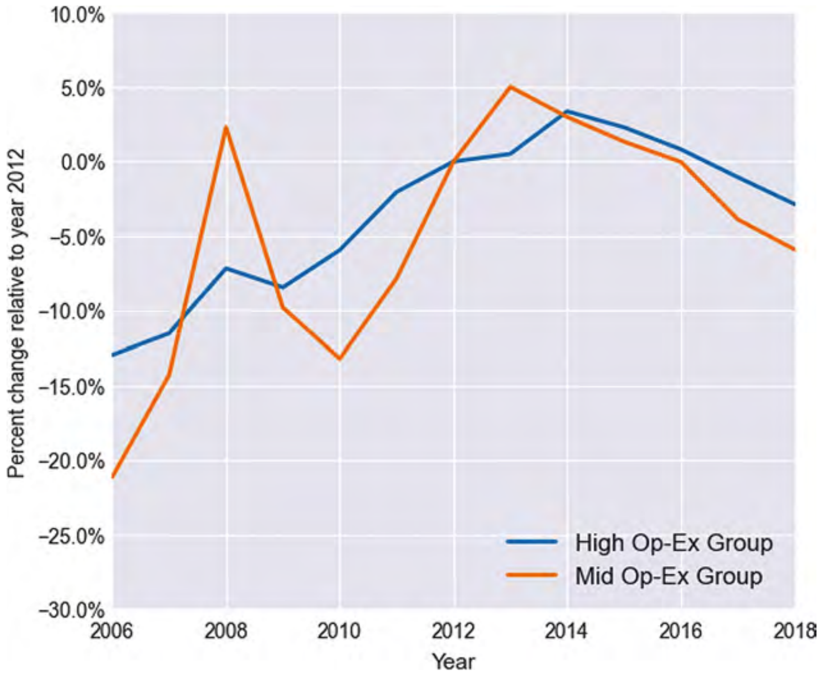


Figure 3-2. Percent change in rail ridership from 2012.

or expanded rail systems in places such as Charlotte, North Carolina; Denver, Colorado; and Seattle, Washington. Rail ridership in the mid operating expenses group peaks in 2013, and by 2018, it is 10% lower than its peak and 6% lower than its 2012 level. Only a handful of MSAs in the low operating expenses group have rail service; these are excluded from the analysis.

Recent transit ridership declines are broad-based—they occurred for both bus and rail and across large, medium, and small cities. The change is especially steep between 2014 and 2018. The predominant causes of ridership declines must also be broad-based and concentrated in those years. In order to understand what those causes might be, a statistical model was estimated to measure how sensitive transit ridership is to a range of factors.

3.2 Sensitivity of Transit Ridership to Different Factors

The research team determined the sensitivity of transit ridership to changes in each variable using a fixed-effects panel regression model. The fixed-effects model estimates coefficients based on the changes within each MSA, rather than from differences between MSAs. The team used data on transit ridership and operating characteristics as reported in the NTD and supplemented it with census data, economic statistics, news reports, and other publicly available data. The detailed methodology and assumptions in the model are presented in Appendix D, which is available in *TCRP Web-Only Document 74*. In developing this model, over 100 different specifications were tested before the researchers arrived at this preferred one. A number of variables were considered but excluded because they were shown to be insignificant (p-value > 0.05) or because a different specification produced a better fit or more defensible result. The specific variables used in the analysis are described as follows and grouped into six broad categories. In all cases when discussing change, this report refers to net changes, with the assumption that all other factors remain constant.

3.2.1 Service

The quantity and quality of transit service provided affects transit ridership. This effect is captured using three measures:

- **VRM of service is a strong determinant of transit ridership.** The results indicate that each 1% increase in bus VRM increases bus ridership by 0.45% and each 1% increase in rail VRM increases rail ridership by 0.66%. Rail ridership may be more elastic to changes in VRM because rail tends to attract more choice transit riders than bus.
- **Bus network restructures are associated with a 4.7% higher bus ridership over the six-year period, but the effect is not statistically significant.** In recent years, transit operators such as those in Baltimore, Maryland; Columbus, Ohio; Houston, Texas; Jacksonville, Florida; and Tallahassee, Florida, have restructured their bus networks—changing routes and the service allocation—in an effort to better serve their passengers. The operators that made these changes saw, on average, a 4.7% bus ridership increase over and above the effect of any VRM increases. However, not enough agencies have completed such a restructure to make the results statistically significant.
- **Major line closures for maintenance work can have an important effect on rail ridership.** Safety incidents in 2015 and 2016 on the Washington Metro in the District of Columbia led to line closures and major maintenance work in the following years, with disruptions lasting from late 2015 to early 2018. Rail ridership in the Washington MSA was found to be 13% lower in the affected years (with half the effect in 2015 and 2018) than would otherwise be expected. This effect was marginally significant. The researchers tested a more comprehensive measure of reliability based on the mean distance between failures, but the reporting of failures to the NTD is inconsistent, so they could not detect a meaningful effect.

The research team tested or considered several other measures of transit service. It was found that average transit speed is negatively correlated with transit ridership, probably because vehicles can travel faster if they do not have to stop to pick up and drop off passengers. The team could not have a widely available measure of on-time performance, nor was there a comprehensive measure of where the service is allocated within a region.

3.2.2 Fare

Higher fares lead to lower transit ridership.

- **Increasing average bus fare by 1% decreases bus ridership by 0.57%, and increasing average rail fare by 1% decreases rail ridership by 0.35%.** The average fare is calculated by taking the total inflation-adjusted fare revenue earned by the transit agency in a year per UPT. The different elasticities for bus versus rail fare may reflect different income mixes of the passengers.

The research team could not test specific fare or pass programs at the system level, but these were tested in case studies, as described in later chapters.

3.2.3 Land Use

Transit connects people to activities and jobs, so the number and location of both affects transit ridership.

- **Each 1% increase in population plus employment is associated with 0.22% more transit ridership.** These effects are correlated with each other and could not be estimated separately, but when taken together, the effect is positive and significant.
- **Higher density leads to more transit ridership.** The researchers considered the percent of the population and employment in a region that is within a transit-supportive density, defined

as more than 10 people or employees per acre. For each percentage point increase (such as from 10% to 11%) in population plus employment living in these denser areas, transit ridership becomes 0.4% higher.

Working at a national level, the researchers could not compile data on the location and size of transit-oriented developments, nor could they compile other, more detailed data on the allocation of land use within transit-supportive areas.

3.2.4 Gas Price

Higher gas prices make driving more expensive and encourage riders to switch to riding transit.

- **Each percent increase in gas price accounts for a 0.14% increase in transit ridership.** The research team measured this with data from the Energy Information Administration and adjusted the measure for inflation.

3.2.5 Household and Income Characteristics

Among the many factors related to the characteristics of households, their income, and the work norms that may affect their transit ridership, the research team found three to be important:

- **With higher per capita income, people are less likely to ride transit.** Several variables were tested to establish the relation between income and transit ridership. Although mean and median values of household-level income both display the expected correlation, the research team chose per capita median income in 2018 dollars because of the better fit of the model. Each 1% increase in median per capita income results in a 0.07% decrease in transit ridership.
- **Higher shares of zero-vehicle households in an MSA have a small positive effect on transit ridership.** People from households without a car constitute an important market for transit riders. However, the share of zero-vehicle households has been relatively stable in recent years, so the results show that it explains little about the *change* in transit ridership over this period. The model indicates that a 1% increase in households owning zero vehicles would result in 0.2% more transit ridership, but this effect is not statistically significant.
- **For each additional percent of workers telecommuting, transit ridership decreases by 0.76%.** This result is based on the journey-to-work mode shares reported in the American Community Survey. This result is particularly interesting going forward considering the large percent of population working from home during the COVID-19 pandemic.

The research team tested the percent of the population living in poverty, the percent of the population born in a different country, and the percent of the population in different age groups and did not find significant effects. The team also tested the distribution of poverty as measured by the percentage of poor households living in areas with transit-supportive density but did not find a significant result.

3.2.6 New Competing Modes

Over the past several years, several new modes of travel have entered or proliferated in urban areas, including ride-hailing, bike-sharing, and electric scooters. It is possible that these modes could complement public transit by serving as first-mile/last-mile connectors or by serving trips at times and locations not well served by transit. However, these new modes could also compete for the same riders that transit serves, especially if they are concentrated in the densest corridors and center cities where transit ridership is highest. The fact that these new modes started operating in different MSAs in different years provides a natural experiment to test their effect—the panel-data models empirically measure whether MSAs with ride-hailing or other modes have higher or lower transit ridership than would be expected when controlling for all other factors in the model. This analysis reveals that:

- **When ride-hailing enters a market, bus ridership decreases.** Ride-hailing—sometimes also known as app-taxi or e-taxi—services are offered by local drivers using personal vehicles via a transportation network company (TNC) or by traditional taxis via an app. The app connects the drivers with potential passengers for a pre-determined fee and transports the customer door-to-door exactly where they would like to go. When ride-hailing enters a market, its effect is not an immediate switch. Instead, the effect builds over time as ride-hailing companies are able to recruit more drivers and serve more passengers. In the largest MSAs (those in the high operating expenses group), bus ridership decreases by a net 1.9% per year after ride-hailing enters the market. For MSAs in the mid and low operating expenses groups, bus ridership decreases by 3.4% per year after ride-hailing enters the market. Both measures are highly significant statistically. The difference may relate to a greater transit resilience in bigger, denser cities. It is also important to note that ride-hailing companies entered smaller markets later, and the companies may therefore have more resources for a faster ramp-up period in those markets. Whether this trend continues or levels off remains to be seen and is complicated by reduced travel during the COVID-19 pandemic.
- **When ride-hailing enters a market, rail ridership in MSAs with medium-sized transit agencies decreases, but rail ridership in MSAs with a larger amount of transit remains resilient.** Ride-hailing's entry affects rail ridership differently than bus ridership. In medium-sized MSAs (those in the mid operating expenses group), rail ridership decreases by a net 2.2% for each year after ride-hailing's entry, and the effect is statistically significant. However, for MSAs in the high operating expenses group, ride-hailing has a slightly positive (0.2% per year) but statistically insignificant effect on rail ridership. Ride-hailing may affect rail ridership less than bus ridership because rail offers a travel-time advantage that bypasses congestion, or because rail tends to serve longer trips that would be more expensive to serve end-to-end with ride-hailing. Rail ridership in bigger cities could be more resilient for those same reasons, or because those rail systems tend to be older and better integrated into the urban fabric.
- **Bike-sharing has a small but insignificant effect on transit ridership.** When a bike-sharing system starts, transit ridership in that MSA is found to be 1% lower in subsequent years than otherwise expected, but this effect is not statistically significant. This effect does not build over time in the same way that the effect of ride-hailing grows.
- **When dockless electric scooters enter a market, transit ridership decreases.** Transit ridership is found to be net 4% lower after e-scooters enter a market. However, e-scooters only started in the last year of the analysis period, so the researchers are less confident in this result than they are in the ride-hailing and bike-sharing findings, where there is a longer record to analyze. Therefore, this topic will be explored further in the route-level analysis.

The researchers tested several other specifications to understand how the effects might vary by location or mode. They found similar results as they varied the specification, with the results presented here based on the best overall model.

3.3 The Contribution of Each Factor to Changes in Transit Ridership

The research team applied the sensitivities calculated above to calculate the total contribution of each of these factors to the change in transit ridership between 2012 and 2018. The coefficients for each variable in the estimation represent either the direct elasticity or the percentage point increase in transit ridership for each unit percent change or unit change in the factors. These coefficients were multiplied by the observed change in each factor to calculate that factor's effect on transit ridership. While competing factors may offset each other, this approach can be used to calculate the net effect of each factor. Applying this approach does not capture 100% of the observed ridership change, and any remaining difference between the modeled and observed ridership is labeled as "unexplained change." These calculations were applied separately for each MSA and transit mode (bus versus rail), then the results were aggregated by group. The results by group (as described in Section 3.1) are shown in the following section, and Appendix C of *TCRP Web-Only Document 74* shows the results for each MSA.

3.3.1 Contributions to Bus Ridership Change

Table 3-1 shows the change in each factor and its contribution to bus ridership change between 2012 and 2018. The rows are grouped by the six categories of factors as described previously, with results for each variable and a subtotal for each category. The columns are specific to the

Table 3-1. Contributions to bus ridership change between 2012 and 2018.

	Change in Average Values by Operating Expenses Group			Ridership Effect by Operating Expenses Group		
Description	High	Mid	Low	High	Mid	Low
Service						
VRM	4.2%	11.9%	9.0%	2.5%	4.7%	4.0%
Network Restructure	0.03	0.03	0.0	0.1%	0.1%	0.0%
Subtotal				*2.6%*	*4.9%*	*4.0%*
Fare						
Average Fare (2018$)	0.0%	1.6%	17.8%	-0.3%	-0.3%	-4.0%
Subtotal				*-0.3%*	*-0.3%*	*-4.0%*
Land Use						
Population + Employment	6.3%	7.9%	5.8%	1.4%	1.7%	1.1%
Percent of Population + Employment in Transit Supportive Density	-0.2%	-1.2%	-1.9%	0.0%	-0.2%	-0.1%
Subtotal				*1.4%*	*1.5%*	*1.0%*
Gas Price						
Average Gas Price (2018$)	-26.4%	-28.8%	-29.5%	-3.4%	-3.8%	-3.9%
Subtotal				*-3.4%*	*-3.8%*	*-3.9%*
Household and Income Characteristics						
Median Per Capita Income (2018$)	12.5%	9.5%	8.4%	-0.8%	-0.6%	-0.6%
Percent of Households with 0 Vehicles	-8.7%	-12.8%	-4.8%	-0.2%	-0.2%	-0.1%
Percent Working at Home	22.7%	32.5%	35.1%	-0.8%	-1.0%	-0.9%
Subtotal				*-1.7%*	*-1.8%*	*-1.5%*
New Competing Modes						
Years Since Ride-Hail Start	5.68	3.86	3.26	-10.2%	-11.8%	-9.8%
Bike-Share	0.79	0.74	0.54	-0.8%	-0.8%	-0.5%
Electric Scooters	0.54	0.41	0.07	-1.9%	-1.3%	-0.3%
Subtotal				*-12.9%*	*-13.9%*	*-10.5%*
Total Modeled Ridership				-14.4%	-13.4%	-15.0%
Total Observed Ridership				-14.4%	-15.8%	-14.6%
Unexplained Change				0.1%	-2.4%	0.4%

groups, which shows how ridership changes differ by group. For example, between 2012 and 2018, bus VRM for MSAs in the high operating expenses group increased by 4.2% on average, resulting in 2.5% more bus ridership in that group. The changes may be higher or lower for individual MSAs, with the values reported here representing the total change across all MSAs within the group. For some factors, the absolute change in the variable is reported rather than the percent change. For example, the bike-sharing variable takes a value of 1 if bike-sharing is present and 0 if it is not. The value of 0.79 in the high operating expenses group indicates that 79% of MSAs in this group did not have bike-sharing in 2012 but did have bike-sharing in 2018. These results show that:

- More service leads to higher ridership for all groups but to different extents.
- Network restructures, while noticeable for individual MSAs, have a small overall effect when added to the remaining MSAs in the group.
- Fares have only a small effect on ridership in the high and mid operating expenses groups; however, the average fare increased by 18% in the low operating expenses group, leading to 4% lower bus ridership.
- All groups added population and employment, leading to higher ridership, but this change was partially offset by much of that growth occurring in low-density areas.
- Gas prices were 26%–30% lower in 2018 than in 2012, leading to 3%–4% lower bus ridership.
- Over this period, incomes increased, a smaller share of households owned zero vehicles, and more people worked from home.
- The biggest portion of bus ridership loss is attributable to ride-hailing; bus ridership is 10%–12% lower in each group due to competition with ride-hailing.
- Competition with bike-sharing and electric scooters leads to slightly lower ridership, although the bike-sharing effect is statistically insignificant.

When applied in this way, the model does a good job of predicting the total ridership change for each group. The modeled and observed changes are within 1% for both the high and low operating expenses groups. For the mid operating expenses group, the model predicts a 13.4% ridership decrease, but ridership actually decreased by 15.8%. This group has a 2.4% ridership decrease that cannot be explained by the factors described here.

Table 3-1 shows how the model can be applied to determine the contributions to ridership change for 2012 and 2018. It can also be applied to estimate the contributions to ridership change for any year for which the researchers have data. In Appendix E of *TCRP Web-Only Document 74,* the model is applied to the period from 2002 through 2012 to validate that it can reasonably predict the observed ridership change for a period that extends beyond the estimation period.

In Figure 3-3, Figure 3-4, and Figure 3-5, the model is applied to each year from 2012 through 2018, and the effect of each factor on bus ridership is plotted. In these plots, the black line shows the observed ridership. Shaded red areas above the black line indicate the amount by which ridership is lower due to the changes in that factor relative to its 2012 value. Shaded green areas below the black line indicate the amount by which ridership is higher due to changes in that factor relative to its 2012 value. For example, Figure 3-3 shows that bus service increases in the high operating expenses group led ridership to be higher than it otherwise would have been.

In each of the figures, bus service increases relative to 2012 levels led to increased bus ridership. Land use changes led to slightly more ridership in each group, while changes to household and income characteristics led to slightly lower ridership. Fare increases had a small effect in the high and mid operating expenses groups and a larger effect in the low operating expenses group. The drop in gas prices between 2014 and 2015 resulted in a decrease in bus ridership for each subsequent year. The biggest contributor to change in bus ridership was the emergence of new competing modes—dominantly ride-hailing. For each group, bus ridership would have been almost level without the losses due to these new modes.

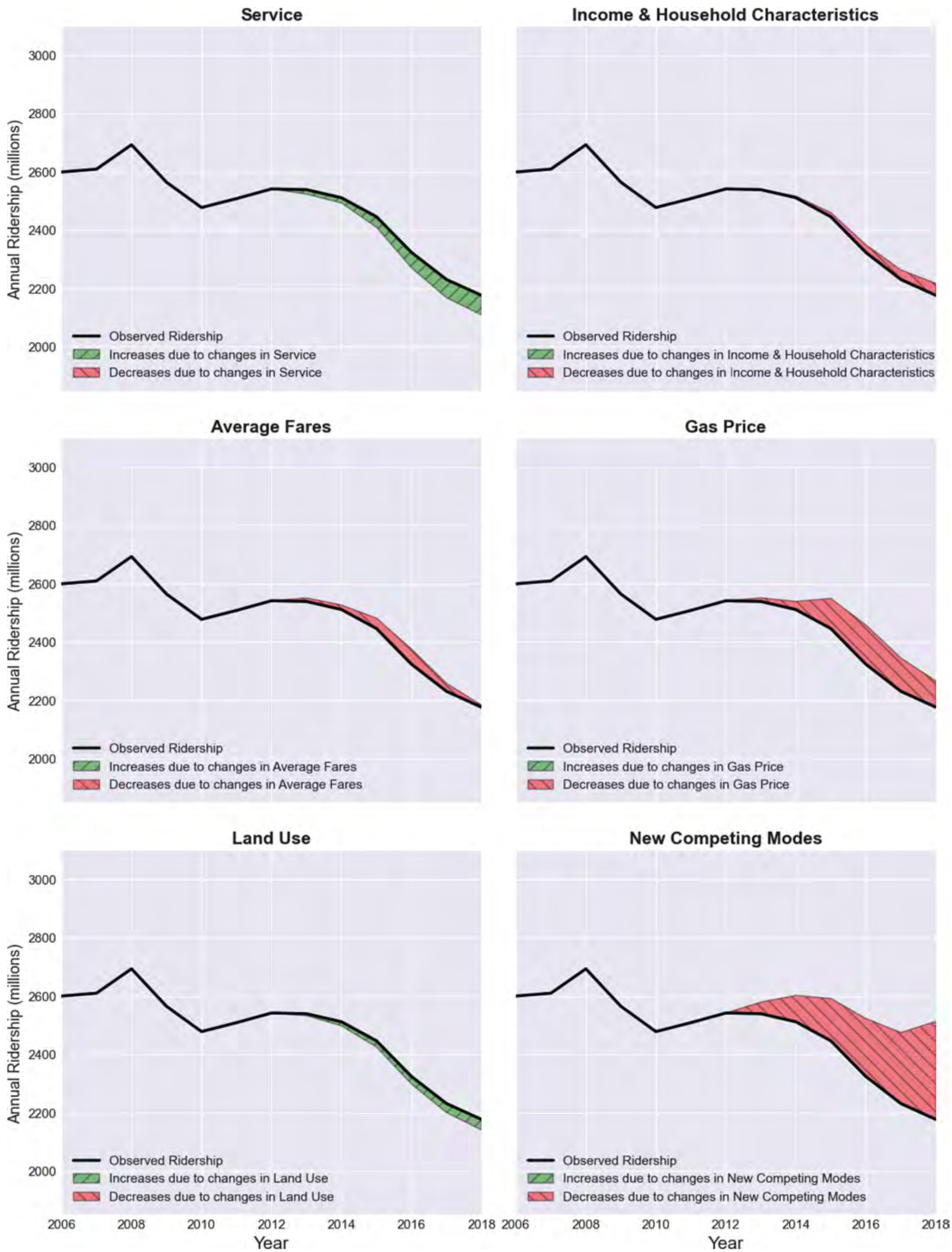


Figure 3-3. Contributions to bus ridership change for high operating expenses group.

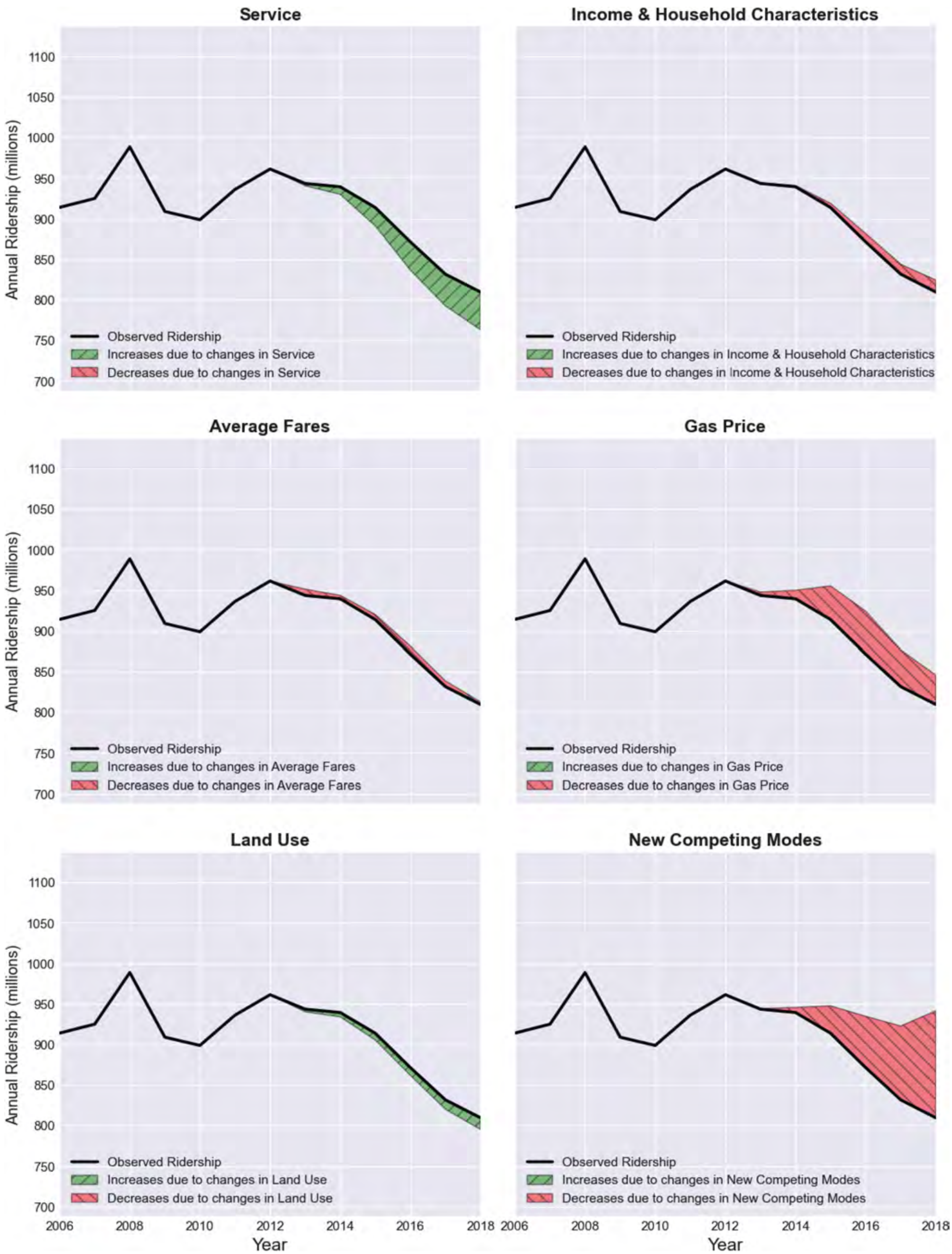


Figure 3-4. Contributions to bus ridership change for mid operating expenses group.

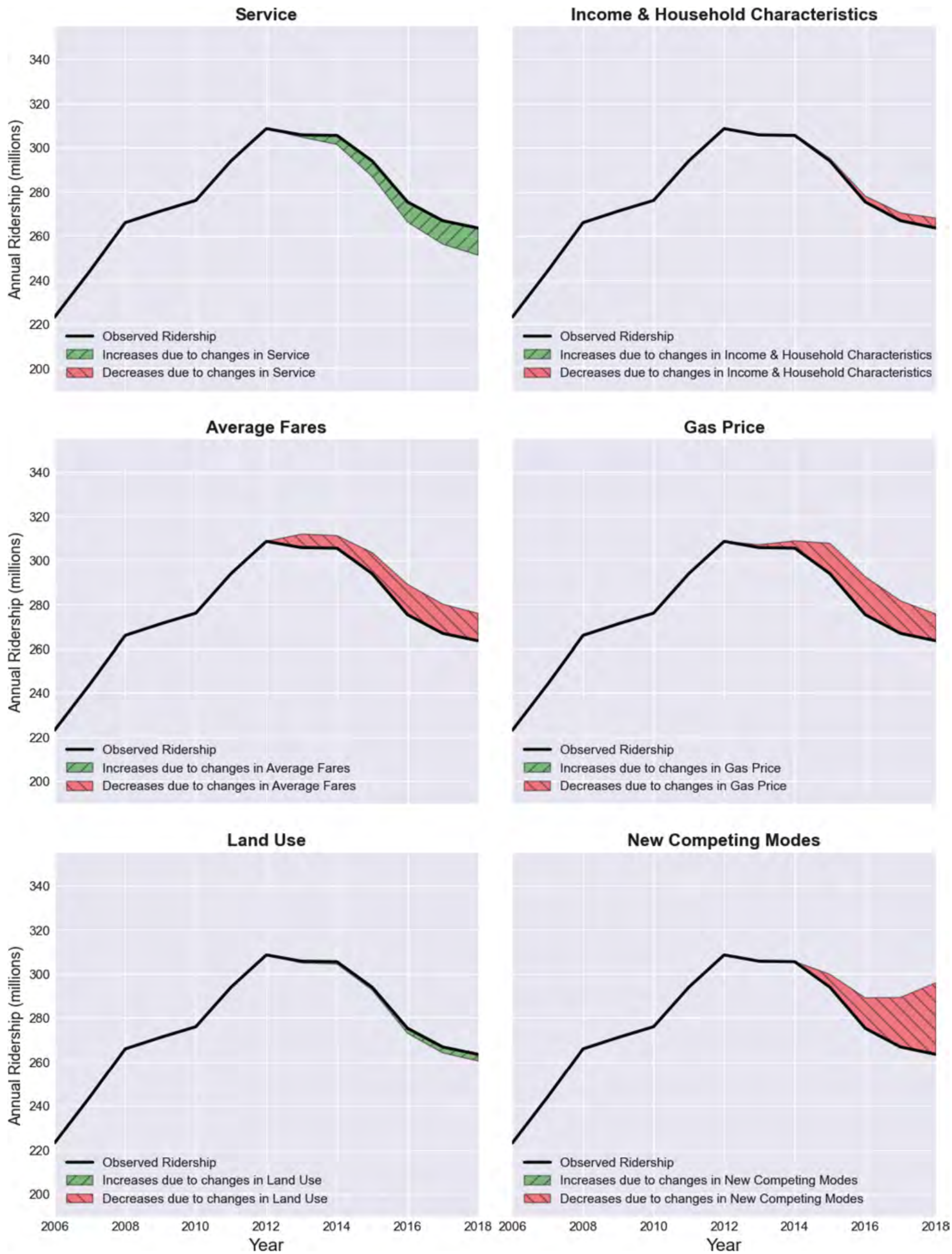


Figure 3-5. Contributions to bus ridership change for low operating expenses group.

3.3.2 Contributions to Rail Ridership Change

Table 3-2 shows the change in each factor and its contribution to rail ridership change between 2012 and 2018, in the same format as Table 3-1. The small number of MSAs in the low operating expenses group that have rail service were excluded from the analysis, as there are not enough MSAs to draw broad conclusions. The 2012–2018 period continues a broad investment in rail service in the United States, with VRM increasing by 12% in the high operating expenses group and by 23% in the mid operating expenses group where more light rail or streetcar systems were opened or expanded. From these service changes, 10% and 18% more ridership in those groups would be expected. Given the fixed nature of rail investment, there are no rail network restructures. However, maintenance of aging rail systems over time has become a major issue. While all systems are conducting maintenance, the more drastic closures

Table 3-2. Contributions to rail ridership change between 2012 and 2018.

	Change in Average Values by Operating Expenses Group		Ridership Effect by Operating Expenses Group	
Description	High	Mid	High	Mid
Service				
VRM	11.8%	22.9%	10.0%	17.9%
Major Maintenance Event	0.09	0.0	0.0%	0.0%
Subtotal			*10.0%*	*17.9%*
Fare				
Average Fare (2018$)	12.7%	7.4%	-2.7%	-0.9%
Subtotal			*-2.7%*	*-0.9%*
Land Use				
Population + Employment	6.0%	6.0%	1.4%	1.5%
Percent of Population + Employment in Transit Supportive Density	0.1%	-2.0%	0.0%	-0.3%
Subtotal			*1.4%*	*1.2%*
Gas Price				
Average Gas Price (2018$)	-28.5%	-28.4%	-3.7%	-3.9%
Subtotal			*-3.7%*	*-3.9%*
Household and Income Characteristics				
Median Per Capita Income (2018$)	11.5%	9.4%	-0.8%	-0.7%
Percent of Households with 0 Vehicles	-7.1%	-13.5%	-0.2%	-0.2%
Percent Working at Home	24.1%	32.5%	-0.9%	-1.4%
Subtotal			*-1.8%*	*-2.3%*
New Competing Modes				
Years Since Ride-Hail Start	5.88	4.21	1.3%	-9.7%
Bike-Share	0.64	0.50	-0.7%	-0.6%
Electric Scooters	0.64	0.55	-2.4%	-2.2%
Subtotal			*-1.8%*	*-12.5%*
Total Modeled Ridership			1.3%	-0.5%
Total Observed Ridership			-2.9%	-5.9%
Unexplained Change			-4.2%	-5.4%

for the Washington Metro system were a factor that the research team wanted to test. While it had an important effect on rail ridership locally, its relative contribution was small when grouped with other MSAs.

Average rail fares increased by 13% in the high operating expenses group and by 7% in the mid operating expenses group, leading to 3% and 1% lower rail ridership, respectively. Population and employment increased 6% on average in MSAs with rail, leading to about 1% more rail ridership. Much like bus, lower gas prices led to 4% lower rail ridership, while income growth, higher car ownership and more people working from home led to 2% lower rail ridership. Bike-sharing and electric scooters contributed to lower rail ridership, although the bike-sharing effect is insignificant. The ride-hailing effect is different for the two groups. Ride-hailing has a positive but insignificant effect on ridership in the high operating expenses group while contributing significantly to a 10% decrease in rail ridership in the mid operating expenses group.

The model suggests that when all of these factors are considered together, rail ridership would be expected to increase slightly in the high operating expenses group and decrease slightly in the mid operating expenses group. In comparison, observed ridership decreased 3% and 6% in the groups, respectively. This means that rail ridership decreased by 4%–5% more than this model explains. It is not surprising that this model does not fully capture the changes to rail ridership because there are fewer MSAs with rail, and rail systems in the United States are diverse—they include heavy rail systems that are many decades old, newly constructed light rail systems, commuter rail systems, and more. The smaller number of observations makes it more difficult to capture some of the dynamics that may affect rail differently. However, it is important to note that considering the large expansion of rail service over this period, a corresponding ridership increase should be expected. The fact that rail ridership declined in spite of its expansion is quite striking, and the model does capture most of this difference.

In Figure 3-6 and Figure 3-7, the model was applied to each year from 2012 through 2018, and the effect of each factor on rail ridership was plotted. These plots take the same format as Figures 3-3 to 3-5, where the black line shows the observed ridership, shaded red areas above the black line indicate the amount that ridership is lower due to changes in that factor, and shaded green areas below the black line indicate the amount that ridership is higher due to changes in that factor.

In both of these figures, there are substantial net rail ridership increases attributable to service increases, with net decreases due to lower gas prices starting in 2015. Changes to land use and household and income characteristics had a small effect on rail ridership in each group. Fare increases led to lower rail ridership in both groups, with a larger effect on the high operating expenses group. The effect of new competing modes can be observed in year 2018 in the high operating expenses group. In the mid operating expenses group, competition with ride-hailing is an important contributor to lower ridership, and rail ridership in this group would have been roughly flat if not for losses to ride-hailing.

3.4 Conclusion

In this analysis, the researchers examined bus and rail ridership trends for MSAs grouped by transit operating expenses per capita. They found that between 2012 and 2018, bus ridership in all three groups decreased by about 15%, with the decline steepest between 2014 and 2018. The decline in rail ridership started later than bus ridership and is less steep, but it was still most concentrated in the 2014–2018 period. By 2018, even rail ridership was 3% lower than its 2012 reference point in the high operating expenses group and 6% lower in the mid operating expenses group.

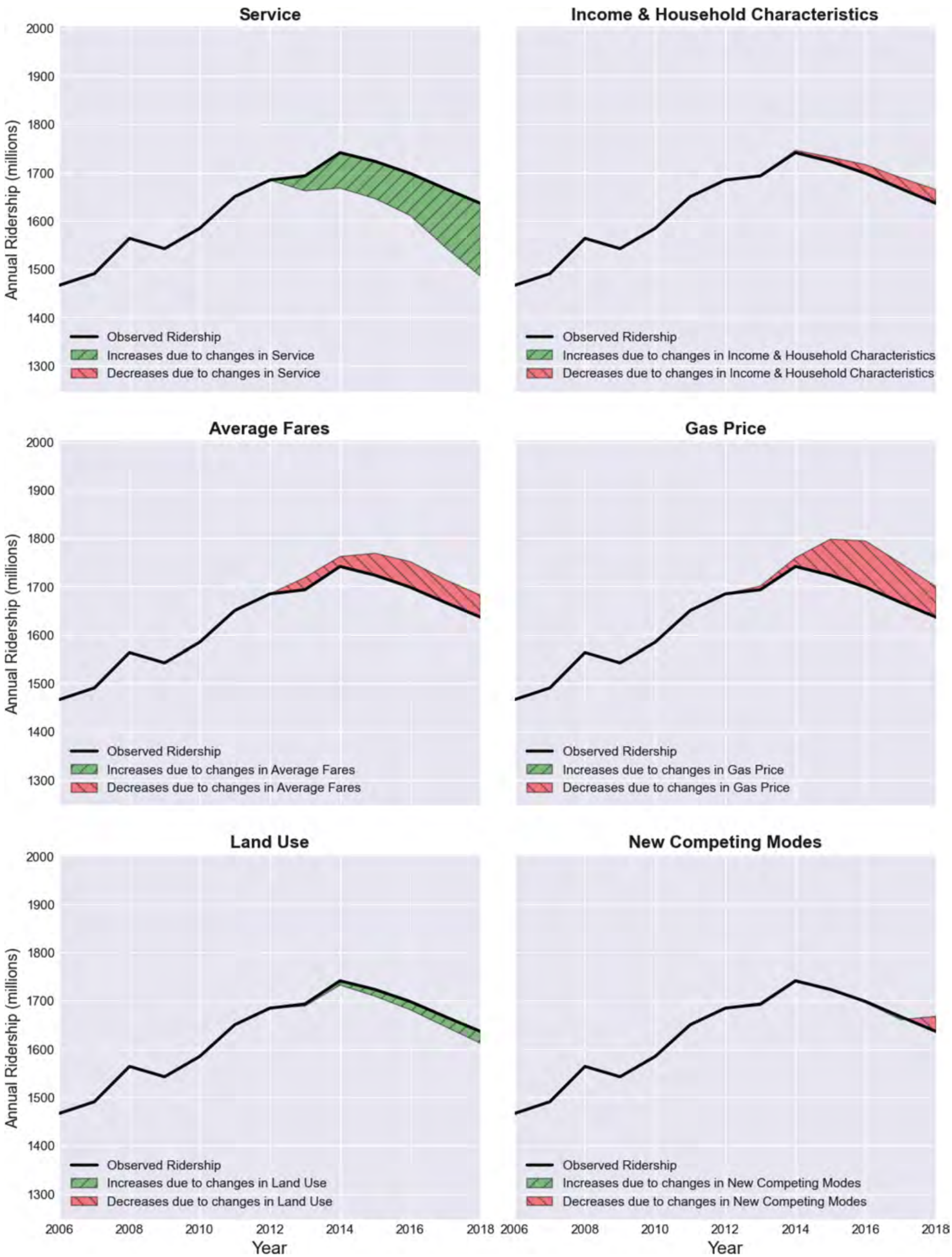


Figure 3-6. Contributions to rail ridership change for high operating expenses group.

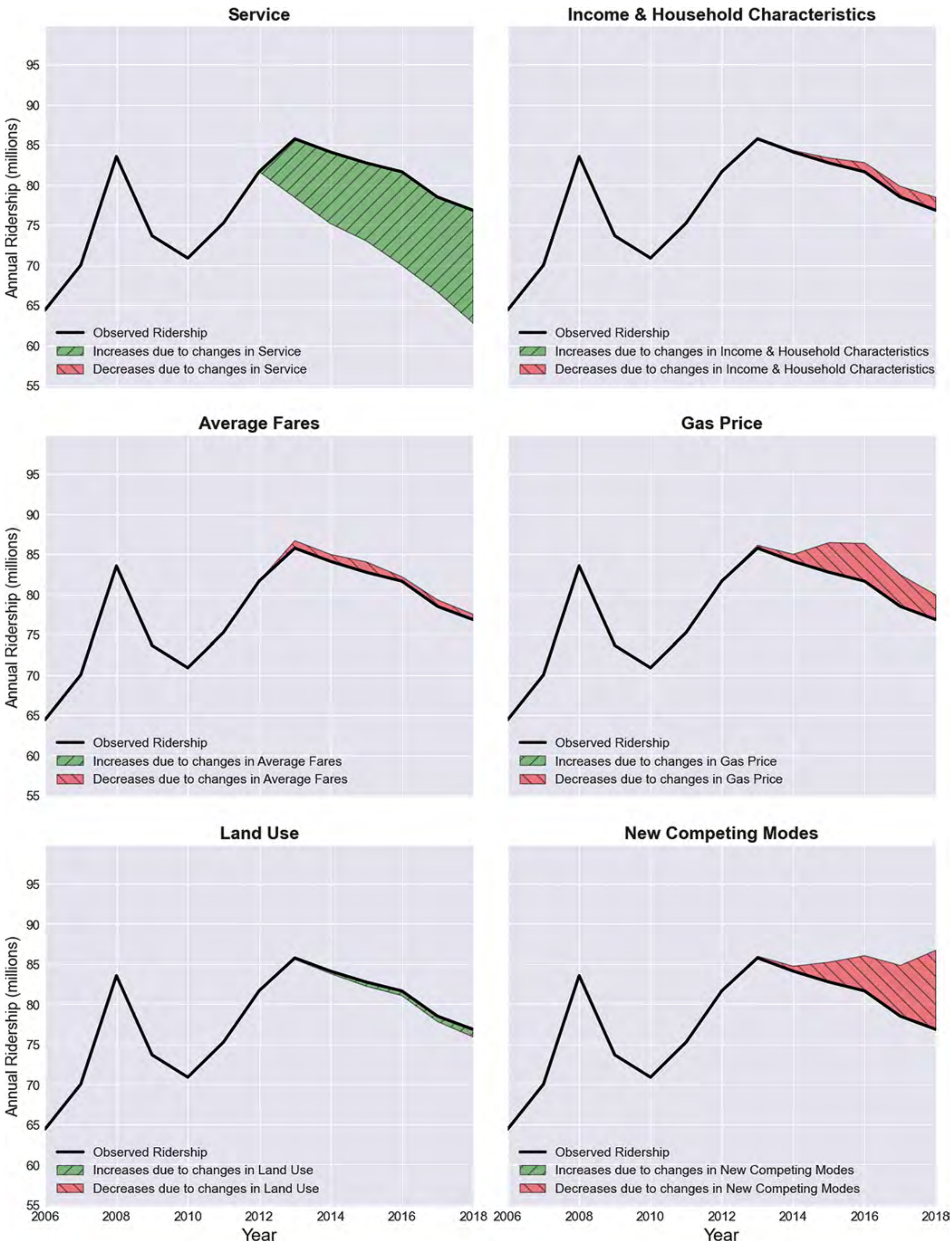


Figure 3-7. Contributions to rail ridership change for mid operating expenses group.

The research team identified a number of factors that affect transit ridership, some of which result in net increases and others in net decreases to transit ridership. Overall, the team found that two sets of factors pushed to increase transit ridership from 2012 to 2018:

- **More service.** Across all groups and modes, transit operators are providing more service in the form of added VRM. These service additions vary by location. They resulted in net bus ridership increases ranging from 3% in the high operating expenses group to 5% in the medium operating expenses group. This period continues a period of investment in expanded rail service, resulting in net rail ridership increases of 10% in the high operating expenses group and 18% in the mid operating expenses group.
- **Land use.** Land use also affects transit ridership, both in terms of total population and employment growth and how centralized that growth is. By cluster, metro areas grew between 6% and 8% in population and employment, with that growth occurring more in less dense suburbs than in centralized areas of the regions. The combined effect of land use changes was net bus and rail ridership increases of between 1% and 1.5%. It makes sense that these effects are modest because while land use is an important driver of transit ridership, changes tend to occur over a long time frame.

The causes of bus ridership decline between 2012 and 2018 come from a combination of four main sources. Together, these sources more than offset the factors listed above that pushed ridership up over this period. They include the following:

- **Income and household characteristics.** Higher incomes, higher car ownership, and an increase in the percent of people working at home contributed to net bus and rail ridership declines of about 2%.
- **Higher fares.** Fare increases are operator-specific—so the effect varies by location—but fares were, on average, higher in 2018 than in 2012 after adjusting for inflation. Average bus fares went up by a maximum of 18% in the low operating expenses group metro areas, accompanied by a 4% decrease in bus ridership. In the other two groups, the effect of little to no change in fares contributed a less than 1% change in bus ridership. Rail fares increased by 13% in the high operating expenses group and 7% in the mid operating expenses group, resulting in 3% and 1% lower ridership, respectively.
- **Lower gas prices.** Average inflation-adjusted gas prices decreased by more than a quarter over this period, leading to between 3% and 4% lower bus and rail ridership.
- **New modes compete with bus.** Three new modes emerged in cities over this period that compete directly with bus: ride-hailing, bike-sharing, and e-scooters. The analysis shows that the effects of bike-sharing systems and e-scooters are much smaller compared to ride-hailing services. Ride-hailing itself contributes to 10%–12% lower bus ridership, with the combined effect of all modes leading to 10%–14% lower bus ridership. For rail, the effect of ride-hailing varies by group. In the high operating expenses group, ride-hailing's introduction increases rail ridership by an insignificant amount, but in the mid operating expenses group, ride-hailing reduces rail ridership by 10%. The combined effect of all three new modes leads to 2% lower rail ridership in the high operating expenses group and 12% lower rail ridership in the mid operating expenses group.

By providing a better understanding of the reasons for recent transit ridership declines, this research puts transit operators and transportation planners in a better position to effectively respond to those declines.

CHAPTER 4

Bus Ridership and Frequency Trends by Time of Day in Four Cities

The analysis conducted in Chapter 3 uses service and ridership information by month at the transit agency level, which was provided by those agencies to NTD. While these data have been used to delineate the broad trends in ridership, they don't help answer the "when" and "where" questions, which are instrumental to identify the causes of ridership decline and define strategies to reverse the trend. Yet, understanding the underlying dynamics of bus ridership is integral for the effective management of bus transit systems.

Data collected from automatic passenger counters (APCs) can provide a unique window into the distribution of ridership by time of day and day of the week. This chapter analyzes transit ridership trends on a hyper-local level: segments of seven consecutive stops on the same route and direction. Combined with standardized schedule data from the General Transit Feed Specification (GTFS), ridership can be compared with service levels. The quantity of service, which is measured in terms of frequency, is fundamental to understanding the distribution of demand, both temporally and spatially. Service frequency determines the feasibility and reliability of transit trips. Therefore, in the following section, trends in bus ridership and service quantity over time are explored together in four transit agencies:

- TriMet in Portland, Oregon
- Miami-Dade Transit in Miami, Florida
- Metro Transit in Minneapolis/St. Paul, Minnesota
- Metropolitan Atlanta Rapid Transit Authority (MARTA) in Atlanta, Georgia

These four transit agencies have all experienced losses in bus ridership, following the national trend. Serving passengers in different regions of the United States, these four bus systems are different in key ways that make them representative of other large to mid-sized transit agencies as a group. The four agencies operate in differently sized cities with varying density profiles. At the same time, they are similar enough in size to be compared to each other. They all serve between 50 million and 57 million bus trips per year. Most importantly, they were all early adopters of passenger counting technology. Over multiple years, they have maintained the high standard of data collection, cleaning, and processing required for this analysis.

4.1 Bus Ridership Trends

Identifying the temporal dimension of the recent bus ridership decline is crucial to understanding the underlying causes and finding solutions to reverse the trend. There is a common narrative that bus ridership has been especially declining during off-peak and weekends (Bliss, 2017b). According to a report from UCLA (University of California, Los Angeles) and the analysis in Chapter 5, the Bay Area Rapid Transit (BART) authority has experienced a concentration of demand during peak hours at the expense of night and weekend service (Blumenberg et al., 2020). Likewise, rail ridership in New York has been declining at a faster rate during nights and on the weekends (Fitzsimmons, 2017). But has bus ridership declined at a faster rate during off-peak and weekends? A report from MBTA shows that between 2014 and 2018, off-peak bus ridership declined by 10% while peak ridership only dropped by 8% (Thistle and Zimmer, 2019). There is still little evidence, however, as to whether the trend in Boston is representative of what is happening in other bus systems. Therefore, more research is needed to identify the temporal dynamics of bus ridership decline.

APC data can be used to track ridership trends by time of day and day of the week over time. Tracking these trends helps determine whether some time periods are driving the decline while others are bucking the trend, or whether all time periods are affected equally. The relative difference in ridership change between time periods may be explained by changes in service levels. Therefore, tracking when transit agencies have modified their service over the last several years is necessary to contextualize the trends. The graphical representation of both the supply and demand for bus service over time can then support a more refined analysis of their causal relationship.

Another temporal element affecting bus ridership is the seasonality. Especially in cities experiencing wide fluctuations in weather throughout the year, cold or hot temperatures may affect mode choice, route choice, times of travel, and the rate of telecommuting. Seasonality also impacts the schedules of universities and school-age children and thus vacations and commuting hours. While the seasonality of ridership is well established in the literature, an understanding of how its impacts are distributed by time of day and day of the week is still lacking (Kashfi et al., 2015; Stover and McCormack, 2012). Understanding how pronounced these fluctuations are may inform the service allocation process. It is also interesting to see how transit agencies respond to the fluctuations in demand with their service. Finally, comparing the seasonality of both service and ridership by time period can help shed light on the yearly fluctuations in travel demand.

Figure 4-1 shows the relative change in bus ridership over time in Portland, Miami, Minneapolis/St. Paul, and Atlanta. As shown in the legend at the bottom, weekday time periods are represented by colored solid lines, whereas the weekend time periods are black and grey dashed lines. The timetable on the right shows how time periods are defined.

There is a clear downward trend in most cities across all time periods. Weekend night ridership (light grey) is declining at a steeper rate than the other time periods in all four cities. While weeknights (light purple) seem to be following weekend trends, middays (dark purple) are much closer to a.m. and p.m. peaks (blue and red, respectively), which experienced the slowest decline across the four MSAs. In sum, although no time period has escaped the downward ridership trend, weeknights and weekend nights are particularly affected.

In order to understand better the ridership trends displayed in Figure 4-1, it is important to take into consideration how service has changed over the years. Figure 4-2 shows the relative change in bus service provided, measured in total vehicle trips, in Portland, Miami, Minneapolis/St. Paul, and Atlanta. Service quantity seems to have some slight seasonality in Minneapolis and no perceptible seasonality in Portland. While the ridership trends explored previously are consistent across cities, there are some important differences in terms of service allocation policies:

- In Portland, bus service quantity has increased in all time periods, especially off-peak.
- In the Twin Cities, bus service increased at night and over the weekends but remained constant during the weekdays.
- In Miami and Atlanta, bus service during peak hours has been reduced. Miami also cut bus service during nights and weekends, while Atlanta increased bus service in those time periods.
- Overall, night and weekend service consistently increased at a faster rate or declined at a slower rate in all agencies except for Miami, where it fluctuated.

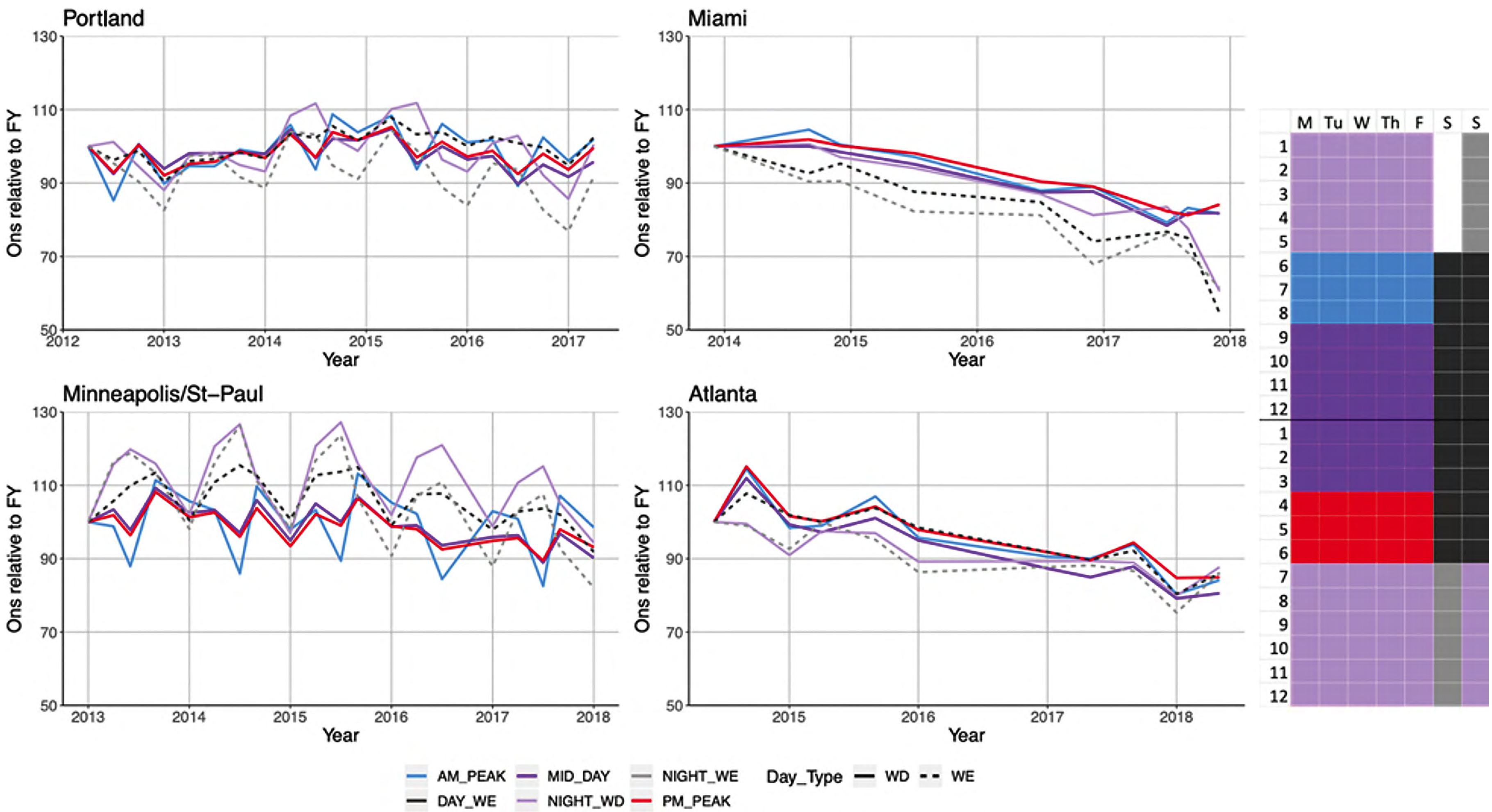


Figure 4-1. Relative change in bus ridership by time period in four MSAs.

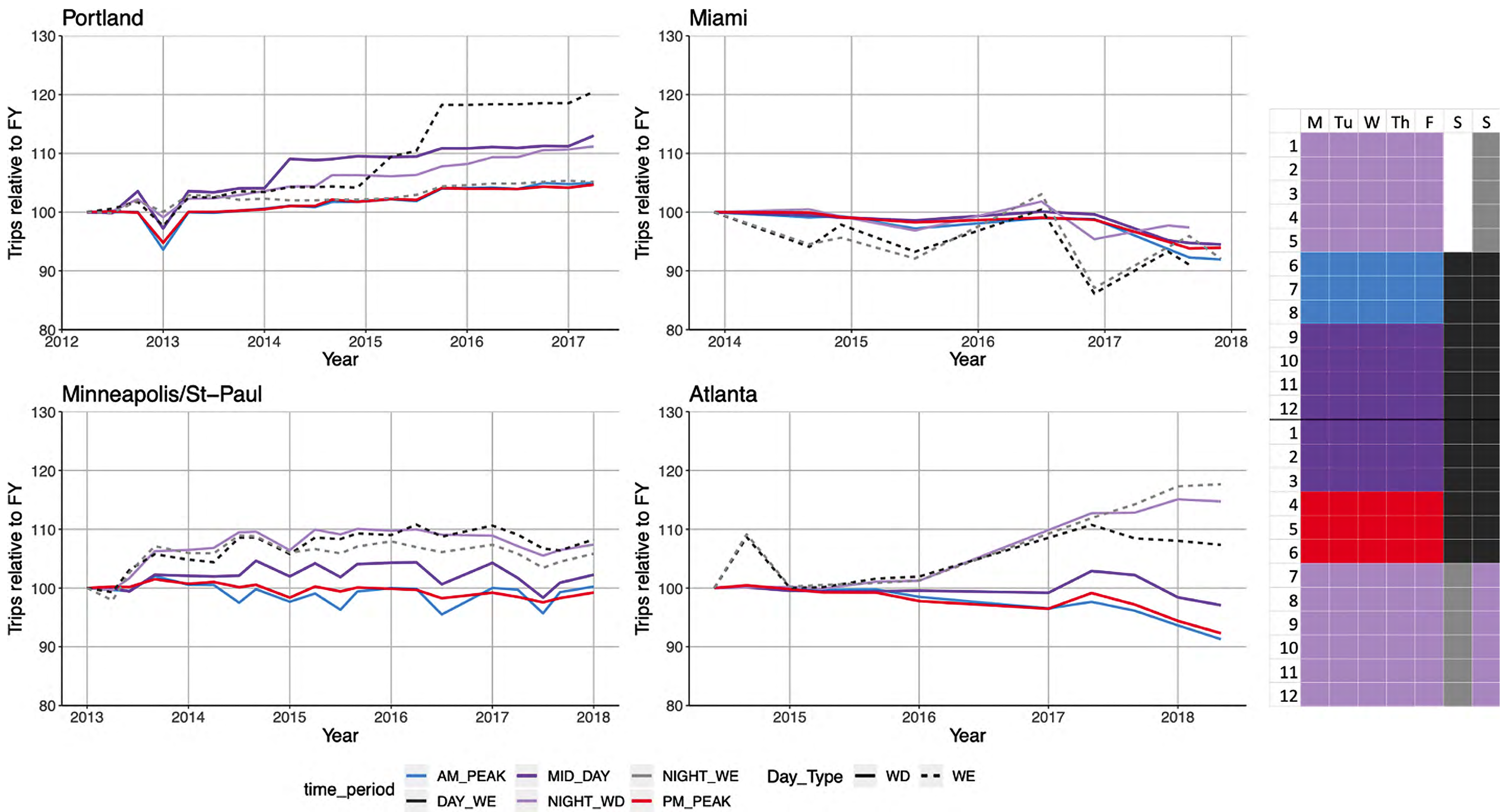


Figure 4-2. Relative change in total vehicle trips by time period in four MSAs.

Seasonality

In addition to ridership trends over the years, Figure 4-1 captures the seasonality of bus ridership. In Miami and Atlanta, ridership barely fluctuates throughout the year. While both cities have a warmer climate in the winter months, they also experience heat waves over the summer. The lack of transit ridership seasonality in Atlanta and Miami may reflect the lack of alternative options for bus riders in both cities. While the Portland and Minneapolis transit systems serve 4.5% and 6.1% of commuting trips, respectively, Atlanta and Miami only have a 3% to 3.1% transit mode share. Therefore, the smaller pool of bus riders in these two cities may be relying on the bus regardless of the weather condition.

Portland and Minneapolis/St. Paul exhibit strong seasonality. Interestingly, weekday ridership is out of phase with nighttime and weekend ridership, which tends to peak in the summer. Weekday ridership, on the other hand, peaks in the spring and fall. Interviews with transit planners revealed that weekday ridership is heavily influenced by students, whose travel demand is diminished over the summer. In the Twin Cities, all public high school students get a transit pass; in Portland, students have access to special fares. Night and weekend ridership is highest during the summer due to the prevalence of leisure activities such as the Minnesota State Fair and various sporting events.

The changes in service quantity in Figure 4-2 do not explain the ridership declines observed in Figure 4-1. Although only Atlanta cut service during the peaks and only Miami cut service across all time periods, bus ridership has been declining for all transit agencies and all time periods, even when service was increased. Paradoxically, in Portland, Minneapolis, and Atlanta, weekdays and weekend nights have experienced the greatest bus ridership losses while also gaining the most or losing the least service. In Miami, night and weekend service was reduced at approximately the same rate as during weekdays. These results indicate that the change in bus service quantity does not correspond to the variation in ridership change between time periods in each transit agency and overall between transit agencies. Therefore, the common causes of bus ridership decline are likely to be external. Among the external factors that may particularly affect evening and weekend ridership is ride-hailing, which started operating in cities throughout the United States in 2012. The analysis in Chapter 3 shows that the entrance of ride-hailing in a metropolitan area is correlated with bus ridership decline. Ride-hailing has been found to be far more prevalent during nighttime and weekends, when bus ridership tends to flatten (Tirachini et al., 2019; Feigon and Murphy, 2018; Dias et al., 2019; Li, 2019).

4.2 Comparing Bus Ridership and Productivity by Time Period

Although the changes in frequency cannot explain why bus ridership has been declining since 2012, they may be key to reversing the trend. While service planners strive to match the supply to the times and places that have the greatest concentration of demand, they must also provide sufficient service throughout the day and across the network to ensure wide accessibility. However, research has shown that demand varies throughout the day beyond what temporal accessibility can explain (Legrain et al., 2015). Therefore, to understand how transit service planners can

Productivity

A metric of comparison is productivity, which measures passengers per vehicle trip. Analyzing the data temporally allows us to identify which time periods are the most productive. This is particularly important since research has shown that providing service during peak hours is more expensive due to the directionality of demand, short or split operator shifts, and the need for high vehicle capacity. By looking at four diverse and large to mid-sized transit agencies, a comparison can be established between agencies to determine how time periods rank among each other across transit agencies.

allocate frequency to maximize ridership, it is important to ask how and why the demand for bus service varies throughout the day. In this section, the relative distribution of demand and supply for buses by time period is compared.

The research team used the bus ridership data from Figure 4-1 and the bus service allocation data in Figure 4-2 to assess the bus service productivity in the four cities. Figure 4-3 shows this bus service productivity in terms of passenger boardings and alightings per trip per stop by time period over the years in Portland, Miami, Minneapolis/St. Paul, and Atlanta. The productivity is normalized by the number of stops to compare routes of different lengths. This is intuitively equivalent to the average number of passenger boardings each time a bus passes a bus stop. All four transit agencies have similar productivities across time periods, although TriMet has slightly greater productivities overall. Across all four agencies, a common thread is that nights—both during the week and over the weekends—are the least productive time periods, whereas peak periods and midday are the most productive. Weekday time periods are the most productive. Interestingly, midday productivity is at the same level as—or in the case of Atlanta and Miami, even higher than—a.m. peak.

4.3 Bus Ridership Elasticity to Frequency

Evaluating the causal relationship between bus service quantity and ridership can help support important policy decisions. Transit service planners are tasked with deciding when and where to add or remove service. The amount of service provided is a key lever available for transit agencies to affect bus ridership. While there are other important factors participating in this decision process—such as equitable access, connection to places of strategic importance, and reliability—the anticipated impact on ridership is the initial consideration. Ridership not only is a measure of impact on local mobility but also it determines revenue through fares, which are instrumental for a transit agency's capacity to deliver service. Fortunately, unlike external factors, which tend to impact travel demand and mode choice continuously over time, changes in frequency typically have immediate effects on ridership that can therefore be measured directly.

The concept of elasticity is closely related to productivity, introduced in the previous section. Elasticity informs the rate of change in productivity. Since productivity measures the number of passengers per trip, an elasticity > 1 means that adding service results in increased productivity. On the other hand, if the elasticity is between 0 and 1, then each additional vehicle trip will generate ridership but not as much as the average vehicle already in operation.

Since productivity varies by route and by time period, comparing the absolute change in ridership would not be overly insightful. If, for example, ridership declined by 5% uniformly across

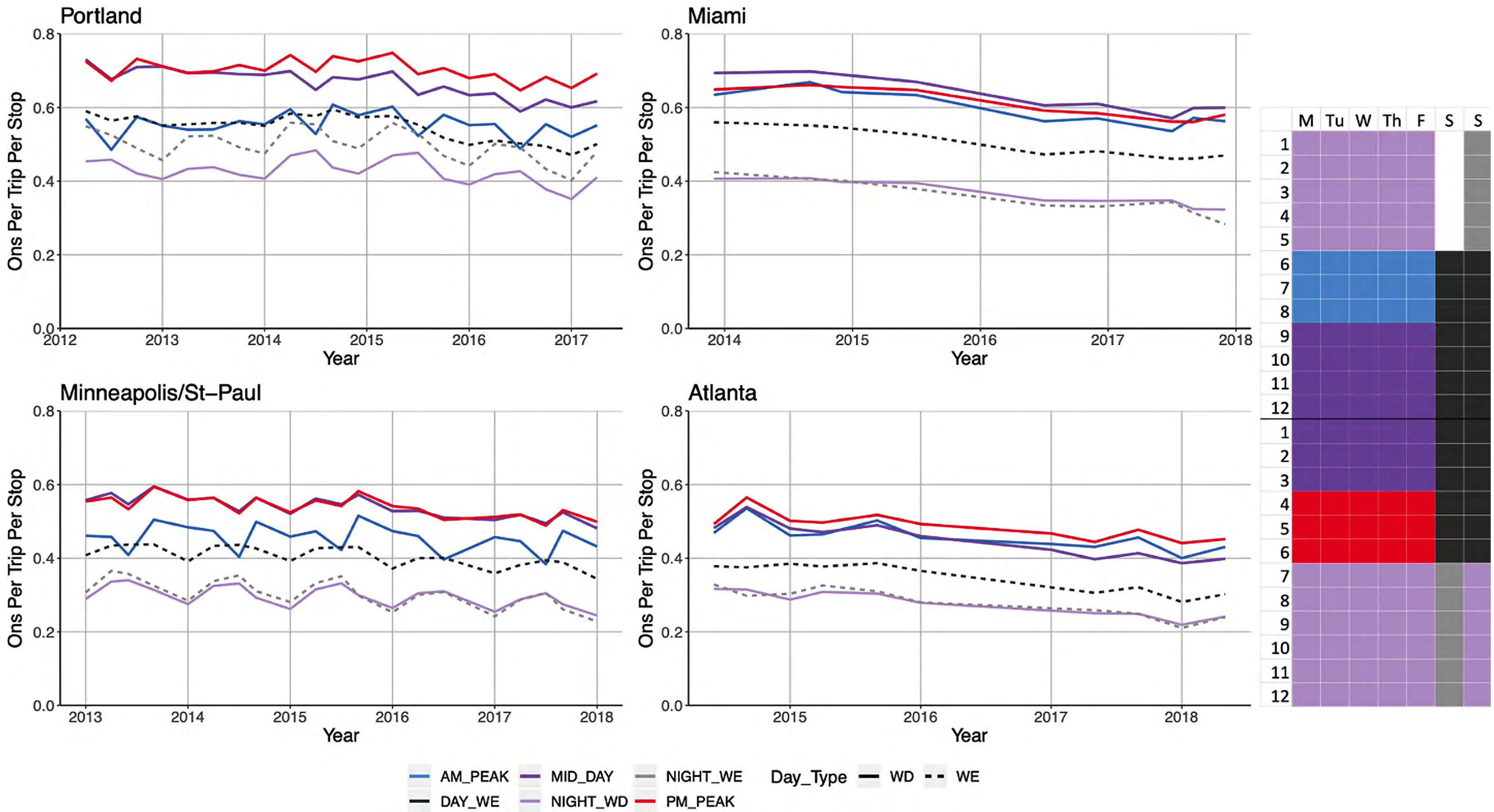


Figure 4-3. Productivity in passenger boardings and alightings by time period.

Elasticity

The relationship between transit ridership and service is quantified as elasticity. Elasticity measures the sensitivity of demand to marginal changes in an explanatory variable. The concept of elasticity is widely used in economics and business to estimate how demand changes in response to changes in price—or in the case of transit, how demand changes with regard to transit fares. In this analysis, however, the research team investigated the impact of service quantity, measured as the total number of vehicle trips. Service elasticity gives the relative change in ridership resulting from the relative change in service. In other words, elasticity is the percentage change in transit ridership assuming that service increased by 1%.

- When elasticity < 1, a 1% increase in service yields a less than 1% increase in ridership.
- When elasticity = 1, a 1% increase in service yields a 1% increase in ridership.
- When elasticity > 1, a 1% increase in service yields a more than 1% increase in ridership.

the population and trip purposes, the routes and vehicle trips with the greatest ridership would experience the greatest loss. Since elasticity is a relative measure, it allows for comparison of times and places that have different levels of demand and supply to begin with. When combined, elasticity and productivity make it possible to anticipate the impact of service changes on ridership. For example, the change in ridership—denoted Δ Ridership—that results from adding one more vehicle on the route (i.e., Δ Frequency = 1) is the elasticity multiplied by the productivity, as shown in the equations below:

$$Elasticity = \frac{\%\,\Delta\,Ridership}{\%\,\Delta\,Frequency} = \frac{\left(\dfrac{\Delta\,Ridership}{Ridership_0}\right)}{\left(\dfrac{\Delta\,Frequency}{Frequency_0}\right)}$$

$$\Rightarrow \Delta\,Ridership = Elasticity * \frac{Ridership_0}{Frequency_0}$$

$$\Rightarrow \Delta\,Ridership = Elasticity * Productivity$$

The last equation shows that the expected change in ridership generated by adding one vehicle trip is the productivity multiplied by elasticity. Therefore, estimating elasticities and productivities allows for comparisons that help anticipate the impact of service changes. The times and places that have high productivity and high elasticity have the greatest potential growth in ridership and could be part of a strategy to reverse the decline.

4.4 Modeling Elasticity for Bus Services

Previous research conducted by the authors in Portland, Miami, Minneapolis/St. Paul, and Atlanta found that at point-in-time, the most frequent routes generally have the most productivity (Berrebi and Watkins, 2020). The research revealed that over time, ridership was inelastic to frequency. In every city besides Minneapolis/St. Paul, this was particularly true on the most frequent routes. Nonetheless, an analysis investigating these dynamics at the time-period level is still lacking. This is important since transit agencies have adopted policies to adjust service differently by time of day and day of the week.

Passengers traveling to their destination will typically use the same set of modes and routes to return to their origin. On a deeper level, perceived service reliability is needed the most when it is the weakest (i.e., when and where frequency is the lowest). These places and time periods have an outsize effect on travel behavior. Being able to compare elasticities to service quantity may provide strategic tools to help transit agencies set frequencies to maximize ridership throughout the day. With four transit agencies serving as case studies, common threads in hyper-local dynamics can be identified to shed light on the broader trends among large to mid-sized bus agencies.

This analysis explores the connection between bus ridership and service frequency at the route-segment level. Figure 4-4 shows a typical map of route-segments in Portland. Using data from the Census Bureau's Longitudinal Employer-Household Dynamics (LEHD) program, the research team collected population and jobs data within a 0.25-mile radius of each route-segment. Some route-segments have bus stops spaced out so that the 0.25-mile buffers do not overlap (see, for example, the blue segment). Others, such as the purple, orange, and green segments, are much

Figure 4-4. Map illustrating route-segment buffers in Portland.

Route-Segment

Route-segments are defined in this report as clusters of seven adjacent stops on the same route and direction. Population and jobs from the LEHD program are assigned to route-segments within 0.25 miles. This distance corresponds to the typical walking distance to access a bus stop, according to the Transit Capacity and Quantity of Service Manual (Kittelson & Associates et al., 2013).

more compact. For those segments, population and jobs are only counted once, even if they fall in the overlap of several bus stops within the same route-segment.

The model results are presented in this section. Modeling steps and assumptions are described in Appendix G of *TCRP Web-Only Document 74.* The objective of this section is to evaluate the elasticity of ridership to frequency by time period, which is defined in the same way here as in Figures 4-1, 4-2, and 4-3.

Table 4-1 shows the results of this analysis for Portland, Miami, Minneapolis, and Atlanta. The top half of the table shows the estimated linear time trend, and the bottom half shows the estimates of ridership elasticity to frequency. The trends observed in Figure 4-1 are also seen in the model of Table 4-1. As shown by the negative values for the time-trend, there is a downward

Table 4-1. Results for ridership elasticity to frequency by time period.

		Portland	Miami	Minneapolis	Atlanta
Weekday Time-trend	Peak (a.m.)	0	-0.05	-0.01	-0.06
	Midday	-0.02	-0.05	-0.03	-0.07
	Peak (p.m.)	0	-0.05	-0.02	-0.06
	Night	-0.01	-0.07	-0.03	-0.08
Weekend Time-trend	Day	-0.01	-0.05	-0.03	-0.06
	Night	-0.02	-0.1	-0.05	-0.08
Weekday Frequency Elasticity	Peak (a.m.)	0.61	0.68	0.77	0.58
	Midday	0.55	0.68	0.73	0.65
	Peak (p.m.)	0.52	0.38	0.83	0.6
	Night	0.72	0.94	0.78	0.76
Weekend Frequency Elasticity	Day	0.42	0.84	0.71	0.5
	Night	0.39	0.94	0.92	0.77
Population and Jobs		Not Significant (p > 0.05)		Positive Effect	

Note: Peak (a.m.) = 6–9 a.m., Peak (p.m.) = 4–7 p.m., Weekend Day = 6 a.m.–7 p.m.

trend in all agencies and time periods except for Portland in a.m. and p.m. peaks, which both have a time-trend value of 0. As shown by the magnitude of this time-trend, Miami and Atlanta experienced greater declines in ridership (declines ranging from 5% to 10%) compared to Portland and Minneapolis (declines ranging from 0% to 5%) across all time periods. In general, peak periods have incurred less of a decline (0% to 6%) than other periods, with nighttime declining the most (1% to 10%).

It is also important to compare ridership elasticity to frequency by time period. As shown in Table 4-1, weeknights are the closest to 1.0, meaning they are among the most elastic time periods across agencies. Except for Portland, weekend nights are also close to 1.0, meaning they are among the most elastic time periods. These elasticities close to 1.0 indicate that investing in nighttime service should not lead to substantial losses in productivity. While nighttime service is unlikely to reach current daytime levels of productivity, it could be part of a broader policy of service expansion. If, for example, a transit agency increased bus service by 10% across all time periods, nighttime productivity would remain lower than daytime but by a smaller margin.

4.5 Conclusion

Automatic passenger count data were used to examine the trends in bus ridership on a hyper-local level by time of day and day of the week. Based on schedule data, the research team investigated the sensitivity of ridership to changes in service frequency. This relationship was explored graphically by looking at the relative changes in ridership, service quantity, and productivity over time. The researchers then evaluated the impact of service changes on ridership while controlling for linear time trends. They found that while bus ridership is declining across time periods, weekday and weekend nights differ substantially from weekday time periods.

In Figure 4-1, Figure 4-2, and Table 4-1, it was found that nighttime bus ridership has declined the most. These factors are unlikely to be internal since service frequencies have increased more during weekday and weekend nights than during weekday periods in all cities except for Miami, where service was cut throughout the week.

Despite the decline in bus ridership at night, there is good reason to be hopeful. While these time periods are generally the least productive, they also have the highest elasticity of ridership to frequency. Unlike other time periods, increasing service at night does not lead to a rapid decline in productivity. The variable cost of increasing service has been shown to be lower than the average operating cost of existing service across time periods, especially for midday and weeknight periods (Taylor et al., 2000).

This study found not only that ridership is affected by service levels in each specific time period but also that all-day frequency impacts ridership independently. Ultimately, measuring how ridership responds to changes in service is one key to reversing the recent decline in bus ridership.

Bus ridership appears to be "peaking," with ridership declining most at night despite having the most increase or least decrease in service. This indicates that some external factor must be at play.

CHAPTER 5

Examining the Peaking Phenomenon in Bay Area Rapid Transit Ridership

Aging rail systems face a dilemma. These systems are often capacity-constrained all day, but particularly in the peak hours. This gives such systems limited opportunities to conduct maintenance activities. How much do maintenance-related service cuts on weeknights and single-tracking impact ridership on the system? Should transit agencies weigh construction savings/efficiencies that can be achieved through single-tracking or shutdowns versus long-term ridership and revenue loss impacts?

BART, or Bay Area Rapid Transit, is a heavy rail system operating in the San Francisco Bay Area, California. BART started operating in 1972 and gradually expanded the rail system. Today, BART serves 411,000 passenger trips per weekday at 48 stations on 112 miles of tracks, making it the fifth-largest rail operator in the United States. As shown in Figure 5-1, much of BART's five main lines (Red, Yellow, Blue, Green, and Orange) operate on the same right-of-way. Four of these lines cross the Transbay Tube, thereby connecting the San Francisco Peninsula with the East Bay.

The San Francisco Bay Area, where BART operates, has experienced profound transformations in recent years. Between 2010 and 2018, the population of the nine-county region has grown by 8.5%, or 600,000 people (Green and Shuler, 2019). In the same time period, the number of jobs in the Bay Area grew by over 25% (Avalos, 2019). This economic growth has led to rising housing costs. According to the California Association of Realtors, housing affordability in the Bay Area dropped sharply following the Recession and has remained low ever since (Zaludova, 2018). The housing crisis has led to greater population growth in the East Bay counties of Almeda (10.4%) and Contra Costa (9.6%). This population and demographic shift has resulted in longer commutes to reach employment centers in San Francisco.

The exclusive right-of-way on which BART trains operate has limited capacity. The Transbay Tube between San Francisco and Oakland already carries 27,000 passengers per hour during the peak, which is close to twice the volume of the Bay Bridge (Bay Area Rapid Transit, n.d.). However, the Tube has already reached its maximum capacity of 23 trains per hour in each direction, leading to crowded conditions inside the vehicles and at stations. This bottleneck determines the frequency for the entire rail system. Since the five main BART lines share right-of-way, vehicles must be dispatched at a constant cadence. In other words, all lines must have the same frequency, even the Orange Line, which does not cross the bay.

BART is planning to expand the capacity of the Transbay Tube by 30% as part of the Transbay Core Capacity Project, which is scheduled to be completed by 2028 at a total cost of $3.5 billion (Bay Area Rapid Transit, n.d.). The project consists of purchasing new vehicles, expanding car storage facilities, and replacing the existing fixed-block train control system with a new communications-based train control system. These improvements will allow BART to increase capacity by running longer trains more frequently.

Source: BART.

Figure 5-1. Map of the BART system.

BART is studying plans to expand capacity across the bay with a second tunnel. According to a report by the Association of Bay Area Governments and the Metropolitan Transportation Commission, the new crossing would carry an additional 25,000 passengers at peak hour and cost between $30 billion and $50 billion.

5.1 Ridership Trends

Figure 5-2 shows UPT and VRM relative to 2008. Both grew between 2002 and 2008, with a sharp fall during the Recession. Starting in 2010, both ridership and service levels started growing again. However, while UPTs reached pre-Recession levels in 2012, it wasn't until late 2015 that the same happened for VRMs. Ridership then started declining in early 2016 and has been on a downward trajectory ever since. Meanwhile, service levels kept increasing until early 2019, when single-tracking had to be implemented to address urgent maintenance needs.

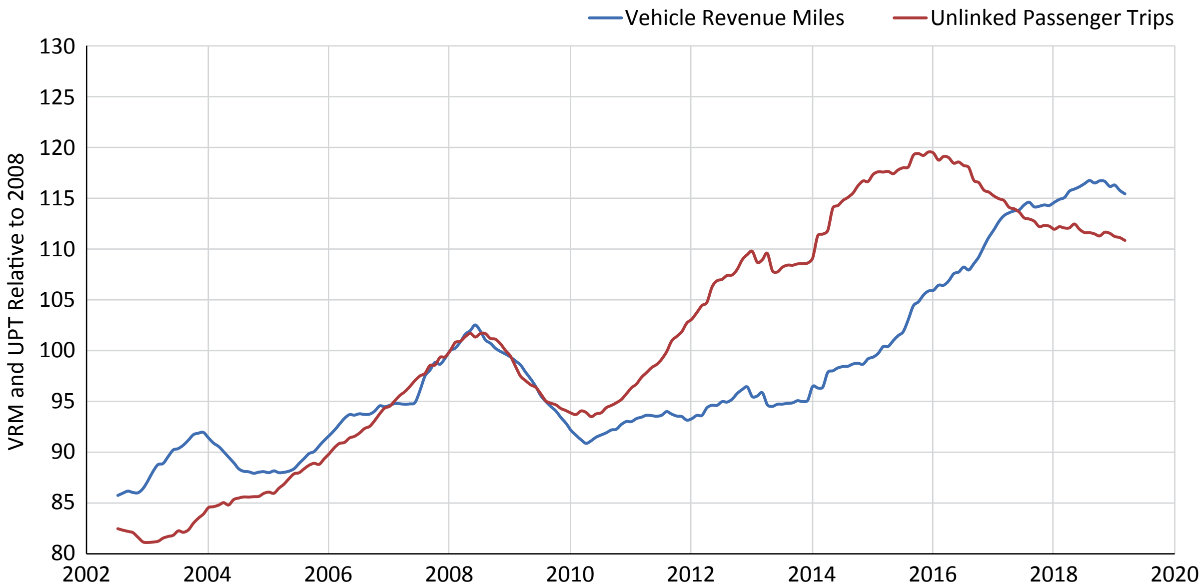


Figure 5-2. Six-month rolling average of BART VRM and UPT.

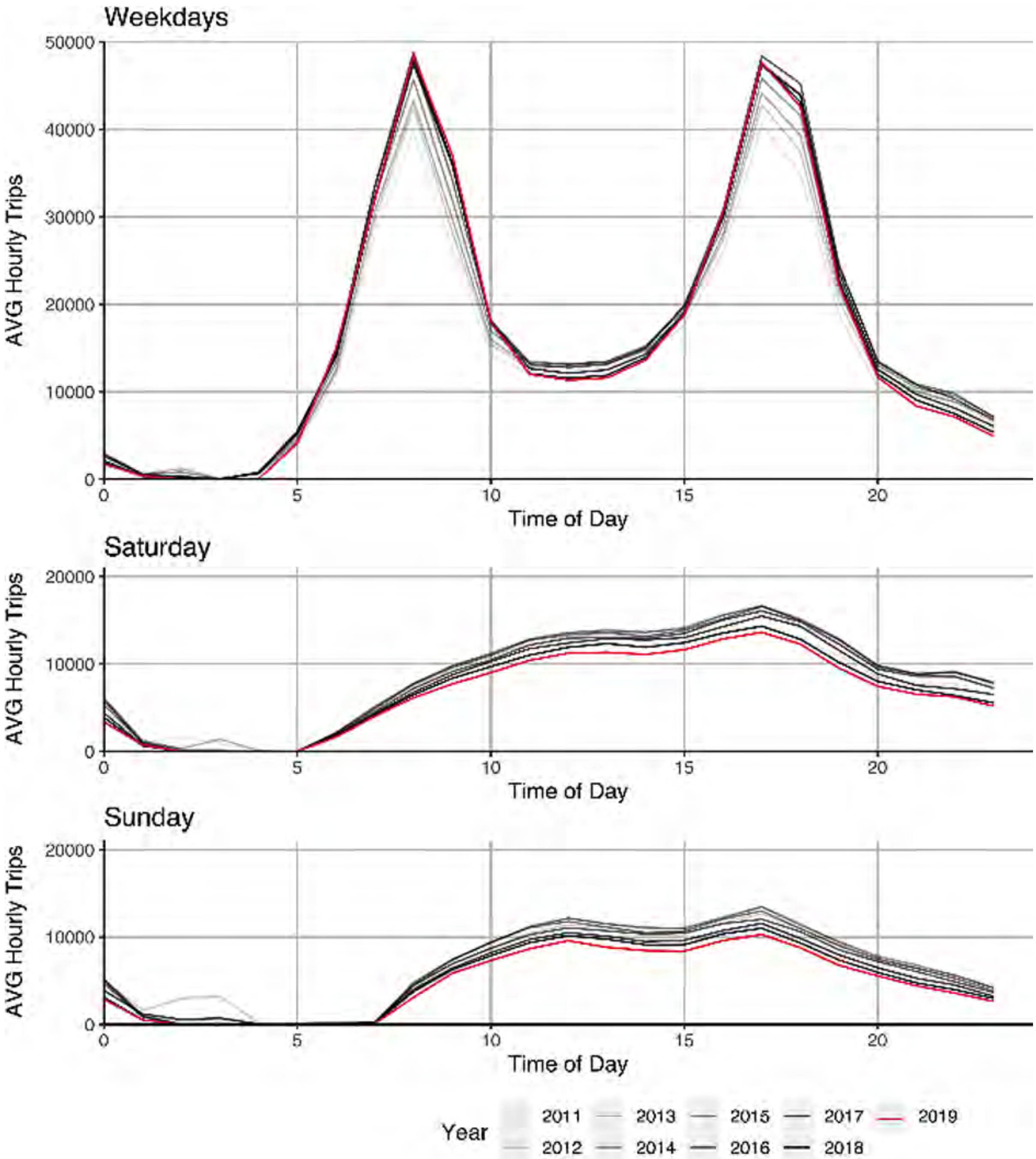
The decline in BART ridership is enigmatic because it coincides with growth in both jobs and population. To better understand how ridership has evolved by time period, Figure 5-3 shows the average hourly passenger trips by time of day for weekdays, Saturdays, and Sundays. Passenger trips presented in Figure 5-3 are linked, meaning that trips involving connections are counted only once, unlike UPTs. The trip time is recorded when passengers exit the station at their destination. Each graph shows years from 2011 to 2019, with more recent years drawn in a darker line. Only 2019 is shown in red for easy identification.

Figure 5-3 shows clearly the peaking phenomenon. On weekdays, 2019 has the highest ridership during peak hours and the lowest ridership during the off-peak. This effect corresponds to a long-term trend, with darker, more recent years clustered toward the top in peak hours and toward the bottom in midday and evening. On Saturdays and Sundays, 2019 has the lowest ridership at all times of day. This, too, corresponds to a trend over the last decade. Therefore, not only has ridership declined in recent years but also it has changed shape—growing in peak hours and decreasing at all other times.

While it is clear that the recent ridership decline was driven by the off-peaks and weekends, the reasons for this shift are not entirely explained. Numerous external factors can account for this peaking phenomenon. The greater residential growth in the East Bay has generated more demand during commuting hours, while the rise of ride-hailing has provided an alternative to transit, which is particularly used at night and on weekends. There is also an internal factor that may have contributed to the trend: a reduction in nighttime and weekend service for track maintenance. The following section examines the rise of single-tracking and evaluates its impact on ridership.

5.2 Single-Tracking

After close to 50 years of operation, the BART system—and particularly the electrical system—requires maintenance. However, since there are not enough hours to perform track work between midnight and 6 a.m., the transit agency must single-track. Single-tracking consists of closing the tracks for repair in one direction while leaving the other directional track open. Trains must wait



Source (data): BART.

Figure 5-3. BART ridership by time of day on weekdays, Saturdays, and Sundays by year.

their turn to cross the track, which slows down operations. Any delay tends to propagate much faster during single-tracking because trains in both directions need to wait for the late vehicle. Single-tracking typically happens during the weekends and in the evenings, when ridership is at its lowest point.

In order to enable single-tracking, BART reduced service on weekday evenings in February 2019. According to BART staff, and as shown in Figure 5-2, these were the first service cuts in several years. Figure 5-4 compares the service frequency of each line before and after February 2019.

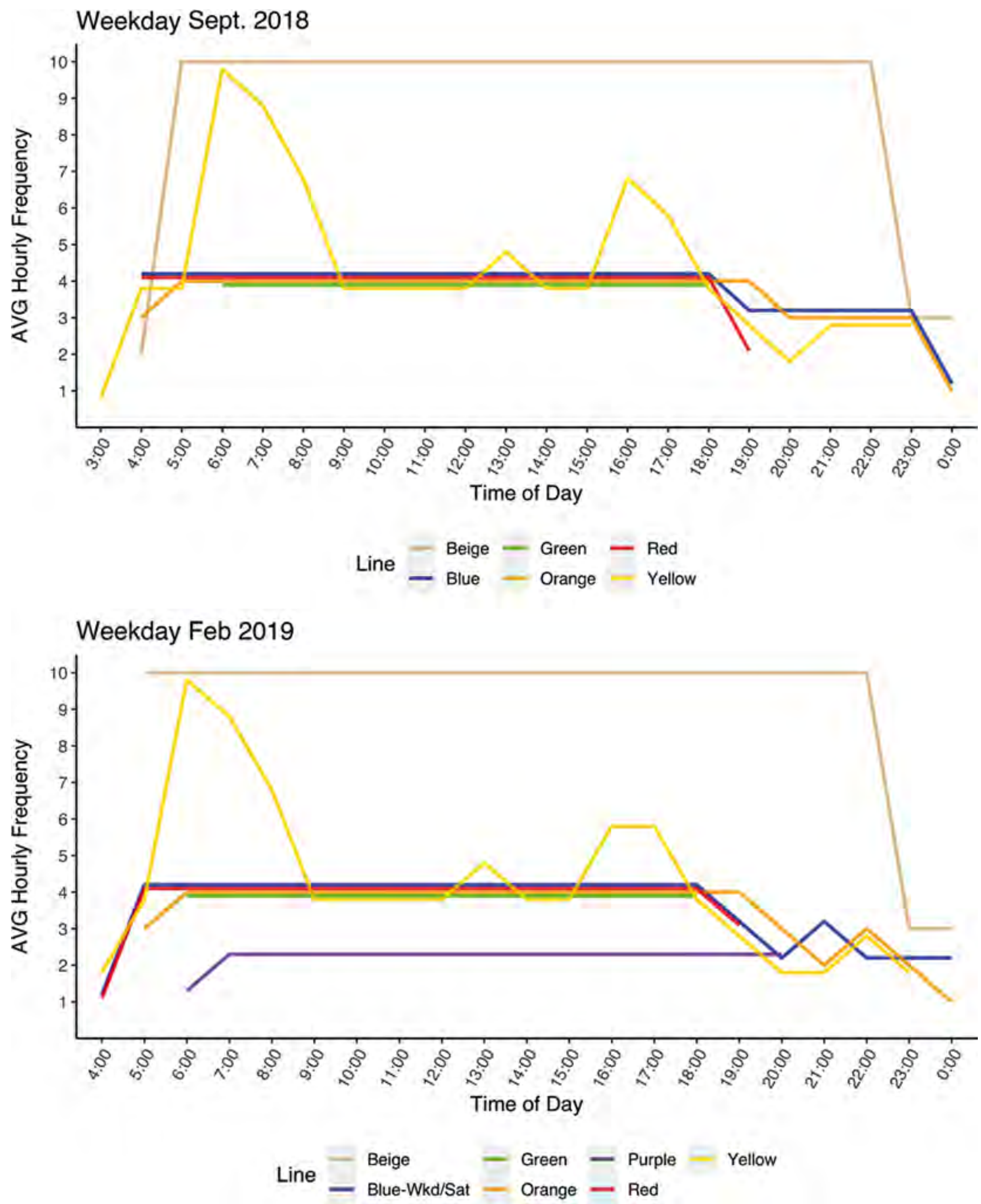


Figure 5-4. BART service frequency by time of day for each line.

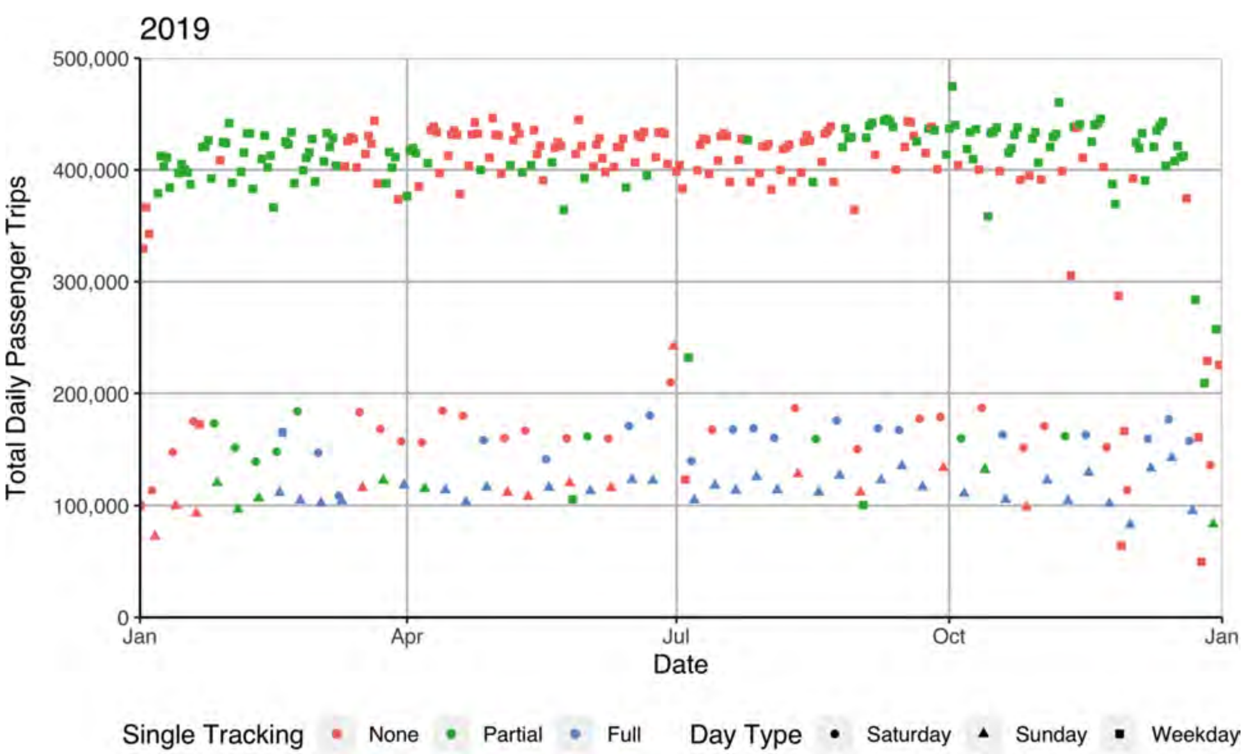
Observable changes in service levels over time do not explain the peaking phenomenon. As shown in Figure 5-4, weekday frequency before 6 p.m. remained the same except for the Purple Line, which opened in February 2019 and only has two stations. In the evenings, however, service was cut on every route. The Yellow Line lost three train trips, while the Blue and Orange Lines lost two trips over the six-hour period. Because the routes only had two or three train trips per hour to start with, even losing two or three train trips over a six-hour period had an appreciable impact on headways.

Although BART changed the weeknight schedule to accommodate single-tracking, not all weeknights had single-tracking. The service cuts on weekday evenings to accommodate single-tracking were in place between February 2019 and March 2020, when service was changed in response to the COVID-19 pandemic. Therefore, the schedule information presented to passengers through the GTFS and related third-party applications distinguished between single-tracking days and regular days. Similarly, although BART implemented single-tracking on and off on weekends, published schedules showed service as if single-tracking was always in place.

Figure 5-5 shows daily ridership over time in 2019. Weekdays are represented as squares, Saturdays as circles, and Sundays as triangles. Data on single-tracking were obtained from the events and track work records. Full single-tracking days are shown in blue, partial in green, and days with no single-tracking are shown in red. Full days are when single-tracking is applied between 8 a.m. and 6 p.m. Partial days are when single-tracking is only implemented for several hours; this typically happened in the evening.

Figure 5-5 shows that single-tracking Saturdays and Sundays have lower ridership than regular weekends. Single-tracking weekdays, on the other hand, are indistinguishable from regular weekdays. At the bottom of the graph, red circles and triangles protuberate over their blue and green counterparts. Interestingly, single-tracking weekend days seem to be uniformly distributed throughout the year, unlike single-tracking weekdays, which are concentrated in the summer. Figure 5-5 also shows that there is no discernible ridership difference on days with and without single-tracking. This could be because single-tracking undermines a seasonality, which would have otherwise abated summer ridership. However, the following explanation of endogeneity is more credible.

BART planners decided whether to carry out single-tracking on weekends based on the anticipated demand that would be affected. For example, the transit agency avoided single-tracking on days when concerts, parades, sporting events, or political rallies were expected to draw large crowds. Therefore, the relationship between ridership and single-tracking is endogenous. While single-tracking causes ridership to diminish, low anticipated ridership causes service planners to schedule single-tracking. Therefore, the high ridership on non-single-tracking days may be both a cause and a consequence of single-tracking.



Source (data): BART.

Figure 5-5. BART single-tracking days in 2019.

50 Recent Decline in Public Transportation Ridership: Analysis, Causes, and Responses

Endogeneity

Identifying causal relationships is key to understanding the world around us and informing important decisions. A powerful tool available to data scientists is the examination of correlations in real-world data. Correlation is useful because it allows scientists to predict one variable based on another. However, correlation does not imply causation. Sometimes, an explanatory variable itself can be determined by the response variable. This happens in cases of reverse causation (when the response variable has a direct causal relationship with the explanatory variable) or simultaneity (when both variables are causally determined by some other, unobserved, variable). In those cases, scientists say the relationship between the explanatory and the response variables is endogenous.

Another perspective is that single-tracking affects ridership in the longer term. Because single-tracking does not involve changing the schedule and would thus not be reflected in GTFS-based information sources, many passengers typically do not know whether their train will be single-tracked. Single-tracking not only makes trips longer but also makes the ridership experience less reliable. This is particularly true on trips that involve a transfer, in which case the penalty for single-tracking is doubled. Passengers, not knowing whether the rail system will be single-tracking the next time they need to travel, have to budget enough time to avoid arriving late at their destination in case single-tracking is unexpectedly happening. This additional cost imposed on passengers mitigates the value of public transit and could lead to long-term shifts toward other modes.

5.3 Conclusion

Decades-old rail systems have capacity constraints that make maintenance problematic. While it is difficult to measure the impact of single-tracking on ridership, it should be considered when weighing maintenance timing.

While the service cuts on weeknights and single-tracking coincide with the ridership decline at nights and on weekends over the last year, they do not entirely explain the ridership trends. The analysis reveals that growth in the peaking phenomenon has been happening over the last decade, while BART ridership started to decline in 2016. What the service cuts and single-tracking demonstrate, however, is the capacity constraints imposed on a heavy rail system built in the early 1970s that requires maintenance. BART has limited opportunities to increase night and weekend ridership due to constraints on right-of-way and hours of operation.

This balance between maintenance and service shutdowns is an issue that many transit agencies face, especially those with aging rail systems similar to BART, such as those in Boston, Philadelphia, and Washington, D.C. Agencies should carefully quantify and weigh the customer experience, equity, and ridership impacts of maintenance shutdowns against the maintenance cost savings afforded by the shutdowns. This type of analysis should be used to determine which maintenance activities warrant shutdowns and which should be restricted to non-service hours.

More than simply a consequence of declining ridership—which transit systems across the country have also been experiencing—the peaking phenomenon is an issue in itself. Due to the limited capacity of the Transbay Tube at peak hours, it is imperative to spread the demand temporally across times of day and days of the week and spatially within the East Bay and San Francisco Peninsula.

To spread out the demand temporally, the region has different potential levers available, including service design, enhanced information, and TDM. While it may be difficult for maintenance reasons to scale back single-tracking that reduces service levels, high-capacity bus service could provide regional mobility at night and on the weekend to supplement heavy rail service. Enhanced, high-quality passenger information is also an important tool to help passengers plan their trips, especially when service is unpredictable. A significant TDM tool is peak/off-peak pricing, which is used by some systems (e.g., WMATA) to create economic incentives to avoid the peak period; however, this tool is recognized as institutionally challenging. Alternatively, BART could work in partnership with local and regional governments to incentivize off-peak travel through various types of fare discounts. Employers could also be engaged to play a TDM role to help reduce the peaking phenomenon by allowing their employees to work flexible hours or work from home.

The COVID-19 pandemic has impacted every aspect of urban transportation systems overnight. In order to minimize the risk of transmission, employers have encouraged workers to telecommute. Meanwhile, transit agencies have shifted service to minimize passenger crowding. While the urgency of these shifts was motivated by a global crisis, the experience gained in the process may reach beyond the moment. Passengers, employers, and transit agencies have learned that managing travel demand and supply is possible.

CHAPTER 6

Competition and Complementarity Between Transit Modes in the Twin Cities

Urban rail systems are in resurgence. Streetcar rail systems were once the predominant transit mode in American cities, until they were dismantled and replaced with bus systems under pressure from the competition of automobiles. Figures 6-1 and 6-2 show UPTs and VRM by mode since the 1920s. Following the financial crash of 1929, rail ridership dropped sharply as transit operators started replacing streetcar systems with buses. Overall, ridership reached its peak during World War II, followed by a decline due to the massive production of automobiles. Rail ridership declined at an even faster rate as streetcar networks faced further cuts (Tennyson, 1989). Starting in the mid-1970s, rail ridership started a slow but steady rise as new heavy rail and light rail systems were built and overall transit service was increasing. Then, following the Great Recession in 2008, transit agencies cut bus service while preserving heavy and light rail service. Finally, rail ridership in the United States surpassed bus ridership in 2017 for the first time since 1947.

One of the keys to understanding the recent ridership trends is to examine the relationship between bus and rail. Between 2010 and 2020, the United States added about the same mileage of high-capacity bus modes as rail (Freemark, 2020). However, the new investments in bus lines only constituted 8% of transit expansion capital funds. When operating on dedicated right-of-way, rail modes can provide high-capacity and reliable service, which may attract passengers. As transit agencies rely on rail expansions to provide capacity in cities, several questions must be answered. The first is how much of the ridership on expanded rail lines is from new transit trips. Some of this ridership could presumably be drawn from local bus routes. The second question is whether rail lines can generate more ridership overall than comparable high-capacity bus routes. Finally, do either rail or high-capacity bus modes have the capacity to generate more ridership on connecting routes?

These questions are answered in this section by comparing two Metro Transit expansion projects in the Minneapolis/St. Paul area. Metro Transit is the 17th largest bus agency in the United States, serving 55 million UPTs per year (American Public Transportation Association, 2020). Metro Transit is also the 7th largest light rail agency in the United States, serving 25 million trips per year. The transit system has expanded both light rail and arterial rapid transit service. The Green Line is a light rail route that opened in June 2014 connecting the downtowns of Minneapolis and St. Paul on dedicated right-of-way. Line A is an arterial BRT route, which operates on Snelling Avenue and Ford Parkway on mixed right-of-way with many BRT features.

The ridership and frequency trends on the Green Line and the A Line are analyzed as follows using hyper-local data at the station and route levels from APCs, automated fare collection systems, and GTFS. These data enable a comparison between the recent deployments of higher capacity services with the local bus services that either were replaced or continue to run in parallel. The objective is to assess how the cumulative ridership changed due to changes in frequency, new amenities, and—in the case of the Green Line—dedicated right-of-way. The impact of the Green

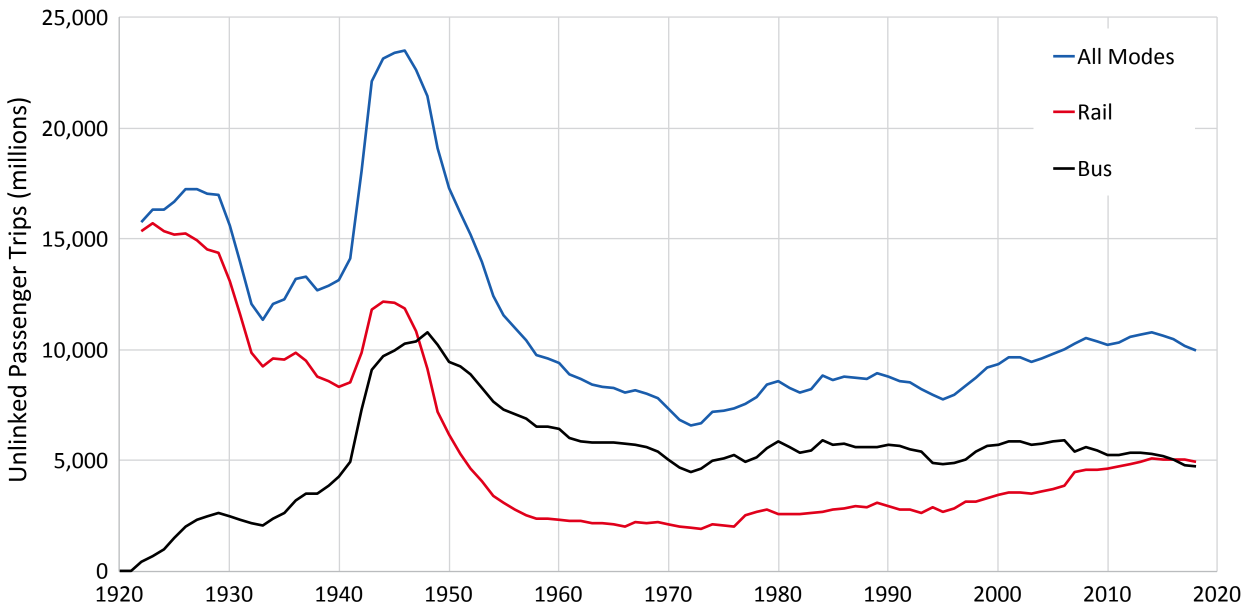


Figure 6-1. UPTs (millions) by mode since the 1920s. (Data: APTA.)

and A Lines on connecting bus routes is also assessed. Finally, this analysis allows for a comparison of the light rail and arterial BRT routes.

6.1 Metro Green Line

The Metro Green Line is a light rail line operating on fully dedicated right-of-way. Figure 6-3 shows the Green Line design at 5th Street and Hennepin Avenue. Some sections—such as the one presented in the Google Street View—are at-grade, only separated from traffic with a yellow line. Other sections, such as the University of Minnesota campus, are separated from traffic with

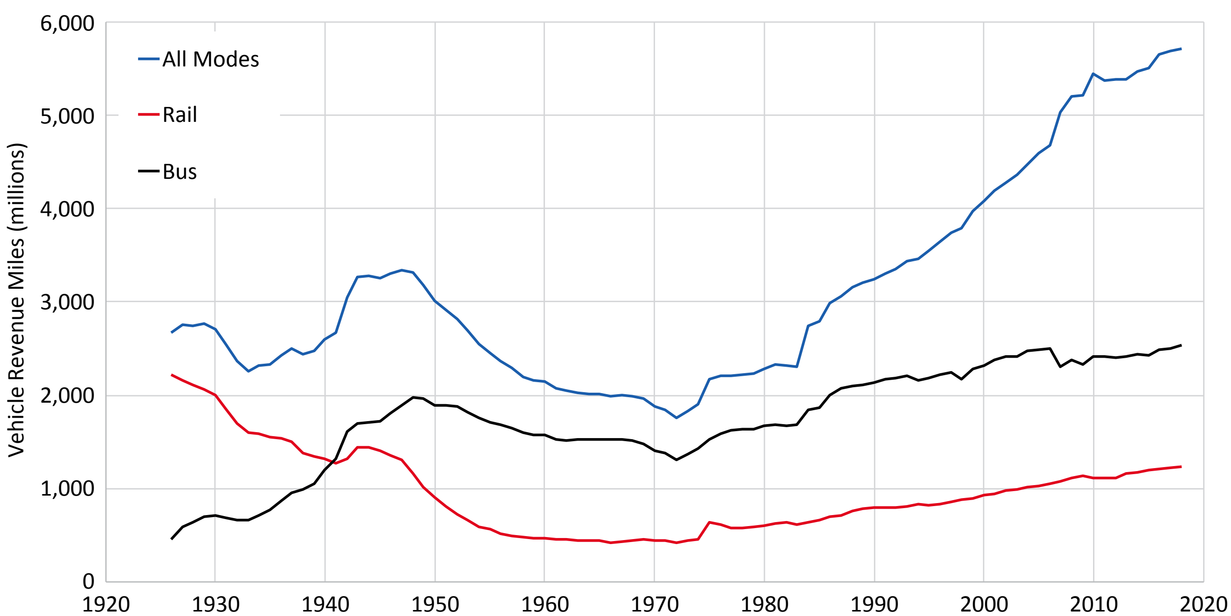


Figure 6-2. VRM by mode since the 1920s. (Data: APTA.)

Source: Google.

Figure 6-3. Street View of Green Line at 5th Street and Hennepin Avenue.

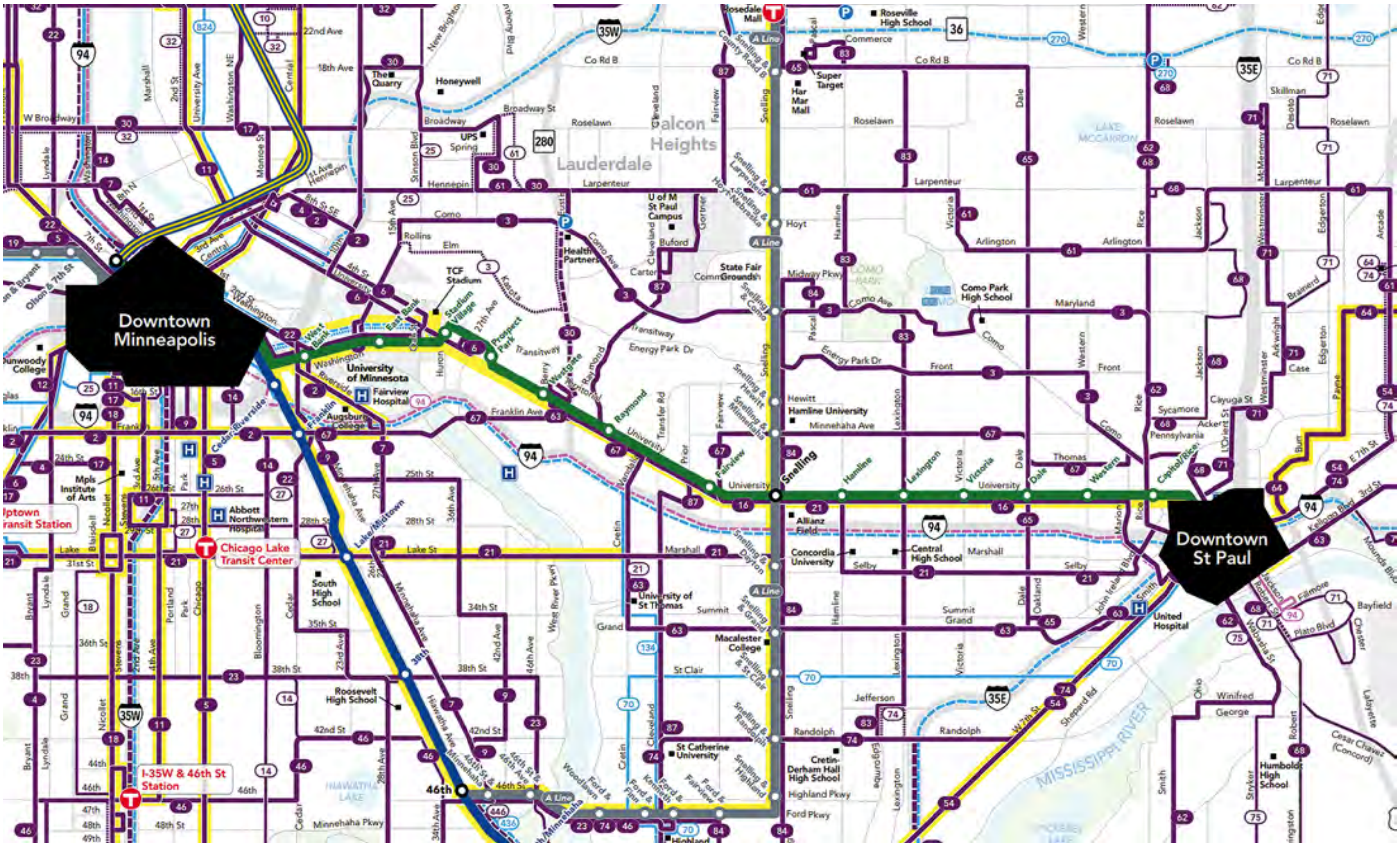
curbs and even physical barriers. Light rail vehicles are also able to avoid delays at intersections through TSP. Finally, the off-board fare collection and all-door boarding help minimize dwell time.

Since it opened to the public in June 2014, the route was operating service 24 hours per day until May 2019, when the service was replaced by buses between 2 a.m. and 4 a.m. to allow time for cleaning and maintenance (Kerr, 2019).

Figure 6-4 shows a map of the Green Line, which runs on University Avenue between the Minneapolis and St. Paul downtowns through the University of Minnesota campus; the East Bank station is located in the heart of the University of Minnesota campus. The Green Line replaces or supplements other routes that were previously running on University Avenue. Figure 6-5 shows a map of the bus routes adjacent to the Green Line. Bus Route 16 used to serve the entire alignment of the current Green Line, from downtown Minneapolis to downtown St. Paul.

Source: Metro Transit.

Figure 6-4. Map of Green Line.



Source: Metro Transit.

Figure 6-5. Map of bus routes adjacent to Green Line.

The route was cut to only cover the eastern section of the corridor up from Fairview Avenue to downtown St. Paul, where it continues to provide local bus service with more frequent stops than the Green Line. Bus Route 50, which was discontinued, used to operate on the same corridor as the Green Line and was also on a limited stop basis. Other routes overlap with the alignment of the Green Line but only on short segments. Route 63 connects the Westgate and Raymond stations, and Route 67 connects the Westgate and Fairview stations. Finally, Route 94 runs on highway I-94, which is located several blocks south of University Avenue, as shown in Figure 6-5.

In order to assess the impact of the Green Line, the research team compared how weekday service frequency and ridership changed on the multiple routes serving the corridor. Figures 6-6 and 6-7 show the average weekday vehicle trips in one direction and average weekday passenger boardings between 2012 and 2018. In both figures, Routes 16 and 50 are represented in light blue and purple, respectively. The Green Line is shown in dark green.

Figure 6-6 shows that the new light rail service on University Avenue did not substantially change overall frequency on the corridor. Before the Green Line opened, the daily frequency was 118 vehicle trips per weekday for Route 16 and 73 vehicle trips per weekday for Route 50. Route 50 was discontinued when Metro Transit rolled out the Green Line. The frequency of Route 16 was first cut to 58 vehicle trips per weekday, then gradually cut to 34 vehicle trips per weekday. Frequency on the Green Line was 115 vehicle trips per weekday from its opening until the end of 2017. By then, the overall frequency on the corridor was 22% lower than it had been prior to June 2014. The main difference is that only 23% of the frequency was local service, whereas previously 62% of vehicle trips had local stops.

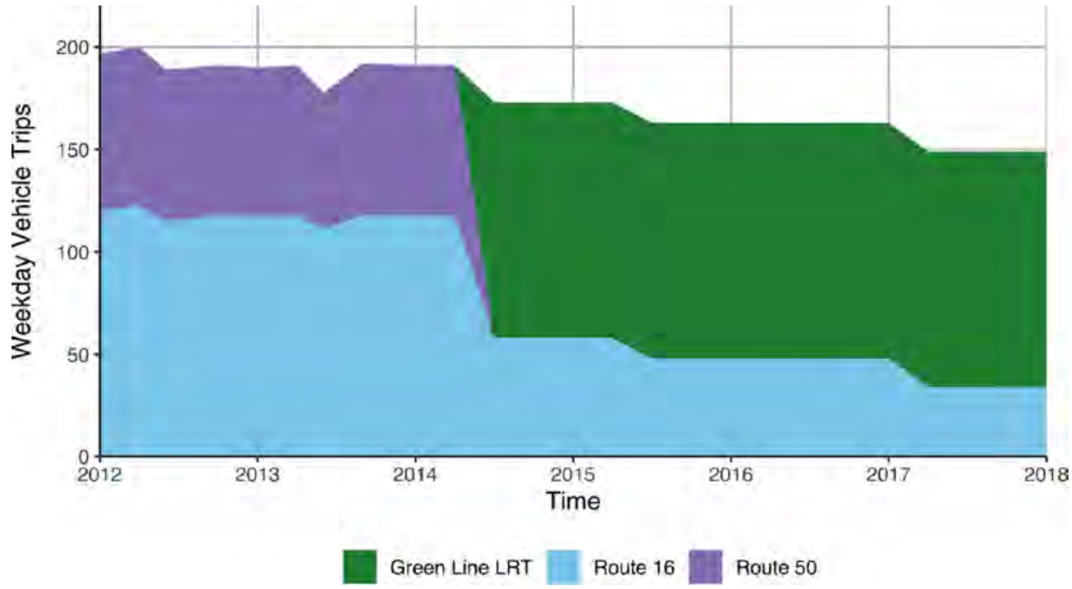


Figure 6-6. Average directional weekday vehicle trips on Green Line corridor.

Figure 6-7 shows how ridership started increasing immediately following the Green Line inauguration. In the first schedule period, overall ridership on the corridor increased by 75%. By the end of 2017, ridership had increased by 97%. At the same time, Route 16, which then only served the eastern section of the University Avenue corridor, lost 94% of its ridership. By fall 2014, the Green Line was carrying 98% of the corridor's ridership. Therefore, Figure 6-6 shows that the light rail opening led to weekday ridership almost doubling, despite a decline in overall ridership on the corridor.

In order to evaluate the connection between the Green Line and connecting bus routes, Figure 6-8 shows ridership at each intermediary station (green) and at intersecting routes. The first and the last stops are not shown because they connect with too many local bus routes. Note that ridership at individual light rail stations is compared with the entire routes with which they connect. Figure 6-8 shows a downward trend in ridership that was also shown in Section 6.1 across local

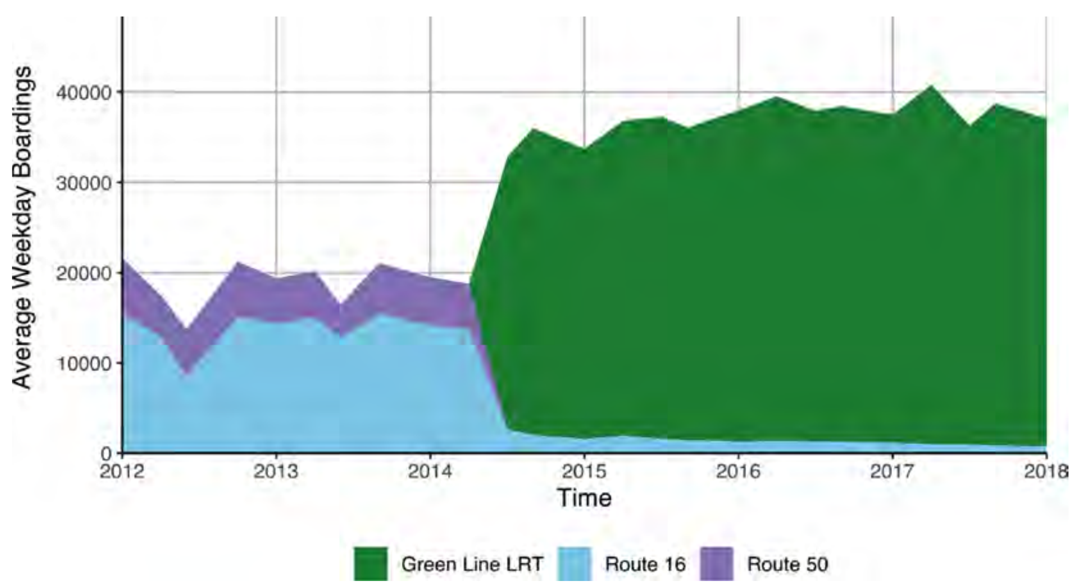


Figure 6-7. Average weekday passenger boardings on Green Line corridor.

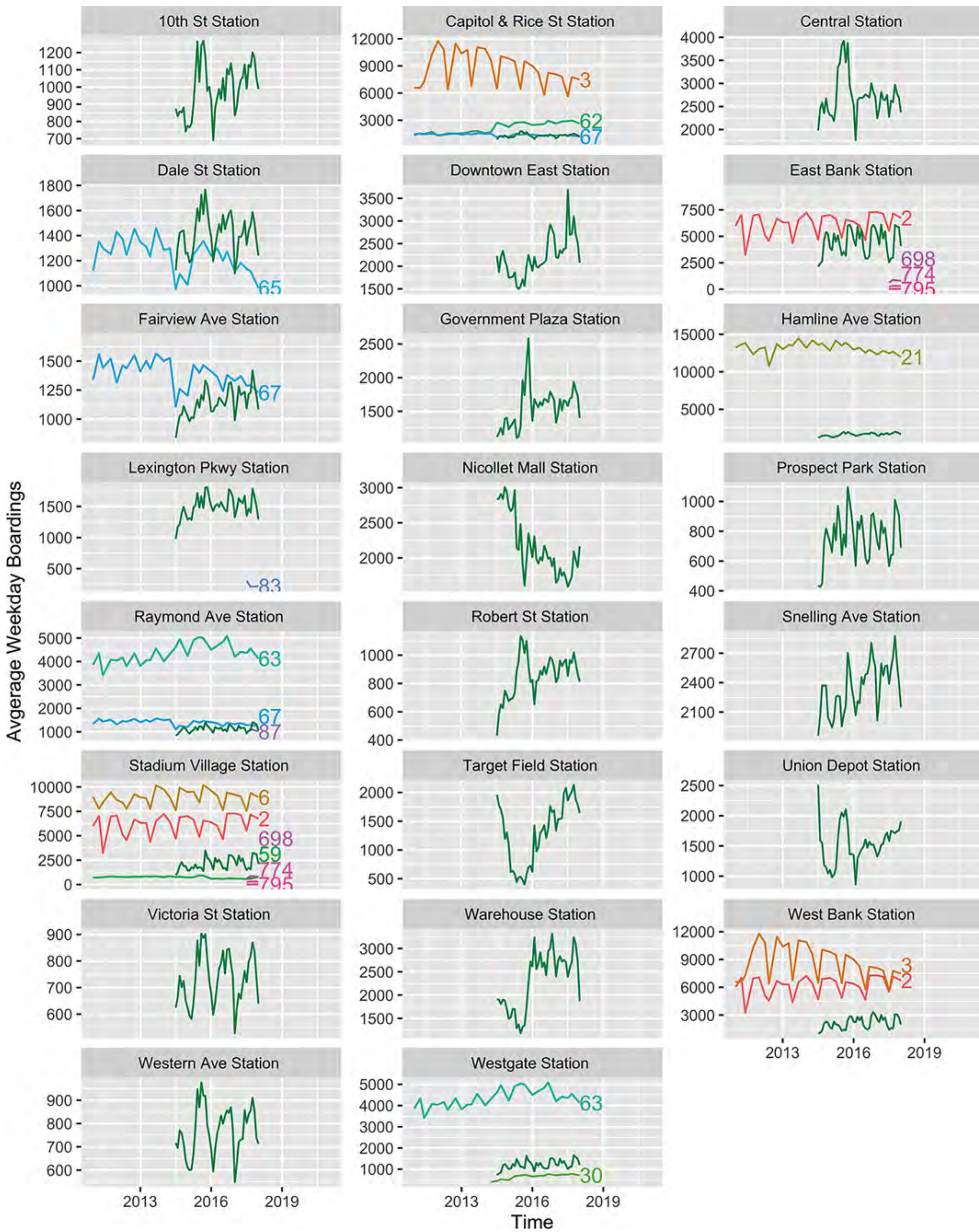
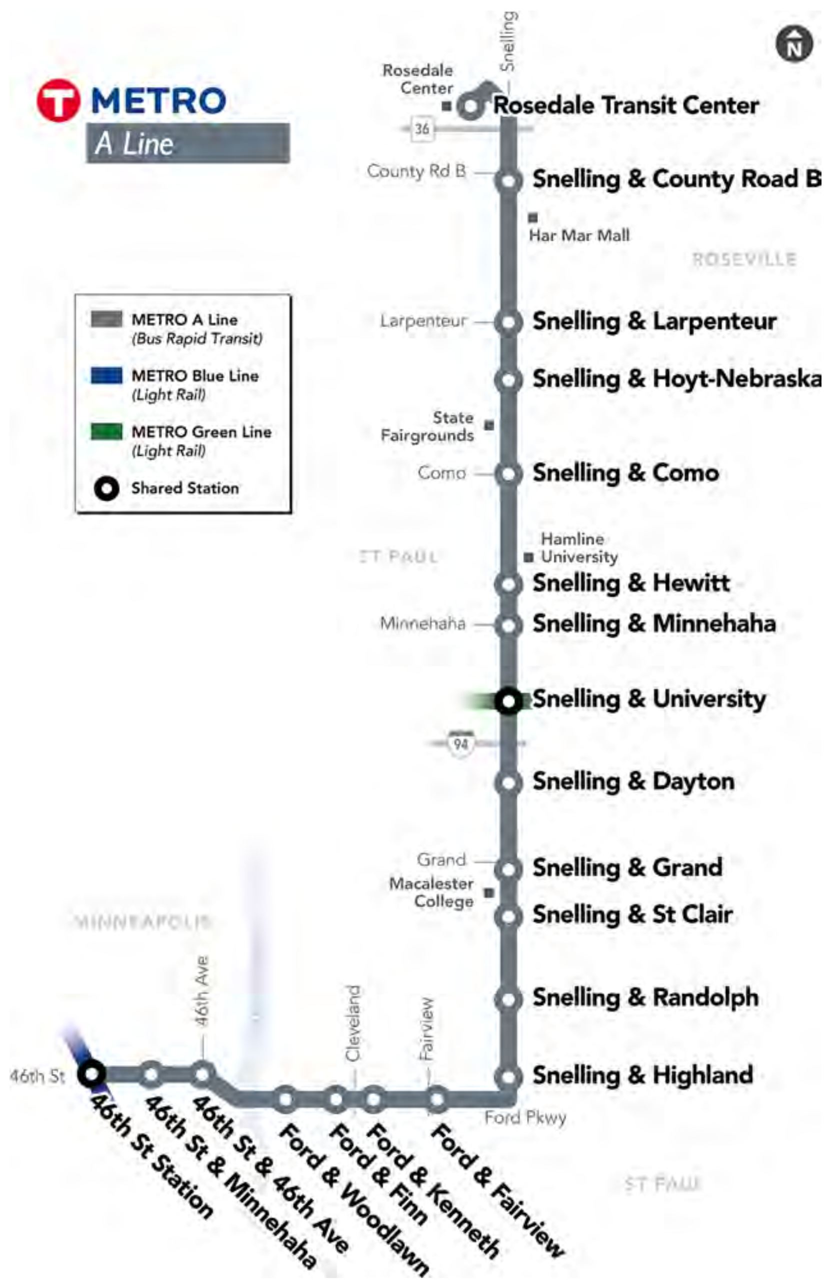


Figure 6-8. Comparison of station-level Green Line ridership with route-level ridership of connecting lines.

bus routes, regardless of the ridership served by the Green Line at the intersecting station. No apparent trend, either positive or negative, can be directly attributed to the Green Line opening.

6.2 Metro A Line

In June 2016, the Metro A Line was the first in a series of BRT and arterial BRT routes rolled out by Metro Transit. The A Line was followed by the C Line, which opened in June 2019. The C Line travels northwest from downtown Minneapolis to Brooklyn Center Transit Center. The D, B, and E lines, which would also fill in gaps in current service, are currently in planning phases or under construction. The route operates on Snelling Ave and Ford Parkway as shown in Figure 6-9. The A Line starts at the Rosedale Transit Center, connects to the Green Line,



Source: Metro Transit.

Figure 6-9. Map of A Line.

Source: Google.

Figure 6-10. Street view of A Line at Snelling Avenue and North Highland Parkway.

and ends on the Blue Line at 46th Street Station. The A Line runs parallel to Route 84 through most of its alignment.

The A Line provides many features that help maximize the route's reliability, but it still operates on mixed right-of-way. Figure 6-10 shows a typical bus stop on the A Line, located at Snelling Avenue and North Highland Parkway. Passengers can enter through the rear doors, which are larger than on regular buses, as fares are collected off-board. Stations are located every 0.5 miles. Each station features light, heat, and real-time information displays. Although the route does not have dedicated lanes, TSP at 19 of the 34 intersections extends green signal phases longer and truncates red phases for the passing buses receiving signal priority (Moore, 2016). Through these reliability improvements, the A Line was able to achieve a 20% to 25% increase in in-service speed compared to Route 84 (Metro Transit, 2017).

Figures 6-11 and 6-12 show the weekday service frequency in one direction and ridership on the A Line corridor between 2012 and 2018. Route 84 is shown in purple, and the A Line is in grey. Following a service increase in June 2014, Route 84 attained a frequency of 104 vehicle trips per weekday. The A Line opened in June 2016 with 101 trips per day, while the frequency on the parallel Route 84 was reduced to 33 vehicle trips per weekday, 25% of the overall frequency

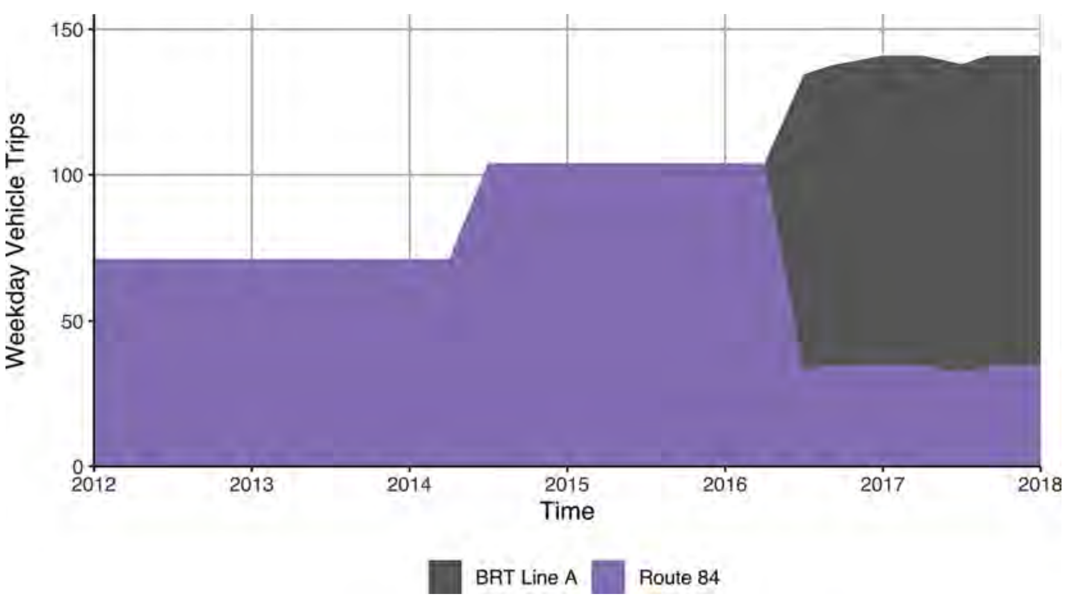


Figure 6-11. Average directional weekday vehicle trips on A Line corridor.

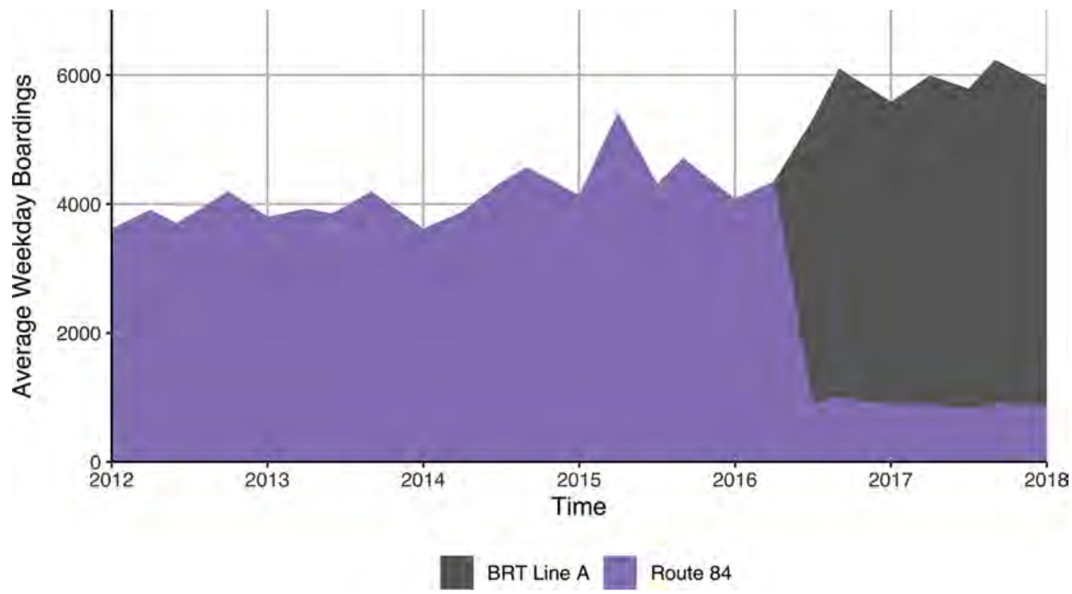


Figure 6-12. Average weekday passenger boardings on A Line corridor.

on the route. By the end of 2017, the combined frequency in the corridor had increased by 36% following the inauguration of the A Line.

Unlike the Green Line corridor, where ridership had been flat or declining since the beginning of the decade, ridership on Route 84 had been on an ascending trajectory. By the end of 2017, overall ridership on the corridor had increased by 34%. The corridor, therefore, maintained the same productivity, which is unusual in cases where service overall increases. As discussed in Chapter 4, ridership is generally inelastic to frequency, which means that additional vehicle trips added to a route typically generate a less-than-proportional increase in ridership. By the end of 2017, Route 84 carried 15% of the ridership on the corridor, which is a disproportionately small share compared to the 25% of frequency it provides.

Figure 6-13 shows a comparison of station-level A Line ridership with route-level ridership in connecting routes. The A Line ridership at each individual station is far less than the entire ridership on the routes that it connects with. The researchers also did not find a noticeable change in local bus ridership that can be attributed to the opening of the A Line.

6.3 Conclusion

This section compared the frequency and ridership on Metro Transit's Green and A Lines with prior, parallel, or connecting local bus service. Ridership on the Green Line almost doubled despite a 22% reduction in overall frequency. Along the A Line corridor, ridership increased by 34% following the opening of the arterial BRT line, which increased the overall frequency by 36%. Even though Chapter 4 showed that ridership is generally inelastic to frequency, Line A was able to maintain constant productivity on a corridor where overall ridership increased. These results indicate that both projects were capable of generating new ridership beyond the trips that were previously served by local bus routes, despite an overall downward trend in ridership in the Minneapolis/St. Paul region. The A line was able to increase ridership with higher frequencies but with minimal new infrastructure, whereas the light rail line increased ridership simply by introducing a new mode.

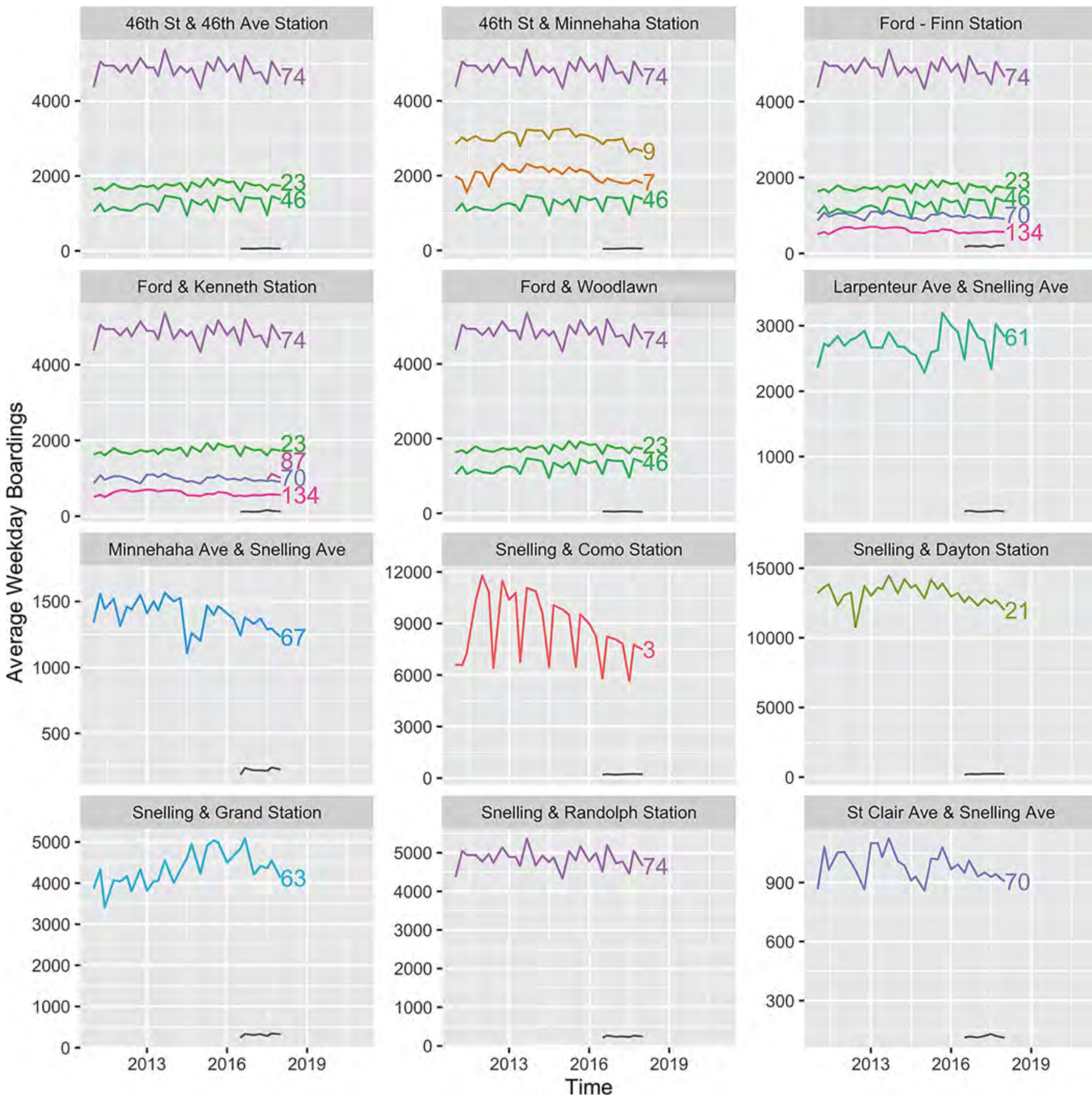


Figure 6-13. Comparison of station-level A Line ridership with route-level ridership of connecting lines.

Light rail in Minneapolis almost doubled ridership while cutting service frequency. However, even BRT was able to increase ridership at a much lower capital cost.

The analysis reveals the power of light rail to almost double ridership while cutting service. One possible explanation could be the more positive attitudes of passengers toward rail, also known as the "rail factor" (Scherer, 2010). The rail factor, however, has not been shown to influence travel behavior in previous studies beyond the specific service characteristics (Currie, 2005; Ben-Akiva and Morikawa, 2002). In the Minneapolis/St. Paul region, the Green Line opening benefited from extensive marketing efforts from the transit agency and widespread coverage from the press. Furthermore, the dedicated right-of-way and transit signal priority on the Green Line helped improve service reliability compared to the local bus routes it replaced. Therefore, it remains unclear whether the startling increase in ridership on University Avenue was due to the light rail mode or the way it was implemented.

On both corridors, local bus services—which were preserved to provide greater stop-density to limit pedestrian access distances—lost a disproportionate share of ridership compared to the changes in frequency. Route 16, which was reduced to only follow the eastern section of the Green Line, and Route 84, which follows most of the A Line, maintained 23% and 25% of the corridors' frequency, respectively. The two routes, however, only carried 2% and 15% of the ridership. Both examples illustrate that many riders are quite willing to walk further in order to access a "superior" transit service.

The analysis presented in this section can inform how transit agencies, including Metro Transit, can grow their ridership by expanding high-capacity transit networks. Whereas the Green Line cost $957 million to build (Metropolitan Council, 2018), the A Line's total construction cost was only $27 million (Moore, 2016). The high cost of the Green Line can be justified by the 14,900 passenger trips per weekday it generated beyond the existing ridership on the corridor. With increased service frequency, the A Line was also able to generate an additional 1,750 passenger trips per weekday. While light rail can be the most appropriate mode for high-demand corridors—such as University Avenue with the major trip generator of the campus—the A Line demonstrated the potential for BRT and arterial BRT to expand ridership with minimal capital cost. Overall, Metro Transit's strategy to expand multiple modes at the same time while providing enhanced bus stops, real-time passenger information, and transit-oriented development may be the best path toward increasing transit ridership in the Minneapolis/St. Paul region.

CHAPTER 7

The Impact of Shared E-scooters on Bus Ridership in Louisville, Kentucky

Shared electric motorized scooters (i.e., shared e-scooters), such as the one shown in Figure 7-1, are one of the fastest-growing micromobility modes in the United States. There were approximately 88.5 million shared e-scooter trips in the United States in 2019 (NACTO, 2020), a 230% increase over 2018. Despite their popularity in nearly every major American city and many other cities around the world, the impact of shared e-scooters on public transit ridership is largely unknown.

Similar to other forms of micromobility, like bike-sharing, there are a number of ways that shared e-scooters could potentially impact transit ridership levels. One notable value proposition frequently promoted by the operators of shared e-scooters is that they can be used as a complement to transit by way of solving the "first-mile/last-mile problem." The idea is that shared e-scooters help make transit more accessible to people whose origin or destination is beyond a short walking distance to a transit stop or station, and therefore, the presence of shared e-scooters could increase transit ridership. Alternatively, given easy access to shared e-scooters, transit riders may substitute their normal transit trips with shared e-scooter trips, which could lead to a decrease in transit ridership. A third possibility is that shared e-scooter users are riding for other purposes, such as recreation, that would neither complement nor substitute transit trips and thus have a negligible effect on transit ridership. By identifying the overall effect of shared e-scooters on transit ridership, transit agencies and city officials can more effectively develop policies to incorporate shared e-scooters into their transportation systems.

7.1 Objective of Shared E-scooters Analysis

Research to date has been inconclusive, with different studies having divergent conclusions as to whether shared e-scooters are a substitute or a complement to transit, with survey results somewhat more frequently showing a complementary relationship (City of Bloomington, 2019; City of Chicago, 2020; SFMTA, 2019; City of Santa Monica, 2019). Considering these mixed findings from prior studies, this study evaluates both local and express bus ridership in Louisville, Kentucky, for the period of February 2016 through December 2019 in order to assess the following three research questions:

1. *Do shared e-scooters decrease ridership on local bus routes?* This would occur if current transit riders primarily substitute their transit trips with shared e-scooter trips.
2. *Do shared e-scooters increase ridership on local bus routes?* This would be the case if they predominantly provide first-mile/last-mile access to new local bus trips.
3. *Do shared e-scooters increase ridership on express bus routes?* This would happen if shared e-scooters provide first-mile/last-mile access to new express bus trips.

It should be noted that shared e-scooters could not replace express bus trips in Louisville since express bus trips are typically much longer distances than would be comfortable for most to

Figure 7-1. Shared e-scooter.

travel by e-scooter. Additionally, one of the trip ends occurs outside the shared e-scooter service area, since shared e-scooters—like those in Louisville—typically operate in a small geographic area in the center of most cities. Thus, this study did not explore the possibility that shared e-scooters could decrease express bus ridership.

7.2 Why Louisville as a Case Study?

As a typical medium-sized city with bus-only transit, Louisville is an excellent case study to evaluate the impact of e-scooters on transit ridership. Louisville was selected as a case study for three reasons:

1. Limited changes to the transit system occurred during the period of February 2016 through December 2019.
2. Shared e-scooters have relatively high ridership levels in Louisville.
3. Louisville is one of a few cities that requires shared e-scooter operators to report trips through Mobility Data Specification and makes an anonymized version of the data publicly available (Github, 2020).

These three reasons allow for a research design that could quantitatively explore the impact of shared e-scooters on transit ridership.

7.3 Data Sources

This study used data from different data sources, as shown in Table 7-1. The unlinked bus trips per route and VRH were obtained from the Transit Authority of River City (TARC). The shared e-scooter trips data were obtained from the Louisville Metro Open Data repository (2020). Other variables—like population, employment, and weather—were obtained from publicly available data sources.

Table 7-1. E-scooter analysis data sources.

Variable	Data Source
Unlinked bus-trips	TARC
Bus VRH	TARC
Shared e-scooter trips	Louisville Metro Open Data repository
Population	One-year American Community Survey
Employment	Bureau of Labor Statistics
Annual median income of individual ($)	One-year American Community Survey
Weather data (average temperature, precipitation, snowfall)	National Oceanic and Atmospheric Administration

7.4 Assigning Shared E-scooter Trips to Transit Routes

The shared e-scooter trip data used in this analysis have the start and end points but not the complete route of the shared e-scooter trip. Therefore, this study proposed an assignment method to attribute shared e-scooter trips to transit routes as described in this section. To assign shared e-scooter trips to transit routes, a tight transit catchment area of 0.1 mile was first drawn around each bus route. Then, using this catchment area and shared e-scooter trip start and end points, different variables were defined for each bus route, as shown in Figure 7-2 and described as follows.

7.4.1 Assignment of Shared E-scooter Trips to Local Bus Routes

Three different variables were defined for local bus routes to assess the first two research questions:

1. Do shared e-scooters *increase* ridership on local bus routes?
2. Do shared e-scooters *decrease* ridership on local bus routes?

The first variable defined for local routes was the shared e-scooter substitute trip count. This variable was defined to assess the possibility that shared e-scooters are used to substitute transit trips, in which case they will result in reduced bus ridership. Shared e-scooter trips were defined

Shared e-scooter substitute trip: *longer than 0.1 miles and both the shared e-scooter trip start and end points were located within the catchment area for a specific local bus route.*

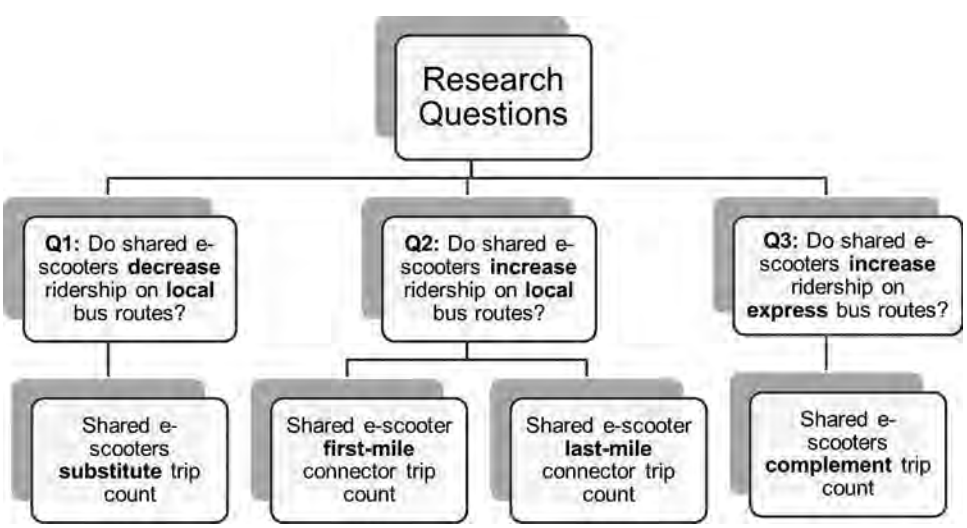


Figure 7-2. Assignment of shared e-scooter trips to bus routes.

as substituting if the shared e-scooter trip distance was greater than 0.1 miles and both the shared e-scooter trip start and end points were located within the catchment area for a specific local bus route. The total count of competing shared e-scooter trips was determined for each local bus route for each day during the period of analysis.

Figure 7-3 shows an example of the shared e-scooter trip assignment method used for one day's worth of trip data for one local bus route. In Figure 7-3, the blue line represents the local bus route, and the orange line shows the catchment area on either side of the bus route. The shared e-scooter trip origins (start points) are shown as red dots, and the destinations (end points) are shown as green dots in Figure 7-3. The inset map shows the trips that would be counted for this day and this route, which is a total of 12 shared e-scooter trips. For these trips, the origin and destination (which are shown as "linked" in the inset) are both within the catchment area for the transit route, implying that these shared e-scooter trips could have replaced transit trips along this route.

The second variable was the shared e-scooter first-mile connector trip count. This variable was defined as the number of shared e-scooter trips that have destinations within the bus route catchment area. The assumption is that users could ride a shared e-scooter to get to a local bus stop, as shown in Figure 7-4. This variable was used to evaluate the possibility that shared e-scooters are used as a first-mile connector from the trip starting point to a local bus stop.

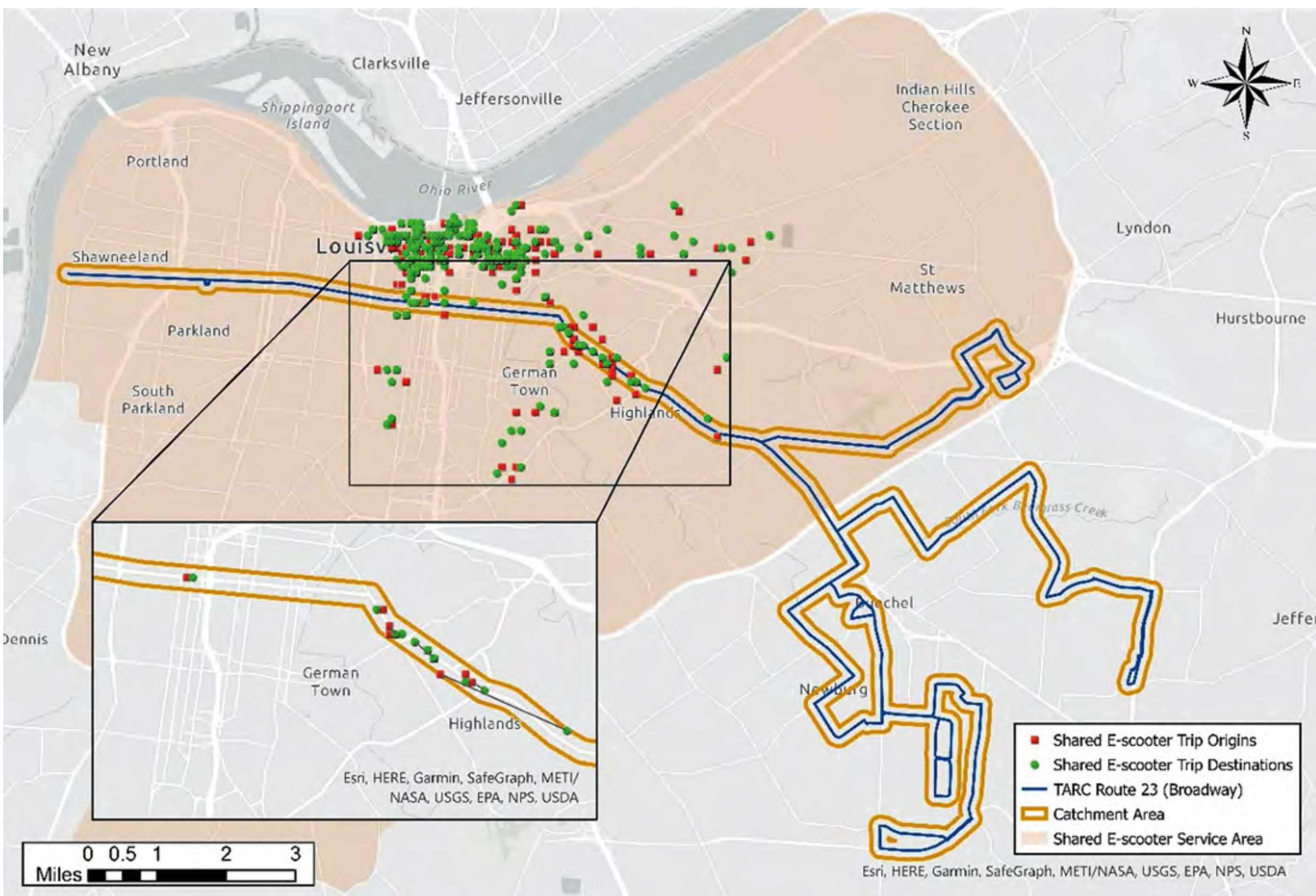


Figure 7-3. Example of shared e-scooter trip assignment to a local bus route.

Figure 7-4. Shared e-scooter first-mile connector trip count.

Figure 7-5. Shared e-scooter last-mile connector trip count.

The third variable was the shared e-scooter last-mile connector trip count. This variable counts the number of shared e-scooter trips that have origins within a bus route's catchment area. The assumption is that riders could take a shared e-scooter from the bus stop to their final trip destination, as shown in Figure 7-5. This variable was used to evaluate the possibility that shared e-scooters are used as last-mile connectors from a local bus stop to the user's trip end point.

7.4.2 Assignment of Shared E-scooter Trips to Express Bus Routes

Shared e-scooters could complement express routes, as they offer a solution to the first-mile/last mile problem that riders may experience between downtown express bus stops and their trip end points (e.g., place of work). Therefore, the shared e-scooter complement trip count was defined for express routes only to assess the third research question.

A shared e-scooter trip was defined as complementary for an express bus route if the shared e-scooter trip origin was located within an express route bus stop catchment area during morning hours, or if the shared e-scooter trip destination was located within the catchment area during evening hours. The assumption is that commuters would exit the express bus downtown in the morning and then could begin a shared e-scooter trip for the last portion of their commute. In the evening, commuters could ride a shared e-scooter from work to the express bus stop for the first portion of their evening commute and then board the express bus for the remainder of their trip home. Morning trips correspond to shared e-scooter trips whose start times were between 4 a.m. and 10 a.m., while evening trips correspond to shared e-scooter trips whose end times were between 1 p.m. and 8 p.m. The morning and evening hours selected correspond to the hours of service for the express bus routes in Louisville. Figure 7-6 shows an example of the shared e-scooter trip assignment method used for one day's worth of trip data for one express bus route.

7.5 Results of Shared E-scooters Analysis

Using multiple fixed-effects regression models, shown in more detail in Appendix G of *TCRP Web-Only Document 74,* this study assessed the three research questions by testing a variety of models using different types of data and/or variables: weekday data, weekly data, monthly data, and an expanded monthly model with other non-related potential demand forecasting explanatory

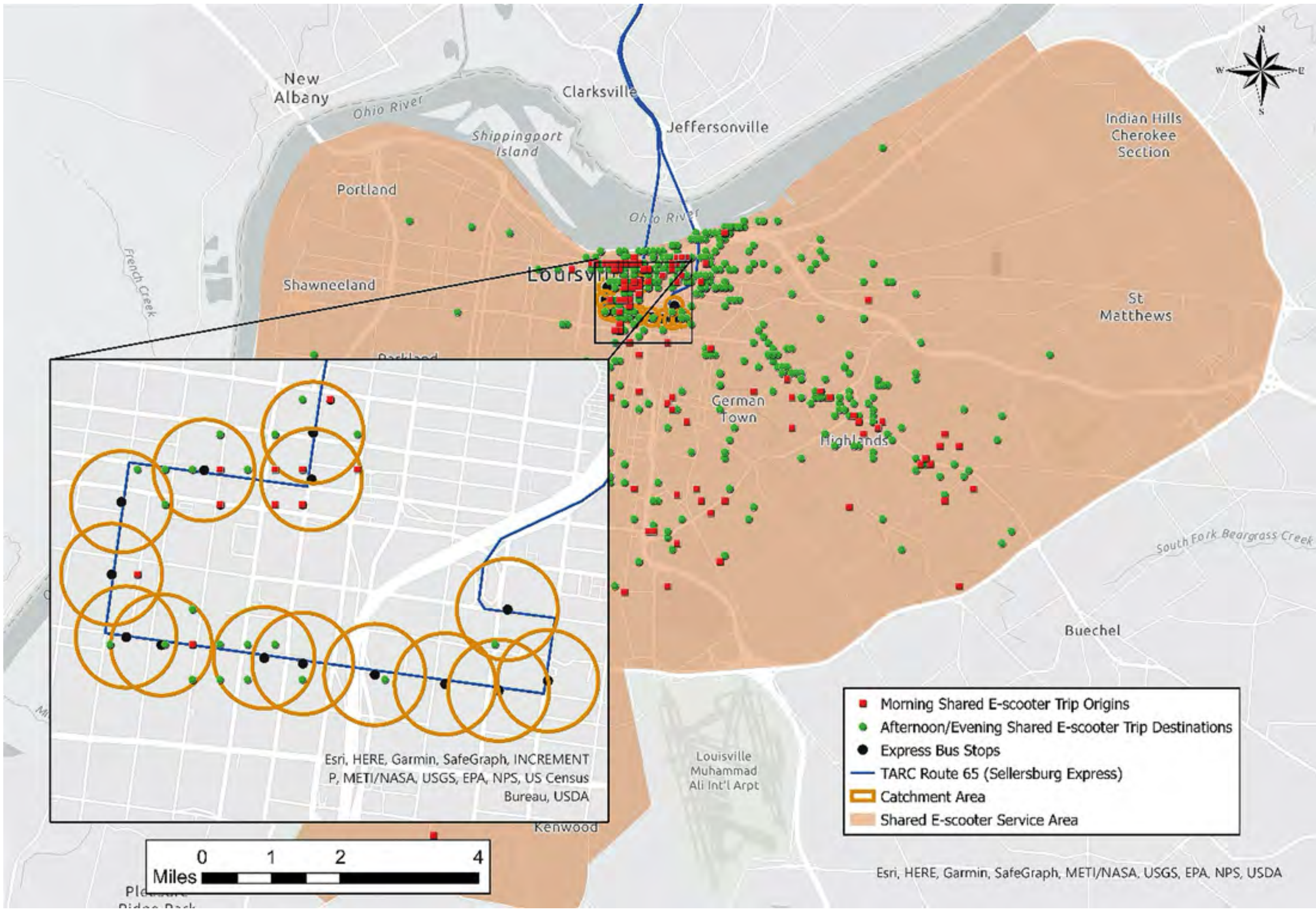


Figure 7-6. Example of shared e-scooter trip assignment to an express bus route.

variables (e.g., population, income, weather). In all the models, the variable being explained is the total unlinked bus trips per route. A summary version of the most important model results is shown in Table 7-2.

Model 1 in Table 7-2 evaluates the first research question (Do shared e-scooters decrease ridership on local bus routes?) and the third question (Do shared e-scooters increase ridership on express bus routes?). The results of Model 1 reveal that, unsurprisingly, the number of VRH is a significant positive predictor for bus ridership, as suggested by the significant positive coefficient. This coefficient indicates that each additional VRH on a route is expected to increase bus ridership by 31 trips per month, holding all else constant.

In terms of the research questions being explored, Model 1 indicates that there is no statistically significant evidence that shared e-scooter trips are being used as a substitute for bus trips. On the contrary, Model 1 suggests that the shared e-scooters complement trip counts for express bus routes; shared e-scooter trips are a statistically significant but very modest predictor for bus ridership. The shared e-scooter complement trip count coefficient indicates that each additional shared e-scooter trip within the catchment area of an express bus route is expected to increase bus ridership by 0.66 trips, holding all else constant. However, this result should be interpreted with caution. In Louisville, all express routes terminate in the same geographic area near downtown, which resulted in similar counts of shared e-scooter trips along all express routes. These

Table 7-2. Impact of shared e-scooters on unlinked bus trips model results.

Dependent Variable: Unlinked Bus Trips per Route per Month	(Model 1)	(Model 2)	(Model 3)
VRH	31.0***	31.0***	30.9***
Shared e-scooter substitute trip count (local routes)	-0.05		
Shared e-scooter first-mile connector trip count (local routes)		-0.14	
Shared e-scooter last-mile connector trip count (local routes)			-0.13
Shared e-scooter complement trip count (express routes)	0.66**	0.65**	0.65***
Population and employment (1,000s)	Not Significant		
Annual median income of individual ($)	Significant Negative Effect		
Average temperature (ºF)	Not Significant		
Rainfall (inches)	Significant Negative Effect		
Snowfall (inches)	Significant Negative Effect		
Route	Controlled for differences between routes		
Month	Controlled for differences between months		
Number of observations	1,980		
Note: Full model results are shown in Appendix G of *TCRP Web-Only Document 74*. Variable significance: ****p*-value < 0.01; ***p*-value < 0.05; **p*-value < 0.10; no star = not significant			

similar counts limit the variability of this variable in the model, which is one of the limitations of this experimental design. Therefore, the relationship between express bus ridership and shared e-scooters requires further study.

Models 2 and 3 in Table 7-2 assess the possibility that shared e-scooters increase ridership on local bus routes. Model 2 assumes that bus riders will use shared e-scooters as first-mile connectors to go from their trip start points to bus stops, while Model 3 assumes that bus riders will use shared e-scooters as last-mile connectors to go from bus stops to their trip end points. The results of these models show that both the shared e-scooter first-mile trip connector count and the shared e-scooter last-mile trip connector count are not significant predictors for bus ridership in Louisville. Those findings suggest that there is no statistically significant evidence that shared e-scooter trips are being used as first-mile/last-mile connectors to local bus routes in Louisville. Also, both models show that the shared e-scooter complement trip count is a significant predictor of bus ridership on express routes as indicated by the significant positive coefficient. This coefficient indicates that each additional shared e-scooter trip within the catchment area of an express bus route is expected to increase bus ridership by 0.65 trips, holding all else constant. This finding is consistent with Model 1, but again it should be interpreted with caution due to limitations in the modeling methodology.

The results of all three models suggest that population and employment have a positive impact on ridership, but it is not significant. The reason behind this is likely the small change in population and employment during the study period, which only lasted about three years. This finding is consistent with prior studies that found changes in population had modest effects on bus ridership in the short term (Berrebi and Watkins, 2020; Ederer et al., 2019). Models 1–3 also show that income has a significant negative impact on bus ridership. Similarly, all three models suggest that rainfall and snow have significant negative impacts on bus ridership. These findings are expected since less transit usage is expected during rain and snow. These findings are consistent with the outcomes of prior studies (Brakewood et al., 2015; Ngo, 2019; Owen and Levinson, 2015).

Shared e-scooters are not one of the primary causes of bus ridership decline in Louisville.

7.6 Conclusions, Discussion, and Implications of Shared E-scooters Analysis

As shared e-scooters are gaining popularity in the United States, their impacts on transit ridership are still largely unknown. This study conducted an empirical analysis to explore the impacts of shared e-scooters on bus ridership using Louisville as a case study. The results of this study suggest that shared e-scooters do not have a significant impact on local bus ridership, either as competitor or as a first-mile/last-mile complement. This finding could possibly be explained by three factors.

- **First, transit and shared e-scooters are often used for different trip purposes**. Transit in Louisville is mainly used for work and school; a recent survey indicates that 70% of the transit trips are for work and school (Copic, 2019). However, prior studies of shared e-scooter trip patterns indicate that shared e-scooters might not be used for commuting and are likely used primarily for recreation (Caspi et al., 2020; Noland, 2019). These different purposes suggest that shared e-scooters are not used to substitute transit trips in Louisville.
- **Second, the average trip length between these modes also suggests they are being used for different trip lengths.** The average transit trip length in Louisville is 4.2 miles compared to 1.2 miles for shared e-scooters.
- **Third, transit users in Louisville are typically minorities and have lower household incomes** (Copic, 2019). This is likely different from typical shared e-scooter users; surveys from different cities suggest that shared e-scooter users are more likely to be white and have higher household incomes (SFMTA, 2019; Mobility Lab, 2019). This suggests that transit and shared e-scooters are used by different demographic groups, which might limit the interaction of these two modes. Overall, this implies that shared e-scooters are not one of the primary reasons for declines in local bus ridership.

Last, this study also explored the relationship between shared e-scooters and express bus routes in Louisville and found that shared e-scooters may complement express bus routes as first-/last-mile connectors. However, this finding should be interpreted with caution because of the similar counts of shared e-scooter trips along all express routes, which is one of the limitations of this experimental design. Therefore, the relationship between express bus ridership and shared e-scooters requires further study. However, transit agencies and shared e-scooter operators could explore ways to integrate these two modes to offer better service for their users. There are many ways that such an integration could occur, such as developing multimodal trip planning platforms and price bundling of the two modes.

CHAPTER 8

The Impact of Fare-Free Promotions on Bus Ridership in Topeka, Kansas

Bus ridership has been declining in all but a handful of cities across the United States. Topeka, Kansas, is one of the few cities that has not experienced this ridership decline. Instead, the Topeka Metropolitan Transit Authority (Topeka Metro) has bucked the industry trend of declining bus ridership and experienced increases year after year in fixed-route ridership—3.7% in FY 2017, 2.0% in FY 2018, and 2.3% in FY 2019 (Berberich Trahan & Co., 2017; Berberich Trahan & Co., 2018; Berberich Trahan & Co., 2019). While different factors could explain why Topeka Metro's ridership has continued to increase when many other transit agencies' ridership counts are decreasing, one clear differentiator between Topeka Metro and other transit agencies is Topeka Metro's use of numerous fare-free promotions as a means of promoting transit for different groups within the community.

Some of these promotions are commonly implemented by other transit agencies, like providing free fares on the Dump the Pump Day and Election Day. However, Topeka Metro also runs several promotions that provide free transit access for a limited period of time to groups that may not typically receive free fares elsewhere. These include a Veterans Ride Free promotion every November (see Figure 8-1), a summer-long ride-free promotion for kids under 18 years of age, and a Families Ride Free promotion every spring and winter during the local school district's breaks. By identifying the impacts of these promotions on ridership, transit agencies can more effectively develop fare policies that could potentially boost ridership.

8.1 Objective of the Fare-Free Promotions Analysis

Prior studies have explored the impacts of systemwide free transit access (Volinski, 2012; Kansas Corporation Commission, 1988). Other studies have explored the impacts of one specific promotion that targets a single group of riders, like seniors or college students (Metaxatos, 2013; Yu and Beimborn, 2018). The objective of this study is to evaluate the impacts of fare-free policies for numerous specific groups—including students, veterans, and seniors—on bus ridership. Topeka Metro is used as a case study because the transit agency's fare policy is unique in that it targets many different groups of riders (often at different times of the year), but it is not free for all riders.

8.2 Fare-Free Promotions in Topeka

For the purpose of this study, the fare-free promotions are divided into two groups: long-term promotions and short-term promotions. More details of the different fare-free promotions offered by Topeka Metro are described in this section.

Figure 8-1. Veterans Ride Free promotion.

8.2.1 Long-Term Promotions

Topeka Metro offers several fare-free promotions that are a month or longer, as shown in Figure 8-2. Promotions that are one month or longer are considered separately from shorter programs (less than one month) since the time-unit of analysis in the models that follow is monthly.

- **Jurors Ride Free:** This promotion was introduced by Topeka Metro in October 2016 to provide free transit access to jurors when going to/from jury duty. Jurors get two tickets per day during the trial (Fry, 2016).
- **Seniors (65+) Ride Free:** Topeka Metro initiated this promotion in 2016. This promotion provides free transit access to seniors (65+) during the month of May.
- **Kids (18 & Under) Ride Free:** Topeka Metro offers free transit access to kids under 18 each summer from mid-May to mid-August.
- **Middle & High School Students Ride Free:** Topeka Metro places a particular emphasis on providing young people with free transit. For this program, local middle and high school students are provided with free transit passes during the school year through a partnership with select local public schools. It should be noted that the school district does pay for these fares at a negotiated rate per pass.
- **Veterans Ride Free:** Topeka Metro offers free transit access to veterans during the month of November.

Jurors Ride Free	Year-Round	•Started in 2016
Seniors (65+) Ride Free	May	•Started in 2016
Kids (18 & Under) Ride Free	May–August	•Started in 2013
Middle & High School Students Ride Free	August–May	•Started in 2012
Veterans Ride Free	November	•Started in 2012

Note: Washburn University students, faculty, and staff have access to transit through a university pass program known as UPass. However, this program is not characterized as a free promotion because some of the costs are paid in part through student fees.

Figure 8-2. Long-term Topeka Metro fare promotions.

8.2.2 Short-Term Promotions

In addition to long-term promotions, Topeka Metro also offers several short-term promotions throughout the year, as shown in Figure 8-3 and described in this section. It should be noted that the following analysis focuses on the long-term promotions (not these short-term promotions) due to data availability. The available data are monthly bus trips; therefore, the impacts of short-term promotions that are less than a month might not have a sizable effect. However, it is worth mentioning that Topeka's 2019 ridership statistics show that some of these short-term promotions are likely to have positive impacts on ridership. For example, the 2019 Families Ride Free (Spring Fling) week had ridership of 1,732 unlinked bus trips, which is about 24 bus trips per route per day. Also, the 2019 Remember Rosa Parks Day ride-free promotion had ridership of 4,507 unlinked bus trips, which is about 376 bus trips per route per day.

- **Families Ride Free:** Topeka Metro offers free rides for families twice each year. Spring Fling is a week during school break in March, and Winter Fling is during the holiday season in late December and early January. This promotion allows families of one to two adults plus at least one kid under 18 to ride the bus for free.
- **Volunteers Ride Free:** Topeka Metro provides unlimited bus trips for local volunteers with a volunteer ID during National Volunteer Week each April to recognize their efforts.
- **No Pay Earth Day:** Topeka Metro celebrates Earth Day by offering free bus access for all riders.
- **Public Employees Ride Free:** Topeka Metro celebrates Public Service Recognition Week by offering free bus access to federal, state, county, and city government workers.
- **Dump the Pump Day:** Similar to other transit agencies, Topeka Metro provides free bus service to all riders on Dump the Pump Day each June to try to attract new bus riders.
- **Election Day:** Like many transit agencies, Topeka Metro offers free bus access to all riders on Election Day each November.
- **Remember Rosa Parks Day:** Topeka Metro offers free bus access to all riders for one day each December in recognition of civil rights activist Rosa Parks.
- **Free After 5 p.m.:** Topeka Metro offers free transit access to all riders after 5 p.m. on several periods during the year. It should be noted that sometimes this promotion is offered for a month. However, this promotion is considered a short-term promotion since Topeka Metro bus service runs only until 7:30 p.m.

It should be noted that some of these fare-free promotions are provided under a partnership with the recipient organization (e.g., university, schools, city), which provides some direct compensation for these promotions.

Families Ride Free (Spring Fling)	**3rd Week in March**	•Started in 2013
Volunteers Ride Free	**One Week in April**	•Started in 2014
No Pay Earth Day	**April 22**	•Started in 2013
Public Employees Ride Free	**1st Week of May**	•Started in 2013
Dump the Pump Day	**3rd Thursday in June**	•Started in 2012
Election Day	**1st Tuesday after Nov. 1**	•Started in 2016
Remember Rosa Parks Day	**Dec. 1**	•Started in 2015
Families Ride Free (Winter Fling)	**Late Dec. to Early Jan.**	•Started in 2013
Free After 5 p.m.	**Various Periods**	•Started in 2016

Figure 8-3. Short-term Topeka Metro Fare promotions.

Table 8-1. Data sources for Topeka Metro Fare promotion analysis.

Variable	Data Source
Monthly UPTs	Topeka Metro
Bus VRM	Topeka Metro
Fare-free promotions	Topeka Metro
Population	One-year American Community Survey
Employment	Bureau of Labor Statistics
Gas prices	Energy Information Administration
Weather data	National Oceanic and Atmospheric Administration

8.3 Data Sources

This study used data from different sources, which are shown in Table 8-1. Unlinked bus trip per route and VRM were obtained from Topeka Metro. Topeka Metro has 12 fixed bus routes that provided an average of about 4,434 UPTs on weekdays and about 2,387 on Saturdays (Topeka Metro, 2018). The details of each of the fare-free promotions were defined from archived Topeka Metro press releases and verified with Topeka Metro. Other variables like population, gas prices, and weather were obtained from publicly available data sources that are shown in Table 8-1.

8.3.1 Fare-Free Promotion Variables

The variables of interest in this study are related to fare-free promotions. This study explored long-term promotions. The reason behind this is that the dependent variable is the total monthly bus trips by route; therefore, the impacts of short-term promotions that are less than a month might not have a sizable effect in a monthly model.

This study defined five variables to explore the impacts of different fare-free promotions, as shown in Table 8-2. Each of these variables is defined as the number of fare-free service days per month. The service days are defined as days of the month minus public holidays and Sundays. (Topeka Metro does not offer transit service on Sundays.) For example, *Veterans Ride Free* for November 2019 is defined as 24 free-service days, as shown below:

24 (Veterans Ride Free) = 30 (days of the month) – 4 (Sundays) – 2 (Thanksgiving holiday)

Table 8-2. Fare-free promotion variables.

Variable	Definition
Jurors Ride Free	Number of free-service days for jurors
Students Ride Free	Number of free-service days for middle and high school students (mid-August to mid-May)
Kids Ride Free	Number of free-service days for kids during the summer (mid-May to mid-August)
Veterans Ride Free	Number of free-service days for veterans each November
Seniors (65+) Ride Free	Number of free-service days for seniors each May

8.4 Results

Using fixed-effects regression techniques similar to those described in Appendix G of *TCRP Web-Only Document 74,* this study assessed the impacts of different fare-free promotions on bus ridership. The dependent variable (the variable being explained/predicted) was the total bus trips per route per month. The explanatory variables were the fare-free promotion variables described in Section 8.3 and other commonly used explanatory variables, such as VRM, population and employment, gas price, and weather. Various model formulations were tested, and the results of the preferred model are shown in Table 8-3.

Consistent with other results in this study and in the literature, the results of this analysis suggest that the number of VRM is a significant positive predictor for bus ridership, as shown in Table 8-3. This coefficient indicates each additional VRM on a route is associated with an additional 0.42 unlinked bus trips. This finding is expected, as providing more service is associated with higher ridership (Evans et al., 2004). Regarding fare promotions, the model's results indicate that each free-service day for students (middle and high school) is associated with an average increase of 37.7 UPTs per route. This finding suggests that offering free transit access to middle and high school students resulted in a significant ridership increase in Topeka. It should be noted that the school district does pay for these fares at a negotiated rate per pass; however, since this cost is not directly paid by the students, it was considered in this analysis as a promotion. Similarly, the model suggests that each free-service day for kids during the summer is associated with an average increase of 54.5 UPTs per route. These two findings suggest that Topeka Metro's emphasis on providing free transit access to young people has had significant positive results. The model results displayed in Table 8-3 also show that each free-service day for veterans is associated with an average increase of 9.1 UPTs per route. Similarly, the findings suggest that each free-service day for seniors is associated with an average increase of 15 UPTs per route. These findings indicate that offering free transit access to veterans in November and seniors during May has resulted in significant positive increases in bus ridership. Finally, the model results reveal that offering free transit access to jurors had a positive impact on ridership; however, it is not statistically significant, which suggests it is effectively zero.

Table 8-3. Impacts of fare-free promotions on bus ridership results.

Dependent Variable: Unlinked Bus Trips per Route per Month	Preferred Model
VRM	0.42**
Students Ride Free	37.7**
Kids Ride Free	54.5**
Veterans Ride Free	9.1**
Seniors (65+) Ride Free	15***
Jurors Ride Free	10
Population and employment (1,000s)	Not significant
Gas price ($)	Significant positive effect
Snowfall (inches)	Significant negative effect
Summer	Controlled for differences between seasons
Routes	Controlled for differences between routes
Years	Controlled for differences between years
Number of observations	552
Variable significance: ****p*-value < 0.01; ***p*-value < 0.05; **p*-value < 0.10; no star = not significant	

The results of this study also suggest that population and employment had a positive impact on ridership, but it is not significant. The reason behind this is likely the small change in population and employment during the study period. This finding is consistent with prior studies that found changes in population had limited effects on bus ridership (Ederer et al., 2019; Berrebi and Watkins, 2020). The results of this study also indicate that increases in gas prices have a positive significant impact on bus ridership, which is consistent with prior findings (Currie and Phung, 2007). Additionally, the results of the model suggest that snowfall has significant negative impacts on bus ridership (Ngo, 2019; Brakewood et al., 2015). This finding is expected since less transit usage is expected during snow. This finding is consistent with the outcomes of prior studies.

Last, the findings from the study for fare-free promotions are supported by a quick comparison with ridership statistics calculated for some of the promotions that were obtained from Topeka Metro for 2019. The 2019 ridership statistics showed that during the promotions period, the numbers of trips made by veterans, seniors, and kids were 6,168 (November), 10,099 (May), and 42,800 (mid-May to mid-August), respectively. These statistics were converted to average trips per route per day by dividing the total ridership by the number of fixed bus routes, then by the number of free service days of each promotion. These calculations showed that in 2019, the average estimated trips per route per day for veterans, seniors, and kids were 17, 32, and 44, respectively. These trip rates from the 2019 statistics are comparable to those found in Table 8-3 for the longer-term analysis, which provides a confirmation of the validity of the analysis.

The slight difference between the two sets of statistics is likely due to two reasons.

- First, the regression model estimates the change in trips, which is presumably the number of new trips generated during the promotion. However, the 2019 statistics show all total trips made by a specific group. Some riders could have been using transit with or without the promotion, but they obtained a free ride because the promotion was in place.
- Second, the ridership statistics show the usage of these promotions in 2019 only, while the model estimates the average usage in the period 2015–2019.

8.5 Conclusions, Discussion, and Implications of the Fare-Free Promotions Analysis

While many transit agencies in the United States are concerned about the recent transit ridership declines, Topeka Metro is one of a few agencies that has experienced a ridership increase. One apparent differentiator between Topeka Metro and other transit agencies that could potentially explain Topeka's increased bus ridership is Topeka Metro's use of fare-free promotions as a means of promoting bus usage among different groups in the community. This study conducted an empirical analysis to explore the impacts of different fare-free promotions on bus ridership in Topeka.

Fare-free promotions for middle and high school students, kids, veterans, and seniors have resulted in significant increases in bus ridership in Topeka.

The findings of this study suggest that fare promotions for middle and high school students, kids, veterans, and seniors have resulted in significant increases in bus ridership. The results of this analysis are important for agencies as they explore ways to get more people to ride transit to reverse bus ridership declines.

Although the findings of this study are positive, it is important to note that offering free bus passes or fare-free promotions to large groups of riders may place a financial burden on the transit agency's operational budget. Topeka Metro has kept a farebox recovery ratio between 10%–13% during FY 2016, 2017, 2018, and 2019 (Berberich Trahan & Co., 2017; Berberich Trahan

& Co., 2018; Berberich Trahan & Co., 2019). This steady farebox recovery ratio can likely be attributed to two factors. First, Topeka Metro partners with other local agencies, like Topeka public schools for the middle and high school students promotion; these partnerships bring in some revenue that offset the lost fares to some extent. Second, Topeka Metro offers staggered promotions that target certain groups during different months. Although Topeka Metro's farebox recovery ratio has remained relatively steady, the transit agency has faced recent budgetary challenges; in December 2019 (prior to the COVID-19 pandemic), the agency cut some bus service due to reductions in local funding (Topeka Metro, 2019).

CHAPTER 9

The Impact of Converting Bus Routes to BRT on Ridership in Cleveland, Ohio

BRT is "a high-quality bus-based transit system that delivers fast and efficient service that may include dedicated lanes, busways, traffic signal priority, off-board fare collection, elevated platforms, and enhanced stations."

BRT, or bus rapid transit, is defined by FTA as "a high-quality bus-based transit system that delivers fast and efficient service that may include dedicated lanes, busways, traffic signal priority, off-board fare collection, elevated platforms, and enhanced stations" (Federal Transit Administration, 2015). This definition suggests that BRT is a combination of different features. Transit agencies follow different approaches when planning and implementing BRT routes (Levinson et al., 2003a). Some transit agencies implement nearly all BRT features available, while others choose to implement only some of the features.

Converting local bus routes to BRT is a strategy used by transit agencies to provide riders with high-quality service without the intensive capital investment required for light and heavy rail. Over the past several decades, the Greater Cleveland Regional Transit Authority (GCRTA) converted three of its highest ridership bus routes into BRT lines, with different BRT features that range from all BRT features to just branding, as detailed in Section 9.2. This section describes research to quantify the ridership impacts of converting local bus routes to BRT. Assessing the impacts of BRT on ridership will inform transit agencies and city officials who are planning new BRT routes or converting existing bus routes to BRT.

9.1 Objective of BRT Analysis

The research evaluated bus ridership in Cleveland, Ohio, for the period of 2004 through 2019 in an effort to assess the following research questions:

- How has converting a local bus route to full BRT impacted ridership?
- How has converting a local route to have some BRT features impacted ridership?
- How has branding a local route as BRT without other enhancements impacted ridership?

9.2 BRT Routes in Cleveland

The transit agency in Cleveland operates three BRT routes: the HealthLine, the Cleveland State Line, and the MetroHealth Line. These were launched in 2008, 2014, and 2017, respectively, as shown in Figure 9-1. Each of these three routes has a unique set of BRT features; this presents a unique opportunity to investigate the impact of different levels of BRT features on bus ridership. More details about the features of each BRT route are discussed in the following subsections.

9.2.1 HealthLine BRT Route

In October 2008, GCRTA opened the HealthLine, a state-of-the-art BRT line replacing Bus Route 6 along Euclid Avenue. The HealthLine was designed in part to support the Euclid Corridor

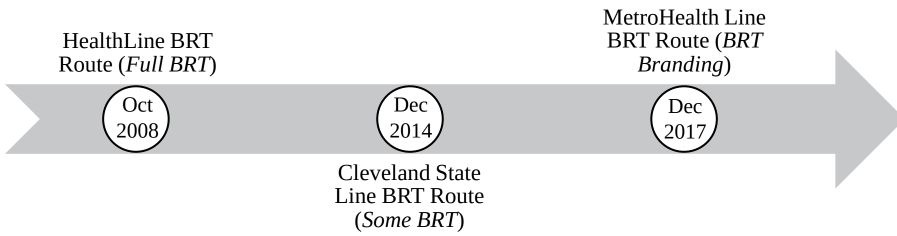


Figure 9-1. The City of Cleveland BRT routes launch dates.

Transportation Project, a multiyear project implemented to revitalize Euclid Avenue as a business district through transit-oriented development along the corridor. According to GCRTA (2020), the HealthLine has the following BRT features:

- 4.5 miles of dedicated right-of-way
- High-frequency service (every 10 minutes during peak hours, 15 minutes during off-peak)
- 24/7 bus service
- TSP
- Real-time information displays
- Bus stop consolidation
- Level boarding stations
- Off-board fare collection
- Unique branding

This conversion of the HealthLine BRT route reduced the average running time from 46 minutes to 36 minutes (Federal Transit Administration, 2012). However, it should be noted that shortly after opening the HealthLine, TSP for portions of the HealthLine's route was discontinued. Additionally, there were policy issues related to the off-board fare collection. GCRTA's fare evasion policing was deemed unconstitutional by a Cleveland Municipal Court judge in October 2017, which resulted in GCRTA switching to onboard validation and requiring riders to pay for or validate a ticket on the bus itself (Allard, 2019). It also worth noting that the HealthLine is the only route that FTA has accepted for reporting as the BRT mode in the NTD.

9.2.2 Cleveland State Line BRT Route

In December 2014, the Cleveland State Line BRT route opened, connecting downtown Cleveland—including Cleveland State University—to the western part of Cuyahoga County. The Cleveland State Line enhanced the 55 family of bus routes. The Clifton Boulevard portion of the Cleveland State Line has the following BRT features:

- Dedicated transit lane for both buses and bikes during peak hours (7:00–9:30 a.m.; 4:00–6:30 p.m.)
- Improved traffic signal system for all vehicles
- New stations
- Bus stop consolidation
- Median landscaping
- Enhanced streetscape
- Unique branding

9.2.3 MetroHealth Line BRT Route

In December 2017, GCRTA rebranded its second-busiest route as the MetroHealth Line BRT route. The MetroHealth Line BRT is a rebranding of the 51 family of bus routes. This BRT route

Source: http://www.riderta.com/news/dec-7-2017-metrohealth-line-buses-debut-week

Figure 9-2. MetroHealth Line bus.

opened with limited changes, namely rebranded buses (see Figure 9-2), refurbished shelters, and customized signage (MetroHealth, 2017). There are plans to implement TSP and dedicated lanes during peak hours on the MetroHealth Line, but these features had not yet been implemented at the time of writing.

9.3 Data Sources

This study used data from different sources, as shown in Table 9-1. The unlinked bus trips, VRH, and BRT features were obtained from GCRTA. Other variables—like employment, gas prices, percent of zero-vehicle households, and years since the introduction of TNCs—were obtained from publicly available data sources.

9.4 Ridership Trends

This section discusses ridership trends for BRT routes and non-BRT routes in Cleveland. Figure 9-3 shows that after the launch of the HealthLine (which has full BRT features) in 2008, the route continued to gain ridership until it peaked in 2014. After 2014, ridership on the HealthLine started to drop. The Cleveland State Line (with some BRT features) also gained ridership after its launch in 2014 and has not suffered a significant decline in ridership. However, the MetroHealth Line (with only BRT branding) did not gain ridership after its launch in 2017 but continued a downward ridership trend similar to the non-BRT routes (see Figure 9-3). Furthermore, the ridership of the three BRT routes declined in 2018 and 2019.

Table 9-1. Data sources for Cleveland BRT analysis.

Variable	Data Source
Unlinked bus trips	GCRTA
VRH	
BRT features	
Employment	Bureau of Labor Statistics
Gas prices	Energy Information Administration
Percent of zero-vehicle households	One-year American Community Survey
Years since the introduction of TNCs	Uber and APTA

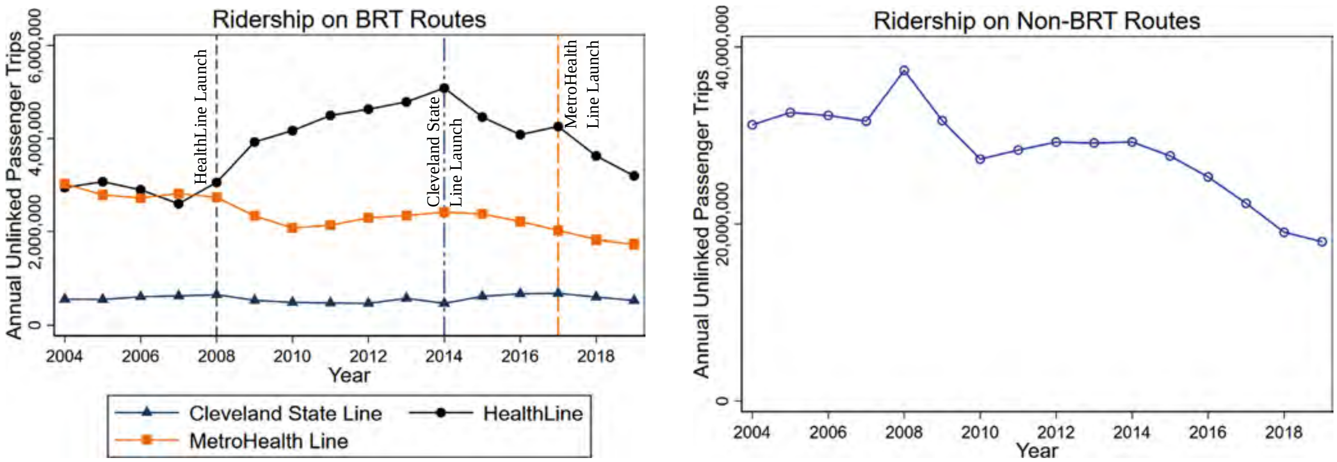


Figure 9-3. Annual bus ridership for BRT and non-BRT routes in Cleveland.

The declines in BRT ridership appear to be similar to general ridership declines occurring in Cleveland since 2014. These declines could be attributed to some internal factors, like reducing service provision and increasing fares, as well as other external factors that affect ridership, such as changing gas prices and the introduction of TNCs. More details about changes in these factors are discussed in the following subsections.

9.4.1 Internal Factors Affecting Ridership

The first contributing factor to ridership declines appears to be a drop in the amount of service provided. Figure 9-4 shows that VRH declined for all three BRT routes in 2018 and 2019, and service reductions for non-BRT routes started in 2016. This is expected to reduce ridership since service provision has been identified as an important determinant of transit ridership based on prior studies (Boisjoly et al., 2018; Evans et al., 2004).

The second potential contributing internal factor is fare increases. Figure 9-5 shows that the average fare per UPT increased from 2016, which is when GCRTA implemented a 25-cent fare increase (GCRTA, 2012). Many prior studies have shown that fare increases often result in ridership declines (Taylor et al., 2009; McCollom and Pratt, 2004).

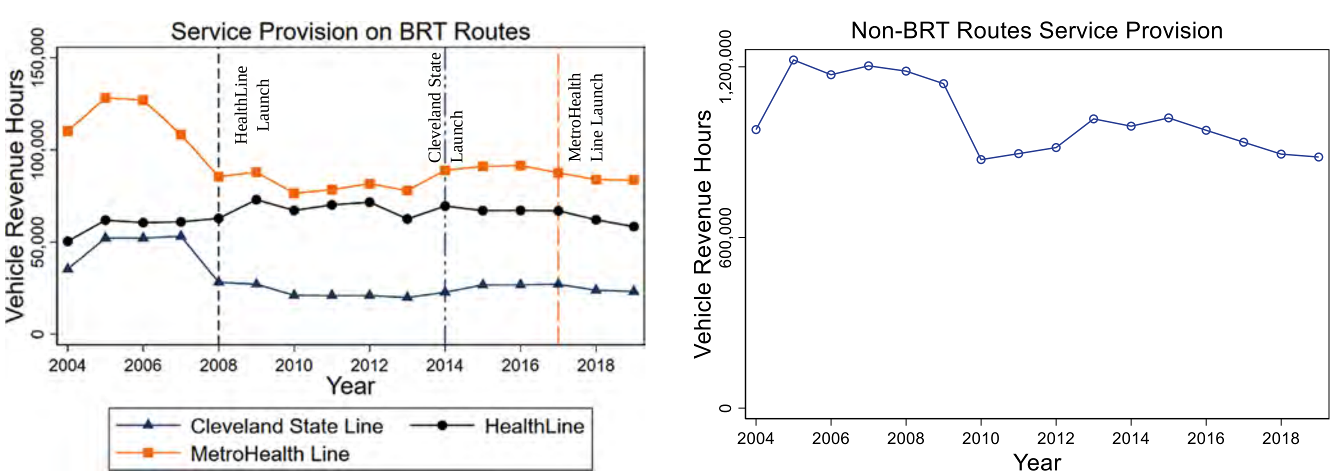
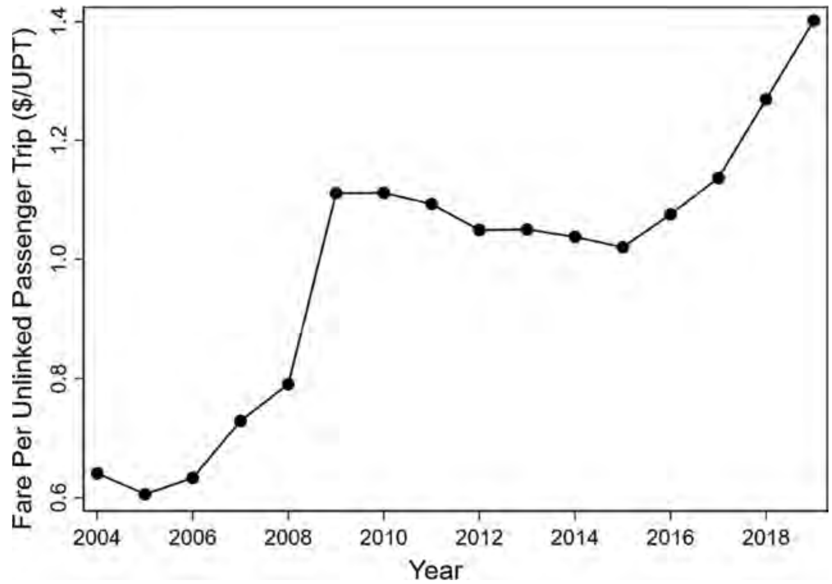


Figure 9-4. Annual bus service provision for BRT and non-BRT routes in Cleveland.



Source: NTD.

Figure 9-5. Fare per UPT.

9.4.2 External Factors Affecting Ridership

In addition to the internal factors, there were changes in some external factors that were expected to reduce bus ridership in Cleveland. Figure 9-6 shows the percent of zero-vehicle households, gas prices, and percent of workers who telecommuted in Cleveland for the period of 2004 to 2019. First, it can be noticed that the percent of zero-vehicle households has decreased since 2014; this is likely to have a negative impact on transit ridership since more residents have access to automobiles. Second, gas prices after adjusting for inflation are cheaper now compared to 2014; this is also expected to negatively impact transit ridership. Furthermore, telecommuting has increased in Cleveland since 2014, which may also have negative effects on transit ridership. Finally, the introduction of TNCs in 2014 could have reduced transit ridership (Graehler et al.,

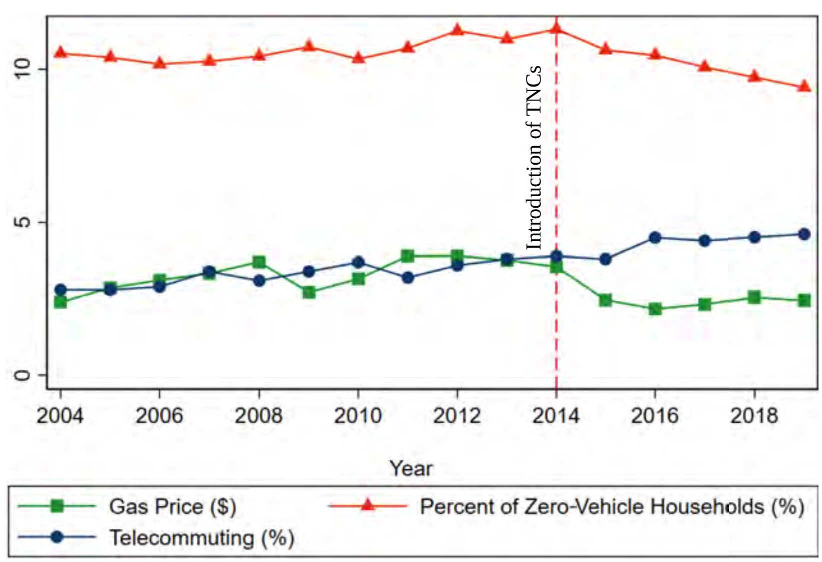


Figure 9-6. Gas prices, percent of zero-vehicle households, and telecommuting in Cleveland.

2019). In summary, all these changes in external factors were expected to cause ridership drops and, as shown in a previous chapter, have impacted ridership in our own analysis.

9.5 Results of the BRT Analysis

Using the fixed-effects regression techniques described in Appendix G of *TCRP Web-Only Document 74,* this study assessed the impacts of BRT routes on ridership over the period from 2004 to 2019. The dependent variable was the total bus trips per route per year. It should be noted that the log transformation of the dependent variable was used; therefore, some of the results of the models can be interpreted as ridership elasticity values. The explanatory variables were the different BRT levels, as described in Section 9.3, and other commonly used explanatory variables such as transit VRH, employment, percent of zero-vehicle households, and years since the introduction of TNCs. The results of two preferred models with similar statistical properties are in Table 9-2.

The results of this analysis suggest that the elasticity of ridership with respect to changes in transit VRH is about 0.9, as shown by both Model 1 and Model 2 in the first row of Table 9-2. This value suggests that increasing/decreasing VRH on a route by 10% will increase/decrease route ridership by 9%. This finding is consistent with the nationwide analysis conducted in this study that found the elasticity of ridership with respect to changes in transit service provision to be about 0.83.

Table 9-2 also shows that converting bus routes to full BRT or adding some BRT features resulted in ridership gains that ranged between 22% (based on Model 2) to 46% (based on Model 1), as shown in the second and third rows of Table 9-2. It should be noted that the coefficient values for full BRT and some BRT features were consistently positive and significant in the model results, which provides evidence that these two routes increased ridership (holding all else equal). However, the value of these coefficients varied some depending on the model specification. Given that a simple dummy variable (i.e., binary variable) was used to represent BRT, the research team suggests that additional research be conducted in the future to help untangle how specific features of BRT impact ridership. Last, just branding routes as "BRT" did not have a significant impact on ridership, as shown by the MetroHealth Line results in Model 1 and Model 2 in Table 9-2.

The results of this study also suggest that total employment and the percent of zero-vehicle households have significant positive impacts on bus ridership, while TNCs have significant

Table 9-2. Impact of BRT on unlinked bus trips model results.

Dependent Variable: Unlinked Bus Trips per Route per Year (Log Transformed)	Model 1	Model 2
VRH (log transformed)	0.88***	0.91***
HealthLine (full BRT features)	0.31***	0.22***
Cleveland State Line (some BRT features)	0.46***	0.42***
MetroHealth Line (only BRT branding)	0.03	0.002
Percent of zero-vehicle households	-	Significant positive effect
Years since the introduction of TNCs	Significant negative effect	-
Total employment	Significant positive effect	
Route	Controlled for differences between routes	
Number of observations	697	
Variable significance: ***p < 0.01; **p < 0.05; *p < 0.10; no star = not significant		

84 Recent Decline in Public Transportation Ridership: Analysis, Causes, and Responses

negative impacts on bus ridership. These findings are consistent with the nationwide analysis conducted in this study as well as prior studies. It should be noted that TNCs and the percent of zero-vehicle households were evaluated separately (in Model 1 and Model 2, respectively) due to multicollinearity; for this reason, two separate models with similar results are shown in Table 9-2.

9.6 Conclusions, Discussion, and Implications of the BRT Analysis

Converting routes to BRT resulted in bus ridership increases of 22% to 46%.

This study conducted an empirical analysis to quantify the impacts of converting local bus routes to BRT using Cleveland as a case study. The results of this study suggest that converting bus routes to full BRT or adding substantial BRT features increased ridership significantly (possibly between 22% and 46%) per year. These results suggest that giving buses priority on streets yielded ridership gains even if this priority was limited to peak hours. However, merely branding routes "BRT" did not result in significant changes in ridership; this is likely because branding does not improve the level of the service. These findings are important for transit agencies that are considering increasing the priority of bus routes on local streets.

It is also important to note that the BRT routes in Cleveland experienced net ridership declines in 2018 and 2019. These decreases appear to be part of general transit ridership declines in Cleveland that have occurred over the past five years (since 2014) and are similar in nature to overall downward trends of transit ridership in the United States. In Cleveland, these decreases are likely driven by both internal and external factors discussed in a previous section. This includes decreases in the amount of transit service provided, fare increases, the introduction of TNCs, and reductions in the cost of owning and operating an automobile. In summary, the positive ridership impacts attributed to BRT in the previous paragraph were not sufficient to outweigh the negative effects of other factors that have impacted ridership in Cleveland, resulting in net ridership declines.

CHAPTER 10

Future Strategy Evaluation

Previous sections of this report presented analyses about the possible factors impacting transit ridership trends. While it is important to use data to understand how these factors contribute toward transit ridership declines, explaining the complex travel behavior choices an individual makes as well as capturing the inherent dynamism of the transport system is a more complicated process. Therefore, there is need for a tool that could be used to map individuals' travel behavior and simultaneously handle the multimodal interactions among existing or proposed transport systems.

This section describes the web-based transportation microsimulation platform CityCast, which uses a data-driven approach for quick but rigorous scenario planning. CityCast is a complementary tool to travel-demand models, which are highly specialized tools that can be cumbersome to develop, calibrate, install, and use for some planning analyses. CityCast enables planners to look at both transit ridership and road traffic impacts of improvements and policies with the latest data.

Through the use of passively collected data, the CityCast platform provides the ability to study and evaluate transit ridership trends for future scenarios, such as those being considered by public transit agencies. Figure 10-1 shows an example of an activity pattern for a simulated traveler in CityCast, while Figure 10-2 shows how the route and mode of trips are determined. This latter portion is important because it explicitly considers both the competition and complementarity (such as other modes serving as connections to/from transit stations) between transit and other modes. Such interactions provide the opportunity to specify various scenarios and study their likely impacts on transit ridership and on other modes.

In the background, CityCast simulates travelers making mode and route choices using the open-source framework Multi-Agent Transport Simulation (MATSim), accessible at https://www.matsim.org.

10.1 MATSim Overview

MATSim is a transport simulation framework that is used to simulate large-scale scenarios. As its name suggests, central to the MATSim framework are its agents and their activity patterns (also called plans). Each agent represents a real-world person, and each person starts with a schedule of activities that includes times and locations covering an entire single day (see Figure 10-1). The initial plans of each agent are created prior to MATSim, and in the CityCast ecosystem this is done using a combination of third-party, passively collected data and survey-based data from the U.S. census, FHWA, and FTA. MATSim focuses on simulating the travel between these initial plans (see Figure 10-2) using coevolutionary principles, meaning that each agent adapts its travel behavior depending upon the travel of other agents and their likely impacts on the transport infrastructure.

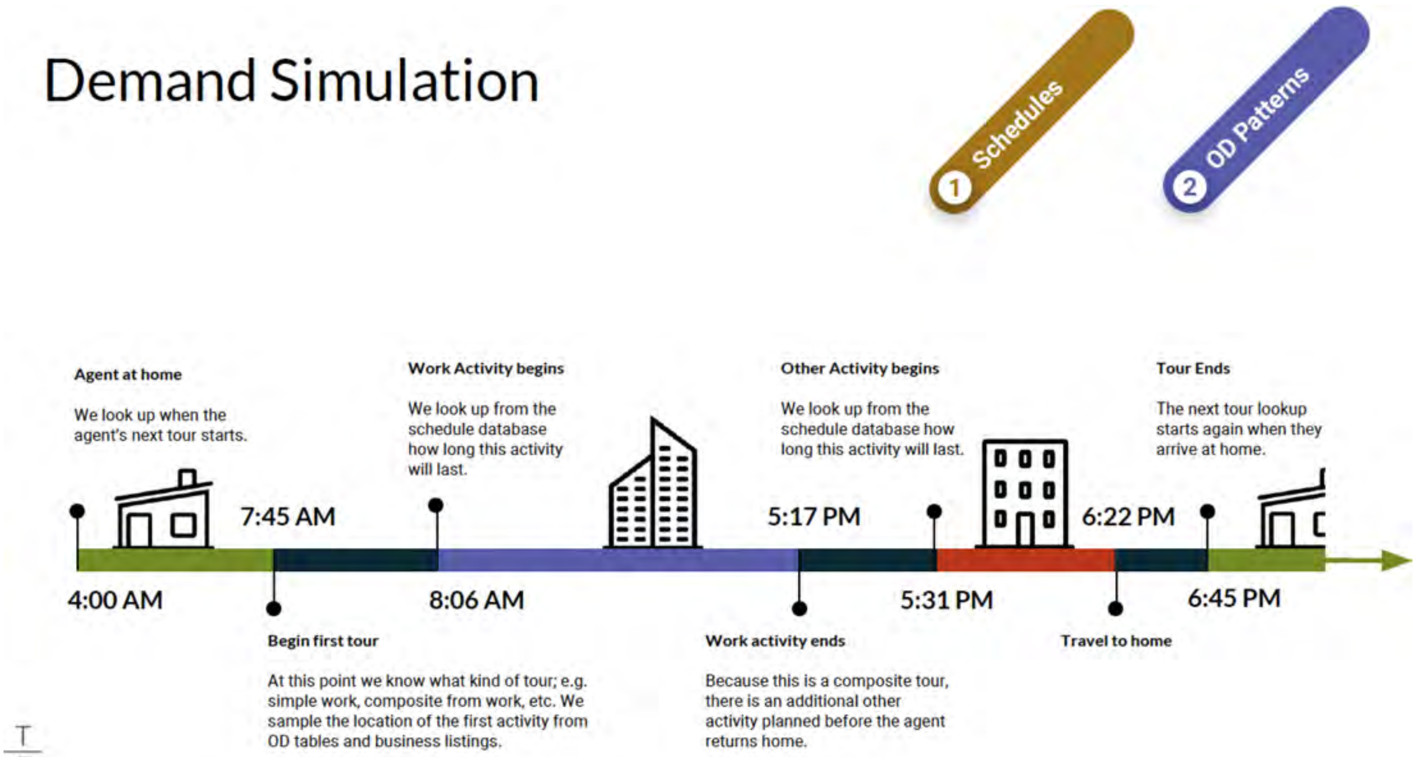


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Figure 10-1. Demand-side components of CityCast platform.

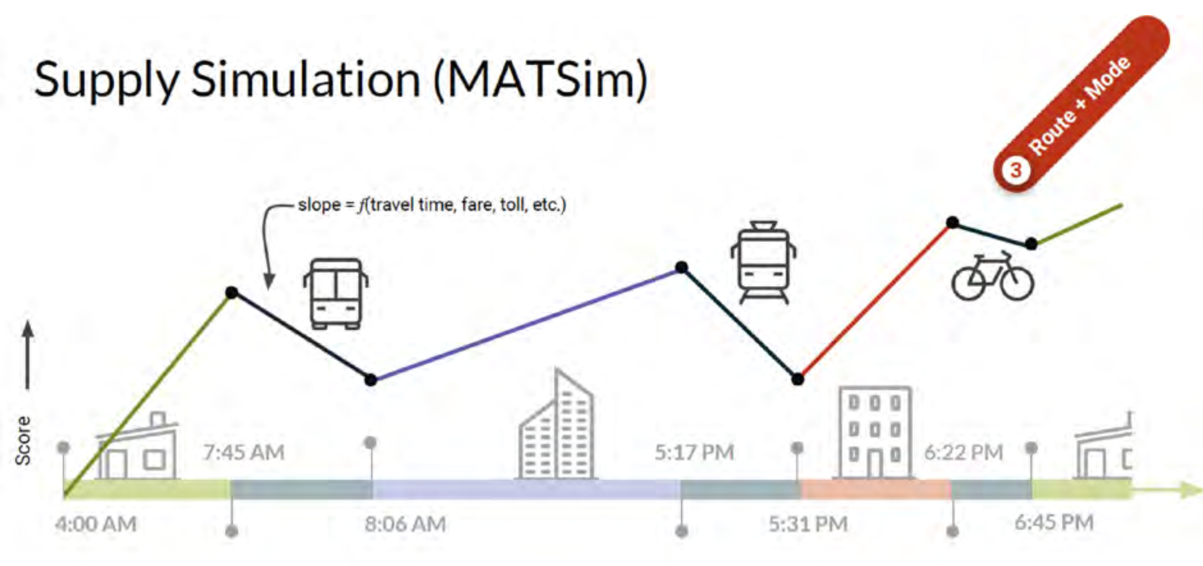

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Figure 10-2. Supply-side components of CityCast platform.

The coevolutionary principles of MATSim are realized by simulating an entire day many times through. After each time through, each agent measures how well it accomplished the day's activities given its travel choices (mode, route, congestion, crowding) and iterates the next time through using those travel choices that perform well. With each iteration of the simulation, MATSim measures each agent's plan using a scoring function by mode that is similar to a utility function in the traditional travel demand–modeling paradigm. When optimizing travel choices through iterations, four dimensions are usually considered by MATSim: departure time, route taken, destination, and travel mode used. If agents' scores remain constant over iterations, this indicates that the system has reached an equilibrium state.

The travel choices observed in a simulated single day in this relaxed state can be analyzed to understand representative populations and how they use the transport network (either a real one or an imagined one). In our study, the simulation was carried out for a total of 50 iterations to reach a relaxed state.

10.2 Input Data

CityCast runs MATSim inside its web-based ecosystem for users, but it also allows users to download MATSim-required files for running MATSim locally with finer-grain control. At a minimum, the MATSim simulation needs the following files:

- Network file: describing the road and public transport networks in the form of links and nodes. Nodes are described by (X, Y) coordinate values, while links hold all the attribute values related to segments (e.g., length, capacity, number of lanes, speed, and allowed travel modes).
- Travel demand file: describing the people and their daily activities. Each activity is specified by location (X, Y), purpose, and time.

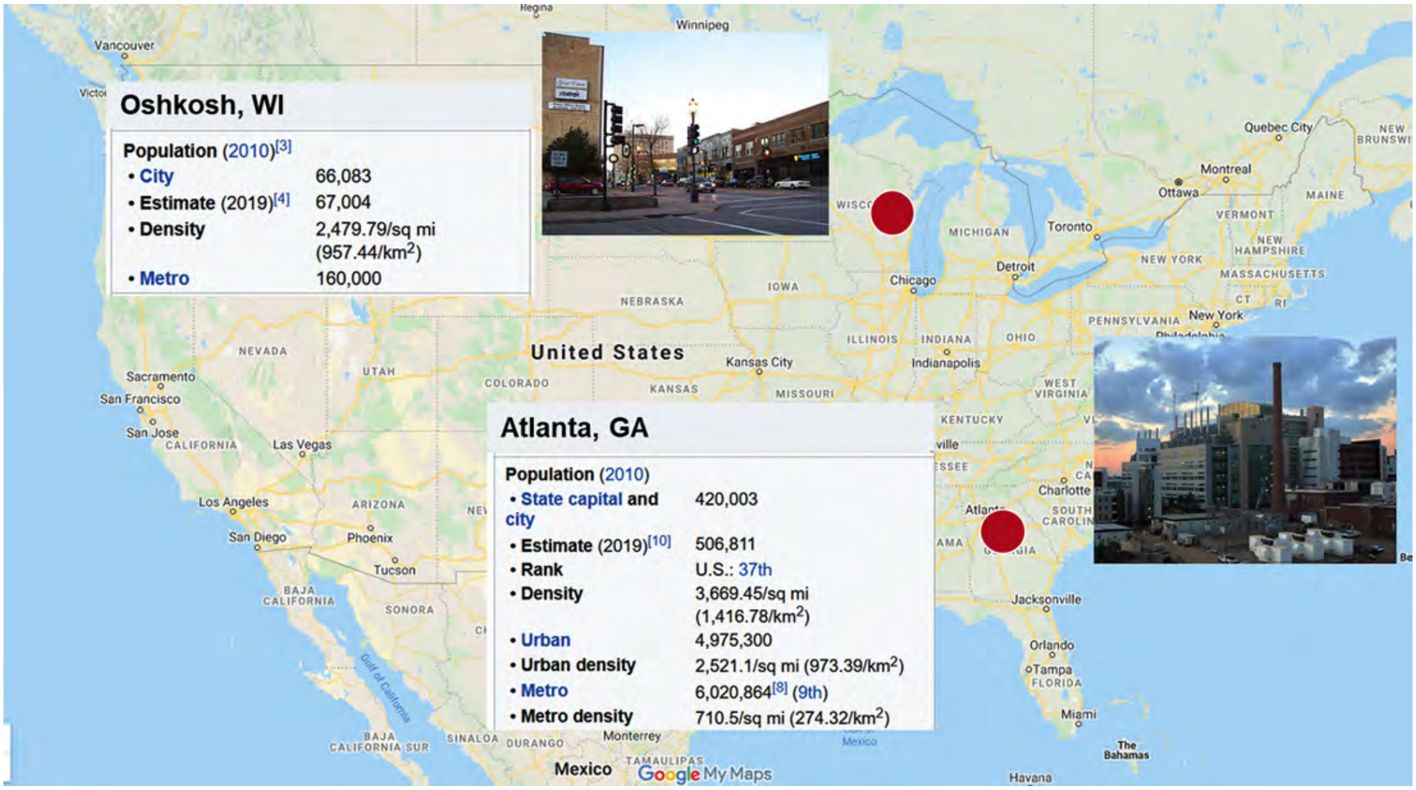
To evaluate the expected effectiveness of the proposed alternatives' transit strategy, two additional files were needed:

- Transit schedule: contains detailed information related to lines, routes, stop locations, and public transport schedule.
- Transit vehicles: defines "type" and number of vehicles, which the simulation could utilize to run across the routes as defined in the transit schedule file. This file describes various characteristics, like seating and standing capacity (number of passengers), maximum speed, and how many passengers can board or depart a vehicle per second.

Network files representing the detailed road networks of the two case study cities (Atlanta, Georgia, and Oshkosh, Wisconsin) were downloaded from CityCast; the platform currently uses HERE Maps for network data but has also used OpenStreetMaps in the past. All relevant modes of transport (i.e., private cars, walking, and bus and rail transit services) were included. The service details from the transit services were obtained using GTFS feeds from the agencies.

10.3 Identified Cities

Atlanta and Oshkosh were identified as the two case studies. These two cities were chosen based on the different population and transit system sizes. As shown in Figure 10-3, Atlanta is a large metropolitan area with a population of around 6 million in the MSA. The Oshkosh-Neenah MSA has around 170,000 population and is adjacent to the Appleton, Wisconsin, MSA, which has another 240,000 population. These differences allowed the researchers to understand how the strategies are interpreted by residents living in cities of different scales. Moreover, Atlanta differs from Oshkosh in that it has more than one public transport operator and multiple modes.



Source: Google Maps.

Figure 10-3. Statistics about case study cities, Atlanta and Oshkosh.

10.4 Development of Scenarios

The goal of these scenarios is to establish a general boundary on the effectiveness of certain strategies. The following scenarios were tested for each city:

- Base scenario: This scenario represents 2019 conditions before COVID-19.
- Low-income focus: This scenario considers the effect of improving bus service on those routes that serve the highest share of low-income riders, while decreasing service elsewhere.
- High-ridership focus: This scenario considers the effect of increasing service on those bus routes with the most riders, while decreasing service elsewhere.
- High-ridership focus with exclusive bus lanes: Building upon the high-ridership scenario, this scenario adds bus-only lanes to those same high-ridership routes to give them a travel time advantage.

10.5 Atlanta, Georgia

Atlanta has 500,000 people living within the city and over 6 million in the metropolitan area. It is the political and economic capital of Georgia and host to the headquarters of major companies including Coca-Cola, AT&T, Delta Airlines, and UPS. Several major universities are based in Atlanta, including Georgia Tech and Emory University.

MARTA anchors the regional transit system, which is supplemented by Georgia Regional Transportation Authority express buses and additional suburban transit agencies. On an average weekday, MARTA's north-south and east-west heavy rail lines carry about 200,000 passengers, with fixed-route bus service carrying about the same number of riders (see Figure 10-4).

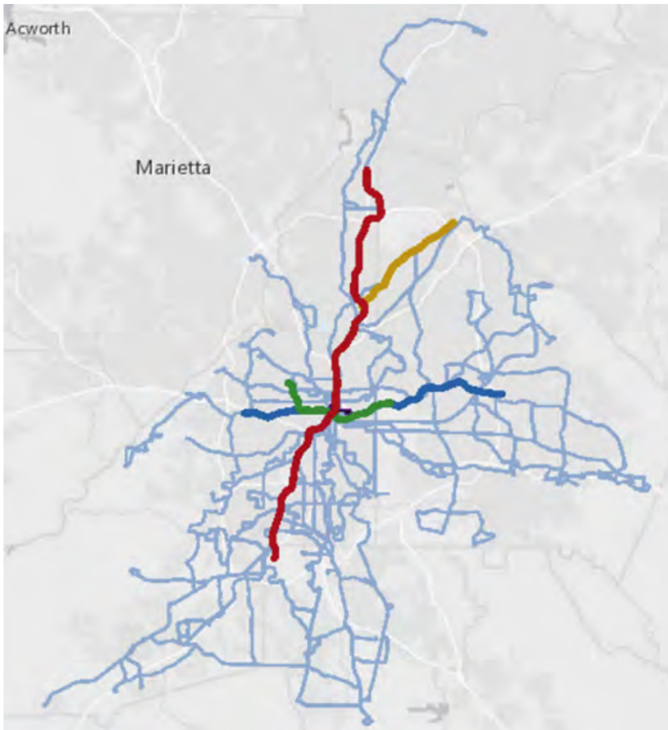


Figure 10-4. MARTA transit system.

The Atlanta scenarios test the potential effectiveness of various strategies in a large and very congested area.

10.5.1 Low-Income Focus

The goal of this scenario is to understand how transit ridership might change if bus service were reoriented better to serve low-income riders. To approximate this, the research team identified the 20% of bus routes within each transport operator that carry the highest share of low-income households. "Low-income households" were defined as those with less than $20,000 in annual income. Then the frequency of service on these routes was doubled. To keep total operating cost of the transit agency constant, the daily services of the remaining 80% of the transit routes were uniformly reduced, such that the VRH did not change from the base scenario. None of the schedules or frequencies of any rail transit modes were changed.

The results indicate that in this scenario, linked bus trips would increase 47% among low-income riders and 44% among the general population. The map in Figure 10-5 shows how this change would be distributed geographically. The ridership gains are observed largely west of I-85, with ridership losses east of I-85 but inside the perimeter (I-285).

10.5.2 High-Ridership Focus

The goal of this scenario is to understand how transit ridership might change if bus service were reoriented to better serve the routes with the highest ridership levels. To approximate this, the research team identified the 20% of bus routes within each transport operator that carry the most passengers, then doubled the frequency of service on these routes. To keep total operating cost of the transit agency constant, the daily services of the remaining 80% of the transit routes were uniformly reduced, such that the VRH did not change from the base scenario. Again, neither the schedules nor the frequencies of any rail transit modes were changed.

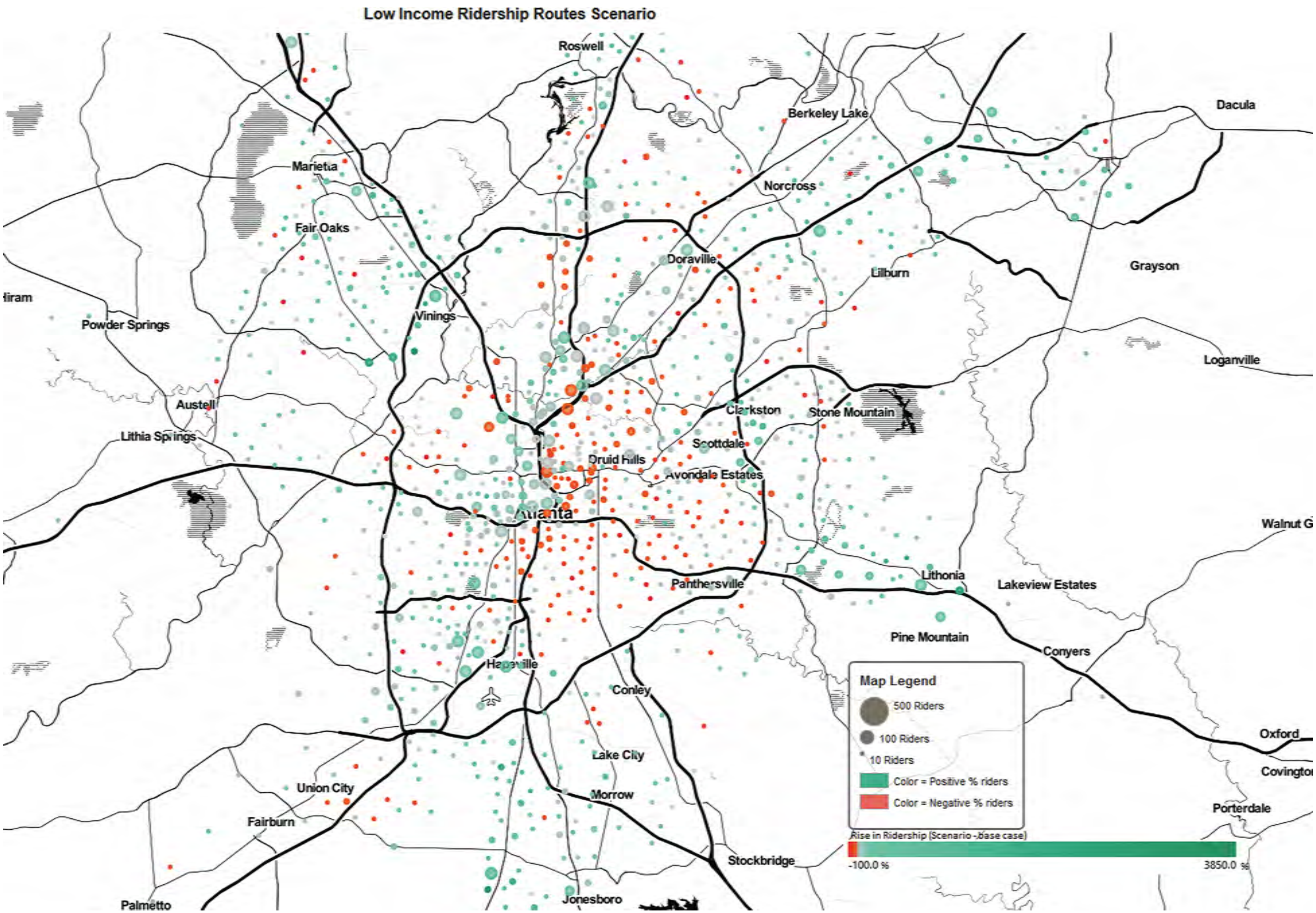


Figure 10-5. Change in bus ridership by census tract for low-income focus in Atlanta.

The results indicate that in this scenario, linked bus trips would increase 70% among low-income riders and 88% among the general population. Somewhat surprisingly, this scenario increases ridership among low-income travelers more than the first scenario. This occurs because the highest ridership routes also carry many low-income riders, even though their *share* of low-income riders may be lower. The map in Figure 10-6 shows how this change would be distributed geographically. The ridership gains are observed to be concentrated north of I-20, with ridership losses on the near south side of Atlanta.

10.5.3 High-Ridership Focus with Exclusive Bus Lanes

This scenario aims to understand the ridership effect of giving exclusive right-of-way to high-ridership bus routes. It builds upon the high-ridership focus scenario, in which the frequency of the 20% of bus routes with the highest ridership was doubled, within each operator, while the frequency of the remaining 80% was reduced. Those 20% of bus routes with the highest ridership were provided with dedicated road infrastructure in the form of exclusive bus lanes, resulting in faster travel times. The researchers assumed that those bus lanes were new capacity, such that the road capacity did not decrease. To be conservative with the results, they did not further increase the frequency to reflect that the buses would complete their routes faster.

The results indicate that in this scenario, linked bus trips would increase 89% among low-income riders and 109% among the general population. The map in Figure 10-7 shows how this change would be distributed geographically. A pattern similar to the high-ridership focus scenario is observed but with ridership gains that are more widespread, such as areas on the south side of Atlanta that lose ridership in the scenario above but gain ridership here.

10.6 Oshkosh, Wisconsin

Oshkosh is a city of 66,000 in Northeast Wisconsin on the shore of Lake Winnebago. The greater metropolitan area also includes Neenah and Appleton for a total population of 160,000. Major Oshkosh employers are involved in manufacturing specialty trucks, emergency vehicles, plastics, and chocolate. The area is a destination for fishing and boating.

Go Transit operates 10 bus routes on 30-minute headways, including one that travels 13 miles north to Neenah. In 2019, these routes carried about 2,000 riders on an average weekday. Valley Transit operates bus service in the Fox River Valley, including Neenah and Appleton, but Valley Transit was not considered in this analysis. The map in Figure 10-8 shows the bus routes in Oshkosh, and the map in Figure 10-9 shows the ridership (boardings plus alightings) by census block group. The largest circle, indicating the most riders, is in downtown Oshkosh. The Oshkosh scenarios align with those described previously and test the potential effectiveness of those strategies for transit operators in small metropolitan areas.

10.6.1 Low-Income Focus

In this scenario, the research team considered the effect of adjusting transit service to better serve low-income riders—those with an annual household income of less than $20,000. The 20% of bus routes with the highest share of low-income riders were identified, and the frequency on those routes was doubled. There are 10 routes in Oshkosh so this meant increasing the frequency of two of those routes, going from 30-minute headways to 15-minute headways. To offset the cost of these service increases, the frequency of the remaining routes was decreased such that the total VRH remained constant.

For this scenario, linked bus trips would decrease by 3% among low-income riders and 1% among the general population. The map in Figure 10-9 shows how this change would be

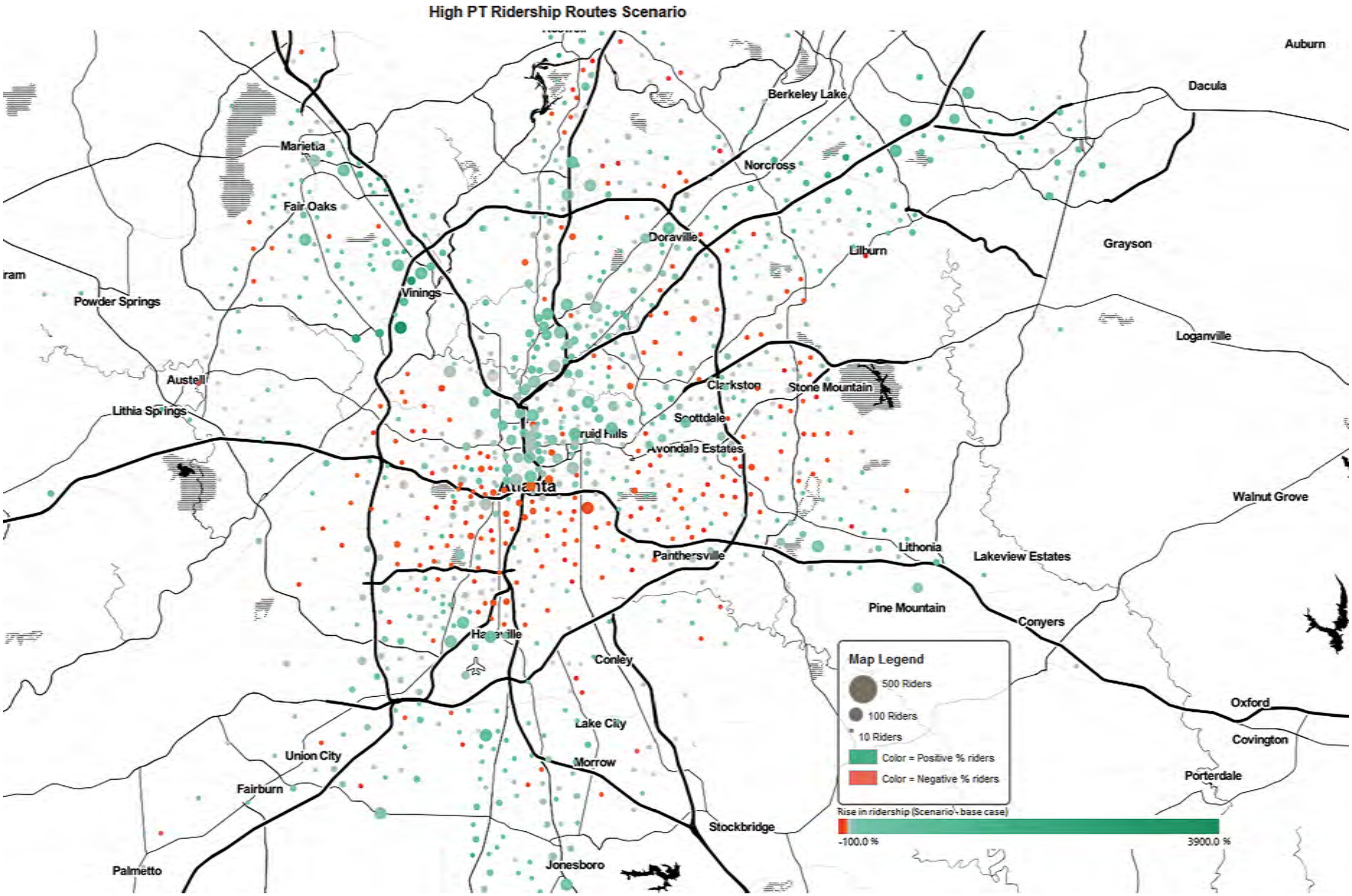


Figure 10-6. Change in bus ridership by census tract for high-ridership focus in Atlanta.

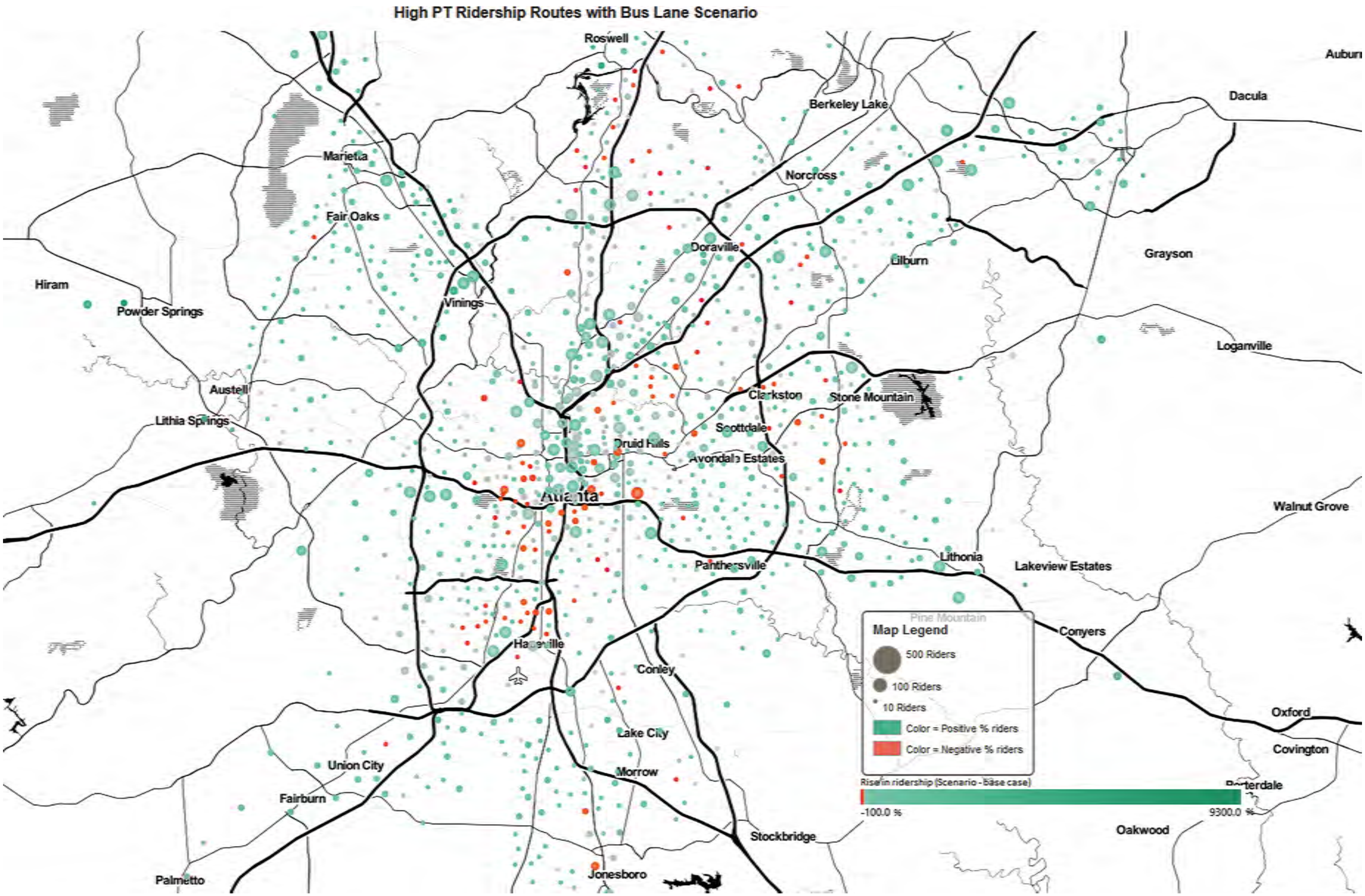


Figure 10-7. Change in bus ridership by census tract for high-ridership focus with exclusive bus lanes in Atlanta.

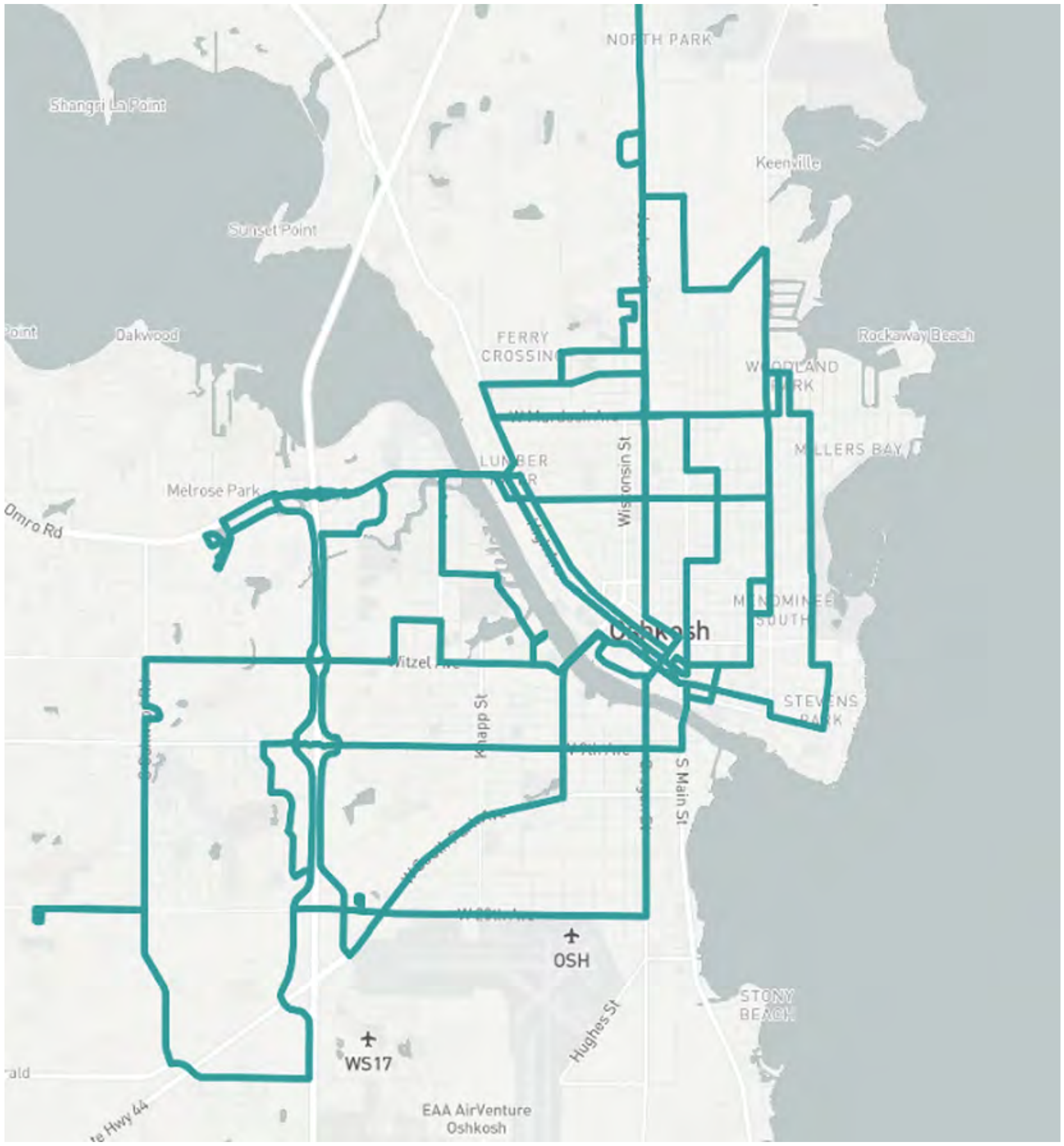


Figure 10-8. Go Transit routes.

distributed geographically. For the routes on which frequency was increased, it is observed that the ridership for low-income riders and general population jumped to 110% and 120%, respectively. However, the overall marginal reduction is the resultant of the decrease in daily frequency on the remaining routes.

10.6.2 High-Ridership Focus

This scenario considers the effect of increasing service on the highest-ridership bus routes in Oshkosh. The frequency on the two bus routes with the most ridership was doubled, and the frequency on the remaining routes was decreased to maintain an approximately constant VRM.

In this scenario, linked bus trips were found to increase 39% among low-income riders and 30% among the general population. The map in Figure 10-10 shows how this change would be

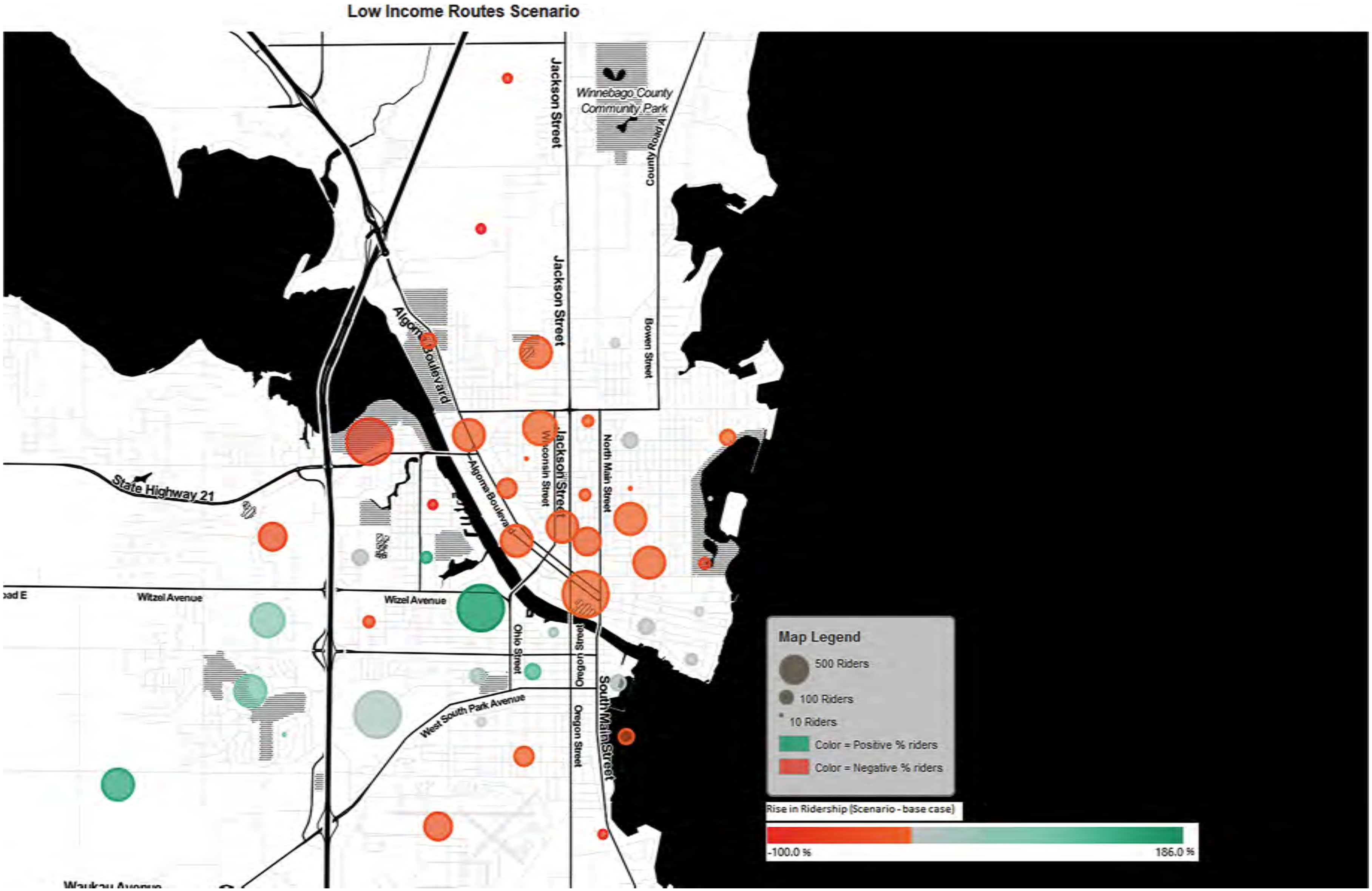


Figure 10-9. Change in bus ridership by census block group for low-income focus in Oshkosh.

Figure 10-10. Change in bus ridership by census block group for high-ridership focus in Oshkosh.

distributed geographically. Again, the high-ridership focus actually increases ridership *more* among low-income riders than the low-income focus. This occurs because the specific bus routes improved in this scenario serve a large number of low-income riders. The research team also observed a geographic difference—the ridership gains in this scenario were more concentrated north of downtown, whereas in the low-income scenario, they were concentrated west of downtown.

10.6.3 High-Ridership Focus with Exclusive Bus Lanes

This scenario considered the effect of giving exclusive right-of-way to the two bus routes with the highest ridership in Oshkosh. These bus lanes were in addition to the service changes in the high-ridership focus that doubled the frequency of those routes while decreasing frequency elsewhere.

The research team found that in this scenario, linked bus trips would increase 37% among low-income riders and 31% among the general population. The map in Figure 10-11 shows how this change would be distributed geographically. In contrast to Atlanta, which shows a notable benefit to adding exclusive bus lanes, the results of this scenario are very close to those for the high-ridership focus. This result occurs because there is much less traffic congestion in Oshkosh than in Atlanta, so the travel-time benefit of giving exclusive right-of-way to buses is less.

10.7 Discussion

On the preceding pages, the results for three simulated scenarios each for Atlanta and Oshkosh were presented. These scenarios are intended to provide a broad idea of the types of strategies that might be effective at increasing transit ridership. Table 10-1 summarizes the ridership change for each of these scenarios.

These scenarios are not intended to be a detailed evaluation of specific policies—it is expected that a local transit agency would conduct a more detailed evaluation of the effects and tradeoffs of specific changes before implementing them. In particular, these scenarios are based on a simulation that assumes travelers will make the choice to drive or take transit based on the relative travel time of each. While this is a sensible assumption, real people may resist switching to transit for a variety of reasons that go beyond what can be captured in a simulation. Therefore, the results should be viewed as indicative of the direction and ordering of the expected outcomes, with uncertainty related to the magnitude. (For agencies that would like to conduct their own similar analysis using MATSim or CityCast, Technische Universität Berlin maintains a fairly updated tutorial set, which covers a step-by-step installation and usage guide for creating scenarios and testing policy cases, found at https://www.matsim.org/docs/tutorials/general.) In this application, CityCast was used to provide information on where people travel as input to the MATSim Scenarios. Further details on CityCast are available at https://citycast.io/.

From these scenarios, the research team was able to draw the following conclusions:

- There is potential to increase transit ridership without major budget increases by reallocating existing service. This outcome is reinforced by empirical findings from Chapter 3 where it was found that bus network redesigns increased ridership by 4.7%.
- Serving high-ridership corridors and serving low-income travelers are not mutually exclusive goals. In fact, many low-income travelers are on the routes with the highest ridership, so the goals often align. However, the spatial difference in the ridership gains and losses in the Atlanta low-income versus high-ridership scenarios highlight that there remains a risk of underserving low-income and minority neighborhoods.

Figure 10-11. Change in bus ridership by census block group for high-ridership focus with exclusive bus lanes in Oshkosh.

Table 10-1. Change in bus ridership for each future scenario.

	Atlanta, GA		Oshkosh, WI	
Scenario	**Total Riders**	**Low-Income Riders**	**Total Riders**	**Low-Income Riders**
Low-Income Focus	44%	47%	-1%	-3%
High-Ridership Focus	88%	70%	30%	39%
High-Ridership Focus with Exclusive Bus Lanes	109%	89%	31%	37%

- While all the strategies tested showed positive ridership results in both locations, the most effective design depends on local conditions. Specifically, bus-only lanes offer higher benefits in more congested settings.

Finally, it is worth considering that while this analysis was focused on ridership, ridership is not the only metric that matters when evaluating the value of public transit. Even when ridership is low, there is value in serving those travelers who have no alternative, and there is value in serving those travelers with short headways and quick travel times.

CHAPTER 11

Strategies, Implementation Resources, and Key Lessons Learned

11.1 Findings from the Research

Taken as a whole, the research presented in this report shows that a mix of factors are contributing to recent transit ridership trends, pushing transit ridership in competing directions. This chapter gives strategies for transit agencies to increase ridership and mitigate or stem declines in ridership based on the key findings from this research. Additionally, this chapter includes useful sources relevant to the various recommended strategies.

First, in the system-level, multicity analysis, the research team found net transit ridership declines between 2012 and 2018. Two major sets of factors were pushing to increase transit ridership, including more service and increases in population and employment. However, other major factors more than offset those for overall declines in ridership; these include factors around the expense of taking transit, such as increasing fares, but also factors that make transit less competitive with automobiles, such as declining gas prices and increasing incomes. Finally, transit must now compete against other, new modes, such as ride-hailing, and factors such as the increased prevalence of telecommuting, thus negating the need for a trip.

Initial case studies at the stop level focused first on understanding how transit ridership has changed by time of day and day of the week as well as the sensitivity of ridership to changes in service frequency. Researchers used detailed bus APC data for four agencies: TriMet (Portland), Miami-Dade Transit (Miami), Metro Transit (Minneapolis-St. Paul), and MARTA (Atlanta). They found that while ridership is declining across all time periods, night and weekend ridership has declined the most. Simultaneously, service frequencies have increased more during nights and weekends than during weekday periods in all cities except for Miami, thus indicating that some external factor is impacting night and weekend ridership. An additional case study for BART showed that this peaking of ridership is also occurring on heavy rail transit. Furthermore, capacity constraints imposed on heavy rail systems built in the early 1970s mean that maintenance often requires service cuts and single-tracking on nights and weekends, thus exacerbating the problem of ridership "peaking."

At both the stop level and route level, the research team also assessed the impact of giving transit priority in the form of light rail and BRT. Ridership on the new light rail line in Minneapolis-St. Paul almost doubled despite a reduction in overall service frequency. Ridership also increased by 34% following the opening of an arterial BRT line in Minneapolis-St. Paul, which increased the overall frequency by 36%. Whether the higher ridership on light rail is due to improved service characteristics or to a "rail factor"—a preference of passengers toward rail—could not be shown. However, further evidence of the impact of BRT on transit ridership came from the route-level analysis in Cleveland. The results suggest that converting bus routes to full BRT or adding substantial BRT features increased ridership significantly (potentially between 22% to 46%) per year. However, merely branding routes with no improvement in the level of service did not result in significant changes in ridership.

At the route level, additional case studies assessed the impact of e-scooters and fare discounts on transit ridership. Using Louisville as a case study, the researchers found that shared e-scooters do not have a significant impact on local bus ridership, either as a competitor or as a first-mile/last-mile complement. Using Topeka as a case study, they found that fare-free promotions for students, kids, veterans, and seniors have resulted in significant increases in bus ridership.

Finally, the research team assessed three simulated scenarios for Atlanta and Oshkosh using CityCast to provide a broad idea of the types of strategies that might be effective at increasing transit ridership. It was found that there is potential to increase transit ridership without major budget increases by reallocating existing service to serve both high-ridership corridors and low-income travelers. This was reinforced in the system-level analysis, in which bus network redesigns also increased bus ridership.

These results have pointed to many things that transit agencies can do to improve ridership, but many of these strategies are nuanced or require agencies to work with or through local, regional, state, or even national partners to ensure that transit remains competitive. These strategies have been organized into five broad categories:

- Rethink Mission, Service Standards, Metrics, and Service Delivery
- Redesign Fare Policy
- Give Transit Priority
- Consider Partnerships with Shared-Use Mobility Providers Carefully
- Encourage Transit-Oriented Density

Each of these categories will be explained as follows in the context of the research findings. Then, in the following sections, implementation resources and lessons learned are presented to aid agencies and their partners in pushing these strategies forward.

11.1.1 Rethink Mission, Service Standards, Metrics, and Service Delivery

Results in the system-level analysis show that service additions resulted in net bus ridership increases from 3% to 5% and net rail ridership increases from 10% to 18%. Service increases from 2012 to 2018 have negated what could have been even greater losses in transit ridership. At the same time, ridership was demonstrated to be peaking, with a.m. and p.m. peak ridership declining the least and nighttime ridership declining the most. The most productive service (ridership per vehicle hour) occurred on weekdays. Meanwhile, the research team found that nighttime ridership was the most sensitive to changes in frequency. Finally, simulations in Oshkosh and Atlanta showed that there is potential to increase transit ridership without major budget increases by reallocating existing service. It is critical that agencies undertake careful analysis of when service is needed the most to improve productivity on routes.

At the same time, it is time for the public transportation industry as a whole to rethink its service standards, service delivery, and performance metrics to ensure that they are reflective of the twin missions of good public transit—both to serve respectfully those who rely on transit on a day-to-day basis through more emphasis on equity of accessibility and service, and to provide mobility efficiently in urban areas. New performance metrics are needed to project transit's role in thoughtfully serving critical worker populations.

11.1.2 Redesign Fare Policy

The system-level analysis shows that fare increases resulted in 0% to 4% lower bus ridership and 2% to 5% lower rail ridership from 2012 to 2018. As fares increase, transit becomes less competitive with other modes, resulting in lower ridership. However, there are strategies that transit agencies can pursue beyond simply keeping fares low. The case study in Topeka showed that strategic fare discounts can substantially increase transit ridership. Fare-free promotions for students, kids in summer, seniors, and veterans showed significant positive impacts on bus ridership.

Other findings in the report point more broadly to the necessity for more innovation in fare policies as well. The system-level analysis shows that more people working at home resulted in lower bus and rail ridership. The longer-term impacts of teleworking during COVID-19 could be significant for regular transit ridership, pointing toward the necessity of moving away from monthly passes and toward fare payment systems that allow discounts for frequent but irregular transit use over less-fixed time spans. Transit agencies must begin to be more creative about fare media and pricing policies to ensure that commuters who have many options and make fewer trips are choosing transit as often as possible, even if it is not for every trip. More flexible fare policies, such as fare capping, compared to traditional monthly passes may be needed to entice commuters back to transit.

11.1.3 Give Transit Priority

Giving transit exclusive right-of-way, to prioritize transit modes above lower-capacity modes, makes transit run faster and more reliably, thereby encouraging transit ridership. Case studies in Minneapolis-St. Paul and Cleveland show that high-quality light rail and BRT can increase ridership substantially, even with limited service increases. The simulation in Atlanta also shows that bus-only lanes could substantially increase ridership.

Furthermore, research on the system level also shows that declining gas prices resulted in 4% lower bus and rail ridership from 2012–2018, and increases in car ownership resulted in lower bus and rail ridership as well. The best way to minimize this competition with the automobile will continue to be giving modes that carry more people priority over those that take up more space.

11.1.4 Consider Partnerships with Shared-Use Mobility Providers Carefully

Integration with shared-use mobility and micromobility providers can help address some first-mile/last-mile issues via e-scooters and bicycles, but such partnerships should be approached carefully so that modes such as ride-hailing do not compete directly with transit in the most productive corridors, further reducing transit ridership. The case study in Louisville showed that e-scooters had limited, if any, impact on local bus ridership and may have even slightly increased express bus ridership. Transit agencies can consider micromobility partnerships to address first-mile/last-mile connectivity issues. At the same time, new competing modes resulted in 10% to 12% lower bus ridership from 2012–2018 in the system-level analysis. The effect of ride-hailing on rail ridership in larger metro areas (with high operating expenses) was much smaller, but the effect on rail ridership in the mid operating expenses group was similar to bus. These partnerships must be struck strategically to ensure that they are working in the best interest of transit agencies and riders.

11.1.5 Encourage Transit-Oriented Density

Finally, regional agencies and municipalities should pursue development and densities that are supportive of transit to ensure that transit can stay competitive in the urban form. In the system-level analysis, the research team found that metro areas have become slightly less centralized in the past decade, partially offsetting gains in ridership due to population and employment, so that the combined effect of land use changes is a less than 2% increase in ridership. Transit agencies can do their part to improve densities near transit stations through transit-oriented development, but regional partnerships are critically important to ensure that transit-oriented density is occurring with regional growth in areas that are already supported by transit or could easily be supported by transit as growth occurs.

11.2 Implementation Considerations and Resources

The previous section describes possible strategies that emerge from this research that could be pursued in an effort to increase transit ridership. However, the research also had as an objective to circle back and consider existing experiences in order to identify key implementation considerations and valuable resources that would aid in the pursuit of these strategies. This involved interviews with experts with experiences related to these strategies in order to solicit candid insights on implementation challenges, hindsight about lessons learned, and useful resources. This was supplemented by an in-depth survey and identification of key internet resources and pertinent literature that provides specific guidance to implement the strategies. In the following sections, the identified implementation considerations and useful resources for each strategy are summarized.

11.3 Rethink Mission, Service Standards, Metrics, and Service Delivery

The research in this report has shown that prior to the COVID-19 pandemic, transit ridership was peaking, with a.m. and p.m. peak ridership declining the least while weekday night and weekend night ridership declined the most. This was likely caused in part by the competition offered by TNC services. These trends suggested the need to rethink transit agency strategy.

However, the COVID-19 pandemic has created newer trends, such as a huge increase in working from home that has dramatically reduced transit service in general and peak commuting ridership in particular. Expert opinion suggests that telecommuting will continue to play a role even in a post-pandemic period, though opinions diverge considerably on how important that role will be, how long it will take for recovery, and what the "new normal" will look like. How the new trends will interact with previous trends is confusing and represents a major challenge for transit agencies as they try to plan for the future and reposition their mission and services.

In light of this, transit agencies will need to rethink their mission, their service standards, the metrics they use to measure success, and service delivery options.

11.3.1 Key Implementation Considerations for Mission, Service Standards, and Metrics

11.3.1.1 Consider a Mobility Management Mission for the Organization

The research suggested the need to review the transit agency's mission even before the pandemic, but this need has become all the more acute given the uncertainty surrounding the shape of the new normal for transit in the future. Even prior to the pandemic, the availability of new modes and of new concepts such as Mobility on Demand (MOD) and Mobility as a Service has led many experts to view urban mobility as requiring an integrated mobility systems approach, where the transit agency might broaden its mission from one of operations delivery to one of mobility management. Several transit agencies have started embarking on this path through their long-range planning and the implementation of innovative partnerships and services. This suggests that agencies should at the very least conduct an internal reflection on pursuing a mobility management mission and assess its benefits, costs, and impacts.

Although beyond the scope of this research, experiences during the pandemic have highlighted the importance of equity as a major concern in how transit service is designed and delivered. This was brought to intense light by comparing the experiences of office workers who could use technology to work from home versus essential workers and low-income employees who needed to continue to use transit service even during severe lockdowns. As transit agencies reflect on their mission, it will be critical for them to explicitly take equity into consideration, which may require the development of new goals and metrics as well as impact the design of services and their delivery.

11.3.1.2 Adopt a More Holistic Perspective on Performance Measurement That Is Human-Centric

MOD projects have highlighted the limitations of current performance metrics and have led to a rethinking of how performance might be approached in new ways. New performance metrics are needed that are more holistic in nature and more human-centric, focusing on rider experience. One such reflection emerges from a 2020 report titled *Mobility Performance Metrics (MPM) for Integrated Mobility and Beyond*, prepared by TransitCenter and others for FTA, that suggests a core and three tiers of potential metrics, as follows:

- Core—metrics measuring how well the integrated mobility system meets the needs of individual travelers. Specifically, how individual travelers view their trip experience is measured through five factors that affect transportation efficiency, effectiveness, and experience: time, budget, reliability, safety, and availability.
- Tier 1—metrics measuring how effectively and efficiently the integrated mobility system performs while meeting the needs of individual travelers.
- Tier 2—metrics measuring how the integrated mobility system impacts the region in terms of sustainability, accessibility, environment, workforce, etc.
- Tier 3—metrics measuring how the integrated mobility system impacts national goals for societal benefits, economic benefits, return on infrastructure investment, etc.

11.3.2 Key Implementation Resources and References for Mission, Service Standards, and Metrics

- TransitCenter et al., 2020, *Mobility Performance Metrics (MPM) for Integrated Mobility and Beyond,* FTA, https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/147791/mobility-performance-metrics-integrated-mobility-and-beyond-fta-report-no-0152.pdf

  This report presents traveler-centric mobility performance strategies and metrics, and the approach for the development of those metrics for use as supplemental measures, to assess how well an integrated public/private mobility system meets the needs of individual travelers, how well the system performs while meeting overall travel demand, and what the system's impact is locally and nationally. By measuring transportation performance from the traveler's perspective, agencies and operators can be incentivized to improve service based on what matters most to travelers. The report identifies a large set of potential measures that align with FTA goals as well as goals of the MOD Sandbox projects. It then presents a comprehensive evaluation process with applicability and feasibility criteria that were used to cull the potential performance measures to a smaller, more appropriate set of performance measures. The report discusses possible data sources and data integration strategies for the application of the new mobility performance measures.

- McCoy et al., 2018, *Integrating Shared Mobility into Multimodal Transportation Planning: Improving Regional Performance to Meet Public Goals,* FHWA, https://www.planning.dot.gov/documents/SharedMobility_Whitepaper_02-2018.pdf

  New shared-mobility services have become increasingly common and important modes of travel in U.S. cities, but transportation planning practices are only beginning to adapt in response. This white paper provides a framework and examples to assist transportation agencies—metropolitan planning organizations

(MPOs), local governments, transit agencies, and states—in anticipating and planning for shared mobility as part of a higher-performing regional multimodal transportation system. It synthesizes noteworthy practices in 13 metropolitan areas collected from online research and conversations with planning practitioners; identifies challenges and opportunities; and provides recommendations for future research needed to improve planning practices related to shared mobility.

- McCoy, et al., 2019, *Integrating Shared Mobility into Multimodal Transportation Planning: Metropolitan Area Case Studies,* FHWA, https://www.planning.dot.gov/documents/regional_shared_mobility_planning_caseStudies.pdf

  New shared-mobility services have become increasingly common, and transportation agencies are beginning to integrate them into regional planning processes. This report provides three case studies of how MPOs and their regional partners are integrating shared mobility into regional multimodal transportation planning.

- Kittelson & Associates, Inc., et al., 2003, *TCRP Report 88: A Guidebook for Developing a Transit Performance-Measurement System,* Transportation Research Board of the National Academies, http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_report_88/Guidebook.pdf

  This report provides a practical, user-friendly guidebook to assist transit system managers in developing a performance-measurement system that uses traditional and non-traditional performance indicators and measures to address customer-oriented and community issues. The guidebook provides a menu of performance indicators and measures, describes how to select and implement the most appropriate performance indicators and measures, and explains how to incorporate the indicators and measures in the decision-making process to monitor and improve service.

- Kittelson and Associates, Inc., et al., 2013, *TCRP Report 165: Transit Capacity and Quality of Service Manual, Third Edition,* Transportation Research Board of the National Academies, https://doi.org/10.17226/24766

  This report provides guidance on transit capacity and quality-of-service issues and the factors influencing both. The manual contains background information, statistics, and graphics on the various types of public transportation, and it provides a framework for measuring transit availability, comfort, and convenience from the passenger and transit provider points of view. In addition, the manual includes quantitative techniques for calculating the capacity and other operational characteristics of bus, rail, demand-responsive, and ferry transit services, as well as transit stops, stations, and terminals.

- Boyle, D., 2019, *TCRP Synthesis 139: Transit Service Evaluation Standards,* Transportation Research Board, https://doi.org/10.17226/25446

  This report addresses the service evaluation process, from the selection of appropriate metrics through development of service evaluation standards and data collection and analysis to the identification of actions to improve service and implementation. The report also documents effective practices in the development and use of service evaluation standards. The report includes an analysis of the state of the practice of the service evaluation process in agencies of different sizes, geographic locations, and modes.

11.4 Redesign Fare Policy

Fare policy is within the control of the transit agency. The research in this report on pre-COVID trends confirms the positive impact on ridership that can be obtained from the implementation of fare discounts. At the same time, recent developments during the pandemic suggest that patterns may be significantly altered in the future, with more working from home and less regular commuting to downtown cores, which suggests that a review of fare policy may be required. The following are some key implementation lessons to consider.

11.4.1 Key Implementation Considerations for Fare Discounts and Policies

11.4.1.1 Strategy for Fare Discounts

Each transit agency should develop a clear strategy related to fare discounts. For example, is the goal of implementing fare discounts to gain ridership at a reasonable cost to the transit agency, or is the goal to build up the image of the transit agency within the community and highlight its community brand? The choice of strategy could lead to potentially different types and numbers of fare discounts. Having a clear strategy on fare discounts also enables a more rational response to the many and diverse interest groups that might seek fare discounts. Additionally, fare-free promotions, similar to the Topeka Metro case study, could be a strategy to gradually move toward offering free fares to all riders, an innovative approach to fare policy currently under consideration by some American transit agencies.

11.4.1.2 Model Business Impacts of Fare Discounts

Having a clear strategy provides a basic framework for assessing potential fare discounts, but it is also important to conduct a detailed assessment of any potential fare discount and model the related business impacts. This evaluation should include modeling ridership impacts, revenue losses, potential partnerships to cover revenue losses, enforcement costs, and spillover impacts. Additionally, fare-free promotions could potentially reduce the overall cost of fare collection (both capital and operating), which should also be evaluated as a potential benefit.

11.4.1.3 Ensure Flexibility and Periodic Reevaluation

Strategies change over time, as do financial situations. Fare discounts provided today may not be affordable in the future. Therefore, it is important to ensure flexibility and build in a process for periodic reevaluation over time. For example, the pricing of UPass discounts are negotiated based on the best estimate of capacity and usage beforehand but should be reevaluated based on the actual experience over time. In the absence of a clear time-horizon and reevaluation process, beneficiaries of fare discounts will assume that the discounts are a right and will be frozen in perpetuity, when neither is the case.

11.4.1.4 Pay Attention to Practical Set-Up and Monitor Usage

In order to enable periodic reevaluation, there must be good data on usage and on related revenues and costs. This requires careful attention to the practical details of how the fare discount is to be applied, monitored, and enforced so as to collect accurate data while minimizing the potential for fare evasion. Does the fare collection system enable this? If not, is the system structured to make it simple for operators to perform their functions?

11.4.1.5 Assess Impact of Fare Discounts on ADA Paratransit Service

Any permanent changes to fare policy—such as fare discounts—must be applied to ADA paratransit service as well as to regular route service, a fact that is sometimes forgotten. In many cases, given the nature of ADA paratransit service and the special needs of its clients, implementing and monitoring fare discounts may be more complex. It should be noted that it is possible to test a fare discount for a limited time period only on fixed-route services.

11.4.1.6 Redesign Fare Policy for a Post-COVID New Normal

There is reason to believe that post-pandemic mobility patterns may be significantly altered in the future, with more work from home and less regular commuting to downtown cores. Transit agencies should therefore reassess fare policies to explore how they might be structured to increase ridership in light of new normal mobility patterns; examples might include fare capping or the implementation of two- or three-day passes to replace weekly or monthly passes, given the likely increase of people working at least part of the week from home.

11.4.2 Key Implementation Resources and References for Fare Discounts and Policies

- Volinski, 2012, *TCRP Synthesis 101: Implementation and Outcomes of Fare-Free Transit Systems,* Transportation Research Board of the National Academies, https://doi.org/10.17226/22753

  This report highlights the experiences of public transit agencies that have planned, implemented, and operated fare-free transit systems. The report focuses on public transit agencies that are either direct recipients or subrecipients of federal transit grants and that furnish fare-free services to everyone in a service area on every mode provided.

- TCRP J-11/Task 39: Evaluation Framework for Fare-Free Public Transportation, https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4888

  The objective of this ongoing research is to develop a framework to evaluate fare-free public transportation. The framework should address the benefits, costs, and trade-offs that must be considered by public transportation providers, policy makers, and other stakeholders as they consider eliminating fares, in whole or in part, for public transportation.

- Brakewood, 2020, *TCRP Synthesis 148: Business Models for Mobile Fare Apps,* Transportation Research Board, https://doi.org/10.17226/25798

  This synthesis documents current practices and experiences of transit agencies that offer mobile fare payment applications to transit riders and the different approaches to business models that they have implemented.

- Kok and Lipták, 2020, *TCRP Synthesis 144: Multimodal Fare Payment Integration,* Transportation Research Board, https://doi.org/10.17226/25734

  Multimodal payment convergence is the ability to use the same payment medium or technology to pay for services on multiple modes of transportation—which provides a more seamless and convenient experience for users. This synthesis explains what payment convergence is, what can be achieved through payment convergence, and the pathways to implementation.

- TCRP Synthesis J-07/SH-21: Transit Fare Capping: Balancing Revenue and Equity Impacts, https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=5013

  The objective of this research is to document the implementation, planning, and assessment of fare capping in North American transit agencies. A fare cap is a practice in which users are charged according to rides taken over a period of time; a user's combined fares over multiple rides cannot exceed the amount a rider would have paid if they had purchased the optimal period pass based on their usage. Fare capping offers many advantages: greater convenience, transit fairness, and most of all more equitable access to the discounts afforded by those who purchase transit passes. The trade-offs include reduction in revenue, uncertain ridership impacts, and required investments in new technology.

11.5 Give Transit Priority

The research in this report has shown that giving transit priority can significantly increase transit ridership. Transit priority helps to increase average speeds, reduce travel times, and increase service reliability, which all contribute to making transit more attractive to potential riders.

There is an array of increasingly complex methods and means to improve transit priority, including:

- Physical priority
- TSP
- BRT
- LRT

Transit agencies can only implement physical priority measures and TSP in cooperation with the traffic engineers who manage traffic signals and the design and operation of streets; and the design and implementation of BRT and LRT systems are by their nature major, complex, multiyear undertakings. The following are some key implementation lessons to consider, focusing more on shorter-term strategies.

11.5.1 Key Implementation Considerations for Transit Priority

11.5.1.1 Build Partnership with Traffic Engineering Counterparts

Pop-up lanes are often referred to as "tactical transit" or "pilots" and have become increasingly implemented.

Municipal or state traffic engineers design, manage, and operate streets and highways as well as the traffic control systems that regulate their operation. There are various physical transit priority measures that might be considered, including queue jumps, bus lanes (permanent, peak-period only, or temporary, such as in recent examples of pop-up lanes), restricted turns for general traffic, transit-only turn exemptions, bump-out curbs, parking restrictions, and restrictions on through traffic. TSP may include such measures as actuated transit-only signals, green phase extension, red phase truncation, and phase rotation. Both physical priority measures and TSP require a partnership with traffic engineering counterparts. Unfortunately, transit agency staff members often only have limited interactions with their traffic counterparts, making it challenging to engage in the required negotiations and compromises that transit measures and TSP require. It is essential to build a strong partnership in advance to systematically pursue these priority measures.

11.5.1.2 Pay Considerable Attention to Parking Strategy

Removal of parking is one of the most contentious issues when implementing transit priority measures, and it is often the source of significant opposition from local merchants. Any effort to implement transit priority will need to pay considerable attention to the related parking strategy—with efforts to monitor parking capacity and usage—and develop a careful strategy that minimizes removal of parking spaces, finds alternative locations, or does both.

11.5.1.3 Explicitly Consider Enforcement

Lack of enforcement can often be a potentially big weakness in all transit priority initiatives. Careful and explicit consideration should assess how potential violations might occur and how the transit priority measures can be enforced. This should encourage the use of technology, such as cameras at intersections or onboard cameras on buses, to design out the need for enforcement. When enforcement is used, it should be applied equitably to ensure violations are taken seriously in order to improve transportation.

11.5.1.4 Take Advantage of All Road or Utility Work to Insert Priority Treatments

Roads and utilities located underneath the road pavement require maintenance or modification on a periodic basis; maintenance may be planned in advance, needed as a result of development of adjacent buildings, or conducted on an emergency basis. Road work and utility relocation cause disruption of existing road geometrics and operation, thereby creating an opportunity for change. Experts agree that transit agencies should have ready-made plans for implementation of priority measures so that they can take advantage of these opportunities. However, this requires a close working relationship with municipal staff responsible for traffic operations and utility relocation so that transit agencies are informed of these developments and can quickly implement desired priority measures.

11.5.1.5 Develop Multitiered Communications Strategy to Engage Riders and Address Concerns of Local Merchants

Implementation of priority measures may be resisted by local affected merchants and auto users, and municipal traffic staff and politicians are very sensitive to the complaints this may generate. Therefore, it is critical to have a multitiered communications strategy that serves three different objectives:

- Engage the active support of the transit users who will benefit from the measures.
- Communicate to the general public (and local politicians) the benefits to transit riders and society from the measures.
- Listen one-on-one to local merchants and their concerns, and address their concerns to the extent possible.

Recent transit priority implementations have involved extensive data gathering on benefits and usage, and practitioners have used this data to support extensive communications in order to serve these three objectives. With respect to the third objective, efforts can also be made to monitor the access mode of shoppers, which can be used to show merchants that transit users and pedestrians may be more important to their sales than car users.

11.5.1.6 Use of a Pilot Project for Rapid Testing of a Concept

Several recent significant transit priority implementations have started out as pilots. This can be useful in two ways. First, a "pilot" requires and justifies an important data gathering effort (both technical information as well as market research and opinion surveys), which in turn supports the communications strategy. Second, it creates an opportunity to improve the project based on the feedback from local politicians and the general public; the pilot will be made permanent if the resulting data prove the value of the initiative. There can be more acceptance and buy-in if the initiative has some room for customization and proves its worth as a pilot.

11.5.1.7 Importance of the Concept of Operations for Implementing TSP

As mentioned previously, all transit priority projects involve a close partnership between transit agency staff and traffic engineers—but this is especially true for the implementation of TSP, which involves complex technological choices. It is critical to clearly articulate the expectations and requirements of the TSP system among the concerned stakeholders, and this can be achieved through the concept of operations (often referred to as the ConOps). The concept of operations, which emerged from the field of systems engineering, defines what the stakeholders want the system to be able to do from the users' point of view and how the system should function. A TSP ConOps defines the operations of the TSP system, the conditions for requesting and granting signal priority, and the traffic control strategies that the TSP system should be able to perform, as well as clarifies how it will be operated and maintained. The ConOps provides the basis for defining the functional requirements for the system, which will in turn be used to select the most effective technological solution for the defined requirements. A clear articulation of the ConOps is critical to ensure that there is agreement and no misunderstanding among the stakeholders.

11.5.1.8 Coalition-Building and Maintenance for the Long Haul Is Key to Success and Critical in Early Stages of Project Management

Physical transit priority measures and TSP require partnerships among transit and traffic engineering staff. However, the design and building of BRT or LRT systems is far more complex, more expensive, and long-term in nature. Such projects will require complex technical planning as well as management of the institutional process. Successful projects will require sophisticated coalition-building among many stakeholders around a common vision and its maintenance over time in order to obtain and maintain the necessary public and political support as well as funding from many sources. Experts have suggested that coalition-building skills may be more important at the outset of a project, while technical expertise may become more important later on during the project, once it has been approved and moves into the technical design phases.

11.5.2 Key Implementation Resources and References for Transit Priority

11.5.2.1 Transit Priority Physical Measures

- Garcia and Wall, 2019, *TCRP Research Report 207: Fast-Tracked: A Tactical Transit Study,* Transportation Research Board, https://doi.org/10.17226/25571

  This report documents the current state of the practice with regard to what are called Tactical Transit projects, specifically for surface transit (bus and streetcar). The report highlights how transit agencies and other entities are using innovative methods to improve transit speed, access, and ridership at a fraction of both the cost and time of conventional projects.

- Danaher et al., 2020, *TCRP Research Report 215: Minutes Matter: A Bus Transit Service Reliability Guidebook,* Transportation Research Board, https://doi.org/10.17226/25727

  This report details eight steps that a transit agency can undertake to develop and maintain a reliability improvement program.

- Boyle, 2013, *TCRP Synthesis 110: Commonsense Approaches for Improving Transit Bus Speeds,* Transportation Research Board of the National Academies, https://doi.org/10.17226/22421

  This report documents approaches transit agencies have taken to realize gains in average bus speeds. The report outlines actions that transit agencies can take to improve service speeds, reliability, and attractiveness.

- Green, 2020, *On-Road Public Transport Priority Tool,* Austroads, https://austroads.com.au/publications/traffic-management/ap-r645-20

  This report presents a practical process (referred to as a “tool”) to guide practitioners through the selection of the appropriate on-road public transport priority treatments for any road scenario. This step-by-step process can be used for applications relating to existing roads or a new/greenfield road development. It considers all forms of priority, ranging from road space to stop design and location to TSP and traffic signal gating. Using this guidance, practitioners will ensure consistency, traceability, and robustness of their decision-making process.

11.5.2.2 Transit Signal Priority

- Smith et al., 2005, *Transit Signal Priority (TSP): A Planning and Implementation Handbook,* https://nacto.org/docs/usdg/transit_signal_priority_handbook_smith.pdf

  This handbook outlines a comprehensive process for planning and implementing TSP, based on a systems engineering approach, that identifies many of the issues that may need to be addressed in a TSP project. It also provides a number of resources to those interested in TSP—including primers on traffic control equipment and systems, on key concepts (e.g., simulation and optimization), as well as on traffic engineering and transit terminology—to assist transit planners and traffic engineers in understanding one another.

- Anderson et al., 2020, *TCRP Synthesis 149: Transit Signal Priority: Current State of the Practice,* Transportation Research Board, https://doi.org/10.17226/25816

  This report documents the current practice of TSP, an important tool that increases bus speeds and reliability, thereby improving transit system efficiency and effectiveness.

11.5.2.3 Bus Rapid Transit

BRT has become increasingly popular as a transit product in the last 20 years, taking on a variety of formats—from BRT-light on shared streets with some operational improvements and different branding to complete and sophisticated full BRT systems operating on their own right-of-way and using an array of technological enhancements, becoming similar to LRT in many respects. Several resources and reports provide practical guidance on the design and implementation of BRT systems, including the following:

- National BRT Institute, https://nbrti.org/

  According to the National BRT Institute, "The mission of the National BRT Institute is to facilitate the sharing of knowledge and innovation for increasing speed, efficiency, and reliability of high-capacity bus service through the implementation of BRT systems in the United States."

- Levinson et al., 2003, *TCRP Report 90: Bus Rapid Transit Volume 2: Implementation Guidelines,* Transportation Research Board of the National Academies, https://doi.org/10.17226/21947

  This report discusses the main components of BRT and describes BRT concepts, planning considerations, and key issues as well as the system development process, desirable conditions for BRT, and general planning principles. The report also provides an overview of system types.

- Kittelson & Associates et al., 2007, *TCRP Report 118: Bus Rapid Transit Practitioner's Guide,* Transportation Research Board of the National Academies, https://doi.org/10.17226/23172

  This report explores the costs, impacts, and effectiveness of implementing selected BRT components. The report examines planning and decision-making related to implementing different components of BRT systems, updates some of the information presented in *TCRP Report 90: Bus Rapid Transit, Volume 2: Implementation Guidelines*, and highlights the costs and impacts of implementing various BRT components and the effectiveness of those components.

- Institute for Transportation & Development Policy, 2017, *Bus Rapid Transit Planning Guide,* https://www.itdp.org/2017/11/16/the-brt-planning-guide/

  Bus Rapid Transit Planning Guide gives a step-by-step description of the BRT planning process, including operational design, financial modeling, physical design, multi-modal and land use integration, business plan development, communications and marketing, contracting, vehicle and fare collection technology, evaluation, and implementation.

11.5.2.4 Light Rail Transit

LRT systems are very complex endeavors to plan, design, and operate, and they require complex and sophisticated project management involving full teams of planners, consultants, engineers, and so on. There are actually few North American resources on LRT design and operation, but the following list identifies a few practical resources from Germany and the Netherlands, plus conference presentations by year for the TRB Light Rail Transit Committee:

- Standing Committee on Light Rail Transit, https://www.trblightrail.org/Meetings

  The Standing Committee on Light Rail Transit is a TRB forum that solicits research on LRT development, experience, and lessons learned.

- VDV-Industry Forum, 2014, *Stadtbahnsysteme* [Light Rail Systems], 992 pages, https://www.vdv.de/blaue-buecher.aspx

  This book deals with the basics, technology, operation, and financing of important aspects of the "Stadtbahn" transport system. It explains how the requirements for a reliable energy supply can be met and how stops and routes can be designed with regard to passenger comfort, environmental protection, and urban planning. Current developments in customer-related telematics, depots and workshops, and personnel and incident management are shown.

- VDV-Industry Forum, 2016, *Gestaltung von urbaner Straßenbahninfrastruktur* [Design of Urban Tram Infrastructure], 168 pages, https://www.vdv.de/blaue-buecher.aspx

  This book covers the different phases of the LRT planning process, including the principles of successful design of the rail track, platforms, stops, electric supply, and vehicle exterior design.

112 Recent Decline in Public Transportation Ridership: Analysis, Causes, and Responses

- Van Der Bijl, R., and Van Oort, N., 2018, *Light Rail Transit Systems: 61 Lessons in Sustainable Urban Development,* Elsevier

  This book shows how to design and operate light rail to maximize its social benefits and how to understand the value of light rail and tactics on its effective integration into communities. Readers will learn how to develop important relationships with local decision makers and communities.

  – Presents applied research by experienced practitioners and academic researchers
  – Draws on more than 50 cases from Europe, the Middle East, United Kingdom, and United States
  – Incorporates five themes on why it's important to invest in light rail, including for effective mobility and for an efficient city, economy, environment, and equity
  – Includes a checklist for planning public transport projects

11.6 Consider Partnerships with Shared-Use Mobility Providers Carefully

Many experts have suggested that transit agencies should develop partnerships with new shared-use mobility providers—such as TNCs, microtransit, car-sharing, and micromobility (e.g., bike-sharing, e-scooters)—in an effort to offer a broader array of services that might encourage people to not use their personal automobiles. However, the research shows that transit agencies need to consider such partnerships with care since these new services can sometimes be competitors to transit, while others may serve a complementary role. For example, the research in this report shows that the introduction of TNC services clearly contributed to a loss in transit ridership, but it also shows that e-scooters may be complementary to express buses. The following are some key implementation lessons to consider.

11.6.1 Key Implementation Considerations for Mobility Partnerships

11.6.1.1 Define the Problem or Service Gap of Concern and the Related Goal of the Partnership

Any partnership must be based on a clear articulation of the problem or opportunity being addressed and the goal being pursued through the partnership. This is all the more important since private and public organizations have very different corporate objectives and will see the problem or opportunity through very different lenses. Clearly defining the basis of the partnership will help to avoid misunderstandings and make negotiations more effective.

11.6.1.2 Assess the Desirable and Feasible Level of Cooperation, Coordination, or Integration with Microtransit, Micromobility, or TNC Providers

There is a wide range of potential shared-use partners and types of partnerships that might be considered. In this respect, one might define three levels of partnership:

- *Cooperation*, such as mutual promotion or joint marketing with shared-use services that the transit agency feels is complementary
- *Coordination,* such as providing space for bike-sharing docks or car-sharing parking spots at transit stations, or the use of a transit smart card to provide access to car-sharing vehicles
- *Integration*, which involves a specific effort to integrate mutual services and can take various forms, including integrated trip planning applications, integrated fare payment, or integrated service delivery, most often through contracts of service

Each level increases the complexity of the partnership in terms of liability, financial commitments, data-sharing, and monitoring and reporting requirements, and each level makes negotiations increasingly challenging.

11.6.1.3 Consider All Alternatives and Carefully Model Business Impacts

As a result of the aforementioned reasons, all possible alternatives should be considered to address the problem or opportunity of interest, and care must be taken in assessing the potential benefits, costs, and related operational, organizational, and institutional challenges in order to define the type of partnership that is desired.

11.6.1.4 Regulatory Compliance Is a Major Issue in Negotiations with TNCs

Partnerships with different shared-use mobility providers will raise different types of concerns. In that respect, experience has shown that partnerships between transit agencies and TNCs have raised some significant and specific challenges. One category of these challenges relates to meeting the regulatory compliance that is federally required of transit agencies and of all the services they operate, whether directly or under contract. Negotiating partnerships with TNCs in order to meet compliance with ADA, Title VI, drug and alcohol testing of drivers, and so on have proven particularly difficult and will require specific attention. Some of the resources in Subsection 11.6.2 from the Shared-Use Mobility Center (SUMC) and others illustrate experience and provide guidance on this challenge.

11.6.1.5 Agreement on Data-Sharing Is a Major Challenge in Negotiations with TNCs

Another category of challenges related to the sharing of data has proved a major challenge in negotiating partnerships with TNCs. Experience with the MOD Sandbox projects and other pilots show this to be a major obstacle given the gulf between transit agencies and TNCs in how they perceive the ownership, transparency, and use of the data resulting from providing their services. Transit agencies typically view data created under any service they contract for as belonging to the transit agency and required for their various reporting requirements. In addition, they often desire to have full access to the data to assist them with planning and future refinements to the integrated services. TNCs, on the other hand, view the data created by their mobile applications as part of their private intellectual property, which provides them with a business advantage in the competitive environment; they do not wish to have the data made public, which can occur as a result of open data regulations. In addition, they are sensitive to possible privacy concerns that may result from tracking the origins, destinations, and travel patterns of individuals. Finding a compromise between these two perspectives has proven very difficult, but some of the following guidance outlines some possible paths to negotiating a compromise. Some of the suggestions include:

- Understand what is absolutely required federally, in particular with respect to NTD reporting requirements.
- Prepare to protect sensitive data.
- Understand the TNC perspective.
- Define must-have and nice-to-have partnership parameters.

11.6.2 Key Implementation Resources and References for Mobility Partnerships

- Mobility on Demand (MOD) Sandbox evaluations, FTA, https://www.transit.dot.gov/research-innovation/mobility-demand-mod-sandbox-program

  FTA developed the MOD initiative to envision a multimodal, integrated, automated, accessible, and connected transportation system in which personalized mobility is a key feature. MOD allows for the use of on-demand information, real-time data, and predictive analysis to provide travelers with transportation choices that best serve their needs and circumstances. MOD leverages technologies that allow for a traveler-centric approach, which provides better mobility options for everyone.

FTA's MOD Sandbox Program provides a venue through which integrated MOD concepts and solutions—supported through local partnerships—are demonstrated in real-world settings. The objectives of FTA's MOD Sandbox Program are to:

- Enhance transit industry preparedness for MOD.
- Assist the transit industry to develop the ability to integrate MOD practices with existing transit service.
- Validate the technical and institutional feasibility of innovative MOD business models and document MOD best practices that may emerge from the demonstrations.
- Measure the impacts of MOD on travelers and transportation systems.
- Examine relevant public sector and federal requirements, regulations, and policies that may support or impede transit sector adoption of MOD.

FTA awarded grants in 2016 to conduct 11 MOD projects. Each will be evaluated, and the evaluation reports provide a valuable resource to summarize experience and lessons learned.

- SUMC Learning Center, https://learn.sharedusemobilitycenter.org/

The SUMC Learning Center is a self-guided learning forum to explore the possibilities of shared mobility. It provides a wealth of resources on experience and lessons learned, including learning modules; case studies; state-of-the-art tools; and a large library of shared-mobility policies, projects, reports, and multimedia.

- SUMC Micromobility Policy Atlas, https://learn.sharedusemobilitycenter.org/atlas/?

Among the valuable tools included in the SUMC Learning Center is the interactive Micromobility Policy Atlas, which classifies policies for shared bikes, e-bikes, and scooters across a dozen areas of regulation and management, providing information on guidelines, permits, and laws from around the world. Each policy page outlines operating rules, like parking and use of bike lanes; fleet size limits, fees, and fares; equity plans and requirements; data standards, communications, and geographic context guidelines; and links to original policy documents.

- Grossman and Lewis, 2019, *Contracting for Mobility: A Case Study in the Los Angeles and Puget Sound Regions, Eno Center for Transportation,* https://www.enotrans.org/eno-resources/contracting-for-mobility/

This paper covers the process that developed the contracts for the MOD Sandbox pilot projects in the Los Angeles and Puget Sound regions. It discusses the nuances of interactions between private companies and public agencies, including non-disclosure agreements; data-sharing; and the challenges and opportunities faced by transit agencies and the MOD provider, as well as by the other entities involved in the service provision and evaluation of the project. It compares and contrasts how contracts developed between transit agencies, private sector providers, and researchers. It concludes with recommendations for how the contracting process can be improved to ensure better project outcomes.

- Curtis et al., 2019, *TCRP Research Report 204: Partnerships Between Transit Agencies and Transportation Network Companies (TNCs),* Transportation Research Board, https://doi.org/10.17226/25576

Public transit agencies are increasingly partnering with TNCs. The transit industry has produced research to describe primary considerations that transit agencies should have in mind for partnerships with TNCs, but existing research has yet to identify specific project frameworks for transit agencies that have decided to pursue such partnerships. This report presents findings pertaining to data and information requirements of both transit agencies and TNCs; the various benefits and outcomes that transit agencies, communities, and customers have pursued through partnerships; and the challenges faced by transit agencies in developing partnerships with TNCs.

- Hernandez et al., 2018, *TCRP Synthesis 132: Public Transit and Bikesharing,* Transportation Research Board, https://doi.org/10.17226/25088

This report explores cooperative transit and bike-sharing relationships and documents the experiences of transit systems with bike-sharing as a mode. An increasing number of transit agencies have developed cooperative arrangements with bike-sharing programs to strengthen the relationship between the modes.

- TCRP J-11/Task 37: Transit and Micro-Mobility (Bikeshare, Scooter-share, etc.), https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4691

  This ongoing research project has four key objectives, which include assessing the impact of micromobility on bus and rail transit ridership, identifying economic impacts of micromobility, assessing the impacts of the implementation of micromobility on the built environment (bike lanes, parking spaces, etc.), and finding ways to strengthen the relationship between micro-mobility and transit.

11.7 Encourage Transit-Oriented Density

The research in this report shows that regions where density increased in the areas accessible by transit experienced growth in transit ridership. The challenge is that density is defined by metropolitan and municipal planning policies and by the practical zoning regulations put in place by municipalities, none of which are under the control of transit agencies. Nonetheless, transit agencies can play an important role in encouraging transit-oriented density. The following are some key implementation lessons to consider.

11.7.1 Key Implementation Considerations for Transit-Oriented Density

11.7.1.1 Increasing Transit-Oriented Density Is a Long-Term Process and Requires Transit Participation in Metropolitan-Level Vision and Planning

The shaping of land use and the built urban form is a very long-term process that is structured through metropolitan and municipal planning efforts and policies. Many transit agencies tend to focus on shorter-term operations and planning considerations, and they often neglect to pay sufficient attention to longer-term efforts, such as those led by the MPO. It is important for transit agencies to participate actively in MPO planning efforts in order to articulate and promote a metropolitan vision that will encourage and facilitate transit-oriented density. This will support longer-term efforts to strengthen the role of transit in the future. FTA commissioned a set of reports, titled *Transit at the Table,* that illustrate best practices and lessons learned regarding how transit agencies can successfully participate in MPOs and influence the development of vision and planning policies.

11.7.1.2 Develop Transit-Oriented Community Vision and Promote with Developers, Local Business Leaders, and Municipal Policymakers

Many types of organizations participate in the development of land use and the built urban form. These include, by definition, the municipal planning staff that develops zoning regulations and approves and supervises the issuance of building permits; transit planning staffs often have a working relationship with their municipal planning counterparts. However, there are other important stakeholders that shape communities, including developers, business leaders, and municipal policy makers. Transit agencies should seek to develop and articulate a transit-oriented community vision, then find ways to communicate and promote this vision to these different stakeholders. For example, some transit agencies have developed detailed transit development guidelines that articulate their requirements and recommendations to ensure that developments can be successfully served by transit. However, beyond formal guidance documents, building a common vision for a transit-oriented community will require an ongoing process of communication and education with developers, business leaders, municipal policy makers, and other key stakeholders to ensure that this vision is the basis of decisions or at least always considered.

11.7.1.3 Build Ongoing Partnership with Municipal Planners to Develop Zoning and Shape Development Through Review of Development Plans and Important Building Permits

Transit-oriented communities are created not only through the adoption of broad planning visions in official long-term municipal plans, but also through the detailed zoning that governs development and the case-by-case permitting of developments and building permits, which are the responsibility of municipal planners. Not all transit agencies participate or even have a voice in the development process, whether it be in the drafting of zoning and other regulations or in the review of major developments. The transit agency needs to develop partnerships with municipal planners to ensure that transit is consulted in development policies and major decisions.

11.7.2 Key Implementation Resources and References for Transit-Oriented Density

- Hoover et al., 2004, *Transit at the Table: A Guide to Participation in Metropolitan Decision-making,* FTA, https://www.planning.dot.gov/Documents/TransitAtTable.pdf

  This report presents the observations, perspectives, and recommendations of a cross-section of transit agencies from large metropolitan areas on how to secure strategic positions in the metropolitan planning process. More importantly, the report can be a guide on how to use those positions to win policy and program support for priority transit services. The challenges to achieving full decision-making partnerships in regional settings, the most effective strategies for addressing these challenges, and the rewards of partnerships are presented by transit industry leaders using their own experiences. Key findings of the report were also used in preparing a self-assessment checklist for transit operators in assessing their profile and participation in metropolitan planning.

- Roisman et al., 2010, *Transit at the Table II: A Guide to Participation in Metropolitan Transportation Decisionmaking for Transit Agencies in Small- and Medium-Sized MPOs,* FTA, https://www.planning.dot.gov/documents/TransPlanning/TransTableII.pdf

  The purpose of the Transit at the Table II project is to answer the question, "Why should transit agencies in small- and medium-sized urban areas (population < 200,000) participate in the metropolitan planning process?" This report discusses the observations, perspectives, and recommendations of regional decision makers regarding transit agency participation in MPOs. It details how transit agencies secured strategic positions in the metropolitan planning process and the results they obtained in an effort to educate and energize transit agencies in small- and medium-sized areas in taking a seat at the MPO "table." The report examines how to win policy and program support for transit services at the MPO level and provides specific examples of benefits realized by transit operators in small- and medium-sized metropolitan areas. This effort builds on a previous study that focused on MPOs representing the largest urbanized areas (population > 200,000). The report also identifies commonalities and differences between the "transit at the table" experiences of operators in large metropolitan areas and those in small- and medium-sized ones.

- WSP–Parsons Brinckerhoff et al., 2015, *TCRP Report 182: Linking Transit Agencies and Land Use Decision Making: Guidebook for Transit Agencies,* Transportation Research Board, https://doi.org/10.17226/24629

  This report addresses improved transit and land use decision making by providing transit agencies with the tools that may help them become more effective at the decision-making table. The tools, which build on successful transit and land use decision-making experiences throughout the United States, can help transit agencies self-assess their readiness to participate effectively in the land use decision-making process and help improve their interactions with key stakeholders in the process, including local governments and developers.

- Christopher, 2006, *TCRP Synthesis 67: Bus Transit Service in Land Development Planning,* Transportation Research Board of the National Academies, https://doi.org/10.17226/14002

  This synthesis examines successful strategies that assist in the incorporation of bus transit service into land developments, as well as the challenges that transit agencies face when attempting to do so. The synthesis also explores the state of the practice regarding the use and components of transit agency development guidelines.

11.8 Future Transit Ridership Impacts

Over the past year, the transit industry has been hit by what may be its biggest challenge to date: a pandemic that uniformly discourages close proximity between people, which transit depends on to be the most spatially efficient mode. Across cities, the research team saw significant declines in rail ridership, as rail modes are often used by workers that have work-from-home options. The team also saw declines in bus ridership, although much of the lower-income and critical workforce populations that buses often serve are still riding transit out of necessity.

As everyone moves forward, researchers are still trying to understand the longer-term impacts that the pandemic might have on mobility and public transit in particular. Using the findings in this report as a basis, a few key ideas emerge:

- **Telecommuting impacts on transit will likely continue.** Already before the pandemic, the impacts of telecommuting could be seen. During the pandemic these impacts have been substantial and inevitable. However, as the pandemic subsides, it is likely that many firms will retain some telecommuting practices; this will likely change expectations around the model of five days per week at the office and reduce the gap between peak hours and off-peak demand.
- **Population density may continue to decline.** Population densities were also decreasing already before the pandemic, offsetting increases in transit ridership being seen from population increases. It remains to be seen how the public will react in the longer term, but with more flexibility in job locations comes more flexibility in living locations and a need for greater space in the home.
- **Low gas prices hurt transit ridership.** During the pandemic, on April 20, 2020, oil prices dropped below zero for the first time in history. As congestion has increased, gas prices have as well, but gas prices have generally stayed very low. If lower demand is sustained, it could continue to keep gas prices low, making driving a much cheaper option and adversely impacting transit ridership.
- **Potential exists for higher transit fares.** Similarly, driving may stay cheap compared to transit if transit agencies raise fares as they begin to recover their financial losses during the pandemic. The key to making transit affordable is high ridership on a per vehicle hour basis. With low ridership per vehicle hour, transit has to be subsidized to keep it affordable.
- **Impact on new modes is unknown.** Ride-hailing services also require shared space, similar to transit. Although ride-hailing use was growing rapidly before the pandemic, its future trajectory and resulting impact on transit remains to be seen.

Although the coming years may continue to be challenging, the transit industry is filled with champions who are eager to rise to the task of creating a more resilient and sustainable transportation system.

Acronyms and Abbreviations

APC	automatic passenger counter
BART	Bay Area Rapid Transit
BRT	bus rapid transit
COVID-19	coronavirus disease 2019
GCRTA	Greater Cleveland Regional Transit Authority
GTFS	General Transit Feed Specification
LRT	light rail transit
MARTA	Metropolitan Atlanta Rapid Transit Authority
MATSim	Multi-Agent Transport Simulation
MBTA	Massachusetts Bay Transportation Authority
MOD	Mobility on Demand
MPO	metropolitan planning organization
MSA	metropolitan statistical area
NACTO	National Association of City Transportation Officials
NTD	National Transit Database
SFMTA	San Francisco Municipal Transportation Agency
SUMC	Shared-Use Mobility Center
TARC	Transit Authority of River City
TNC	transportation network company
TDM	transportation demand management
TSP	transit signal priority
UCLA	University of California, Los Angeles
UPT	unlinked passenger trip
VRH	vehicle revenue hours
VRM	vehicle revenue miles
WMATA	Washington Metropolitan Area Transit Authority

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Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GHSA	Governors Highway Safety Association
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TDC	Transit Development Corporation
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S. DOT	United States Department of Transportation

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