EMPLOYING PUBLIC TRANSIT TO REDUCE EMISSIONS IN COLUMBUS, OHIO

The John Glenn College of Public Affairs
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Executive Summary

Emissions produced by the transportation sector have been rising since 2012. In an effort to combat this phenomenon, many cities have begun using transit incentives to increase public transit ridership and lower emissions production. This analysis explores whether transit incentive programs are a sustainable solution to lower Columbus’ transportation emissions.

Ultimately, the analysis found that transit incentive programs are not a sustainable solution to reduce transportation emissions in Columbus. Though Columbus’ transit incentive program led to emissions reductions, it did so at an extremely high cost. This suggests that instead of focusing on altering individuals’ habitual modal choices, Columbus’ approach to emissions reduction should prioritize systematic changes that can lead to increased transit ridership.

Additionally, Columbus’ emissions reduction programs should focus on accomplishing trips’ purposes through means that do not require transportation. Such programs would not require individuals to change their habitual transportation mode and would lead to more sustainable emissions reductions.
Introduction

In 2016, the amount of emissions produced by the United States’ transportation sector surpassed the electricity sector for the first time in history (Rhodium, 2019). To date, the transportation sector has remained the nation’s largest source of CO₂ emissions (Rhodium, 2019). Excessive CO₂ emissions negatively impact the environment as well as public health. The environment is a classic public good, which is characterized by the facts that no person can be excluded from “using” the environment and one person’s usage does not hinder another’s. Because excessive CO₂ emissions negatively impact the environment, lowering the United States’ transportation emissions is essential to ensuring society’s general welfare and protecting every individual’s access to a fundamental public good.

In 2017, 59% of emissions from the transportation sector were produced by passenger vehicles (EPA, 2017). Since such a large proportion of emissions from the transportation sector are generated from passenger vehicles, reducing the occurrence of single-occupant vehicle (SOV) trips is an important factor in reducing overall transportation emissions. The Federal Transit Administration presumes that public transit can reduce greenhouse gas emissions by

![Estimated CO₂ Emissions per Passenger Mile](FTA, 2010)

*Note: Average occupancy for private auto is one person; full occupancy is a four person carpool*
providing a low-emissions alternative to driving (Hodges, 2010). Public transit is considered a low-emissions alternative to driving because as passenger load increases there are only slight increases in CO₂ emissions (Davis & Hale, 2007). Figure 1 compares the estimated CO₂ emissions per passenger mile for private vehicles and various modes of public transit. The graph shows that even when public transit modes are not operating at full occupancy, they still produce fewer emissions than an SOV trip.

Since individuals’ private transportation choices have consequences on the environment, public policy tools are applicable interventions to reduce emissions from the transportation sector. In an effort to increase the number of Americans using public transit, many cities across the nation have begun experimenting with financial incentives, such as free-fare public transit, to increase public transit ridership and reduce emissions. As transit incentive programs gain popularity across the country, it is important to understand whether they are a viable and sustainable solution for emissions reduction, or if the funding for such programs would be better allocated to programs with a higher environmental impact. Such programs are hypothesized to be a strong solution to the nation’s ever-rising level of transportation emissions. This analysis will provide an in-depth exploration of whether such programs are effective and efficient.

**Background**

This analysis is informed by a literature review focusing on two main topics: determinants of modal choice and results from evaluations of transit incentive programs. The section examining determinants of modal choice explores behavioral theory as the underpinning of modal choice and Transportation Demand Management as a mechanism to
alter modal choice. Next, the literature review analyzes the results of numerous studies that have evaluated the effectiveness of transit incentive programs. The types of programs included in this section vary widely, but all offer a financial incentive that aims to increase transit ridership. The overall goal of the literature review is to provide a general framework that can be used to evaluate the impact of transit incentive programs on transportation emissions.

**Determinants of Modal Choice**

Across the literature, the Theory of Planned Behavior (TPB) is a common theory applied to analyze modal choice. TPB outlines the mechanisms that influence an individual’s intention to perform a behavior. An individual’s intentions then influence whether a behavior will be performed (Ajzen, 1991). By combining TPB with behavioral habit (the idea that past behavior is the best predictor of future behavior), Chen and Chao (2011) formed a model that gauges commuters’ ability to switch to public transit. The authors used survey data to test their model and found that habit has a significant, negative effect on intentions to switch travel mode (Chen & Chao, 2011). Their results imply that to instigate a modal switch from SOV to public transit, transit incentive programs would need to be powerful enough to interrupt the individual’s habitual travel mode.

Transportation Demand Management (TDM) applies TPB (as it relates to modal choice) through public policy. Meyer (1999) defines TDM as any action or set of actions aimed at influencing people’s travel behavior in a way that presents alternative mobility options. Such actions can fall into the following three distinct categories: 1) offering one or more alternative transportation modes/services with higher vehicle occupancy, 2) providing (dis)incentives to reduce travel or push trips to off-peak hours, and 3) accomplishing the trip’s purpose through
means that do not require transportation, for example substituting telecommuting for daily work trips (Meyer, 1999). Implementing TDM strategies are meant to alter an individual’s travel behavior and can be implemented at either a specific site or at an area-wide level; many TDM strategies are designed to incorporate both levels (Meyer, 1999). Further, TDM strategies fall on a spectrum that ranges from “push” to “pull” activities. Push activities discourage car use and pull activities encourage the use of alternate modes. Transit incentive programs lean toward the “pull” side of the spectrum and, depending on the specifics of the program, can fall under either the first or second category of TDM strategies (Gärling et al., 2002).

To evaluate the effectiveness of transit incentive programs on reducing transportation emissions, it is imperative to also understand the mechanisms that drive successful TDM strategies. To dive deeper into how TDM strategies work, Gärling et al. (2002) produced a conceptual framework to analyze changes in transportation due to TDM policies. Their framework suggests that TDM affects “trip-chain attributes,” which are factors such as travel cost or perceived travel time. After TDM strategies are implemented, individual factors such as income or age then determine whether, in reaction to the TDM strategy, an individual sets a goal to change modes. Gärling et al. (2002) also assert the importance of a principle-program connection to the success of TDM strategies, with the principle being the “goal” and the program being a specific behavioral action plan. In the case of transit incentive programs, the goal is considered “commuting” and the behavioral action plan is “choosing public transit.” The incentive serves as the link between the goal and the behavioral action plan. The ultimate objective of TDM strategies is to solidify the behavioral action plan as a habitual action (Gärling et al., 2002). Combining this framework with the previously mentioned behavioral theory
suggests that the success of financial incentivization of public transit hinges on the incentive’s ability to not only interrupt SOV drivers’ habitual travel mode choice but to also promote public transit as their new habitual choice.

**Evaluation of Transit Incentive Programs**

Numerous studies have investigated how financial incentives, such as lowering or eliminating transit fares, impact transit ridership. The literature is fairly evenly divided on whether transit incentive programs have any impact on ridership. In cases where transit incentive programs have increased ridership, the literature documents a wide variety of effect sizes. This phenomenon is likely attributed to the fact that most incentive programs are implemented at the local level and different localities may have different contextual factors, such as quality of public transportation, that affect whether individuals choose public transit. A table summarizing the results from the public transit incentive studies reviewed can be found in Appendix A.

Though some evaluations have found transit incentive programs effective in increasing transit ridership, the results of many evaluations demonstrate an array of caveats to their success. In an experiment conducted by Thøgerson and Møller (2004), a treatment group was granted a free public transit pass while a control group received no benefit. Comparing the control groups’ public transit ridership to the treatment groups’ showed that providing free public transit neutralized, or counteracted, the impact of habit (in this case driving a car) on modal choice (Thøgerson & Møller, 2004). Another powerful conclusion in the study was that public transit incentives increase ridership, but the increase is not sustained when the incentive is discontinued (Thøgerson & Møller, 2004). This finding suggests that transit incentive
programs would need to be in place perpetually, and therefore, would need to be financially sustainable as well as exhibit high levels of political and administrative feasibility.

Several other studies have shown positive effects of transit incentive programs. By analyzing survey data, Su and Zhou (2012) found that in Seattle, when transit subsidies increased by 10%, the likelihood of choosing transit increased by 0.73% and the likelihood of driving alone decreased by 0.7%. A study based on survey data collected in New York and New Jersey concluded that public transit benefits make commuters nine times more likely to take public transit than drive alone (Bueno et al., 2017). Similarly, Ghimire and Lancelin (2019) found that employees with free/subsidized parking had a 71% lower likelihood to use transit compared to those who had not received free/subsidized parking while those who received a free/subsidized transit pass had a 156% higher likelihood to use transit compared to those who had not received a free/subsidized transit pass. Though these studies found transit incentive programs effective in instigating modal shift, they make no mention of whether they efficiently reduce transportation emissions.

Overall, the literature is lacking in terms of examining transit incentive programs’ effect on emissions. A study conducted by Studenmund & Connor (1982) found that when bus fares were eliminated in Trenton New Jersey and Denver Colorado, 43% of new bus trips were made by individuals who did not previously use the bus system and over half of those trips were diverted from cars. The conversion of car trips to bus trips does suggest emissions were reduced. In contrast, Liu et al. (2019) found that while decreased transit fares in Australia did increase the number of trips made, the program did not attract new users; instead, the additional trips were generated by increased use by individuals who already used transit before
the fare decrease. Additionally, a study conducted across multiple cities found that transit fare subsidies did not reduce car usage and concluded funding could be better spent on transit network expansions; the study estimated that a 10% transit network expansion would be linked to a 3% increase in transit usage (de Grange et al., 2012). Lastly, Rivers and Plumptre (2018) analyzed Canada’s public transit tax credit and found that while ridership increased, many people likely bought transit passes to claim the tax credit without modifying their transportation mode. Their study also estimated that 1 ton of emissions reduction cost the Canadian government between $1,000 and $15,000 (Rivers & Plumptre, 2018). After comparing this figure to global carbon prices, which range from $5 to $50 per ton of carbon, Rivers and Plumptre concluded that the tax credit was not a cost-effective means to reduce transportation emissions in Canada. Despite there being a gap in literature directly exploring the ability of transit incentive programs to reduce transportation emissions, the results of the studies mentioned seem to suggest that such programs do not efficiently reduce transportation emissions.

In addition to examining the effectiveness of transit incentive programs, some studies have also explored confounding factors that contribute to the effectiveness of such programs. When examining college students’ commute behaviors, Zhou (2012) found that gender, status (undergraduate versus graduate), and age are significantly correlated to biking, walking, or using public transit. Similarly, Singh et al. (2018) found that socio-demographic variables (including age, race, income, household type, and family structure) explain 33% of household vehicle miles traveled in the New York metropolitan region. These findings support the idea
that cities’ unique contextual circumstances explain the large variation in transit incentive programs’ effect sizes.

Overall, the literature covering modal choice and transit incentives provides a strong framework to evaluate whether transit incentive programs effectively reduce emissions. The Theory of Planned Behavior underlines the ability for SOV drivers’ habitual actions to impede modal shift, which suggests TDM strategies could be an answer to interrupting habit and inducing a modal shift from SOV to public transit. In terms of the effectiveness of transit incentive programs as a TDM strategy, it is apparent that the effectiveness greatly varies based on contextual factors that influence individuals’ modal choices. Additionally, at least one study suggests transit incentive programs are an extremely costly mechanism to reduce transportation emissions, which may indicate that funding would be better allocated toward programs with improved cost to emission reductions ratios. For these reasons, it is unclear whether focusing on individual modal choice is the ideal strategy to reduce transportation emissions.

**Columbus, Ohio as a Case Study**

Though the state of Ohio has seen substantial yearly reductions in total CO₂ emissions since 2014, most of these reductions have been due to reductions in emissions from the electric power sector; meanwhile, emissions from the transportation sector have hovered around 63 million metric tons since 2009 (EIA, 2019). Transportation emissions have been a problem in Columbus Ohio, where over 700,000 commuters drive alone to work each day (an SOV commuter rate of approximately 82%) (Davis, 2019). Similar to the United States’ transportation sector as a whole, Columbus’ transportation sector is responsible for the largest
portion of the city’s emissions (White & D’Aversa, 2018). Located in a region that is projected to add one million residents by 2050, Columbus could be faced with incredibly large increases in greenhouse gas emissions which would negatively impact the environment as well as the community at large (Davis, 2019).

Since 2016, Columbus has been exploring innovative options to reinvent transportation and lower the city’s emissions output. Beginning in June 2018, a partnership between Capital Crossroads Special Improvement District (CCSID), the Central Ohio Transit Authority (COTA), and the Mid-Ohio Regional Planning Commission (MORPC) facilitated the distribution of a free bus pass, the C-pass, to all employees of eligible downtown Columbus businesses (City of Columbus, n.d.). The C-pass grants employees free, unlimited access to all COTA bus routes regardless of day or time (City of Columbus, n.d.). Though the ultimate goal of Columbus’ C-pass program was to make downtown employees’ commutes easier and more affordable (Ferenchik, 2019), the nature of the program facilitates exploration of whether transit incentive programs are an effective way to reduce transportation emissions in Columbus, Ohio.

**Stakeholders**

Primary stakeholders of the C-pass program include COTA, MORPC, and CCSID. These groups all exhibit high levels of both power and interest in the C-pass program because the C-pass program was developed through a partnership between these three organizations. Of the stakeholders with high levels of power, MORPC and downtown property owners have the highest level of power because they are the primary funding sources of the program. Property owners pay through assessments for the program and MORPC contributes through the stewardship of federal funds (Ferenchik, 2019). Downtown property owners are given a choice
of whether they want to fund the program, and if so, how much they will contribute. Because property owners contribute half of the documented program costs, they are at least partially responsible for the program’s future. Secondary stakeholders include downtown Columbus employers eligible to enroll in C-pass and downtown Columbus employees working for companies enrolled in C-pass. These groups have high levels of interest in the C-pass program but do not possess the power required to make or influence decisions related to the program.

Additional stakeholders that are important to consider include downtown Columbus employers (and their employees) ineligible to enroll in C-pass, Columbus employers (and their employees) who are not located in the downtown area, Columbus residents who currently ride COTA routes, and Columbus residents who do not currently ride COTA routes. These stakeholders are individuals who have low levels of both power and interest in the C-pass program, however, each stakeholder in this category has the potential to exhibit high interest in the program if they become eligible.

**Data and Methodology**

As made apparent by the existing literature, the success of transit incentive programs on public transit ridership varies widely and may be dependent on the contextual factors of the location in which they are implemented. Therefore, such programs exhibit varied levels of success in reducing emissions. This conclusion, coupled with Columbus’ problematic SOV commuter rate raises the question: could a transit incentive program efficiently reduce transportation emissions in Columbus? To begin to explore this question, this analysis will evaluate the effectiveness of Columbus’ C-pass program on reducing emissions.
The data for the analysis was collected by CJI Research in May 2019. The 16-question survey was sent to each company enrolled in the C-pass program and garnered 2,655 employee responses. The variables “most frequently used transportation mode before enrollment in C-pass” and “most frequently used transportation mode after enrollment in C-pass” were used to create the variables “switch to COTA from SOV” and “switch to COTA from non-vehicle,” which measure the number of individuals who made a relevant modal shift. The variable “zip code” was used to estimate the downtown employee’s average commute distance and, in conjunction with the “switch to COTA from SOV” variable, estimated the total emissions reduction achieved by the C-pass program. The survey collected additional information that was used to explore if relationships exist between specific characteristics and whether the participant made a modal change. These characteristics include: whether the respondent has an employer-provided parking benefit, whether the respondent has daily access to a vehicle, and the age, gender, and income of the respondent.

This analysis of the survey data considers two questions: 1) did the C-pass program achieve emissions reductions and 2) is there a relationship between specific participant characteristics and whether they made a modal switch. Methodology to test for these outcomes includes a cost-benefit analysis, which objectively compares the costs and benefits of a program, and chi-square tests of independence, which are a form of hypothesis testing that evaluates whether or not there is a relationship between categorical variables. Cost-benefit analysis is an imperfect tool since the true value of environmental preservation is difficult to capture by a dollar amount. However, it is important to understand how the cost to emission reductions ratio of the C-pass program compares to other programs’ ratios to determine where
funding is best allocated. In this case, a chi-square test of independence is the most applicable statistical tool because all data are categorical. Unfortunately, the survey was not conducted as a simple random sample so the results of the chi-square tests will only apply to the C-pass participants.

Analysis

Analysis Plan

Cost-benefit analysis was the first procedure used to explore whether the C-pass program efficiently reduced transportation emissions. The structure of the cost-benefit analysis was based on the study conducted by Rivers and Plumptre (2018). The environmental benefit (reduced emissions) was calculated based on the number of individuals that made a switch from an SOV. This calculation was used to estimate the approximate cost of reducing one ton of carbon emissions. To put the cost of the program into perspective, the cost of reducing one ton of carbon emissions was compared to the social cost of carbon, which is a dollar measure that estimates the long-term damage caused by one ton of CO₂ emissions (EPA, n.d.).

Next, a chi-square test of independence was used to explore if participant characteristics affected whether an individual switched to COTA from an SOV. In chi-square test of independence, the null hypothesis is that there is no relationship between variables and the alternative hypothesis is that there is a relationship between variables. An alpha of 0.05 was used to determine whether the results from the chi-square tests were statistically significant. Chi-square tests of independence can only determine whether two variables are related. They cannot describe the direction or strength of the relationship. Due to data limitations, tests to determine the direction or strength of the relationship cannot be conducted in this analysis.
Results: C-pass Effectiveness on Reducing Emissions

The first step in the analysis of the C-pass program was to examine the effect size of the program over one year. Survey data showed that 420 individuals shifted from an SOV to COTA. 38 individuals who previously commuted via a non-vehicular mode of transportation (for example, walking or biking) also switched to COTA, but such a small number of additional passengers would not have a meaningful impact on emissions. Respondents’ reported zip codes were used to determine their average commute distance. The group switching from an SOV had an average commute of 11.2 miles (22.4 miles round trip). Finally, average estimated CO₂ emissions per passenger mile as reported by the Federal Transit Administration (FTA, 2010) were used to calculate the estimated CO₂ emissions reduction. The final estimate of annual CO₂ reduction for buses operating at average capacity is 787,886.40 pounds of CO₂ (393.93 tons).

The emissions reduction is a rough estimate and is likely to have inaccuracies. One source of potential inaccuracies arises from the fact that the estimate is based on a two-way commute every workday, which likely does not apply to every program participant. Additionally, the figure could be deflated because it only accounts for workday trips. C-pass holders can ride COTA any day or time, but based on the available survey data it is impossible to accurately estimate any non-work related trips that participants took. Though the total emissions reduction achieved by the program is only a rough estimate, assuming a two-way commute every workday was the best way to estimate the emissions impact with the survey data at hand. Gaining a more accurate estimate would require highly intensive data collection and analytical methods.
Estimating the cost of the C-pass program was less direct. The total cost of funding the program has not been officially reported. As such, this analysis bases the cost of the program on the amount paid by two verified funding sources: property owners ($2.5 million through assessments for the program) and MOPRC ($2.5 million through federal funding) (Ferenchik, 2019). Therefore, this analysis assumes the cost of the C-pass program is $5 million. The program was funded from June 2018 through December 2020, so the annual cost of the C-pass program is over $1.9 million. Because the program’s cost has not been officially reported, the actual cost may be higher. The assumed annual cost of $1.9 million led to the conclusion that one ton of emissions reduction achieved by the C-pass program cost over $4.9 thousand.

Next, the cost to reduce one ton of emissions was compared to the social cost of carbon (SC-CO₂). The SC-CO₂ reported for 2020 was used because the SC-CO₂ is only estimated in five-year increments and 2020 is the year closest to the year of the survey data collection. The estimated SC-CO₂ for 2020 is $42 (EPA, n.d.). Comparing the SC-CO₂ to the estimated cost for the C-pass program to reduce one ton of emissions shows that the program’s cost to reduce one ton of emissions is about 117 times higher than the SC-CO₂.

Results: Chi-square Test of Independence

A table summarizing the results from the chi-square tests of independence can be found in Appendix B. The results of the tests show that a relationship exists between whether an individual made a modal change and the following variables: gender, age, whether an individual has a vehicle at home, and whether an individual’s employer subsidizes their parking cost (either partially or fully). As previously mentioned, this analysis cannot determine the direction or strength of these relationships. Though the chi-square results are not generalizable to
Columbus’ population as a whole, they do point to some contextual factors that could impact the success of transit programs in Columbus. Additional research should be conducted to further understand how these relationships relate to Columbus’ general population.

**Recommendations**

There are no official guidelines on how program costs should relate to the SC-CO\(_2\), but it is clear over $4.9 thousand per ton of emissions reduction is an extremely high cost, especially when compared to the $42 SC-CO\(_2\). Results from Thøgerson and Møller (2004) suggest that transit incentive programs need to remain in effect perpetually to sustain increased public transit ridership. The extremely high cost of the C-pass program brings into question the financial sustainability of a transit incentive program in Columbus. For this reason, targeting downtown employees’ individual behaviors as a means of combating Columbus’ high SOV commuter rate and transportation emissions is not recommended. It is important to note that this analysis is conducted through a purely environmental lens and makes recommendations based on a transit incentive program’s ability to reduce emissions in Columbus. Offering subsidized public transit can have other benefits, such as improved traffic flow, increased accessibility of transportation, etc., that are important to consider but are outside the scope of this analysis. This analysis solely focuses on the C-pass program’s ability to reduce emissions; it does not evaluate the program’s performance in terms of its main goal, which is to make downtown employees’ commutes easier and more affordable.

The results of this analysis have made it clear that transportation incentive programs focused on altering individual behavior have an extremely high price tag for moderate levels of emissions reduction. For this reason, Columbus’ approach to reducing transportation emissions
should focus on programs that prioritize systematic change, rather than changing individual behaviors. This recommendation is informed by De Grange et al. (2012), who found that a 10% network expansion would lead to a 3% increase in transit ridership. Further expansion of Columbus’ existing transit system or the implementation of new transit systems would have a high cost, but would likely lead to much more sustainable increases in transit ridership than transit incentive programs. This option would require a large amount of additional research to better understand how land-use relates to ridership increases.

Moving forward, Columbus’ emissions reduction programs, should focus on objectives that fall under the third category of TDM strategies: accomplishing the trip’s purpose through means that do not require transportation. Unlike the other two categories of TDM strategies, strategies in the third category achieve emissions reductions without requiring individuals to alter their already-established habitual travel mode. While achieving a trip’s purpose through non-transportation means could be considered a habit change, it does not require a change in habitual travel mode, which is where the effectiveness of transit incentive programs begins to break down. Possibilities for programs that fit in the third category of TDM strategies are endless. One example of a program that Columbus could explore would be providing financial incentive for downtown employers if they achieve a certain threshold of telecommuting employees.

Conclusion

Against expectation, this analysis shows that transit incentive programs are not an efficient way to reduce emissions from the transportation sector. In practice, transit incentive programs are not always successful and their effect size is largely dependent on contextual
factors of the city/region in which the program is implemented. Columbus Ohio has observed high transportation emissions and SOV commuter rates. This fact, coupled with Columbus’ recently implemented C-pass program, makes it a strong candidate for analysis of whether transit incentive programs to reduce emissions are a feasible policy solution in Central Ohio. Analysis of the C-pass program has shown that in Columbus, a transit incentive program would likely be an extremely expensive and potentially unsustainable mechanism by which to lower transportation emissions. Instead of focusing on changing individuals’ choices, Columbus should focus its emissions reduction efforts on making systematic changes, such as continuing to expand their existing transit network or adding new transit options.

In the future, Columbus’ emissions reduction programs should focus on TDM strategies that achieve a trip’s purpose through non-transportation means. Such strategies do not require individuals to alter their habitual modal choice. For Columbus, programs in line with this approach would have a better cost to emissions reduction ratio and make a much more sustainable impact on transportation emissions than programs that focus on altering individual behaviors.
## Appendix A: Results from Public Transit Incentive Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Location</th>
<th>Type of Incentive</th>
<th>Key Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thørgreson and Møller (2004)</td>
<td>N/A</td>
<td>Free public transit pass to a treatment group</td>
<td>Free public transit neutralized the effect of habit; The incentive increased ridership while in effect, but the increase was not sustained when the incentive was discontinued</td>
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<tr>
<td>Su and Zhou (2012)</td>
<td>Seattle</td>
<td>10% transit subsidy increase</td>
<td>Likelihood of choosing transit increased by 0.73%; likelihood of driving alone decreased by 0.7%</td>
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<td>Bueno et al. (2017)</td>
<td>New York and New Jersey</td>
<td>Public transit benefits</td>
<td>Commuters are nine times more likely to take public transit</td>
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<tr>
<td>Ghimire and Lancelin (2019)</td>
<td>Atlanta, Georgia</td>
<td>Free/subsidized transit pass vs. free/subsidized parking</td>
<td>Employees with free/subsidized parking were 71% less likely to use transit compared to those who did not receive free/subsidized parking; employees with a free/subsidized transit pass were 156% more likely to use transit compared to those who did not receive a free/subsidized transit pass</td>
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<td>Studenmund and Connor (1982)</td>
<td>Trenton, New Jersey and Denver, Colorado</td>
<td>Free bus fare</td>
<td>43% of new bus trips were made by individuals new to the bus system; over half of those trips were diverted from private cars</td>
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<tr>
<td>Liu et al. (2019)</td>
<td>South East Queensland, Australia</td>
<td>Decreased fares</td>
<td>Decreased fares increased the number of trips made but did not attract new users</td>
</tr>
<tr>
<td>De Grange et al. (2012)</td>
<td>41 cities across various countries</td>
<td>Fare subsidies</td>
<td>Fare subsidies did not reduce car usage; funding could be better spent on network expansions</td>
</tr>
<tr>
<td>Rivers and Plumptre (2018)</td>
<td>Canada</td>
<td>Public transit tax credit</td>
<td>Ridership increased but likely did not reduce emissions (findings show individuals likely bought a pass to claim the tax credit without modifying their behavior)</td>
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## Appendix B: Chi-Square Test of Independence Summarized Results

<table>
<thead>
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<th>Variable 1</th>
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<th>df</th>
<th>p-value</th>
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<td>Age</td>
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<td></td>
<td>Whether respondent has a vehicle at home</td>
<td>13.57</td>
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<td></td>
<td>Whether respondents’ employer subsidizes parking</td>
<td>8.45</td>
<td>2</td>
<td>0.015</td>
</tr>
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</table>

*Note: $\alpha = 0.05$*
References


