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WILL NEW TRANSPORTATION TECHNOLOGIES INCREASE URBAN DENSITY

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ABSTRACT

Will 21st century transportation innovations work against urban density, as the car did in the 20th century, or promote urban centralization, as the railroad did in the 19th century? Reducing the cost of commuting always reduces urban centralization in the classic Alonso-Muth-Mills model but that result reverses if the number of trips is endogenous and the elasticity of trips with respect to their costs is greater than one. That elasticity may have increased over time, as an increasing share of daily trips seems to be discretionary and city centers increasingly provide entertainment. This paper asks discusses the urbanizing effects of four trends in transportation technology: shared mobility (such as Uber), autonomy (such as Waymo), vertical travel and green mobility, as provided by bike lane. As people spend more time travelling in denser, large areas, innovations that reduce the time cost of travel, such as autonomous cars, seem likely to complement urban living, as long as they don't excessively increase traffic. Sharing is also easier in big cities, so technologies that involve sharing are also centripetal. The other trends seem less likely to have major effects. Moreover, the forces of inertia, which include both regulation and legacy infrastructure, are likely to limit the impact of any new technologies in Europe and the U.S., so that the biggest changes in urban form are likely to appear in east Asia and the developing world.

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I. Introduction

How will future transportation technologies change cities? In the 19th century, canals, railroads and streetcars enabled the growth of vast cities that were positioned at key nodes on the transportation network. In the 20th century, the automobile above all, facilitated a massive shift to sprawl (Baum-Snow, 2007),[2] and improvements in inter-urban transportation, like the container ship, led to the decline of erstwhile industrial cities in the U.S. and Europe (Glaeser & Kohlhase, 2004).[3] Will 21st century transportation innovations be centripetal like the 19th century Boulton and Watt steam engine or centrifugal like the 20th century Model T Ford?

In Section II of this essay, I argue that there are both theoretical and empirical reasons to believe that future transportation technologies may lead to more, rather than less, urban concentration even in the West. In a classic Alonso-Muth-Mills model with fixed travel patterns, better transportation flattens the bid-rent curve and leads to sprawl. However, if the number of trips to the city center is a choice variable, not a fixed parameter, and if the elasticity of the number of trips with respect to the cost of a trip is greater than one, then people who live close to the city center will actually "spend" more on mobility than people who live farther away. In this case, improvements in transportation technology will steepen the bid-rent curve and increase urbanization.

Alonso (1964) wrote during a time in which commuting was typically seen as a chore done only by a household's primary breadwinner. If going to work is more discretionary and cities have evolved into playgrounds in which trips downtown represent voluntary forms of consumption (Couture & Handbury, 2020; Glaeser, Kolko, & Saiz, 2001), then it is possible that the elasticity of trips has increased, especially in cities centers.

Using the National Household Travel Surveys and focusing on trips that are less than 100 miles, I document that the share of trips that appear to be fun and discretionary increase from 23.7 percent in 1995 to 28.6 in 2017 to 30.4 percent in 2022. Moreover, the negative relationship between number of trips and both tract-level density and living in a large metropolitan area was negative in 1995 and effectively zero in 2017. In 2017, households in dense tracts traveled shorter distances but they spent more time travelling. Households in the largest metropolitan areas both travelled longer distances and spent far more time making those trips. These facts suggest that technologies that reduce the time cost of travel will benefit both larger metropolitan areas and dense neighborhoods. Technologies that benefit longer-distance trips will help households in larger metropolitan areas and lower density neighborhoods alike.

[2] Heblich, Redding and Sturm (2020) provide evidence on how London's transit system enabled the sprawl of that "modern metropolis."

[3] Those same technologies, however, enabled the rise of East Asian metropolises which benefited from tighter connections to the global trading network.

Section III of this essay discusses four aspects of current and possible transportation technologies: the sharing economy, autonomous vehicle, travel in the skies and eco-friendly travel models. Shared and eco-friendly transportation innovations are most likely to complement urban life, because density makes sharing easier and shorter distances work well with reduced energy use. Travel innovations that rely on matching in a network are centripetal, because urban density supports statistical returns to scale. Vertical technologies create enormous congestion effects because of the risks of inter-air collision, and that makes controlled flight unlikely to be a good fit with urban density. Controlled in-air transport, such as Medellin's gondolas are a far more plausible form of mass transit in poorer-world cities. Autonomous driving particularly reduces the costs of travel time, which suggests it will help in cities where travel times are particularly onerous, but the benefits of such cars could easily backfire if they make congestion worse.

In Section IV, I turn to the forces of inertia, which include the existing stock of structures and infrastructure, and the regulation of both transportation technology and other sectors, such as housing, which impacts the benefits of new technologies. The role of regulation and existing infrastructure suggests that many changes will be felt first in the developing world and middle-income countries, rather than in the regulated, built-up West. Given the power that insiders have already shown in blocking Uber in some parts of Europe, we should not expect to see autonomous taxis proliferating there as they already have in China. Drones are playing an outsized role in making deliveries in Africa, because the existing road network is imperfect and regulatory oversight is limited. It is quite possible that there will be numerous leapfrog events, in which developing places hop over existing technologies, like rail lines, and go straight to newer technologies, such as autonomous trucks on dedicated lanes. Section V concludes.

II. When Do Transportation Improvements Increase Urban Density?

In this section, I discuss an alternative Alonso-Muth-Mills model with an endogenous choice of the number of trips to the city center. In this model, improvements to transportation technology can steepen the relationship between proximity to the city center and to both density and prices, so long as the relationship between the number of trips and the cost of trips is sufficiently elastic. I then discuss how the world diverges from key aspects of the model, and what that could mean for the actual impact of transportation on urban form.

A Modified Alonso-Muth-Mills Model

In this alternative version of the Alonso-Muth-Mills (AMM) model, ex ante identical individuals choose both where to live and how many trips to take to the city center. Everyone consumes one housing unit, and receives welfare:

(1) $Y - P(d) - tdN + B(N)$

where *P(d)* is the price of a housing *d* units from the city center, *t* is the strictly positive cost of transportation, *Y* represents exogenous income, *N* is the endogenous number of trips to the city center, and *B(N)* captures the benefits of these trips. These benefits are meant to include the gains from showing up at work (which would presumably include income that is added to Y) or the amenity advantages of visiting a restaurant or a museum. I assume that B(N) is everywhere concave and continuously differentiable. I also assume that B'(N) > 0 for sufficiently low values of N. Otherwise there would be no travel. While B(N) may be decreasing with N for sufficiently high values of N, consumers would never take that many trips because they will not take trips that generate negative returns. The optimal number of trips, denoted $N^*(td)$, will satisfy $B'(N^*(td)) = td$, which can only be satisfied if N is sufficiently low so that B'(N) > 0.

I follow the AMM model in assuming a spatial equilibrium, so that all individuals receive the same welfare, which I denote $\underline{U}$. The spatial equilibrium assumption and the optimal trip choice assumption together imply:

(1) $P(d, t) = Y - \underline{U} + B\big(N^*(td)\big) - tdN^*(td)$,

where $N^*(td)$, satisfies $B'(N^*(td)) = td$. Differentiating this equation and using the envelope theorem yields $P_d(d, t) = -tN^*(td)$, using the standard convention $f_x(x, y)$ represents the derivative of the function f(.,.) with respect to its argument "x". The derivative of price with respect to distance, $P_d(d, t)$, represents the willingness to pay for proximity to the city center. Perhaps the most famous of all the predictions of the AMM model is that the willingness to pay for proximity falls when transportation costs decline (or $P_{dt}(d, t) < 0$), and that implication would hold here as well if $N^*(td)$ was a constant. Yet the following proposition, which is proven in the Appendix, illustrates how that logic can become reversed if $N^*(td)$ is sufficiently responsive to changes in transportation costs.

Proposition: When B(N) is everywhere twice differentiable and concave in N and B'(N)>0 for sufficiently low levels of N, the land rent becomes steeper when t decreases (or $P_d(d, t)$ increases in absolutely value with t or $P_{dt}(d, t) < 0$), if and only if the elasticity of the optimal number of trips with respect to distance ($-\frac{tdN^{*'}(td)}{N^*(td)}$) is greater than 1.

This result means that lower transportation costs can make access to the central business district more, rather than less, valuable. When people who live close to the central business district travel to the center more than people living on the outskirts, then they benefit far more from further reductions in travel costs. At the extreme, households who live so far from the center that they make no trips experience no benefit from reductions in travel costs. Their willingness to pay for a closer location where they would make trips will always increase when travel costs decline.

To build intuition, I assume that $B(N) = \frac{b_0}{1-\rho} N^{1-\rho}$, with $\rho > 0$.[4] This functional form implies that $N^*(td) = \left(\frac{b_0}{td}\right)^{\frac{1}{\rho}}$, $P(d,t) = Y - \underline{U} + \frac{\rho}{1-\rho} b_0^{\frac{1}{\rho}} (td)^{\frac{\rho-1}{\rho}}$, and $P_d(d,t) = -b_0^{\frac{1}{\rho}} t^{\frac{\rho-1}{\rho}} d^{\frac{-1}{\rho}}$. The derivative of $P_d(d,t)$ with respect to t is $\frac{1-\rho}{\rho}\left(\frac{b_0}{td}\right)^{\frac{1}{\rho}}$, which is positive if and only if $0 < \rho < 1$. When $0 < \rho < 1$, then the function is only modestly concave and the amount of trips taken moves significantly with the cost of trips. In that case, the differences in travel between households close to the center and households far from the center will be large, and further reductions in travel costs will favor more urban households. When $\rho > 1$, the B(.) function is more concave and the differences in travel between households will become smaller. As long as differences in travel behavior are small, then reductions in travel costs will favor the more distant households.

To close the model, we could assume that there is a building technology such that 1 unit of land produces Q units of housing by building up at a cost of C(Q), where C is an increasing and convex function. Consequently, the housing equilibrium will give us that $P(d) = C'(Q)$, and $\frac{dQ}{dd} = \frac{P'(d)}{C''(Q)}$, so that density is a monotonic function of proximity to the city center. If new transportation technologies steepen the bid-rent curve, they will also steepen the relationship between density and distance from the city center.

When the number of trips taken is relatively invariant to either distance or transportation technology, then better transportation technology will produce a flatter relationship between prices and proximity to the city center. But when the number of trips is elastic, then households living near to the city center take more trips, and better transportation technology can increase demand for urban closeness. This result suggests that if cities are increasingly used as optional playgrounds rather than as once-per-day office hubs, then future improvements in intra-urban transportation technology could be an urbanizing force. The direct effect of working-from-home (WFH) is to reduce the demand for proximity to the city center, but if WFH makes future work trips more elastic with respect to cost, then it could also mean that future improvements increase the willingness to pay for central locations.

Urban centers can also benefit more from innovations that reduce the time cost of travel if traffic congestion is sufficiently severe. Personal self-driving cars are one technology that should reduce

[4] This function will be negative when $\rho > 1$, but it will still be increasing, concave and differentiable. In that case, taking zero trips will lead to unboundedly negative welfare but that does not contradict any of our assumptions.

the cost of sitting in traffic. Consider a modified AMM model in which people both commute to the city center and make local trips.[5] If the number of trips is fixed, then the people who live close to the center will spend less time commuting to the center, but they may spend more time on local trips because of congestion. Whichever group spends more total time travelling will benefit more from innovations that reduce the time costs of traveling.

Evidence on the Changing Nature of Trips and Trip Variability

The proposition links the cross-sectional relationship between distance to city center and trips, with the impact that future improvements in transportation technology will have on the demand for urban proximity. We now turn to that cross-sectional relationship, which in the model reflects the concavity of the relationship between trips and welfare. We look at changing travel patterns with the National Household Travel Survey (NHTS), which "is the only source of national data that allows one to analyze trends in personal and household travel" in the U.S (Federal Highway Administration). While our AMM-style model focused on distance to city center as the key measure of urban location, the NHTS allows us to focus on neighborhood density and MSA-size. In the model, neighborhood density is determined by a central location and so those two measures are closely linked.

While the simple monotonic model has two measures of travel intensity, number of trips (N) and total cost of trips (Ntd), the NHTS contains three measures: number of trips, total physical length of trips and total time spent in travel. The number of trips should map between the data and our model, but the cost of travel is presumably some combination of time and length. There are two proxies for urban location in the NHTS: size of the metropolitan area and population density of the block group.

Before turning to the relationship between trips and urban density, we examine the changing nature of trips over three waves of the NHTS. We use the household level files and include all trips that are less than 100 miles in the sample. In all three years, we provide the breakdown of "person trips" per household into five categories: work, shopping, obligations, social and other. Work includes work and other work-related business. Obligations include school, church, medical or other personal business. Social includes both social and recreational travel and visits to friends. The 2017 wave is much larger than the 1995 wave, partially because it includes both phone and online surveys. The 2022 wave is much smaller than either of the other two waves and was done during the COVID pandemic. We will exclude it from our later analysis.

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[5] Consider a two-location model in which N people live in a central location and P-N people live on the periphery. The time costs of commuting are T(P) for the centralized individuals (since everyone commutes to the center) and T(P)+t(P-N) for the people on the periphery. The time costs of local travel are aT(N) for the centrally located and at(P-N) for the peripheral individuals. As long as aT(N) > (1+a)t(P-N), the peripheral individual will spend less time on travel and will benefit less from technologies, like self-driving cars, that reduce the cost of spending time in traffic.

Two obvious trends occur in the data: (1) the number of trips is declining and (2) the share of trips that are social is increasing. Both trips to work and work-related trip dropped substantially between 1995 and 2017, both due to working from home and exiting the labor force. Running errands appears to have declined substantially, which has reduced the share of trips to fulfill obligations. The share of trips that are social increases from 23.7 percent in 1995 to 30.4 percent in 2022, suggesting that this more discretionary category has become more important, which help justify that model's focus on endogenous trip choice. Church-related trips have remained steady, and calling these trips social would have further bolstered the growing share in that category.

Tables 2 and 3 contain information related to the size of the metropolitan area; Tables 4 and 5 focus on the density of the block-group. Tables 2 and 4 look at the 1995 NHTS; Table 3 and 5 report results for the 2017 NHTS. I do not use the 2022 NHTS, because of the issues associated with the pandemic. All regressions control for household size and income and age of the respondent.. In all tables, the first five regressions include the key dependent variable as a continuous variable, which allows me to estimate an elasticity. I transform the discrete categories provided by the NHTS into a continuum by assuming that each household is associated with a metropolitan area size or density level equal to that of its range's midpoint. In the highest density range, we assume that population and density equal 1.5 times the lower limit of the category.

Table 2 shows the connection between trips and size of the metropolitan area. In the first two regressions, we see that in 1995, the elasticity of trips with respect to city population is -.04 and the elasticity of distance with respect to city population is -.03. People in bigger cities spent more time in travel, and have trips that last longer but do not go further distances. Regression (6) shows that the number of trips is significantly higher for people who live in smaller metropolitan areas or rural areas, and significantly lower for people who live in the largest metropolitan areas.

Table 3 shows that the elasticity of the number of trips with respect to metropolitan area size fell to -.009 by 2017, and the distance elasticity fell to zero. The elasticity of time spent in trips with respect to metropolitan area size increased to .08, and the elasticity of average trip time rose to .09. In regression (6), we see that residents of the largest metropolitan areas no longer take significantly fewer trips. They also travel longer distances overall and spend more time in transit. Average trip length and duration is also higher in big cities. Akbar et al. (2023a) and Akbar et al. (2023b) show in India and around the world that big cities are associated with spatial proximity, which should suggest a predominance of shorter-length trips and congestion. This also implies trips that take a long time.

The official 2022 "Summary of Travel Trends" reports changes over time in trips by size of Metropolitan area and confirms this basic pattern of big cities becoming more travel intensive over time (Bricka et al., 2024). In 1983, households in metropolitan areas with more than three million inhabitants made 2,326 trips, which was substantially less than the American average of 2,628 trips. The gap between large metropolitan areas and the nation narrowed, and by 2001, households in these large areas were making slightly more trips than the average household. Big metropolitan area households also made more trips than residents of smaller areas in 2009 and 2017 as well.[6]

We now turn to travel behavior within the metropolitan area. Regressions (1) and (2) in Table 4 show that residential density was negatively associated in 1995 with the number of trips and the total distance traveled.[7] Regression (3) shows that there is no correlation between density and time spent in transportation. Regressions (4) and (5) show that higher density levels were associated with trips that cover less ground but last slightly longer. Regression (6) shows that the negative association between density and the number of trips is driven by the densest block groups. The typical household traveled -.18 log points fewer trips (around 18 percent) in the densest block category. The distance travelled is -.92 log points lower in the densest block category. The time spent in transit is .065 log points higher in the densest block groups.

Regression 1 of Table 5 shows that there is no longer any overall association between density and the number of trips taken in 2017. Regression (2) shows that the connection between density and total miles traveled is still negative, but regression (3) shows an elasticity of time spent traveling with respect to density of .06. Regression (6) confirms that the number of trips is now essentially independent of density. Regressions (7) and (8) show that the negative relationship between total miles traveled and density persists (although it is slightly weaker than in 1995) and there is now a strong positive relationship between density and time spent in transit. Density is still associated with trips that take longer but that feature shorter distances.

These tables do not conform with the simple logic of our adjusted AMM model in which people who are close to the city center face a lower cost of trips and consequently make more trips. The time cost per trip appears to be much higher for people who live in dense areas, even though the distances are much shorter, presumably because of traffic and the high time involved with public transportation.

These results also do not support the view that urbanites make more trips because their costs are lower. Urbanites used to make fewer trips, but now they make the same number of trips as non-urbanites. Moreover, urbanites now spend substantially more time in travel than non-urbanites. Residents of the largest metropolitan areas also travel longer overall distances, but the residents of the densest neighborhoods travel shorter distances.

We take these regressions to imply that technologies that reduce the time cost of moving around congested areas or that make that time more palatable are likely to benefit high density living in big metropolitan areas. Technologies that reduce the costs of traveling significant distances are

[6] In 2022, travel fell, especially in the largest areas, and trips in big areas were slightly lower than in the nation as a whole, presumably because of COVID.
[7] Duranton and Turner (2018) document that the relationship between distance traveled and population density is extremely robust.

more likely to benefit low density areas in larger metropolises. We now turn to a catalog of innovations.

III. New Transportation Technologies

In this section, we discuss four broad features of current transportation innovations: shared use, greenness, verticality and autonomy. Two of these features – joint use and greenness – seem likely to be centripetal. Shared vertical mobility, such as gondolas, are also likely to be urbanizing, and large-scale individual use airborne transportation seems infeasible. The impact of autonomy on demand for urban proximity is particularly unclear.

The Sharing Economy

The car sharing company Zipcar was founded in 2000 in Cambridge, Massachusetts. A decade later, Uber was founded in San Francisco. Both companies enable consumers to share cars and rely on information technology to create trust. The benefits of sharing apps increase with the numbers of cars and users because demand and supply become more predictable. This provides an example of statistical returns to scale and it creates a complementarity between sharing and urban density.

Alfred Marshall introduced statistical returns to scale when he argued that workers benefit from cities because when their employer hits a downturn, another employer in the city may be able to give them a job. A ride app matches someone who wants a ride from point A to point B with a nearby driver willing to make that ride. The law of large numbers means that this match is more likely to occur quickly when the number of riders and drivers are both large.

Mouratidis (2022) reports that the average Uber user in Oslo lives in a denser neighborhood that is on average six kilometers away from the city center, as opposed to 17 kilometers for his entire sample. Alemi et al. (2018) focus on California and also find that "more urban locations are associated with higher adoption of on-demand ride services." Sikder (2019) reports that 83 percent of all households in the National Household Trade Survey were urban, 96 percent of the ride-hailing service users were urban as well. The rise of sharing technologies seems likely to complement urban density.

Waymo and flying taxis are other examples of shared transportation services, but so are better buses, faster forms of rail or airplanes, and even hyperloop systems. Cities are likely to benefit from all forms of transportation with fixed investment costs and significant carrying capacity. Only a place with an abundance of people and firms could afford new types of expensive infrastructure, which is why Elon Musk's 2013 hyperloop proposition focused on travel between

Los Angeles and San Francisco.[8] Large scale inter-city connectors, like hyperloops, are likely to disproportionately benefit more compact, typically older places, with more destinations close to a central station, while Uber is particularly beneficial in more car-oriented and sprawling metropolitan areas.

Autonomous Mobility

The most stunning and certain technological change in transportation is the rise of autonomous vehicles. Waymo is currently providing 250,000 paid trips per week (Kolodny & Elias, 2025), and its Chinese competitor Pony.ai has delivered 28 million miles around the world (Lo, 2025). In Section IV, I will discuss the possibility that regulation will block autonomous cars from most major cities and highways in the US and Europe, but here I discuss the implications for urban density if autonomous vehicles become ubiquitous.

Three major possible uses for autonomous vehicles are shared taxicabs, shared high-speed interurban buses and autonomous personal vehicles. Several papers (Larson & Zhao, 2020; Zakharenko, 2016) focus on the shared use model which is likely to be urbanizing. Both Zakharenko (2016) and Larson and Zhao (2020) emphasize that if shared autonomous cars replace individual passenger cars, then this will reduce the demand for downtown parking spaces, although shifting from Uber to Waymo may have only incremental effects on parking since many Uber drivers live far from the city center.[9] Autonomous buses are shared and consequently also likely to be urbanizing.

Yet the largest impact of autonomous driving will surely occur in the non-shared cars of ordinary drivers. Muller (2025) reports that S & P Global Mobility estimates that there were 3.6 billion ride-hailing trips in 2024 and that number will rise to 15 billion by 2040. By contrast, despite the reduction in the travel due to COVID-19, the National Household Travel Survey (NHTS) reports that the average American household made 1,730 private car trips in 2022 (Bricka et al., 2024), which implies that Americans are currently making 222 billion car trips per year. Advanced new cars already provide drivers with forms of electronic assistance; this will surely continue to expand thereby reducing the effective time cost of driving.

In the standard AMM model, autonomy can be treated as a reduction in "t," the cost per unit distance per trip. As discussed in section II, a fall in t will flatten the bid rent curve and disperse

[8] To adjust the standard AMM model to include an abstract version of shared travel, assume that for some fixed cost, travel costs are reduced from t to θt with $\theta < 1$, and that it can be used only by the people within $\hat{d}$ units of the city center. This will cause a discreet upward jump in the willingness to pay for housing at the $\hat{d}$. After that point, the curve takes the same path as it takes without the innovation. This will lead to more density at all points where $d < \hat{d}$, which means it will be an urbanizing force.

[9] Obi, an app that allows the comparison of prices across different transportation providers, reports that Waymo currently costs about 30 percent more than Uber or Lyft, which may reflect the fact that, according to Tan (2024), Waymo cars cost $100,000. Presumably these costs will decline over time, which will make Waymo trips more competitively priced.

the population, unless the elasticity of the demand for trips is greater than 1. Section II also emphasized that urbanites already spend more time in travel than non-urbanites. As autonomy effectively reduces the time costs of driving, this should be an urbanizing force, especially for high wage workers who want to locate close to city centers (Edlund, Machado, & Sviatschi, 2021). The magnitude of this change depends on the value drivers place on the new activities that autonomy enables, relative to the current driving activities such as talking on the telephone or listening to podcasts.

The benefits of autonomous driving may also be offset by added congestion. As the costs of sitting in traffic will be lower in an autonomous car, more people may be willing to sit in traffic. People who currently drive at off-peak hours may switch to peak hours, which will make things worse for those drivers who were already driving at those times. Boffa, Fedele and Iozzi (2023) argue, the benefits of autonomous vehicles may come from the ability to manage congestion, especially if "operators of fleets of AVs will be able to assign different travelers to different routes, potentially inducing different congestion levels (and speed)." This seems plausible in fleets or if congestion pricing is used in a sophisticated, route-specific fashion, but not if autonomous cars are operated independently or uncharged when traveling congested routes.

While autonomous vehicles are marvels of human ingenuity, they seem unlikely to revolutionize urban life. The most plausible scenario is that these cars will modestly reduce costs of time spent in traffic, which should benefit travelers in dense areas who spend more time in traveling, but some fraction of this benefit will be lost to added congestion. The more that autonomous technology is limited to shared cars, the more likely the technology is to be disproportionately centripetal. The effects seem likely to be largest in the most car-oriented and congested cities, like Los Angeles, and less impactful in European cities that are currently dominated by public transportation and pedestrian travel.

Using the Skies

A third aspect of new transportation technologies is that some of them involve the sky – especially drones and Vertical Take Off and Land (VTOL). In 2016, Holden and Goel (2016) of Uber Elevate published a white paper titled "Fast-Forwarding to a Future of On-Demand Urban Air Transportation," which envisions a largely urban world in which people use VTOL taxis. While Uber Elevate no longer exist, companies such as Joby Aviation (which bought Uber Elevate) and Volocopter continue to develop VTOL technology for use personal transportation. Volocopter conducted a crewed air taxi flight in Seoul in 2021 and is working towards wider implementation.

Cornell, Mahan and Riedel (2023) estimate that there were 875,000 drone deliveries made in 2022, and the number has surely increased since then. Cornell, Mahan and Riedel (2023) estimate that in the first half of 2023, 43% of drone deliveries were in Asia, 32% were in Africa and only 15% were in North America. Drone costs tend to be prohibitively high in the US, because of the Federal Aviation Administration requirements that a drone's driver always see the drone. Cornell et al. (2023) estimate that while it costs $1.90 to deliver a package by truck, it costs $13.50 to deliver the same package by drone. Yu (2025) reports that Meituan made 450,000 drone deliveries between 2017 and 2024 in China. Meituan drops off food in a central kiosk, which makes it a particularly "shared" form of technology. An American company, Zipline, has been using drones to deliver medical supplies to non-urban parts of Africa (Leedom, 2024).

In addition to these independent airborne transportation systems, there are also centrally controlled airborne systems, such as Medellin's Metrocable gondola system, which has been in operation since 2004. Metrocable carried 22.4 million passengers in 2024 (DANE, 2024) and it moves at approximately 10 miles per hour. This system is a particularly natural fit for a hilly city, like Medellin or La Paz, where street grids can be compromised by informal settlements, and cable systems can move significant numbers of people without the challenges of routing thousands of personal airplanes.

Drones, VTOL taxis, and cable cars are shared technologies, and that attribute makes them urbanizing. The other great urbanizing advantage of using the skies is that it can alleviate the burden on crowded streets. VTOL taxis could just be seen as a shared technology that reduces "t" for people with a particularly high opportunity cost of time. However, flying technologies have particularly acute congestion costs, since midair collisions are disastrous, which means that travel costs for flying technologies rises steeply with the number of in-air vehicles. Since drones move goods rather than people, they do not fit so readily into the AMM model, but they also suffer from in-air congestion costs.

Car accidents can be fatal, but airplane collisions seem even more likely to lead to death. Even if drones and VTOL taxis spread to different heights during their flights, they will compete for space during ascent and descent. If even one percent of Los Angeles' four million commuters took to the skies, that would be 40,000 people. If everyone in that 40,000 people group shared a VTOL taxi with only one person, that would mean 20,000 planes in the air during commuting hours, which is more than the total number of planes in the air everywhere in the world in 2026 Managing an independently directed flow of that nature seems almost impossible and quite risky. A centrally directed system seems far more plausible, especially if the fleet contained unmanned drones rather than human beings.

I suspect the humble gondola is far more likely to carry numbers than the VTOL taxi over the next century. In that case, verticality will primarily impact ultra-dense cities of the developing world, although it will be an incremental rather than a radical shift. In the wealthy world, the great 19th century invention, the safety elevator, is likely to remain the most important form of intra-urban vertical transportation long into the 21st century.

The Green Revolution

Cities are investing in bicycle lanes and pedestrianizing former driving areas. By 2024, New York City has 1550 miles of bike lines and it is still adding more (NYC DOT). New York City has made plazas like Times Square more pedestrian friendly and created the High Line. San Francisco has 464 miles of lanes (Anzilotti, 2021). Pedestrianization came to Copenhagen's central thoroughfare in 1962 and has expanded since then. There are also 237 miles of bicycle lanes in Copenhagen (VisitCopenhagen, 2020), which is the third most bike-intensive city in *The European Commission Report of Quality of Life in European Cities* (de Dominicis et al., 2023). Both Rome and Paris have shifted significant amounts of prime urban real estate from driving to walking spaces.

Yet it is less clear whether these changes are accompanied by changes in transit patterns. In the U.S., the share of people who commute by walking or bike dropped significantly from 2019 to 2021. As of 2023, 2.44 percent of workers report walking to work, while .47 percent commute by bicycle— both still being below pre-pandemic levels. The 2020 *European Commission's Report on the Quality of Life in European Cities* reported that 16 percent of European urbanites bicycled on any given day (Bolsi et al., 2020). Although not directly comparable to the US statistic of bicycle commuters that share declined to 14 percent in 2023 (de Dominicis et al., 2023), The 2023 Quality of Life report finds that the share of Europeans who walk in a day is 27 percent.

While these numbers do not show growth, 2023 may have been influenced by the COVID pandemic, and an uptick in biking and walking will occur in future years, partially because of physical changes, like bike lanes, that complement these travel modes. The AMM can capture these changes by allowing for two commuting technologies. The first technology has a fixed cost of "k" and a variable cost of td per trip. The second technology has only a variable cost of ωtd, where $\omega > 1$. This second technology is meant to capture either bicycling or walking. If the number of trips is fixed at 1 or if the fixed cost if per trip (which is appropriate for public transport, but not for cars), then the fixed cost is paid only when $(\omega - 1)td > k$ or $d > k/(\omega - 1)t$. The derivative of willingness to pay with respect to d equals $-\omega t$ if $d < k/(\omega - 1)t$ and -t elsewhere. Consequently, improvements in walking and cycling technology will increase the range of areas where walking and cycling occurs and increase the willingness to pay for space close to the city center.[10] Bicycles are particularly well-suited for compact, middle-density European cities, where they seem most likely to be an urbanizing force.

Reallocating urban space from drivers to walkers disadvantages suburban drivers but enhances the experience of urban pedestrians. Bou Sleiman (2023) examines "the 2016 closure of the Voie Georges Pompidou," and she finds that "closure lowered average speed by over 15% on two sets

[10] If the number of trips are endogenous, k is paid once not per trip, and if $B(N) = \frac{\alpha N^{1-\rho}}{1-\rho}$, then paying the fixed cost is optimal if and only if $\left(1 - \omega^{\frac{\rho-1}{\rho}}\right)\frac{\rho\alpha^{\frac{1}{\rho}}(td)^{\frac{\rho-1}{\rho}}}{1-\rho} > k$. Consequently, the fixed cost technology is paid further from the city if only if $1 > \omega^{\frac{\rho-1}{\rho}}$ or $\rho > 1$. As we have already seen, existing data does not suggest that this condition holds, and so we expect the green technology to dominate closer to the city center even when trips are endogenous.

of substitute roads." The ability to traverse city streets with more speed and safety seems likely to continue to make cities more attractive, which is surely one reason why city leaders are making these investments.

The rise of electric and hybrid cars, however, is unlikely to be particularly urbanizing and will impact many more commuters, especially in the U.S. In the U.S., Edmunds reports that only 1.4% of the stock of cars on the road are electric, but that the share of new car sales that are electric is 7.9% (Montoya, 2025). International energy agency data shows that the share of new cars that are electric is about twice as high in Europe as it is in the United States. Hybrid cars are also extremely common. The relatively short range of electric cars may have made them somewhat urbanizing, but the largest effect of these technologies, especially hybrids, is to reduce the cost per mile of travel, which makes these technologies centripetal.

IV. The Forces of Inertia: Durability and Protection for Insiders

New transportation technologies typically unfold in three stages. First, the technology is invented, such as trains or cars. Second, infrastructure is built to empower this technology, such as rails or paved roads. Third, our living and working spaces are built around the new technology and infrastructure. In this section, I discuss three forces of inertia – durable structures and infrastructure, regulation and lack of state capacity – and how these may impact the path of future transportation technologies and urban change.

Urban space is typically not a tabula rasa, and the existing infrastructure and buildings can limit the amount of adaption. In the 20^{th} century, the automobile offered stunning improvements in mobility, but it was ill suited for cities that had been built around walking and trains. New York City's F.D.R. drive, built by Robert Moses at the dawn of the car era and Boston's much later Big Dig are both examples of shoe horning cars into older cities. Much larger shifts in urban form occurred in new cities, like Atlanta and Phoenix, that grew after the car became ubiquitous. Most of the new technologies, except for hyperloop systems, don't need big infrastructure investments (perhaps by design) and that will make adoption easier. More landing areas could be built for drones and VTOL taxis.[11]

While implementing most of the possible transportation changes might not require much new infrastructure, changing our cities to respond to the new transportation will mean new buildings. As of the week of October 1, 2025, average office occupancy levels were 45 percent below pre-

[11] As discussed above, the largest congestion problem in vertical transport involves ascent and descent. It is conceivable that one could imagine drones flying from enormously high towers that eliminated the need for descent and ascent in the open air. Drones would just go down to the ground is some sort of assembly line. Such a system could eliminate some of the congestion problem with a significant investment in infrastructure.

COVID levels according to Kastle Technology (2025).[12] Yet despite the massive shift in office use, conversion of offices to rentals has been modest. The Rent Café Blog reports that there were 70,000 apartments in the office to apartment conversion pipeline across in the United States in 2025, which is much more than the 23,000 conversions in the pipeline in 2022 (Petrut, 2025). Yet this is a tiny number relative to America's stock of urban apartments. New York City alone has 1.43 million apartments in buildings that are neither condominium nor cooperatives and another 770,000 condominium and cooperative units.

Regulation can also limit technological adoption. While Boston aspires to be a science-friendly metropolis, its politicians have opposed Waymo to protect current cab and Uber drivers. One city councilor has said "My main concern with this technology in Boston — and honestly across the country — is the loss of jobs" (Ali, 2025). Another councilor told a labor rally "The app drivers, the teamsters, 32BJ, UFCW, SEIU, IAM and every single worker fighting to be seen and heard, I see you, I'm with you and I'll fight with you to make sure the future of Boston transportation is equitable and filled with working people at the center" (Wintersmith, 2025). As Mancur Olson argued more than forty years ago, in stable societies, insiders get protection and change gets blocked. Autonomous options that replace human driver ride apps will face more regulatory challenges than autonomous options for private driving.

But not all new technologies will harm insiders. Some pedestrianizations and bike lanes will benefit current residents of a city at the expense of external commuters (Bou Sleiman, 2024). This fact will make them politically attractive to urban politicians even if the net social value is negative. Significant new air travel in cities will annoy many urbanites, and this will push against mass adoption of vertical options.

The final barrier to transportation change is the level of state capacity. California's quest for high speed rail is now decades old, and as of late 2025, the state has completed only 70 miles of rail (California High Speed Rail Authority). By contrast, China has built about 30,000 miles of high-speed rail. For any transportation system that requires public investment, the level of state capacity will determine the level of change. Public-private partnerships (PPPs) might seem to offer a feasible means of building infrastructure in places with weak public capacity, Engel, Fischer and Galetovic (2014) study PPPs and find that they typically work quite poorly in places where the public sector is weak.

Perhaps because of skepticism about America's state capacity, many of the possible new technologies require little public input other than permission. Only the options with large shared infrastructure, like Hyperloop, would seem to be blocked by low state capacity. Pedestrianization requires remarkably little from governments, other than the enforcement of a no drive zone.

[12] Kastle Technology, which provides security related entry technology for high end office buildings, has been measuring the decline in occupancy levels relative to March 4, 2020 in ten major markets.

The challenges of changing physical structures means that most new technologies will have limited impact on European and older America cities. These places will also tend to have the greatest regulatory opposition to technological change, as illustrated by the example of Waymo in Boston. The biggest physical changes to these cities are likely to be bike lanes and more pedestrian zones. Yet the difficulties of building in these core urban areas mean that we are unlikely to see these changes lead to added density nearby.

New technologies will have more impact in growing parts of the world, such as the still-growing sunbelt cities (Glaeser & Gyourko, 2025) and the developing world. These places typically have less fixed structures and infrastructure along with more openness to change. In poorer places, shared technologies, including shared cable cars, are likely to be particularly appealing. Autonomous options, such as Waymo, make less sense in places where labor is inexpensive, and the green options of walking or bicycling will be less appealing in extreme heat.

Asian countries that produce the new technologies are also more likely to allow their use. Non-democracies, such as China, will probably be permissive towards new technology as well. Consequently, we expect to see far larger urban shifts that are associated with the technological change in the cities of the east, especially those in China. Places with stronger state capacity, such as East Asia or some European countries, will be most likely to build new forms of shared infrastructure, such as a Hyperloop.

V. Conclusion

For much of the last 60 years, transportation technology has felt remarkably static. Automobile improvements were incremental. Plane speeds stagnated (Dourado & Kotrous, 2016). Now we are in a moment in which radical change appears possible yet again. It is at least possible that this change will be, unlike the car, urbanizing, but it is also possible that this change will be blocked by considerable barriers to innovation and changing our cityscapes.

This paper modifies the standard AMM model and shows that better transportation technology can actually increase the demand for central locations if the demand for trips is sufficiently elastic with respect to the cost of trips. The substantial increase in the share of social trips between 1995 and 2017 may have made travel demand more elastic, and that increases the possibility that future travel innovations will be urbanizing.

Ultimately, the demand for non-commuting trips depends also on the benefits of those trips, which may also change over time. Twenty-five years ago, Glaeser, Kolko and Saiz (2001) argued that increasingly levels of education and income would generate increased demand for higher-end amenities that are found disproportionately in dense urban areas. Today, competition from computerized entertainment and e-commerce makes it less likely that all cities will continue to thrive by providing shared amenities. Cities with entertainment advantages, such as beautiful historic downtowns and large stock of fun-oriented entrepreneurs, may benefit more from improvements in future transportation technology.

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Appendix: Proof of Proposition

The optimal number of trips, $N^*(td)$, satisfies $N^*(td) = B^{-1}(td)$ and this implies $N^{*\prime}(td) = \frac{1}{B\prime(N^*(td))}$ and long is the inverse function is differentiable, which is in turn implied by the assumed differentiability of the original function (B(N)), and the non-zero value of B'(N), which is guaranteed by the fact that consumers will always choose a value of N that is sufficiently low so that B'(N)>0.

Differentiation of equation (1) with respect to d yields $P_d(d,t) = B'\left(N^*(td)\right)tN^{*\prime}(td) - t^2dN^{*\prime}(td) - tN^*(td) = -tN^*(td)$, which follows from differentiability of B(.) and the envelope theorem. Differentiating $P_d(d,t) = -tN^*(td)$ with respect to t yields $P_{dt}(d,t) = -N^*(td) - tdN^{*'}(td)$ and this is positive if and only if $-\frac{tdN^{*'}(td)}{N^*(td)} > 1$, and $-\frac{tdN^{*'}(td)}{N^*(td)} = -\frac{t\partial N}{N\partial t}$ or the elasticity of trips with respect to the travel costs or the elasticity of trips with respect to distance.

Table 1: Trip Purpose by Year

	1995		2017		2022	
	Average Trips per Household	Share of Total Trips	Average Trips per Household	Share of Total Trips	Average Trips per Household	Share of Total Trips
Work	2.12	20.68%	1.41	18.12%	0.98	19.61%
Shopping	2.08	20.30%	1.55	19.91%	0.94	18.80%
Obligations	3.58	35.02%	2.33	29.79%	1.48	29.62%
Social	2.43	23.72%	2.23	28.60%	1.53	30.43%
Other	0.02	0.29%	0.28	3.58%	0.08	1.54%
Total Households	38,772		116,647		6,102	

Notes: Work is defined as travel to/from work or other work-related business. Obligations are defined as school, church, medical, dental, or other family/personal business. Social is defined as visits to friends/relatives or other social/recreational travel. Other includes alternate responses as well as refused, missing, or absent responses for travel purposes. All data is from the 1995, 2017 and 2022 National Household Travel Surveys.

Table 2: Log MSA Population vs Trips in 1995

VARIABLES	(1) Log Trips	(2) Log Distance (Miles)	(3) Log Duration (Mins)	(4) Log Average Distance (Miles)	(5) Log Average Duration (Mins)	(6) Log Trips	(7) Log Distance (Miles)	(8) Log Duration (Mins)	(9) Log Average Distance (Miles)	(10) Log Average Duration (Mins)
Log MSA Population	-0.0390***	-0.0308***	0.0243***	0.00821	0.0633***					
	(0.00622)	(0.0109)	(0.00820)	(0.00929)	(0.00586)					
MSA Population Categories (Omitted is <250,000 people in MSA)										
250,000-499,999						-0.0611*	-0.0477	-0.0129	0.0134	0.0482
						(0.0345)	(0.0597)	(0.0465)	(0.0496)	(0.0317)
500,000-999,999						-0.0711**	0.0647	0.0455	0.136***	0.117***
						(0.0325)	(0.0524)	(0.0403)	(0.0446)	(0.0289)
1,000,000-2,999,999						-0.0860***	0.0764	0.0760**	0.162***	0.162***
						(0.0284)	(0.0472)	(0.0361)	(0.0399)	(0.0252)
3,000,000 or more						-0.144***	-0.0782*	0.0784**	0.0657*	0.222***
						(0.0264)	(0.0443)	(0.0339)	(0.0382)	(0.0240)
Log Household Size	0.700***	0.664***	0.660***	-0.0362*	-0.0396***	0.700***	0.663***	0.661***	-0.0368*	-0.0396***
	(0.0137)	(0.0251)	(0.0188)	(0.0218)	(0.0141)	(0.0137)	(0.0250)	(0.0188)	(0.0217)	(0.0141)
Log Household Income	0.119***	0.392***	0.142***	0.273***	0.0235**	0.119***	0.392***	0.142***	0.274***	0.0234**
	(0.00987)	(0.0181)	(0.0132)	(0.0161)	(0.00976)	(0.00986)	(0.0180)	(0.0131)	(0.0160)	(0.00974)
Age Categories (Omitted is 25-34 yrs)										
35-54 yrs	0.0811***	0.00750	0.0880***	-0.0736***	0.00689	0.0812***	0.00774	0.0883***	-0.0735***	0.00708
	(0.0173)	(0.0305)	(0.0228)	(0.0259)	(0.0165)	(0.0173)	(0.0304)	(0.0228)	(0.0259)	(0.0165)
55-65 yrs	0.0663***	-0.0558	0.0750***	-0.122***	0.00873	0.0665***	-0.0544	0.0755***	-0.121***	0.00891
	(0.0216)	(0.0383)	(0.0288)	(0.0331)	(0.0207)	(0.0216)	(0.0382)	(0.0288)	(0.0330)	(0.0207)
Observations	**20,374**	**20,374**	**20,374**	**20,374**	**20,374**	**20,374**	**20,374**	**20,374**	**20,374**	**20,374**

Notes: MSA population represents the number of people in the metropolitan statistical area of the household's home location. Households not in an MSA were not considered in this analysis. Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Log MSA Population vs Trips in 2017

VARIABLES	(1) Log Trips	(2) Log Distance (Miles)	(3) Log Duration (Mins)	(4) Log Average Distance (Miles)	(5) Log Average Duration (Mins)	(6) Log Trips	(7) Log Distance (Miles)	(8) Log Duration (Mins)	(9) Log Average Distance (Miles)	(10) Log Average Duration (Mins)
Log MSA Population	-0.00914**	0.000253	0.0814***	0.00939	0.0905***					
	(0.00466)	(0.00840)	(0.00610)	(0.00740)	(0.00472)					
MSA Population Categories (Omitted is <250,000 people in MSA)										
250,000-499,999						0.0227	0.111***	0.100***	0.0883**	0.0773***
						(0.0258)	(0.0431)	(0.0338)	(0.0373)	(0.0253)
500,000-999,999						0.0392*	0.161***	0.159***	0.121***	0.120***
						(0.0220)	(0.0400)	(0.0293)	(0.0349)	(0.0223)
1,000,000-2,999,999						0.0323	0.165***	0.189***	0.133***	0.157***
						(0.0214)	(0.0383)	(0.0283)	(0.0332)	(0.0209)
3,000,000 or more						-0.00943	0.0732**	0.297***	0.0825***	0.307***
						(0.0196)	(0.0364)	(0.0265)	(0.0319)	(0.0199)
Log Household Size	0.672***	0.756***	0.664***	0.0836***	-0.00784	0.672***	0.754***	0.664***	0.0828***	-0.00768
	(0.0102)	(0.0175)	(0.0128)	(0.0158)	(0.0105)	(0.0102)	(0.0174)	(0.0128)	(0.0158)	(0.0105)
Log Household Income	0.0707***	0.272***	0.0499***	0.202***	-0.0207***	0.0713***	0.274***	0.0498***	0.203***	-0.0215***
	(0.00596)	(0.0111)	(0.00778)	(0.00995)	(0.00629)	(0.00595)	(0.0111)	(0.00777)	(0.00995)	(0.00628)
Age Categories (Omitted is 25-34 yrs)										
35-54 yrs	0.0966***	0.0887***	0.0877***	-0.00796	-0.00891	0.0966***	0.0888***	0.0873***	-0.00790	-0.00931
	(0.0143)	(0.0255)	(0.0181)	(0.0226)	(0.0138)	(0.0143)	(0.0254)	(0.0181)	(0.0226)	(0.0137)
55-65 yrs	0.0631***	0.0595**	0.0551***	-0.00370	-0.00795	0.0629***	0.0590**	0.0544***	-0.00393	-0.00845
	(0.0152)	(0.0272)	(0.0190)	(0.0242)	(0.0148)	(0.0152)	(0.0272)	(0.0190)	(0.0242)	(0.0148)
Observations	**56,780**	**56,778**	**56,780**	**56,778**	**56,780**	**56,780**	**56,778**	**56,780**	**56,778**	**56,780**

Notes: MSA population represents the number of people in the metropolitan statistical area of the household's home location. Households not in an MSA were not considered in this analysis. Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Table 4: Log Population Density vs Trips in 1995

VARIABLES	(1) Log Trips	(2) Log Distance (Miles)	(3) Log Duration (Mins)	(4) Log Average Distance (Miles)	(5) Log Average Duration (Mins)	(6) Log Trips	(7) Log Distance (Miles)	(8) Log Duration (Mins)	(9) Log Average Distance (Miles)	(10) Log Average Duration (Mins)
Log Population Density	-0.0115**	-0.124***	-0.00284	-0.112***	0.00868*					
	(0.00465)	(0.00863)	(0.00631)	(0.00747)	(0.00484)					
Population Density Categories (Omitted is <100 people per square mile in block group)										
100-499						-0.0112	0.0490	0.0787	0.0602	0.0899*
						(0.0430)	(0.0746)	(0.0609)	(0.0639)	(0.0504)
500-999						-0.0176	-0.0528	0.0157	-0.0352	0.0333
						(0.0439)	(0.0754)	(0.0630)	(0.0647)	(0.0520)
1,000-1,999						-0.0169	-0.0992	0.0119	-0.0823	0.0289
						(0.0432)	(0.0724)	(0.0605)	(0.0622)	(0.0503)
2,000-3,999						0.0251	-0.170**	0.0132	-0.196***	-0.0119
						(0.0412)	(0.0707)	(0.0586)	(0.0609)	(0.0492)
4,000-9,999						-0.00495	-0.220***	0.0236	-0.215***	0.0285
						(0.0402)	(0.0693)	(0.0573)	(0.0596)	(0.0484)
10,000-24,999						-0.0494	-0.522***	0.0262	-0.472***	0.0756
						(0.0440)	(0.0788)	(0.0628)	(0.0685)	(0.0522)
25,000-999,999						-0.185***	-0.919***	0.0650	-0.734***	0.250***
						(0.0485)	(0.0863)	(0.0656)	(0.0780)	(0.0562)
Log Household Size	0.709***	0.654***	0.666***	-0.0547***	-0.0426***	0.707***	0.647***	0.667***	-0.0600***	-0.0404***
	(0.0132)	(0.0242)	(0.0180)	(0.0212)	(0.0139)	(0.0132)	(0.0240)	(0.0180)	(0.0210)	(0.0138)
Log Household Income	0.104***	0.365***	0.151***	0.261***	0.0473***	0.101***	0.354***	0.152***	0.253***	0.0513***
	(0.00922)	(0.0171)	(0.0124)	(0.0151)	(0.00928)	(0.00929)	(0.0170)	(0.0124)	(0.0150)	(0.00931)
Age Categories (Omitted is 25-34 yrs)										
35-54 yrs	0.0820***	-0.0175	0.0837***	-0.0995***	0.00165	0.0797***	-0.0253	0.0840***	-0.105***	0.00437
	(0.0166)	(0.0293)	(0.0219)	(0.0252)	(0.0162)	(0.0166)	(0.0290)	(0.0219)	(0.0249)	(0.0162)
55-65 yrs	0.0635***	-0.0969***	0.0596**	-0.160***	-0.00387	0.0583***	-0.112***	0.0610**	-0.170***	0.00273
	(0.0208)	(0.0376)	(0.0279)	(0.0325)	(0.0204)	(0.0208)	(0.0373)	(0.0279)	(0.0322)	(0.0203)
Observations	**21,815**	**21,815**	**21,815**	**21,815**	**21,815**	**21,815**	**21,815**	**21,815**	**21,815**	**21,815**

Notes: Population density represents the number of people per square mile in the census block group of the household's home location.
Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Log Population Density vs Trips in 2017

VARIABLES	(1) Log Trips	(2) Log Distance (Miles)	(3) Log Duration (Mins)	(4) Log Average Distance (Miles)	(5) Log Average Duration (Mins)	(6) Log Trips	(7) Log Distance (Miles)	(8) Log Duration (Mins)	(9) Log Average Distance (Miles)	(10) Log Average Duration (Mins)
Log Population Density	0.00274	-0.111***	0.0574***	-0.114***	0.0547***					
	(0.00432)	(0.00761)	(0.00553)	(0.00687)	(0.00439)					
Population Density Categories (Omitted is <100 people per square mile in block group)										
100-499						-0.0127	0.122	0.162*	0.134	0.175**
						(0.0901)	(0.119)	(0.0953)	(0.124)	(0.0861)
500-999						-0.0445	0.0400	0.159*	0.0844	0.204**
						(0.0894)	(0.118)	(0.0942)	(0.123)	(0.0851)
1,000-1,999						-0.0183	-0.0194	0.167*	-0.00106	0.185**
						(0.0885)	(0.116)	(0.0931)	(0.121)	(0.0849)
2,000-3,999						-0.0251	-0.0628	0.169*	-0.0377	0.194**
						(0.0882)	(0.115)	(0.0923)	(0.121)	(0.0841)
4,000-9,999						-0.0216	-0.126	0.210**	-0.105	0.232***
						(0.0880)	(0.115)	(0.0920)	(0.121)	(0.0839)
10,000-24,999						-0.0148	-0.220*	0.366***	-0.205*	0.381***
						(0.0887)	(0.117)	(0.0931)	(0.123)	(0.0849)
25,000-999,999						-0.00797	-0.633***	0.464***	-0.626***	0.472***
						(0.0898)	(0.121)	(0.0945)	(0.125)	(0.0858)
Log Household Size	0.674***	0.715***	0.673***	0.0411***	-0.000416	0.674***	0.703***	0.680***	0.0287*	0.00536
	(0.00997)	(0.0171)	(0.0128)	(0.0154)	(0.0105)	(0.00998)	(0.0172)	(0.0128)	(0.0154)	(0.0105)
Log Household Income	0.0684***	0.274***	0.0727***	0.205***	0.00434	0.0682***	0.277***	0.0713***	0.209***	0.00310
	(0.00573)	(0.0105)	(0.00748)	(0.00939)	(0.00605)	(0.00572)	(0.0105)	(0.00745)	(0.00936)	(0.00605)
Age Categories (Omitted is 25-34 yrs)										
35-54 yrs	0.102***	0.0795***	0.114***	-0.0222	0.0123	0.102***	0.0730***	0.119***	-0.0293	0.0172
	(0.0141)	(0.0248)	(0.0179)	(0.0219)	(0.0138)	(0.0141)	(0.0246)	(0.0178)	(0.0216)	(0.0138)
55-65 yrs	0.0691***	0.00795	0.0804***	-0.0612***	0.0112	0.0698***	-0.00355	0.0885***	-0.0734***	0.0187
	(0.0150)	(0.0266)	(0.0190)	(0.0236)	(0.0151)	(0.0151)	(0.0264)	(0.0191)	(0.0234)	(0.0151)
Observations	**60,764**	**60,762**	**60,764**	**60,762**	**60,764**	**60,764**	**60,762**	**60,764**	**60,762**	**60,764**

Notes: Population density represents the number of people per square mile in the census block group of the household's home location.
Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1