Can Public School Buses Help Solve the Urban Congestion Problem?

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Abstract

Congestion is a persistent and expensive problem, costing the nation collectively over \$300 billion each year. Cities have generally attempted to address congestion using an unoriginal set of expensive strategies, like building new roads or expanding public transit, and many cities are considering implementing congestion pricing. Expanding school bus service may be a palatable solution because it provides a service instead of involving lengthy and costly construction or charging a new fee. School travel is also a sizeable portion of total daily traffic. Indeed, over 50 million children travel to and from school each day and their commutes account for about one-quarter of total daily commuter trips. School travel and school-provided transportation is generally the domain of school districts and not city governments and the school districts in most large cities are independent from city governments. This may lead to a coordination problem if school districts ignore congestion caused, or exacerbated by, school travel. To determine whether pupil transportation reduces congestion, I exploit idiosyncratic variation in the percentage of weekdays that are instructional school days in a month and variation in pupil transportation spending within districts over time. I build a rich, monthly, longitudinal data set for congestion, school days, and transportation policy for 51 cities from 2013 to 2019 and find congestion is significantly higher on school days, measured using either the TTI or PTI, and pupil transportation alleviates congestion caused by school children's travel. A back-of-the-envelope calculation suggests cities should subsidize the additional spending needed by the school district to transport more students and lower congestion.

1 Introduction

Highway congestion has plagued cities since automobile ownership grew during the 20th century. Congestion costs the nation collectively over $300 billion each year, or nearly $900 for every American (McCarthy 2018; Texas Transportation Institute 2019). Cities have generally attempted to address congestion using an unoriginal set of strategies, like building new roads, expanding public transit, and promoting active transit like biking and walking. There is now frequent consideration of congestion pricing – a strategy where drivers are charged to drive into a pre-defined urban zone, but congestion pricing remains politically fraught because it imposes a new cost on something that has long been free. In contrast, little attention has been paid to school transportation. Expanding school bus service may be a palatable solution because it provides a service instead of involving lengthy and costly construction or charging a new fee.

School travel is also a sizeable portion of total daily traffic. Over 50 million children travel to and from school each day and their commutes account for about one-quarter of total daily commuter trips (FHWA 2017). Providing school buses or subsidized transit passes to more students may be a viable urban congestion mitigation strategy. In this paper, I evaluate cities' ability to leverage school transportation policy to reduce urban congestion and estimate the credibly causal effect of school transportation policy – per-pupil transportation expenditures and the percentage of students bused – on urban congestion in the 51 largest urban areas in the US. Specifically, to determine if pupil transportation is a viable congestion mitigation strategy, my primary research question is whether additional school bus use – measured by per-pupil transportation expenditures or the share of students bused – exacerbates or ameliorates urban congestion.

School travel, and whether – and to what extent – to provide pupil transportation to school students, is typically an education issue handled by the school district. While there may be some coordination between schools and transit authorities in a few select cities, urban transportation departments are uninvolved in how students get to school. One possible reason for this coordination problem is that the majority (72.5% – 37 school districts) of urban school districts in the 51 largest urban areas are independent from the city government. In many cities, the central city and school district are not even coterminous. With their own taxing authority and independent leadership and decision making, school districts focus on educational outcomes, like test scores and graduation rates. Even if school districts could leverage school transportation, including school buses or transit passes, to reduce congestion, this would either require school districts to raise tax levies to fund additional transportation or to cut other spending. Given recent evidence that bus riders have higher attendance (Cordes et al. 2019; Edwards 2021), increasing cooperation between municipalities and school districts could benefit the cities (reduced congestion) and school districts (improved attendance). This presents an institutional collective action dilemma (Feiock 2013) and a solution may be for cities to fund the additional pupil transportation, allowing the city and school district to both benefit.

Key to my identification strategy is the idiosyncratic variation in the percentage of weekdays that are instructional school days in a month. One factor in this variation is state policy that dictates when school years can begin and when they must be finished. Several states, for instance, do not allow school districts to begin school until September 1, and the combination of September 1 and Labor Day on the calendar creates wide variation in the percentage of school days in September from year to year. Other calendar features, like the particular placement of Thanksgiving, Christmas, and Easter, create year-to-year variation in the percentage of school days in November, December, March, and April each year. Because most states require 180 school days per year, having a smaller share of school days in November or December necessarily requires a higher share in other months – or to extend the school year by having more days in June. I also exploit the difference in timing during the AM school commute – which is coterminous with a typical office worker's commute – and the PM school commute – which begins about 90 minutes before the end of the standard 9-to-5 workday.

I build a rich, monthly, longitudinal data set for congestion, school days, and transportation policy for 51 cities from 2013 to 2018. I use congestion data from the Federal Highway Administration that includes three measures of congestion by time of day – travel time index (TTI), planning time index (PTI), and congested hours – and collect transportation policy data from the National Center for Education Statistics and School Bus Fleet for the center city school districts in each MSA. I count the number of school days in each month for these school districts and calculate the percentage of weekdays that are school days. I link with other city-level characteristics, like population, density, city size, employment, per-capita income, and highway stock.

To preview my results, I find congestion is significantly higher on school days, measured using either the TTI or PTI. With city fixed effects, congestion is 1.79 percent higher for months with an additional two school days – roughly a ten percentage point increase in the share of weekdays with school. A full month of instructional days, such as a June at the end of the school year, is associated with congestion being 18 percent higher compared to a month with no school days, like July.

Answering my primary research question, I find that pupil transportation alleviates congestion caused by school children's travel. Increasing per-pupil spending by twenty-five percent – about 162 dollars for the average district, while holding percentage of school days constant, causes a 0.005 point decrease in TTI – two percent of baseline congestion. The effect is modestly larger with city fixed effects. I find similar effects for busing a higher share of students.

Performing separate analyses for AM and PM rush hour periods, school causes two to five times more urban congestion during the AM peak period than the PM peak period. Increasing share of students bused reduces AM congestion (TTI and PTI) with significantly smaller, or null, effects on PM congestion. Examining log spending per pupil, I find that higher spending reduces congestion in both AM and PM peak periods, with effects that are not significantly different from each other.

I perform a back-of-the-envelope calculation and conduct a crude cost-benefit analysis to determine if increased pupil transportation spending –from the school district– is a cost-effective way to reduce urban congestion – to the benefit of the entire city. Using per-pupil spending results, I find a net benefit for 36 of 51 cities. Los Angeles and San Francisco – large cities with high congestion costs and low transportation spending – stand to benefit the most. This back-of-the-envelope calculation suggests cities and school districts can solve this ICA dilemma if the city subsidizes the additional spending needed by the school district to transport more students and lower congestion.

The paper is organized as follows. In Section 2, I first provide background on urban congestion and school travel to inform why cities should consider school transportation policy for urban congestion mitigation. In Section 3, I review relevant literature, including research examining what factors are linked with congestion and what cities have tried to remedy congestion. Section 4 details data sources, sample construction, empirical strategy, and estimating equations. In Section 5, I provide results and in Section 6, I provide discussion, including back-of-the-envelope estimates for net benefit.

2 Background

2.1 Congestion

Urban congestion is a persistent, expensive, and worsening problem throughout the United States. Estimates for the cost exceed \$300 billion each year, with direct costs of wasted time and fuel reaching \$179 billion (McCarthy 2018; Texas Transportation Institute 2019). There are numerous components to the total cost of congestion. The largest, by far, is the additional travel time needed to make the same trip (Office of Economic and Strategic Analysis 2009). Wasted time alone is estimated to cost nearly \$2,700 per traveler every year in the 12 largest urban areas in the United States. Other "person" costs are trip unreliability – the variability in how long a trip will take – requiring travelers to build buffer time into their trip. This unreliability results in leaving too early some days, arriving late other days, and the psychological effect of uncertainty.

Congestion also increases vehicle operating costs, because vehicles are running for longer periods of time and travel is stop and go. In addition to stop-and-go driving burning more fuel than driving at steady speeds, there is also additional wear-and-tear on braking and other mechanical systems as vehicles stop and start repeatedly (Office of Economic and Strategic Analysis 2009). There are also environmental and broader societal consequences of congestion. Excess vehicle wear-and-tear and fuel usage contribute to increased emissions and environmental damage. Transportation accounts for 29% of total greenhouse gas emissions - primarily carbon dioxide from burning fossil fuels - and longer travel, and idle, time due to congestion contributes to this pollution (EPA 2021). Congestion also contributes to higher crash rates, although evidence suggests higher crash rates might not lead to more severe crashes because travel speeds are slower (National Center for Statistics and Analysis 2021).

To address congestion, cities have primarily invested in supply-side solutions, like building or expanding roads, adding capacity to transit systems, such as rail and bus systems, and investing in intelligent transportation systems that improve signal timing, implement cashless tolling, and use ramp metering. In recent years, cities have also considered demand-side solutions that generally increase the cost of car travel. Perhaps most famously, London implemented congestion pricing and charges £15 to drive into the urban core. American cities, like New York and Los Angeles, have approved or are seriously considering similar systems. Other strategies to increase the cost of car travel during congested hours include dynamic tolling and strategic parking pricing. Cities have also tried to promote flexible scheduling so that fewer people are all trying to arrive at work at the same time.

One thing that cities have not leveraged is influencing how, and when, schoolchildren travel to school. For instance, nearly 60 percent of city schools across the US start their school day between 8AM and 9AM – precisely when congestion is at its worst each morning (NCES 2018b). Just ten percent of city schools begin the school day after 9AM, after most office workers have arrived at work. Strategically scheduling the school day outside of peak congestion hours may reduce congestion. For a more drastic change, school districts could move to a four-day school week to remove all school-related travel on one workday. Alternatively, if changing school schedules is undesirable or not politically feasible, busing more students or subsidizing transit use for more students may take cars off the road during the busy morning commute.

2.2 School Travel

Over 50 million children travel to and from school each day. Their commutes account for about one-quarter of total daily commuter trips (FHWA 2017). An additional seven million teachers commute to schools each day.

Despite the ubiquitous image of the yellow school bus in American society, there is no national standard or set of guidelines for school transportation policy. Individual states, and often individual districts or even schools, are left to decide who should ride the bus, how far students should live from school to be eligible for a bus, and for which grades to provide buses. There is no national policy or guidance from the U.S. Department of Education on whether bus service should even be provided, who should pay for it, and whether districts can pass on the cost to students to ride the school bus. As a result, there is considerable variation in how students get to school throughout the country. School districts in some states, like California, are allowed to charge students user fees to ride the school bus. Perhaps unsurprisingly due to this user fee, just ten percent of students in California ride the bus. In other states, like Minnesota and Mississippi, that offer free bus service for distance-eligible students, over 90 percent of students ride the school bus.

How far students live from school – and how they travel there – has changed dramatically over the past fifty years. In 1969, 41 percent of elementary and middle school students lived within one mile of school, and, nearly nine in ten of those walked or biked to school (Safe Routes to School n.d.). As suburbanization spread in the latter half of the 20th century and school choice expanded in the late 20th and early 21st century, students began traveling further to school. Only

31 percent of elementary and middle school students lived within one mile of school in 2009 and only 35 percent of these students walked or biked. As a result, students are now increasingly reliant on either school buses or automobiles to get to school. About 54 percent of students (25 million) travel to school by private automobile, while one-third ride a school bus, 10 percent either walk or bike, and two percent use transit (FHWA 2019).

There are two key reasons to expect school travel to contribute to congestion. First is the raw number of students traveling each day. The number of commuters on a typical summer day is a full quarter less than on a typical day during the school year. Indeed, popular press reports note the link between the beginning of school in late summer and increased congestion – when 50 million commuters return to school. While adult workers may also avoid commuting some days during summer vacation, most workers are unable to take off the same number of days as students. Nearly one-third of all adult commuters would have to take off work on the same day to achieve the same reduction in commuters caused by school's summer vacation. Second is that students have no flexibility in the time they are required to be at school every day. Millions of students must arrive at school at precise times – often during peak-period travel times – and, therefore, travel to school during the most congested hours each day. Most choose to do this in a private vehicle (NCES 2018b). While municipalities and large employers often encourage flexible scheduling so that workers stagger their commutes over a longer period of time, students lack this flexibility.

Broadly, however, school districts have little motivation to reduce congestion. School administrators are primarily focused on the educational experience and performance of students and less so on what happens outside the classroom. Except in a hypothetical extreme case where congestion is so severe students cannot get to school on time, school administrators seem unlikely to care. There are also financial reasons for school administrators to ignore congestion. Most schools are operated by school district governments with their own taxing authority and are therefore not dependent on other governments for funding. Indeed, the school districts in 37 of the 51 largest cities in the US are independent from the municipality. So, even if school districts might be able to leverage school transportation or other policies to reduce congestion, this would come at a cost of other educational spending or increased school tax levies. It is very unlikely that school districts would tax residents or cut other spending to reduce congestion costs for the entire municipality with no obvious expected benefit to its core educational mission[1]. Leveraging

[1] There is a growing literature that the school bus is beneficial for student's educational outcomes, so expanding

school transportation or school policies to reduce congestion would likely require cooperation between the city – which bears most of the costs of congestion – and the school district – which may have the solution.

3 Literature

Theories, models, and studies of the causes of – and remedies for – congestion have a long history. Relevant literature spans the early history and causes of congestion, what factors and characteristics are linked with congestion, and what scholars have argued may remedy congestion.

Early work focused on pedestrian and transit congestion. Vickrey (1955) proposed a fare pricing structure for the New York City subway system to relieve congestion during travel periods. Vickrey's plan – likely the first proposed congestion pricing plan – would charge passengers more during peak travel periods because traveling during these times is more expensive – both to operate the subway and for the externalities caused by crowding a subway car. As automobile use expanded, it was initially believed automobiles would ease pedestrian congestion because trips would take less time (Caro 1974). Following widespread suburbanization in the United States, however, highway congestion became the focus. Downs (1962) describes the "fundamental law of highway construction" as the proportionate increase in traffic from expanding highways. Meyer, Kain, and Wohl (1965) detail the problems of transporting millions more commuters traveling from suburbs to the urban core for work each day. They rightly note the strong preference among Americans for private automobile use as opposed to rail or bus. The Urban Mass Transportation Act of 1964 recognized that private automobile use during peak travel times "is often contradictory of such other community objectives as pure air, quiet and privacy, socially-desirable land use, efficient concentration of economic activity without undue congestion" (Verbit 1975).

A deep body of work examines what factors or characteristics are linked with congestion. These characteristics generally fall into three buckets: population characteristics, features of the built environment, or combinations of population and the built environment (Ewing, Tian, and Lyons 2018; Albalate and Fageda 2019; Rahman et al. 2021). Population characteristics include things like population size, age, employment, and vehicle ownership. Features of the built environment include highway stock, transit stock, walkability, compactness, poly-centricity.

the bus to reduce congestion may also provide educational benefits. See, for example, Cordes, Leardo, Rick, and Schwartz (2019).

Combinations of the two include population density and employment density. These studies generally find that population is the most significant predictor for urban congestion, with similar, smaller relationships between per-capita income and employment agglomeration. (Rahman et al. 2021). A small set of factors – like weather or fuel prices – do not neatly fall into these buckets. To the best of my knowledge, I am unaware of any work examining the relationship between schools and congestion, including how students get to school or the number of students in a city[2].

Using similar data as this paper, Dadashova et al. (2021) determine what factors best predict traffic congestion performance measures – travel time index, planning time index, and congested hours. These congestion measures are well established in the literature (Levinson and Lomax 1996; Lyman and Bertini 2008; Memmott and Young 2008; Pu 2011; Choi, Coughlin, and D'Ambrosio 2013; Kong, Jiawen Yang, and Z. Yang 2015). In the list of 32 factors they test, they find that monthly average daily traffic, employment, rental vacancy rate, building permits, fuel prices, and economic conditions are the most significant predictors of these congestion measures. While Dadashova et al. (2021) identifies several significant correlates with congestion, they do not attempt to identify potential congestion solutions.

The last section of relevant literature is work evaluating potential congestion mitigation strategies. While there is work exploring various topics like freight rail (Bryan, Weisbrod, and Martland 2007; Rowangould 2013), active transport (Koska and Rudolph 2017; Wang and Zhou 2017; Hamilton and Wichman 2018), use of autonomous vehicles (Karpilow and Winston 2017; Metz 2018a; Cohen and Cavoli 2019; Gurumurthy, Kockelman, and Simoni 2019; Ramezani and Ye 2019), highway construction (Winston and Langer 2006; Duranton and Turner 2011; Hsu and Zhang 2014), and many economists' oft-preferred strategy – congestion pricing (Evans 1992; Small 1992; Palma and Lindsey 2011; Basso and Jara-Dıaz 2012; Wu et al. 2012; Metz 2018b), work estimating the effect of public transit and congestion is most likely to inform on the role of school bus service expansion because school bus service is similar to public transit. To the best of my knowledge, there is no literature estimating the effect of school transportation or school policy on urban congestion.

There is a theoretically ambiguous effect between building or expanding public transit service and highway congestion. On the one hand, highway congestion may decrease because travelers may change mode from driving to transit because of the availability of better transit service. On

[2] Controlling for age may indirectly control for school-aged population.

the other hand, the relative reduction in highway travel may induce more drivers to travel on previously crowded roads or drive during the peak period offsetting any improvement. Evidence from the US and China finds that transit availability reduces congestion and increases travel speeds. Exploiting a transit shutdown due to a sudden transit worker strike, Anderson (2014) finds that highway delay increases by nearly 50 percent when transit service halts. Examining the opening of six subway lines in Beijing from 2009 to 2015, Jun Yang et al. (2018) find a 15 percent reduction in delay following subway opening. Studying 45 new subway lines over 25 Chinese cities from 2016–2017, Gu et al. (2021) find speeds increase four percent on nearby roads for one year following subways opening. This effect is most pronounced for subway openings near congested roads, and the effect declines with distance to subway lines. Congestion reduction is not limited to subway transit. Bus transit in Melbourne reduces total congestion delay by seven percent in the most-congested downtown areas and three percent throughout the city (Nguyen-Phuoc et al. 2018). This work suggests that expanding bus service in the most-congested areas may be a viable congestion mitigation strategy.

While there is evidence public transit is effective in reducing congestion, its high costs – especially in developed, American urban areas, like New York City where the recent Second Avenue Subway extension cost \$2.5 billion per mile (Rosenthal 2017) – make widespread subway expansion unlikely. Many of the other strategies are not viable solutions because they do not reduce congestion (highway construction), are politically fraught (congestion pricing), are expensive (freight rail) or are years away from widespread adoption (autonomous vehicles). Expanding school bus service may be a viable congestion reduction strategy if it provides the congestion-relief benefits of public transit, but at a lower cost. I will fill this gap in the literature and evaluate the viability of school transportation as an urban congestion remedy.

4 Data, Sample, and Empirical Methods

4.1 Data and Sample

Critical to this project is data on urban congestion, school bus use and transportation spending, and school calendar data.

I use urban congestion data from the National Performance Measurement Research Data Set from the Federal Highway Administration (FHWA 2020). This monthly data includes three congestion measures – travel time index, planning time index, and congested hours – for 51 metropolitan areas for 2012–2020[3]. The measures are created using "vehicle probe-based travel time data" that record average driving time along road segments, called traffic message channels, of the National Highway System twenty-four hours per day. The average traffic message channel is 0.75 miles long and driving time is captured in five-minute intervals. The congestion measures are reported for interstates and principal arterials.

Travel time index (TTI) is the ratio of the peak-period travel time to the free-flow travel time. A TTI value of 1.5 indicates a 30-minute trip during free-flow conditions takes 45 minutes during peak-period travel. Planning time index (PTI) is the ratio of the 95th percentile travel time to the free-flow travel time and is the amount of time a driver should plan for a trip to take, including buffer time, to arrive on time. A PTI value of 1.5 means a driver should plan 45 minutes for a 30-minute free-flow period drive. Congested hours is the number of hours between 6AM and 10PM that travel speeds are less than 90 percent of free-flow speed. TTI and PTI are calculated using travel speeds during the AM (6AM to 9AM) and PM (4PM to 7PM) peak period on weekdays. Congested hours is collected on weekdays from 6AM to 10PM. Congestion metrics are not calculated using weekends.

I use school bus data from two sources: F-33 reports from the National Center for Education Statistics (NCES) and annual survey data from School Bus Fleet (SBF). F-33 data is annual, school district finance survey data and includes revenue and expenditure data by activity. The data includes every school district in the US and is available for academic years 1995 to 2017. Transportation categories include student transportation expenditures, transportation fee revenue from students, and state aid for transportation. School Bus Fleet publishes an annual ranking of the top 100 largest school bus fleets, and reports the percentage of students bused in those top 100 school districts. This data is available for 2010-2019. Between 28 and 40 of the center city school district are recorded in the 100 largest bus fleets each year.

I collect monthly school calendar data for the center city school district for the 51 largest MSAs for 2013-2019. Using academic calendars for those school districts for academic years 2013-2019, I count the number of instructional days per month and record the first and last day of school. I create a measure using this data, *WeekdayPct*, that equals the number of instructional days divided by the number of weekdays in a given month.

[3] The data is only provided at the MSA level and is not available at the city level. This data also includes San Juan, Puerto Rico but I limit my analysis to the continental US.

Following the literature, I also collect annual data on relevant MSA- and city-level characteristics. Data on population, square miles, population density, per-capita income, and unemployment come from the American Community Survey. Data on road stock, including interstate and principal arterial street miles, are calculated using geographic shapefiles from the Federal Highway Administration. I calculate the number of school districts per MSA using geographic shapefiles from the NCES. Data on school district dependency – whether a school district is governed independently from other local governments – from the NCES and Census of Governments. A robust set of controls is most useful in cross-sectional analyses. While a robust set of controls is valuable in a cross-section analysis, in my six-year panel, many of these characteristics vary minimally from year to year and will be captured with a city fixed effect.

I link MSA-level congestion data with data on the center city school district for each MSA because congestion is typically worst in the center city and the center city often has the highest employment, so more people travel in this area every day[4]. The center city school district is also most relevant because congestion is most costly in the center city, so a congestion mitigation plan for this school district would be most beneficial for congestion relief. Simply, eliminating vehicle trips in the center city is likely to reduce congestion more than eliminating vehicle trips in the outerlying suburbs. The geographic mismatch between MSA-level congestion and city-level school districts would only bias any potential effect to zero, assuming that city-level congestion is greater than or equal to congestion in the rest of the MSA.

The sample is the center city of the 51 largest MSAs in the country for 2013-2018. These MSAs cover about 55 percent of total US population and account for about 87 percent of total congestion costs. These are precisely the cities and MSAs that could most benefit from congestion reduction. The sample is a balanced panel for bus spending variables, but only cities in the top 100 bus fleets are in the bus use panel. I will estimate all models with both panels to test whether the results are sensitive to being included in the top 100 bus fleets in a given year. The sample contains 3,672 city-month observations.

4.2 Empirical Strategy

I exploit idiosyncratic variation in the percentage of instructional days per month to obtain credibly causal estimates of the effect of school transportation spending and school bus use on

[4]For example, I use the New York City Department of Education as the school district for the New York-Newark-Jersey City, NY-NJ-PA MSA.

urban congestion. Variation in the percentage of school days in a month comes from a variety of sources. One is that individual state laws govern when schools can begin their school year. States like Virginia, New York, and Wisconsin prohibit districts from beginning a new school year before September (Carloni 2017; DeSilver 2020). Other states have laws about when school must end for the summer. Districts in Maryland, for instance, must end by June 15 (Ujifusa 2020). Thirty-five states leave school calendar decisions entirely to local districts. Of the 51 cities in my sample, ten never have a school day in June and a different ten never have a school day in August.

Different states also have different requirements for the number of instructional days per year. While most states require schools to have 180 days, this is not unanimous. Schools in Colorado are required to have just 160 school days per year, and schools in Kentucky are only required to have 170 days (NCES 2018a).

Instructional days per month also depends on where particular holidays fall on the calendar in a given year. One such holiday is Christmas. In 2014, Christmas falls on the fourth Thursday of the month and many districts, such as Los Angeles, have school for 15 days before beginning winter break. In December 2018, however, when Christmas falls on the fourth Tuesday of the month, students in Los Angeles have just 10 school days that month[5]. Another non-stationary holiday is Easter[6]. During my sample period, Easter occurs as early as March 27 and as late as April 21. Table 3 shows the variation, by month, in percentage of school days per month.

To determine if pupil transportation is a viable congestion mitigation strategy, my key research question is whether busing more students or spending more on transportation per pupil lowers urban congestion. My first hypothesis is that districts that have higher per-pupil transportation spending or bus a higher share of students will have smaller increases in congestion caused by school days. To test this hypothesis, I interact each of the key bus variables with percentage of school days because the hypothesized effect of busing more students or spending more on transportation can only work if school is in session. Busing, on its own, should not have any effect on congestion in a month with no school – when no one rides the bus.

I can interpret the result of the interaction as the causal effect of school bus spending or

[5]While Christmas changes by just two days, the earlier placement in the week allows students to return to school just after New Year's Day the following week, instead of having another weekend as part of winter break. This gives administrators flexibility to give students more vacation prior to Christmas.

[6]Easter occurs the day after the first Paschal/Ecclesiastical full moon each year, which is the first full moon occurring on or after March 21. Surely the phases of the moon are outside the control of school administrators and exogenous to any congestion. [Gregory XIII 1582]

ridership on urban congestion for two key reasons. First is that the exogenous variation in school days guards against the worry that there is endogenous decision making from school administrators related to congestion. Specifically, a district may spend more on school buses in an area with higher congestion, but this only works when school is in session, which is exogenous. Exploiting the random variation of the calendar eliminates this concern. Second is that school bus spending or ridership addresses the worry that any link between school calendar and congestion works through adult commuting choices, because school bus spending can only work through school travel, and not adult's commutes.

While I control for city-level characteristics that are linked with congestion, there may be unobserved differences between cities that are also correlated with congestion. To address this concern, I estimate all models with and without city fixed effects. In models with city fixed effects, the model is identified by within-city variation in transportation spending and percentage of school days.

To further address concern that school days percent is also capturing adults shirking work for the day, I examine the difference between AM and PM congestion. Morning school travel occurs during the AM peak period, but most afternoon school travel happens before the PM peak period. 89.7 percent of city schools begin during the AM peak period (6AM to 9AM), right when office workers are commuting (NCES 2018b). But while office workers typically work an eight-hour day, students are in school, on average, just six-and-a-half hours a day (Voght 2019). This puts afternoon school travel before the PM peak period (4PM to 7PM). My second hypothesis is that the effect of school transportation on congestion will be stronger during the AM peak period. Simply, removing vehicles from the road – one result of busing – will be most beneficial in the morning.

4.3 Estimating Equations

With daily congestion data, the ideal model to estimate is the following:

$$Y_{idmt} = \beta School_{idmt} + \gamma X_{it} + \psi_t + \phi_m + \theta_w + \epsilon_{ist} \tag{1}$$

Where Y_{idmt} is one of the three urban congestion measures – travel time index, planning time index, or congested hours – in city i on day d in month m in year t; $School_{idmt}$ is an indicator variable that takes a value of one if it is a school day in city i on day d in month m in year t; X_{it}

is a vector of city characteristics, including log population, log square miles, log highway miles, school district area, and school enrollment; and ψ are year effects, ϕ are month effects, and θ are day of the week effects. The coefficient of interest, β, is the additional congestion caused by school. I could also define an additional variable, $Holiday_{dmt}$, equal to one if individual dates are holidays so that the effect of $School_{idmt}$ would be identified by days that are not school days but are workdays.

In the absence of daily data, I aggregate Eq.1 to the monthly level and estimate the following equations.

The first equation estimates the link between the percentage of weekdays that are school days on urban congestion. I estimate the following equation, where β is asymptotically equivalent to β in Eq. 1.

$$Y_{imt} = \beta WeekdayPct_{imt} + \gamma X_{it} + \psi_t + \phi_m + \theta_w + \epsilon_{ist} \tag{2}$$

Where $WeekdayPct_{\mathrm{imt}}$ is the percentage of weekdays that are school days in city i in month m in year t; and all other variables are as they were in Eq. 1. β is the additional congestion for a month if there is school 100% of weekdays in a month compared to a month with 0% of days. I estimate this model with and without city fixed effects.

The second equation estimates the effect of school bus spending or school bus ridership on urban congestion.

$$Y_{imt} = \beta_1 BUS_{it} \times WeekdayPct_{imt} + \beta_2 BUS_{it} + \beta_3 WeekdayPct_{imt} + \gamma X_{it} + \psi_t + \phi_m + \theta_w + \epsilon_{ist} \tag{3}$$

Where BUS_{it} is one of two bus measures – transportation spending per pupil or percentage of students bused – in city i in year t; and all other variables are as they were in Eq. 1. β_1 is the variable of interest and is the change in congestion caused by a change in interaction of the bus variable and percent of school days in a month. For example – holding *WeekdayPct* constant – a 1 percentage point change in the bus spending share would cause a $0.01\beta_1$ change in congestion. I estimate this model with and without city fixed effects.

To estimate whether the link between schooldays, school transportation, and congestion depends on time of day, I stratify my sample and estimate all models separately for the AM and PM peak periods.

5 Results

5.1 Descriptive Statistics

The average month in my analytic sample has a TTI of 1.24, a PTI of 2.24, and 5.25 congested hours per day (Table 1). A 30-minute, congestion-free trip takes 37.2 minutes because of congestion and drivers should plan 67 minutes to make that 30-minute trip. There is wide variation in all three congestion measures. For instance, the travel time index ranges from 1.02 – a minimal amount of congestion – in Birmingham in December 2013 to a high of 2.09 – where trips take more than twice as long during peak periods than during free-flow travel – in San Francisco during June 2013. Similarly, planning time index ranges from just 1.22 to 5.49 – in June 2013 in San Francisco, drivers should budget 5.49 times the free-flow travel time to arrive on time 95% of the time. January 2017 in Portland experienced 13.18 congested hours per day, compared with a minimum value of just ten minutes in Birmingham in January 2014.

Importantly, there is variation, by month, in all three congestion measures. The smallest range between minimum and maximum for TTI is 0.53 (in December), for PTI is 2.1 (in July), and for congested hours is 8.89 hours (in September). While the ranges in Table 1 reflect differences within, and between, school districts, Figures 1 shows the variation in monthly congestion (TTI) across years for one city – Los Angeles – to demonstrate within-city variation in congestion. This variation is similar for all cities in the sample.

The PM peak period is worse than the AM peak period on both dimensions of congestion that are measured separately for AM and PM (Table 2). Trips take longer during the PM rush than AM (TTI of 1.28 vs 1.20), drivers should plan for 0.43 times more travel time (PTI of 2.44 vs 2.01).

The average month has school on 68.2 percent of weekdays, ranging from 0 percent in some summer months to 100 percent. This translates to an average of 14.78 school days, with a range from 0 days to a max of 23 (Table 3). Within individual months – excluding July[7], there is wide variation in the percentage of school days per month. Few districts have days in both June and August, so that the range between the min and max is 100 both months. Excluding the summer months, within each month, the range between maximum and minimum is at least 25.48 percent in every month and is as high as 52.38 percent in March and October (with both a 10-day month

[7] Indianapolis (2017) is the only district in the sample that has any school days in July from 2013-2019. It has one school day in July that year.

and a 23-day month). Figure 2 is similar to Figure 1 and shows the variation in percentage of school days in the month across years for one city – Los Angeles – to demonstrate within-city variation in both measures.

The average district spends \$650 on transportation per pupil and buses 48 percent of students (Table 4). As with congestion and school days, there is wide variation in the percent of students bused (6 to 98) and spending per pupil (\$50 to \$2,600).

5.2 Regression Results

Is there more congestion on school days? Is it worse in the AM than the PM?

School travel is linked with a significant amount of congestion in urban areas. Congestion is 0.031 points higher for months with school on all weekdays in a month – about 12.9 percent of total congestion (Table 5, Column 1). To put this into perspective, a one standard deviation decrease in weekday school percent is linked with total congestion 4.2 percent lower. Including city fixed effects, the association between a month full of school days is 38.7 percent larger. TTI is 0.043 points higher – or 17.9 percent of total congestion – for months with school on every weekday. I find similar results for the PTI, but no link between school days and congested hours. This may be because school start time is fixed and students lack travel flexibility.

The link between school days and urban congestion is two to five times stronger during the AM peak period than the PM peak period (Table 6). The effect of a complete school month increases the AM TTI by 0.059 points and the PM TTI by 0.030 points, accounting for 24.6% of total AM congestion and 10.7% of total PM congestion (Columns 1 and 2). The ratio of the AM/PM effect is even stronger for PTI. A month full of school days increases the AM PTI by 0.153 points (15.1% of total) and PM PTI by 0.031 points (2.2% of total).

Does pupil transportation reduce congestion?

Pupil transportation significantly reduces urban congestion. Both higher per-pupil transportation spending and higher bus ridership cause decreases in TTI and PTI.

Busing a higher share of students significantly reduces congestion, with similar results with or without city fixed effects (Table 7). A ten percentage point increase in the share of students bused lowers TTI by 0.0056 points (2.3 percent of total congestion) and PTI by 0.0146 points (1.2 percent of total congestion) with city effects (Columns 2 and 4). The effect is also significant, but modestly smaller, without city effects (Columns 1 and 3).

Higher per-pupil transportation spending also reduces congestion (Table 8). Increasing spending by ten percent (just 65 dollars for the average district) lowers TTI by 0.0021 points (0.88 percent of total congestion) and PTI by 0.006 points (0.50 percent). I find no effect for congested hours for either busing student share or spending per pupil. Examining independent school districts, I find similar results as using the full panel of cities, but with larger magnitudes, suggesting there may be less coordination between independent school districts because busing would yield even larger congestion reductions (Tables 10 and 11). Because the effect of the bus depends on the exogenous variation in the school calendar, the estimate of the interaction remains causal even if there is endogenous school decision making.

Is the effect of transportation on congestion stronger during the AM peak period?

Like school days, the congestion-reducing effect of bus ridership is stronger – both in magnitude and significance – in the AM peak period than in the PM (Table 9). In fact, busing more students has no significant effect on PM congestion. In models with city fixed effects, increasing the share of students bused by ten percentage points reduces AM TTI by 0.009 points (4.5 percent of total congestion – Column 1) and AM PTI by 0.019 points (1.9 percent – Column 3).

There is a modestly larger effect of log per-pupil spending on AM TTI than PM, though the effects are not significantly different from one another. Similar to results not stratified by time of day, increasing spending by ten percent (again, just 65 dollars for the average district) lowers TTI by 0.0022 points in both time periods. Despite a similar effect size, lower baseline congestion in the morning peak period means the reduction is 1.10 percent of total AM congestion, and just 0.68 percent of total PM congestion. The effect of increasing spending by ten percent reduces AM TTI by 0.0051 points and PM TTI by 0.0067 points. Again, these estimates are not significantly different from one another[8]. While the magnitude of the effect estimate is actually larger for PM congestion than AM, again the lower baseline AM congestion results in a larger reduction in congestion – 0.51 percent in the AM and 0.47 percent in the PM. While increases in per-pupil spending reduces AM and PM congestion, there is a larger percentage reduction in the AM.

[8] Because these estimates are farther apart than the TTI estimates, I perform a Wald test for these estimates: $\chi 2 = 1.91$; p = 0.16.

6 Discussion

While school is linked with increased congestion within a city, these results offer evidence that providing school transportation is one lever city officials can pull to lower urban congestion. The results do not suggest, however, whether expanding school transportation is a cost effective solution to congestion. To answer this question, I perform a back-of-the-envelope analysis to determine whether spending more on transportation is worthwhile for all, or any, of the 51 largest MSAs.

If the average MSA increased per-pupil transportation spending by 327 dollars – the difference from the median to the 75th percentile –, they would benefit by about \$18 million (the benefit is about \$56 million and additional transportation spending is about \$38 million). 36 cities would have a net benefit using TTI and per-pupil results, while 20 cities would benefit using PTI and per-pupil results. At the high end, Los Angeles, Washington DC, and San Francisco stand to have a net benefit of \$208 million, \$91 million and \$91 million, respectively (Table 12). On the low end, Las Vegas, Raleigh, and Orlando would lose \$78 million, \$41 million and \$38 million respectively.

Examining which cities benefit the most from expanding spending, I find that, perhaps unsurprisingly, cities with very high congestion benefit the most from expanded transportation. Los Angeles, for instance, has the highest congestion costs – nearly \$20 billion per year – so a small reduction in congestion is very valuable (Figure 3) On the other hand, cities with low total congestion costs, like Birmingham, AL or Rochester, NY, do not receive enough benefit to make expanded busing worthwhile.

Cities with low initial spending also stand to benefit more from additional spending (Figure 4). Big cities, like Los Angeles, San Francisco, and Phoenix, all have low spending per pupil, and are among those that would gain the most. On the other end, cities with high transportation spending shares like Rochester, Buffalo, and Indianapolis, have net losses or smaller benefits than cities with lower current per-pupil spending.

This paper offers the first known credibly causal results of the effect of school transportation on urban congestion. These results offer evidence that pupil transportation policy is a potential lever for urban congestion mitigation. While school districts are unlikely to provide additional transportation on their own, cities would be better off if they subsidized the additional transportation to lower congestion. As congestion costs balloon into the hundreds of billions of dollars

– with no end in sight, pupil transportation policy should be an arrow in the quiver for urban planners in large cities across the country.

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Table 1. Congestion Measures by Month, 2013-2018

	Mean	SD	Min	Max
	Travel Time Index			
January	1.23	0.12	1.03	1.96
February	1.25	0.14	1.03	2.02
March	1.23	0.14	1.03	2.02
April	1.24	0.13	1.02	2.05
May	1.25	0.14	1.03	2.08
June	1.25	0.16	1.03	2.09
July	1.21	0.11	1.02	1.60
August	1.23	0.12	1.03	1.69
September	1.26	0.13	1.03	1.73
October	1.27	0.14	1.02	1.78
November	1.25	0.13	1.03	1.71
December	1.22	0.11	1.02	1.55
Annual	1.24	0.13	1.02	2.09
	Planning Time Index			
January	2.25	0.55	1.25	5.34
February	2.14	0.50	1.28	3.96
March	2.15	0.52	1.25	5.27
April	2.16	0.53	1.27	5.11
May	2.22	0.53	1.32	5.40
June	2.20	0.56	1.30	5.49
July	2.13	0.47	1.35	3.45
August	2.24	0.45	1.30	3.49
September	2.35	0.50	1.29	3.83
October	2.37	0.52	1.28	3.88
November	2.38	0.54	1.30	3.93
December	2.36	0.55	1.22	4.37
Annual	2.24	0.53	1.22	5.49

Table 1-cont. Congestion Measures by Month, 2013-2018

	Mean	SD	Min	Max
	Congested Hours			
January	5.52	2.27	0.18	13.18
February	5.60	2.24	0.26	11.45
March	5.19	2.04	0.25	11.05
April	5.06	1.99	0.28	11.01
May	5.07	1.99	0.27	10.75
June	5.07	2.09	0.28	11.22
July	4.83	1.88	0.25	9.30
August	5.08	1.89	0.25	9.26
September	5.25	1.88	0.29	9.18
October	5.38	1.94	0.24	9.34
November	5.46	1.99	0.22	9.65
December	5.59	2.15	0.16	11.93
Annual	5.25	2.05	0.16	13.18

Table 2. Congestion Measures by Time of Day, 2013-2018

	Mean	SD	Min	Max
	Travel Time Index			
AM	1.20	0.12	1.01	2.28
PM	1.28	0.16	1.02	2.40
Total	1.24	0.15	1.01	2.40
	Planning Time Index			
AM	2.01	0.47	1.16	5.22
PM	2.44	0.63	1.22	6.90
Total	2.23	0.59	1.16	6.90

Table 3. Percentage and Number of School Days by Month, 2013-2018

	Mean	SD	Min	Max
	Percentage of Weekdays in School			
January	83.3	6.1	60.9	95.5
February	89.9	7.3	70.0	100.0
March	84.2	12.8	47.6	100.0
April	85.9	11.0	65.0	100.0
May	90.4	8.6	52.2	95.7
June	28.4	26.4	0.0	90.5
July	0.0	0.3	0.0	4.8
August	33.9	31.3	0.0	100.0
September	91.2	6.8	54.5	95.5
October	91.3	10.2	47.6	100.0
November	79.0	5.3	65.0	90.5
December	64.9	6.9	40.9	77.3
Annual	68.2	33.1	0.0	100.0
	Number of School Days			
January	18.49	1.33	14	21
February	18.15	1.52	14	21
March	18.56	2.88	10	23
April	18.32	2.42	13	22
May	20.11	2.02	12	22
June	6.18	5.65	0	19
July	0.00	0.06	0	1
August	7.14	6.70	0	23
September	19.82	1.50	12	21
October	20.36	2.46	10	23
November	16.60	1.27	13	19
December	14.60	1.54	9	17
Annual	14.78	7.19	0	23

Table 4. Summary Statistics, Key Congestion, Transportation, and MSA-level Variables, 2013-2018

n=3,672	Mean	SD	Min	Max
Monthly				
Travel Time Index	1.24	0.13	1.02	2.09
Planning Time Index	2.24	0.53	1.22	5.49
Congested Hours	5.26	2.06	0.16	13.18
WeekdayPct	68.18	33.06	0.00	100.00
School Days	14.78	7.19	0.00	23.00
Annual				
Bus Students Share	0.48	0.28	0.06	0.98
Transportation Spending Share	0.04	0.02	0.00	0.10
Transportation Spending per Pupil (000)	0.65	0.47	0.05	2.60
Enrollment (000)	117.64	172.46	6.54	995.19
Population (000000)	3.50	3.37	1.08	20.32
Density	734.69	540.41	148.43	2,754.06
Unemployment	0.06	0.02	0.03	0.13
Once				
MSA Square Miles (000)	5.48	4.07	1.45	27.26
School District Square Miles (000)	0.42	1.14	0.02	7.89
Interstate Miles	261.96	138.91	42.44	658.77
Other Road Miles	886.62	693.45	193.20	3,946.30

Table 5. Percent of Weekdays and Congestion, 2013-2018

	(1)	(2)	(3)	(4)	(5)	(6)
	Travel Time Index		Planning Time Index		Congested Hours	
WeekdayPct	0.031***	0.043***	0.028	0.083***	0.188	0.169
	(0.004)	(0.003)	(0.016)	(0.010)	(0.166)	(0.163)
Ln(Enrollment)	-0.003	-0.001	-0.026*	0.155**	-0.158***	-0.214
	(0.002)	(0.006)	(0.012)	(0.050)	(0.023)	(0.513)
Ln(Population)	0.188***	0.637***	0.643***	1.103***	1.157***	15.465***
	(0.010)	(0.078)	(0.040)	(0.236)	(0.162)	(1.862)
Ln(Density)	-0.007		-0.009		0.352**	
	(0.010)		(0.024)		(0.129)	
Ln(Unemployment)	-0.115***		-0.467***		-0.181	
	(0.012)		(0.063)		(0.342)	
Ln(InterstateMiles)	-0.098***		-0.387***		-0.384*	
	(0.008)		(0.028)		(0.164)	
Ln(OtherRoadMiles)	-0.004		-0.013		0.282	
	(0.005)		(0.020)		(0.192)	
Constant	-1.067***	-8.041***	-7.439***	-17.424***	-8.251	-216.191***
	(0.190)	(1.198)	(1.525)	(3.315)	(5.409)	(34.787)
Observations	3,672	3,672	3,672	3,672	3,672	3,672
R-squared	0.580	0.873	0.576	0.831	0.262	0.725
Month Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-Week Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
MSA Fixed Effects		Yes		Yes		Yes

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 6. Instructional Days and Congestion, by Time of Day, 2013-2018

	(1)	(2)	(3)	(4)
	Travel Time Index		Planning Time Index	
	AM	PM	AM	PM
WeekdayPct	0.059***	0.030***	0.153***	0.031*
	(0.005)	(0.004)	(0.010)	(0.014)
Ln(Pupils)	-0.008	0.007	0.162**	0.154**
	(0.006)	(0.011)	(0.057)	(0.052)
Ln(Population)	0.601***	0.656***	1.426***	0.811**
	(0.091)	(0.073)	(0.267)	(0.247)
Constant	-7.431***	-8.419***	-22.109***	-13.270***
	(1.358)	(1.167)	(3.759)	(3.290)
Observations	3,672	3,672	3,672	3,672
R-squared	0.823	0.861	0.790	0.813
Month Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Day-of-Week Fixed Effects	Yes	Yes	Yes	Yes
MSA Fixed Effects	Yes	Yes	Yes	Yes

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Notes: unit of observation is school district-time of day-month-year. All models include the number of times each day of the week is in a month divided by the total number of days in a month.

Table 7. Bus Ridership and Congestion, 2013-2018

	(1)	(2)	(3)	(4)	(5)	(6)
	Travel Time Index		Planning Time Index		Congested Hours	
BusShare×WeekdayPct	-0.050***	-0.056***	-0.113**	-0.146***	0.258	0.201
	(0.010)	(0.011)	(0.031)	(0.033)	(0.208)	(0.224)
BusShare	-0.151***	0.096	-0.543***	0.429**	0.008	1.062
	(0.030)	(0.056)	(0.105)	(0.154)	(0.703)	(1.341)
WeekdayPct	0.064***	0.074***	0.117**	0.166***	0.284*	0.090
	(0.015)	(0.015)	(0.035)	(0.033)	(0.140)	(0.097)
Ln(Enrollment)	-0.017**	0.025	-0.058**	0.180	-0.369**	4.541**
	(0.006)	(0.063)	(0.019)	(0.258)	(0.142)	(1.625)
Ln(Population)	0.106***	0.501***	0.367***	1.526***	1.458***	14.425***
	(0.015)	(0.072)	(0.036)	(0.325)	(0.223)	(3.294)
Ln(Density)	0.017***		0.047		0.370**	
	(0.004)		(0.028)		(0.136)	
Ln(Unemployment)	-0.209***		-0.824***		0.352	
	(0.013)		(0.117)		(0.853)	
Ln(InterstateMiles)	-0.036***		-0.175***		-0.246	
	(0.008)		(0.024)		(0.221)	
Ln(OtherRoadMiles)	0.003		0.013		-0.001	
	(0.013)		(0.040)		(0.229)	
Constant	-0.480	-6.523***	-5.560**	-24.585***	-6.052	-256.603***
	(0.251)	(0.657)	(1.824)	(4.456)	(4.414)	(31.867)
Observations	1,806	1,806	1,806	1,806	1,806	1,806
R-squared	0.606	0.886	0.590	0.839	0.263	0.717
Month Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-Week Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
MSA Fixed Effects		Yes		Yes		Yes

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 8. Log Spending per Pupil and Congestion, 2013-2018

	(1)	(2)	(3)	(4)	(5)	(6)
	Travel Time Index		Planning Time Index		Congested Hours	
Log SpendingPupil × WeekdayPct	-0.020***	-0.021***	-0.059**	-0.060***	0.048	0.038
	(0.005)	(0.004)	(0.015)	(0.013)	(0.080)	(0.063)
Log Spending per Pupil	-0.029***	0.062*	-0.130***	0.206	0.266***	0.392**
	(0.003)	(0.030)	(0.025)	(0.127)	(0.065)	(0.148)
WeekdayPct	0.163***	0.171***	0.416***	0.461***	-0.144	-0.071
	(0.032)	(0.030)	(0.092)	(0.086)	(0.548)	(0.466)
Ln(Enrollment)	-0.013***	0.021**	-0.065***	0.229***	-0.089**	-0.030
	(0.002)	(0.007)	(0.015)	(0.015)	(0.033)	(0.528)
Ln(Population)	0.160***	0.604***	0.530***	0.993***	1.356***	15.177***
	(0.012)	(0.069)	(0.030)	(0.229)	(0.148)	(1.767)
Ln(Density)	0.015		0.078*		0.198*	
	(0.012)		(0.038)		(0.093)	
Ln(Unemployment)	-0.123***		-0.498***		-0.127	
	(0.012)		(0.063)		(0.331)	
Ln(InterstateMiles)	-0.078***		-0.310***		-0.519**	
	(0.009)		(0.026)		(0.137)	
Ln(OtherRoadMiles)	0.006		0.028		0.210	
	(0.005)		(0.020)		(0.198)	
Constant	-0.686**	-8.209***	-5.828***	-17.947***	-11.325*	-216.527***
	(0.205)	(1.130)	(1.338)	(3.126)	(5.220)	(34.479)
Observations	3,672	3,672	3,672	3,672	3,672	3,672
R-squared	0.619	0.876	0.617	0.834	0.270	0.726
Month Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-Week Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
MSA Fixed Effects		Yes		Yes		Yes

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 9. Bus Ridership, Log Spending per Pupil, and Congestion, by Time of Day, 2013-2018

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Travel Time Index		Planning Time Index		Travel Time Index		Planning Time Index	
	AM	PM	AM	PM	AM	PM	AM	PM
BusShare x WeekdayPct	-0.090***	-0.024	-0.191***	-0.095				
	(0.011)	(0.015)	(0.021)	(0.052)				
BusShare	0.065	0.123	0.234	0.585**				
	(0.055)	(0.063)	(0.188)	(0.151)				
Log Spending×WeekdayPct					-0.022***	-0.019**	-0.051**	-0.067***
					(0.004)	(0.005)	(0.013)	(0.016)
Log Spending per Pupil					0.042*	0.079*	0.159	0.243
					(0.020)	(0.039)	(0.094)	(0.157)
WeekdayPct	0.199***	0.146***	0.469***	0.449***	0.110***	0.044**	0.284***	0.068
	(0.024)	(0.036)	(0.084)	(0.102)	(0.017)	(0.014)	(0.030)	(0.042)
Ln(Enrollment)	0.004	0.037**	0.217***	0.242***	0.008	0.043	0.162	0.213
	(0.009)	(0.011)	(0.038)	(0.023)	(0.055)	(0.081)	(0.198)	(0.334)
Ln(Population)	0.584***	0.611***	1.343***	0.679*	0.591***	0.397***	2.201***	0.864
	(0.083)	(0.067)	(0.242)	(0.268)	(0.107)	(0.082)	(0.344)	(0.465)
Constant	-7.580***	-8.601***	-22.529***	-13.868***	-7.564***	-5.252***	-33.678***	-15.735**
	(1.330)	(1.067)	(3.656)	(3.050)	(1.203)	(1.048)	(6.215)	(4.197)
Observations	1,806	1,806	1,806	1,806	3,672	3,672	3,672	3,672
R-squared	0.805	0.882	0.789	0.820	0.826	0.865	0.794	0.816
Month Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-Week Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MSA Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 10. Bus ridership and Congestion, Independent Districts Only, 2013-2018

	(1)	(2)	(3)	(4)	(5)	(6)
	Travel Time Index		Planning Time Index		Congested Hours	
BusShare x WeekdayPct	-0.072***	-0.073***	-0.173***	-0.186***	-0.206	-0.127
	(0.012)	(0.012)	(0.039)	(0.042)	(0.258)	(0.264)
BusShare	-0.208***	0.079	-0.870***	0.390	-1.957	-0.586
	(0.044)	(0.089)	(0.165)	(0.270)	(0.998)	(1.890)
WeekdayPct	0.056*	0.070**	0.073	0.153*	0.171	0.027
	(0.023)	(0.019)	(0.069)	(0.063)	(0.091)	(0.088)
Ln(Enrollment)	0.000	0.030	0.001	0.164	-0.452***	7.245*
	(0.005)	(0.177)	(0.021)	(0.616)	(0.051)	(3.263)
Ln(Population)	0.138***	0.518**	0.442***	1.567	2.218***	14.196**
	(0.016)	(0.183)	(0.055)	(0.948)	(0.520)	(4.785)
Ln(Density)	0.018*		0.026		0.063	
	(0.008)		(0.051)		(0.173)	
Ln(Unemployment)	-0.343***		-1.333***		-1.512	
	(0.015)		(0.136)		(0.954)	
Ln(InterstateMiles)	-0.021*		-0.091*		-0.011	
	(0.010)		(0.036)		(0.240)	
Ln(OtherRoadMiles)	-0.027*		-0.089		-0.784	
	(0.013)		(0.061)		(0.430)	
Constant	-1.352***	-6.830***	-7.843***	-24.711**	-10.512*	-280.592***
	(0.236)	(1.285)	(1.708)	(8.196)	(4.932)	(45.904)
Observations	1,290	1,290	1,290	1,290	1,290	1,290
R-squared	0.671	0.888	0.661	0.837	0.300	0.726
Month Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-Week Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
MSA Fixed Effects		Yes		Yes		Yes

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 11. Log Spending per Pupil and Congestion, Independent Districts Only, 2013-2018

	(1)	(2)	(3)	(4)	(5)	(6)
	Travel Time Index		Planning Time Index		Congested Hours	
Log SpendingPupil x WeekdayPct	-0.033***	-0.031***	-0.105***	-0.100***	-0.028	-0.033
	(0.006)	(0.006)	(0.021)	(0.019)	(0.121)	(0.094)
Log Spending per Pupil	-0.024***	0.087	-0.123***	0.309	0.226*	0.443
	(0.004)	(0.066)	(0.027)	(0.278)	(0.106)	(0.377)
WeekdayPct	0.227***	0.230***	0.651***	0.676***	0.157	0.282
	(0.039)	(0.037)	(0.124)	(0.115)	(0.715)	(0.570)
Ln(Enrollment)	-0.009***	0.034	-0.062**	0.252**	-0.088**	0.008
	(0.002)	(0.025)	(0.016)	(0.063)	(0.026)	(0.561)
Ln(Population)	0.175***	0.630***	0.515***	1.092***	1.498***	22.437***
	(0.010)	(0.063)	(0.027)	(0.254)	(0.297)	(2.171)
Ln(Density)	0.021		0.106*		0.211	
	(0.014)		(0.048)		(0.110)	
Ln(Unemployment)	-0.140***		-0.502***		-0.445	
	(0.012)		(0.068)		(0.410)	
Ln(InterstateMiles)	-0.075***		-0.288***		-0.402***	
	(0.009)		(0.025)		(0.086)	
Ln(OtherRoadMiles)	-0.010*		0.002		-0.128	
	(0.005)		(0.024)		(0.283)	
Constant	-0.902***	-8.852***	-5.517***	-20.196***	-7.231*	-320.948***
	(0.143)	(1.263)	(1.355)	(4.524)	(3.105)	(40.884)
Observations	2,344	2,344	2,344	2,344	2,344	2,344
R-squared	0.596	0.868	0.587	0.820	0.175	0.720
Month Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-Week Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
MSA Fixed Effects		Yes		Yes		Yes

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 12. Back-of-Envelope, Net Benefit from $327 Per-pupil Increase

Rank	City	Congestion Costs	Spending per Pupil	Benefit	Cost	Net
1	Los Angeles CA	19,490	279	415	207	208
2	Washington DC	5,010	1,350	107	16	91
3	San Francisco CA	5,175	94	110	20	91
4	Atlanta GA	4,754	684	101	17	84
5	Phoenix AZ	3,300	368	70	2	68
6	Boston MA	3,829	2,095	82	18	64
7	Detroit MI	3,352	737	71	15	57
8	Seattle WA	3,405	610	73	18	55
9	Dallas-Fort Worth TX	4,511	358	96	52	44
10	San Jose CA	2,577	246	55	10	44
– – –	– – –	– – –	– – –	– – –	– – –	– – –
42	Milwaukee WI	862	856	18	25	-7
43	Salt Lake City UT	612	138	13	23	-10
44	Louisville KY	595	806	13	33	-20
45	Memphis TN	565	247	12	36	-24
46	Charlotte NC	1,015	471	22	48	-27
47	Jacksonville FL	698	435	15	42	-27
48	Tampa FL	1,730	310	37	70	-33
49	Orlando FL	1,275	367	27	66	-38
50	Raleigh NC	546	450	12	52	-41
51	Las Vegas NV	1,377	375	29	107	-78

Note: All dollars in millions, except spending per pupil, which is in dollars.

Figure 1. Travel Time Index by Month and Year, Los Angeles, 2013–2018

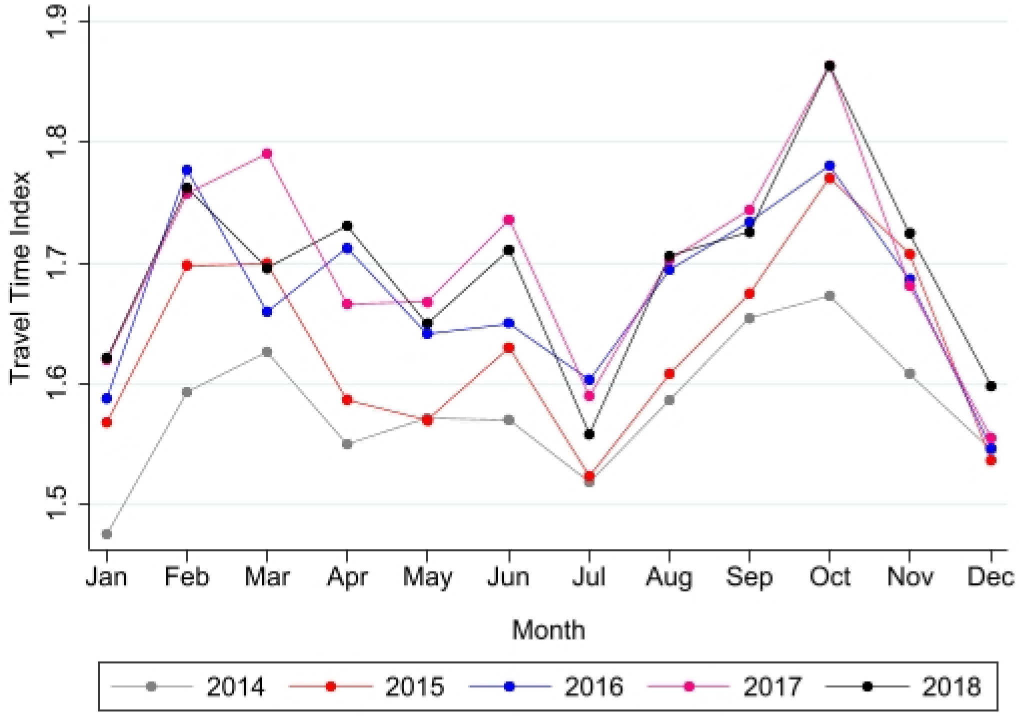


Figure 2. Percentage of Weekdays with School by Month and Year, Los Angeles, 2013–2018

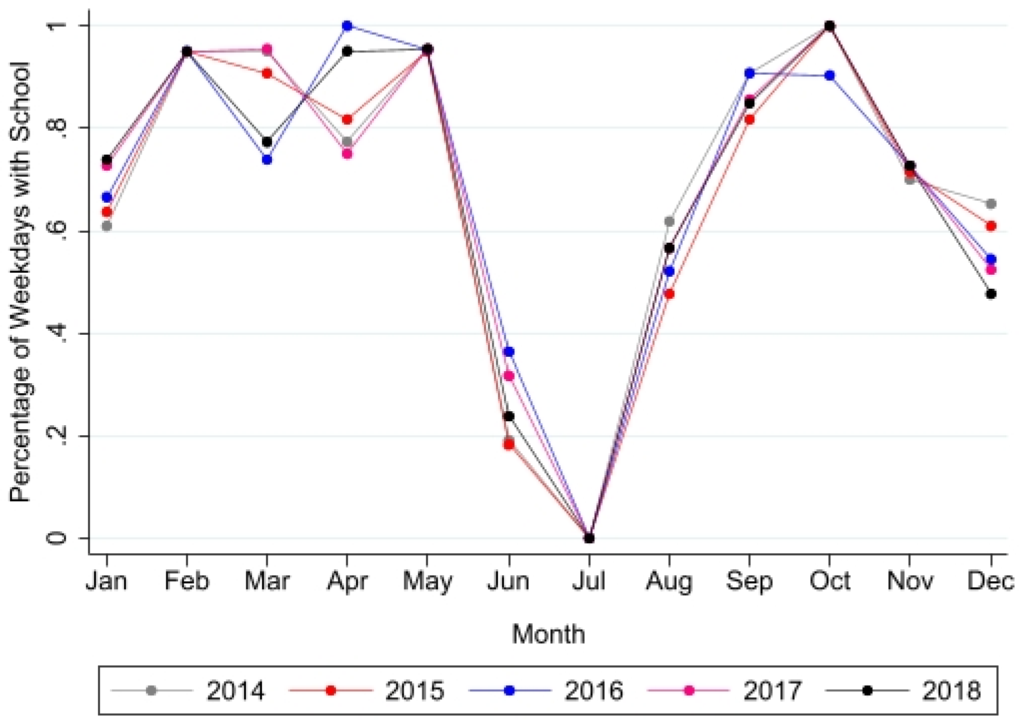


Figure 3. Net TTI Benefit of Add'l Bus Spending by Congestion Costs

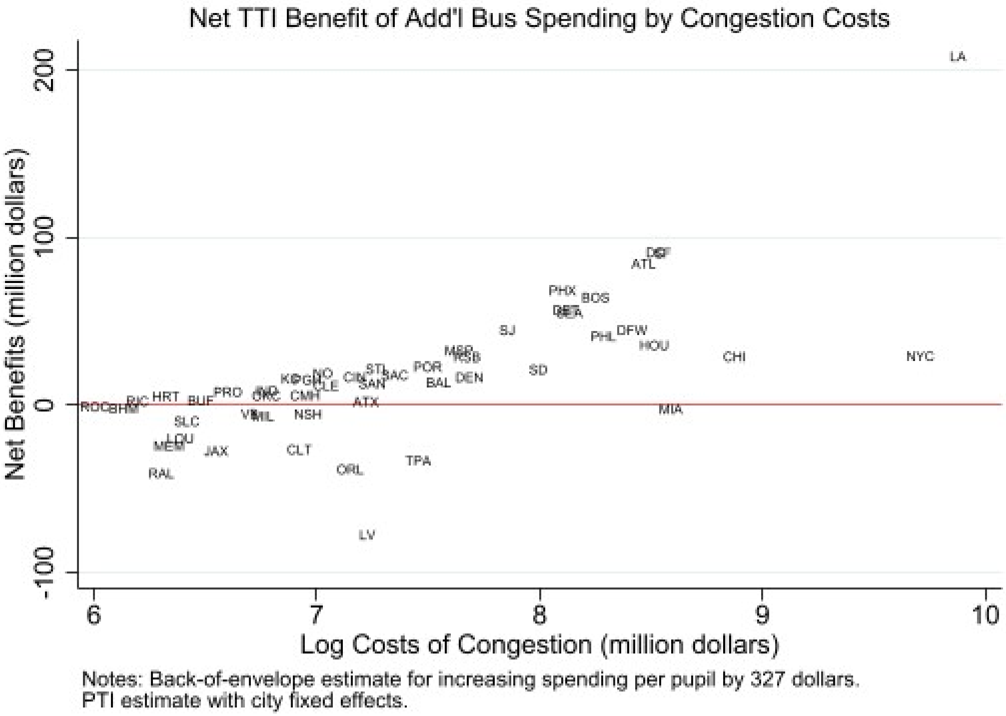
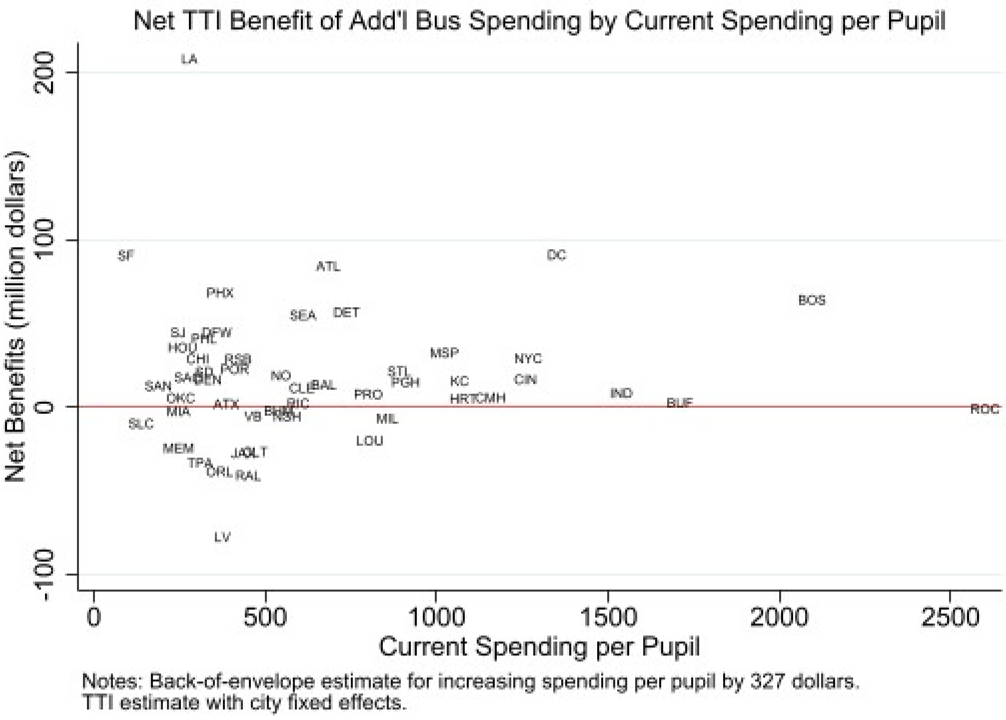


Figure 4. Net TTI Benefit of Add'l Bus Spending by Per-pupil Spending



Appendix Table 1. Back-of-Envelope, Net Benefit from $327 Per-pupil Increase

City	Congestion Costs	Spending per Pupil	Benefit	Cost	Net
Los Angeles CA	19,490	279	415	207	208
Washington DC	5,010	1,350	107	16	91
San Francisco CA	5,175	94	110	20	91
Atlanta GA	4,754	684	101	17	84
Phoenix AZ	3,300	368	70	2	68
Boston MA	3,829	2,095	82	18	64
Detroit MI	3,352	737	71	15	57
Seattle WA	3,405	610	73	18	55
Dallas-Fort Worth TX	4,511	358	96	52	44
San Jose CA	2,577	246	55	10	44
Philadelphia PA	3,967	321	85	44	41
Houston TX	4,982	258	106	71	35
Minneapolis-St. Paul MN	2,078	1,023	44	12	32
New York NY	16,466	1,267	351	322	29
Chicago IL	7,150	302	152	124	29
Riverside-San Bernardino CA	2,154	421	46	17	29
Portland OR	1,806	410	38	16	23
St Louis MO	1,442	892	31	9	21
San Diego CA	2,960	322	63	42	21
New Orleans LA	1,127	546	24	5	19
Sacramento CA	1,557	273	33	15	18
Cincinnati OH	1,301	1,258	28	11	17
Denver CO	2,177	332	46	30	17
Kansas City MO	974	1,068	21	5	16
Pittsburgh PA	1,052	910	22	7	15
Baltimore MD	1,897	671	40	27	13
San Antonio TX	1,407	188	30	17	13
Cleveland OH	1,144	607	24	13	12
Indianapolis IN	876	1,538	19	10	9
Providence RI	736	800	16	8	8
Columbus OH	1,041	1,157	22	16	6
Oklahoma City OK	874	253	19	13	6
Hartford CT	557	1,078	12	7	5
Buffalo NY	652	1,709	14	11	3
Richmond VA	490	596	10	8	2
Austin TX	1,368	386	29	27	2
Rochester NY	405	2,600	9	10	-1
Birmingham AL	461	539	10	12	-2
Miami FL	5,367	247	114	117	-2
Virginia Beach VA	812	464	17	23	-5
Nashville TN	1,055	563	22	28	-5
Milwaukee WI	862	856	18	25	-7
Salt Lake City UT	612	138	13	23	-10
Louisville KY	595	806	13	33	-20
Memphis TN	565	247	12	36	-24
Charlotte NC	1,015	471	22	48	-27
Jacksonville FL	698	435	15	42	-27
Tampa FL	1,730	310	37	70	-33
Orlando FL	1,275	367	27	66	-38
Raleigh NC	546	450	12	52	-41
Las Vegas NV	1,377	375	29	107	-78

Note: All dollars in millions, except spending per pupil, which is in dollars.