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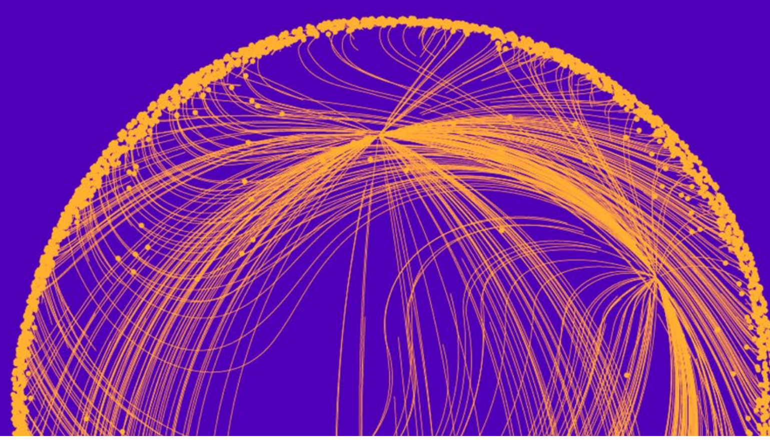

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Mobility, segregation and inequality: Who gains from urban transportation improvements?

Prottoy A. Akbar[*,†] **Victor Couture**[‡]
Aalto University *University of Toronto*

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Abstract

Urban transportation projects are massive public investments that can transform cities. This article reviews how they shape where people live and how they affect the rich and poor differently. Existing empirical evidence and a simple model point to three factors that matter most: who uses the new mode, where it is built, and how easily people can relocate. Projects serving a narrow group in a specific area tend to raise income segregation and inequality. These effects can be severe if poorer households face barriers to relocation, as with the Interstate Highway System. Projects with broad ridership and broad spatial coverage, like Bus Rapid Transit in developing countries, have smaller segregation effects and more widely shared welfare gains.

Key words: urban transportation, segregation, welfare
JEL classification: R41, O18

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[†]Aalto University and Helsinki Graduate School of Economics (email: prottoy.akbar@aalto.fi); https://www.prottoyamanakbar.com/.

[‡]Rotman School of Management, University of Toronto (email: victor.couture@utoronto.ca); https://www.victorcouture.org/.

1. Introduction

Urban transportation investments are some of the largest and most consequential that governments make. They directly affect people by reducing travel times to reach venues, jobs, and friends. These investments also have large indirect effects: new transportation options can reshape cities as people relocate in response to better access, and house prices adjust.

This article studies who benefits from urban transportation improvements, and whether they affect the rich and poor differently. These distributional effects matter because the concentration of poverty and rising welfare inequality have broader societal costs, like reduced upward mobility (Chetty, Hendren, Kline, and Saez, 2014). We first consider how these improvements affect where people choose to live, possibly leading to segregation or gentrification. We then consider the welfare effect of transportation projects, taking their impact on location choices into account. We start by reviewing the empirical literature, then present a simple model to interpret these patterns.

Our review and simple model point to three factors that help policymakers anticipate the distributional consequences of new projects: mode use by income group, the income of residents near planned improvements, and, though harder to measure, how easily people can relocate. For example, these factors help predict that a new bus line in a low-income area will raise the welfare of poor residents, who are more likely to take the bus, and attract more low-income households if relocation is easy.

Across the studies we review, transportation improvements typically increase income (and racial) segregation. These investments allow households to sort based on preferences that often depend on income. For example, the construction of the Interstate Highway System in the United States made suburban areas more attractive to richer (generally White) households, who placed a higher value on time and were better able to afford cars. As a result, highways contributed to the suburbanization of the rich, rising poverty in inner cities, and greater segregation (Weiwu, 2024, Bagagli, 2024, Mahajan, 2024). A number of studies, also in the United States, show that new transit stations tend to raise segregation, for instance because they attract poor riders and concentrate poverty (Glaeser, Kahn, and Rappaport, 2008, Pathak, Wyczalkowski, and Huang, 2017, Heilmann, 2018).

Who uses each mode differs between developed and developing countries, and this difference shapes how transit investments affect segregation. In the United States for instance, poor people rely more on transit, while in many poor countries, richer people use transit more and the poor tend to walk or bike. In our simple model with two travel modes, transit is slow relative to driving, so poor households use it more, and new bus lines concentrate poverty in the low-income neighborhoods they serve. Projects that our model suggests could reduce segregation, such as bus routes that draw low-income residents into wealthier neighborhoods, rarely occur in practice. When richer people also use transit, as in many developing countries, the logic can reverse: new stations can produce gentrification as higher-income riders move into poorer neighborhoods. Transit projects in developing countries may also be more likely to serve affluent areas. The evidence in developing countries is accordingly more mixed. Tsivanidis (2023) and Warnes (2024) find increased segregation following BRT construction in Bogotá and Buenos Aires, as high-income riders congregated in already-affluent areas. Balboni, Bryan, Morten, O'Connor, and Siddiqi (2025) document the opposite in Dar es Salaam, where higher-income residents moved into poorer neighborhoods near new BRT stations. The same theoretical framework can rationalize both patterns: what matters is who uses the mode, where the improvement is built, and how easily people can relocate.[1]

Turning to welfare, the evidence is more nuanced. Recent work in quantitative spatial economics measures the full welfare effects of transportation improvements by income group, accounting for how households relocate within the city. This allows welfare and segregation to be studied jointly. Two main patterns emerge. First, welfare studies of Bus Rapid Transit systems in developing countries - Tsivanidis (2023) in Bogotá and Warnes (2024) in Buenos Aires - find broadly shared gains across the income distribution. These results reflect that BRT is widely used by both rich and poor people and typically serves diverse areas of the city. Second, studies of the Interstate Highway System in the United States (Weiwu, 2024, Bagagli, 2024) find that highways benefited richer and White households while harming poorer and Black households. Highways were more valuable to car owners and sped travel in suburban areas where richer households lived. For poorer urban residents, they created disamenities by cutting through their neighborhoods.

Our model highlights the role of residential mobility in generating a trade-off between these welfare gains and segregation. When transportation modes are expanded in areas where their primary users are concentrated, as is often the case in practice, easier relocation increases income segregation, but also allows more households to move in to capture the benefits from improved access (or to move out if they rarely use that mode and want to avoid associated house price increases).

Finally, recent research also illustrates how the political process, through land-use restrictions, can amplify segregation and limit the benefits of transportation investments. These barriers work by preventing people from relocating to new opportunities or by blocking housing construction near improved transit. For instance, New York's 1916 zoning law reinforced segregation after subway expansion by reserving wealthy areas for single-family homes while allowing multi-family housing and industrial uses in poorer ones (Lee, 2022). Redlining in the 1960s prevented Black residents from leaving neighborhoods cut through by U.S. highways (Weiwu, 2024). Land use restrictions in Bogotá during the 2000s likely

[1]Empirically, the determinants of urban travel speed (road infrastructure, city size, congestion) also operate similarly in both developed and developing countries (Akbar, Couture, Duranton, and Storeygard, 2023).

blocked new housing near Bus Rapid Transit stations (Tsivanidis, 2023). These examples suggest that complementary policies, like relaxing zoning or subsidizing construction near new stations, could mitigate the segregation effects of transportation investments and broaden their welfare gains.

Overall, both theory and evidence suggest that the impact of transportation investments on segregation and welfare inequality depends primarily on who uses them and where they are placed. Projects that serve a broad range of income groups and areas tend to have smaller effects on segregation and more balanced welfare gains. Investments that are disproportionally used by one group and target specific areas are more likely to increase both segregation and inequality.

2. Empirical evidence

This section reviews the existing empirical literature on how urban transportation investments affect the location choices and welfare of higher- and lower-income residents. We first discuss evidence on spatial segregation, i.e., on whether income groups concentrate in different areas of the city after a transportation improvement. We show that transportation improvement typically raise segregation.[2] Segregation matters not only in its own right but also because it shapes the welfare effects of transportation projects. As people adjust their residential choice in response, housing prices and other amenities also adjust, which alters the gains from the project. We review recent work that studies segregation and welfare jointly, using quantitative spatial models that account for changes in location choices. We find that for projects serving a broad range of people across diverse areas, the benefits tend to be shared widely. Projects that target specific groups and locations tend to increase inequality.

2.1 Location choice of the rich and poor

Who benefits from a new transportation improvement, or relocates in response to it, depends in part on who is most likely to use it. For example, a new bus stop in the United States is unlikely to directly benefit richer households if they rarely use buses. Table 1 reports modal shares from household travel surveys in three metropolitan areas. For Atlanta and New York City, the data come from the 2017 National Household Travel Survey and compare people

[2] While our focus is on segregation, we also consider a related process, gentrification, defined here as higher-income households moving into lower-income neighborhoods. There is no agreed-upon definition of gentrification. Most often, it refers to richer households moving into poorer neighborhoods, which can reduce segregation locally, at least initially. A broader definition, such as rising house prices or rising share of college-educated residents in a neighborhood, may coincide with either rising or declining segregation. For instance, Couture and Handbury (2023) find that rising college shares in downtowns with initially low education levels led to more segregation, as college-educated residents clustered together.

below and above median household income ($75,000). For Buenos Aires, the data come from a 2010 mobility survey reported in Warnes (2024) for high- and low-skill people, where low skill is defined as having no post-secondary education. Each row of the table reports the share of all trips taken by survey respondents during the survey period by one of five modes: car (includes motorcycles), bus, subway, train, walking & bicycling, and others. Appendix A describes this data in more detail.

Table 1: Mode Share by City and Income Group (%)

	Atlanta		New York		Buenos Aires	
Mode	Low income	High income	Low income	High income	Low skilled	High skilled
Car/Motorcycle	86.8	87.2	49.1	64.9	18.6	26.6
Bus	3.3	0.9	7.2	2.2	37.1	39.3
Subway	0.6	0.9	9.2	7.7	4.4	14.5
Walking/Bicycle	8.0	9.9	33.0	22.4	38.1	16.3
Other	1.3	1.2	1.6	2.8	1.8	3.2

Notes: Columns 1-4 use data from the National Household Travel Survey 2017 to report the shares of trips by different transportation modes in the Atlanta and the New York metropolitan area, for households with income above and below $75,000. Columns 5 and 6 instead use data from the 2010 "Encuesta de Movilidad Domiciliaria" for the Metropolitan region of Buenos Aires for people with and without a post-secondary education, as reported by Warnes (2024). All columns show shares for adults aged 18 and over.

In the United States, a rich country, bus use is higher among lower-income residents. In Argentina, a poorer country where the lowest-income urban residents often walk or bike, bus ridership is more evenly distributed.[3] In all three cities in Table 1, subways have relatively more high-income riders than buses. Given these patterns, Akbar (2024*a*) classifies transit into two categories: "slow transit," mainly buses with a poorer user base, and "fast transit," including subways, trains, and Bus Rapid Transit (BRT), which tend to have more mixed ridership.

In all three cities in Table 1, car use is more prevalent among higher-income households, reflecting the costs of purchase and maintenance. In developing countries poorer residents may still rely on highways using low-cost motorcycles. There are also notable differences within a country. In a car-oriented city like Atlanta, car use accounts for more than 85 percent of trips for both high- and low-income people. By contrast, in New York City car use is lower overall, and the gap between income groups is larger, with higher-income households more likely to drive.

We do not emphasize walking and cycling in the paper, even though creating walking paths and bike lanes is an increasingly common policy objectives. In Atlanta, the combined

[3]The single-digit bus shares in both Atlanta and New York reflect not only the limited use of public transit in the United States, but how we split the data at the median rather than focus on the poorest households. The American Community Survey Briefs report that in 2017, median income in New York and Atlanta MSA were $75,368 and $65,381, `https://www.census.gov/content/dam/Census/library/publications/2018/acs/acsbr17-01.pdf`, retrieved on September 22^{nd} 2025. So using the 2017 NHTS brackets, "below median" most closely correspond to household incomes under $75,000.

share of walkers and cyclists is similar across income groups, while in New York City and Buenos Aires it is higher among low-income residents. In the Appendix, Table A.2 presents additional evidence for the cities of Atlanta and New York (as opposed to their metropolitan areas), focusing on commute trips only, as well as alternative data on commute mode shares from the Census Transportation Planning Products (CTPP).[4] Within city boundaries and for commute trips, walking and cycling shares no longer differ much by income in Atlanta and New York, so it is less clear whether the two are really more common among poorer households in high-income countries. In low-income countries, walking and cycling are almost certainly more prevalent among poorer residents.

Highways Existing evidence on how highway construction affects the location choices of higher- and lower-income residents comes from the United States, in particular the construction of the Interstate Highway System (IHS). Car usage is now broad-based in the United States: in 2023, 70% of households in the lowest income quintile owned at least one car. This was less the case in the 1950s and 1960s when the Interstate Highway System (IHS) was built.[5] So the lessons from that era remain relevant for developing countries where major highway investments are currently being planned or implemented. Studies by Bagagli (2024) on Chicago and by Weiwu (2024) and Mahajan (2024) on U.S. metropolitan areas, find that the IHS increased Black–White segregation. This effect operated through three distinct mechanisms, the first two of which are more specific to highways and the political context in which they were built. First, highways often acted as physical barriers between neighborhoods, reinforcing existing racial boundaries. Bagagli (2024) shows that highways in Chicago were deliberately routed along the boundaries between Black and White neighborhoods.[6] Second, highways created disamenities in dense urban areas, where the costs to nearby residents (noise, pollution, destroyed housing) often outweighed the access benefits (Brinkman and Lin, 2024). Valenzuela-Casasempere (2025) documents how local governments built urban highways disproportionately targeting Black neighborhoods, even though the 1947 federal plan did not have a racial bent after controlling for poverty. These routing decisions worsened living conditions in already disadvantaged areas, accelerating White flight to the suburbs. Black residents often lacked the means or legal ability to relocate (Weiwu, 2024), which further raised segregation and the concentration of poverty.

[4]The city only vs whole metropolitan area comparison highlights variation in mode use within metropolitan areas (with transit and walking more prevalent in the city than in the suburbs). The comparison between two different surveys (NHTS and CTPP) highlights the difficulty of measuring mode shares consistently.

[5]Bureau of Transportation Statistics, `https://data.bts.gov/stories/s/Transportation-Cost-Burden-Transportation-Spending/v67s-yiqd/` retrieved on August 10th 2025.

[6]Transportation infrastructure acting as physical barriers between neighborhoods is not unique to highways. Ananat (2011) shows that 19th-century railroads subdivided cities into physically separated areas, which raised racial segregation after the Great Migration. Chyn, Haggag, and Stuart (2023) show that railroad-induced segregation reduced intergenerational mobility for Black children.

Finally, the IHS also contributed to segregation through a more general mechanism that applies across transportation modes: the placement of infrastructure and differences in mode usage. Cars were more commonly used by richer, often White, individuals. Highways disproportionately improved access to suburban areas, encouraging the affluent to move further out. So in the case of the IHS, the two main channels that shape where people relocate, who uses the mode and where the infrastructure is placed, aligned in a way that increased segregation.

Transit Turning to how transit improvements affect location choices, Glaeser *et al.* (2008) find that poverty rates increased within one mile of newly built rail stations in 16 large U.S. metropolitan areas, using data from 1980 to 2000.[7] Pathak *et al.* (2017) study Atlanta from 1970 to 2010 and also find that census tracts gaining bus stops between 1970 and 1990 became poorer in the long run. Heilmann's (2018) study of a suburban light rail line in Dallas in the early 2000s finds that poorer neighborhoods receiving the line became poorer still, while richer neighborhoods that received a line became richer. One possible explanation is that poorer residents who previously needed to live in higher-income neighborhoods to access transit could relocate to poorer neighborhoods that gained access. In car-oriented cities like Atlanta and Dallas, transit is used primarily by poorer residents, so transit expansions tend to concentrate poverty and raise segregation.

Subways, in contrast, are typically faster than buses and attract a broader share of higher-income riders.[8] They are also more expensive to build. Lee (2022) shows that in early 20th-century New York, subway construction increased income segregation, and the city's 1916 zoning law exacerbated this segregation by assigning single family zoning to wealthy, White areas while permitting multi-family and industrial uses in lower-income, minority areas. As with the Interstate Highway System, this subway network gave local policymakers an opportunity to amplify segregation.

Recent studies of bus rapid transit (BRT) systems in developing countries also find that they can increase segregation. In Buenos Aires, Warnes (2024) finds that the BRT built in the 2010s led high-skilled residents to concentrate in already-affluent areas that gained better access, while their share in the poorest neighborhoods declined. Similarly, Tsivanidis (2023) finds that Bogotá's BRT, opened in 2000, drew high-skilled residents into neighborhoods with better market access, increasing residential segregation.[9] But BRT can also work in the opposite direction. In Dar es Salaam, Balboni *et al.* (2025) find that higher-income

[7] The one-mile radius makes these stations accessible on foot for poorer residents without cars. Kahn (2007) distinguishes between "Walk and Ride" stations in denser, more walkable neighborhoods and "Park and Ride" stations near parking facilities. He finds stronger signs of gentrification (rising house prices and college share) around Walk and Ride stations.

[8] For example, Akbar (2024*b*) finds that in cities with fast transit networks, higher-income commuters are more likely to sort into the most transit-accessible residential locations.

[9] The segregation result appears in an earlier working paper version of this article.

residents moved into poorer neighborhoods near new BRT stations, which could suggest gentrification. Liang, Huang, Yip, and Li (2022) document a similar pattern in Hong Kong, where new rail lines attracted higher-educated residents into lower-income areas. In all cases, higher-income people were more likely to relocate, either because of greater willingness or ability to move.

Gentrification Gentrification occurs when richer households move into poorer neighborhoods, raising house prices and potentially hurting local residents. It can either reduce or increase segregation, depending on the share of rich people moving in and that of poor people leaving. In the next section, our model illustrates conditions under which transportation projects drive gentrification. A key empirical issue is whether poorer residents are displaced or simply replaced as they eventually move out. Displaced residents would bear moving costs without gaining from improved access. The broader gentrification literature, however, finds little evidence of displacement.[10] The transportation evidence is similar. Warnes (2024) in Buenos Aires and Balboni *et al.* (2025) in Dar es Salaam both track individuals over time following BRT installation. Neither finds that BRT raised the rate at which residents moved out. In Dar es Salaam, however, newcomers were higher-income than leavers, and renters near stations faced substantial rent increases. So even without displacement, gentrification likely imposed costs on incumbent renters.

Overall, the studies we reviewed find that transportation improvements tend to raise segregation. Evidence from different periods, modes, cities, and countries points to similar patterns. New infrastructure makes some areas more or less desirable depending on preferences for access and ability to pay, which often vary by income. This leads to residential resorting. These effects are strongest when political decisions take advantage of sorting responses to deliberately reinforce segregation, as happened during the construction of the Interstate Highway System and the New York City subway. We do not interpret these results to mean that segregation is an inevitable outcome. The evidence is consistent with households responding to transportation improvements in ways that reflect their income and the location of the new infrastructure. So in principle, segregation could have declined if the Interstate Highway System had instead destroyed affluent neighborhoods and improved access primarily in poorer areas. Our model in the next section illustrates this possibility.[11]

[10] In the United States, gentrification operates more through replacement than displacement (Ellen and O'Regan, 2011). That is, low-income residents of gentrifying neighborhoods are generally no more likely to move than low-income residents of non-gentrifying neighborhoods. Beauregard (2024) also finds no evidence of displacement from gentrifying neighborhoods in Canada. Establishing the causal effect of transit-oriented development on low-income displacement remains difficult (Padeiro, Louro, and da Costa, 2019).

[11] Our model implies that a sufficiently large improvement in travel time always raises segregation, as richer households concentrate where access is best. A large highway project may be one such case.

2.2 *Welfare impact on the rich and poor*

Over the past decade, quantitative spatial models with detailed urban geography have become widely used. Building on Ahlfeldt, Redding, Sturm, and Wolf (2015), these models account for travel costs, amenities, and endogenous location choice. They are especially useful for measuring welfare gains from infrastructure investments (see Redding, 2025, for a review). Recent extensions with non-homothetic utility (Tsivanidis, 2023) allow researchers to study both how location choice and welfare vary across income groups. In the next section, we present a simplified two-neighborhood version of such a model.

Weiwu (2024) applies this class of model to study the impact of the Interstate Highway System (IHS) on racial segregation and welfare. She finds that the IHS sharply raised welfare inequality. Highways were primarily used by richer, often White individuals, and improved access in areas where they lived, which raised welfare by almost 3% for White residents but reduced it by about 1% for Black residents. Features of the IHS that reinforced segregation also amplified its impact on inequality. Highways created disamenities by destroying parts of neighborhoods (often majority-Black) and leaving behind physical barriers and environmental degradation. Many Black residents could not move away from affected neighborhoods because of redlining, which accounts for much of their welfare losses.

In contrast, studies of Bus Rapid Transit (BRT) in developing countries find more equal welfare effects. Tsivanidis (2023) finds that both rich and poor residents of Bogotá benefited from the new BRT, with the rich gaining only slightly more. Low-skill individuals benefit mainly through increased BRT use, while high-skill individuals benefit through improved job access. Only 54% of total welfare gains come from travel time savings; the rest arise from equilibrium effects through location changes. Tsivanidis (2023) also finds that housing supply did not rise near transit stations following BRT construction, another example of zoning and the political process affecting location choice and welfare following a transportation improvement. Targeting more housing near BRT stations would have increased total welfare gains by 44% by allowing more people to relocate closer to stations. Where new housing cannot be built near stations, more of the gains from better access go to landowners through higher land prices, rather than to residents.

Warnes (2024), using a dynamic spatial model that tracks intra-city migration in Buenos Aires, finds that a new BRT system generated similar welfare gains of about 1% for high- and low-skilled incumbent residents living near the lines, and 0.6% over the entire city. This aggregate similarity hides substantial spatial variation: residents of the city's poorest neighborhoods (both high- and low-skill) saw net welfare gains more than twice as large as those in the richest areas. Once again, these spatial welfare patterns are tied to resorting. Specifically, the new BRT drove housing prices up in richer neighborhoods where the rich concentrated, which reduced the net gains for incumbents there. Different station placement would have produced different welfare outcomes, but when stations are evenly distributed across rich and poor neighborhoods and use is broad-based, welfare gains tend to be broadly shared.

Overall, existing evidence on the welfare and inequality impacts of transportation improvements is mixed. Studies of BRT systems in developing countries suggest that when usage is relatively broad, investments are unlikely to affect welfare inequality much, provided stations do not overwhelmingly favor one group and people can move. The Interstate Highway System, by contrast, had special features that raised inequality: highways were often routed through Black neighborhoods where living nearby is a disamenity, and redlining prevented Black residents from relocating. Land-use barriers can further limit the gains from transportation improvements, not only by preventing people from moving, but by preventing new housing from being built near improved transit. In all these cases, how easily households can relocate shapes whether the benefits of a project are broadly shared or concentrated among those already well-placed to gain.

3. Model

This section presents a model of travel mode and residential location choices, following the framework of Akbar (2024*a*). The model illustrates the types of underlying preferences that may drive the changes in location choice and welfare documented above. As in quantitative spatial models, households have idiosyncratic preferences for neighborhoods, but here we simplify by considering only two neighborhoods.

3.1 Setup

We model a closed city with two modes of travel, $m \in \{d, t\}$, two residential neighborhoods, $n \in \{1, 2\}$, and measure 1 of households of one of two types ($g \in \{L, H\}$): Λ households of type L and $(1 - \Lambda)$ households of type H. Household types differ in their incomes w_g and, consequently, in their value of travel time savings $\beta_g > 0$. Assume, without loss of generality, that $w_H > w_L$ and $\beta_H > \beta_L$. Additionally, each household i has an idiosyncratic preference ξ_{in} for residing in neighborhood n. Besides these idiosyncratic differences, neighborhoods also differ systematically in their (mode-specific) travel times to the city center τ_n^m and their housing prices p_n.[12]

[12]Without loss of generality, we can replace "city center" with a different destination or a set of destinations and re-interpret τ_n^m as an aggregation of travel times to these destinations from neighborhood n using mode m. In Appendix B, we allow neighborhoods to also differ on other local amenities that may change endogenously with travel times.

3.1.1 *Travel costs and travel mode choices*

Each household faces a continuum of trips to the city center. For each trip, the household chooses to either drive ($m = d$) or ride transit ($m = t$) to minimize the following travel cost function:

$$\tilde{C}_{gn}(m) \equiv \beta_g \cdot \tau_n^m + \kappa^m - \gamma \cdot \mathbb{I}[m = d] \tag{1}$$

which is the sum of the household's value of their time spent traveling, a mode-specific fixed cost κ^m, and a trip-specific preference γ for driving over transit. The γ reflects how one may find a trip sometimes more desirable on a private vehicle (such as when carrying enough bags to fill a car trunk) and at other times more desirable on mass transit (such as when parking is scarce). Assume the trip-specific preferences γ are drawn from independent and identical distributions with cumulative distribution function Ψ, and driving is faster than transit ($\tau_n^d < \tau_n^t$) but has a higher fixed cost ($\kappa^d > \kappa^t$). Then, minimizing the travel cost function in Equation 1 implies that the household chooses transit on trips where:

$$\gamma < \beta_g \cdot (\tau_n^d - \tau_n^t) + (\kappa^d - \kappa^t) \equiv \bar{\gamma}_{gn} \tag{2}$$

and the fraction of trips where the household chooses transit is $\Psi(\bar{\gamma}_{gn})$.

Equation 2 shows that transit ridership is high when driving travel times are high or transit travel times are low (relative to fixed costs). Given that driving is faster than transit, transit ridership is higher among low-income households, who have a lower value of travel time (β_g). As the gap in travel times between driving and transit decreases, so does the difference in transit ridership between the household types.

3.1.2 *Consumption and location choices*

Every household consumes a fixed unit of housing h and spends the rest of its income on consuming x units of some composite good at a (normalized) price of 1:

$$x = w_g - h \cdot p_n. \tag{3}$$

Subject to this spending constraint, each household i chooses consumption to maximize the following utility function:

$$U(x;\ \xi_{in}, \beta_g) = x - C_{gn}(\beta_g, \tau_n^d, \tau_n^t) + \xi_{in} \tag{4}$$

where C_{gn} denotes the aggregate travel cost (across all trips) from neighborhood n.

Plugging in the spending constraint (equation 3) into the utility function (equation 4) results in the following household indirect utility function:

$$V_{gn} + \xi_{in} \equiv w_g - h \cdot p_n - C_{gn} + \xi_{in}. \tag{5}$$

Assuming that idiosyncratic preferences for neighborhood 2 over 1, denoted by $\bar{\xi}_i \equiv (\xi_{i2} - \xi_{i1})$, are drawn independently from a distribution with c.d.f. F_g, a household of type g resides in neighborhood 1 if and only if

$$\bar{V}_g \equiv V_{g1} - V_{g2} \geq \bar{\xi}_i.$$

So, the fraction of households of type g residing in neighborhood 1 is $\bar{F}_g \equiv F_g(\bar{V}_g)$ and that in neighborhood 2 is $1 - \bar{F}_g$.

3.1.3 Housing market equilibrium

Without loss of generality, we define neighborhoods such that housing supply in each neighborhood is fixed at exactly half of the city's housing consumption.[13] For the housing markets to clear, aggregate housing demand must equal housing supply in each neighborhood:[14]

$$h \cdot \left[\Lambda \cdot \bar{F}_L + (1 - \Lambda) \cdot \bar{F}_H\right] = \frac{1}{2}. \tag{6}$$

3.2 Segregation

We now characterize how a transportation improvement affects the location choice of high- and low-income households across neighborhoods. We also define the conditions under which it raises residential segregation in the city.

3.2.1 Residential neighborhood sorting

Suppose we decrease τ_1^m, travel time by mode m to neighborhood 1. Then the fraction of type g households in neighborhood 1 shifts as follows:

$$\frac{d\bar{F}_g}{d\tau_1^m} = -f_g \cdot \left(h \cdot \frac{dp_1}{d\tau_1^m} + \frac{dC_{g1}}{d\tau_1^m}\right)$$

where f_g is the evaluation of the probability density function of the distribution of $\bar{\xi}_i$ at $\bar{V}_g$. Assuming the distribution is uniform, f_g is a constant. We know that households prefer lower travel times ($dC/d\tau > 0$). In the Appendix, we show that when travel times drop, housing prices increase ($dp_1/d\tau_1 < 0$) to capitalize the higher willingness to pay for housing in the more accessible neighborhood (given the housing supply constraint in Equation 6).

[13]Making housing supply price elastic would change how many households sort across neighborhoods in response to a transportation improvement but not the income composition of these households, unless the improvement also changes the price elasticity of housing supply, for instance due to changes in zoning regulations near new transit stops.

[14]Because total city population is fixed (normalized to 1), market clearing in one neighborhood implies market clearing in the other. Clearing the housing market in any one of the neighborhoods is sufficient to solve for $(p_2 - p_1)$, the housing price in neighborhood 2 relative to neighborhood 1.

Thus, the effect on the share of type g households in neighborhood 1 depends on how the marginal utility of lower travel times compares to the marginal disutility from higher housing costs:

$$\frac{d\bar{F}_g}{d\tau_1^m} < 0 \Leftrightarrow -h \cdot \frac{dp_1}{d\tau_1^m} < \frac{dC_{g1}}{d\tau_1^m}. \tag{7}$$

So, the share of the household type that is most sensitive to travel times by mode m (i.e., with the largest $dC_{g1}/d\tau_1^m$) increases in neighborhood 1 while the share of the type that is least sensitive decreases.

So far these results are general to reduction in travel time by any mode m. We now review the impact of changes in either driving or transit time.

Proposition 1. Marginal improvements in:

- driving time τ_n^d increases the neighborhood's share of high-income households.
- transit time τ_n^t increases the neighborhood's share of low-income households if and only if transit is slow enough relative to driving.

High-income households, with the highest value of travel time, are more responsive to changes in driving times than low-income households. Proposition 1 states that, despite transit being slower, once transit becomes fast enough high-income households are also more responsive to transit improvements. It follows that:

Remark 1. Large enough improvements in either transit or driving travel times in a neighborhood necessarily increase the share of high-income households in that neighborhood.

3.2.2 *Residential segregation in the city*

We define segregation as $S \equiv \left|\bar{F}_H - \bar{F}_L\right|$, the difference in the share of high- and low-income households in neighborhood 1. This definition of segregation is proportional to the commonly used dissimilarity index, which is the minimum fraction of the city's population that needs to relocate to achieve the same distribution of incomes in each neighborhood.[15] Transportation improvements increase segregation when they attract more households of type g to the neighborhood that already has the highest share of type g households. So, the result below follows easily from Proposition 1:

[15]The dissimilarity index measures how the fraction of households of each type in a neighborhood deviates from the fraction of all households residing in the neighborhood:

$$\text{Dissimilarity} \equiv \Lambda \cdot \left|\bar{F}_L - \frac{\eta_1}{h}\right| + (1-\Lambda) \cdot \left|\bar{F}_H - \frac{\eta_1}{h}\right| = 2\Lambda \cdot (1-\Lambda) \cdot \left|\bar{F}_H - \bar{F}_L\right| = 2\Lambda \cdot (1-\Lambda) \cdot S$$

where the second equality follows from substituting η_1/h from the housing market clearing condition.

Corollary 1. Suppose idiosyncratic preferences ξ of both high- and low-income households are drawn from the same distribution ($F = F_H = F_L$). When transit is slow enough relative to driving, marginal improvements in:

1. driving time to the high-income neighborhood or transit time to the low-income neighborhood increases income segregation.

2. driving time to the low-income neighborhood or transit time to the high-income neighborhood decreases income segregation.

As before, the result for transit improvements holds only if transit is slow enough that higher transit ridership among low-income households dominates higher value of travel time savings on the transit trips taken by high-income households. A large enough transit improvement, however, can transform the originally low-income neighborhood into the higher-income neighborhood, and even raise segregation beyond its original level.

Remark 2. Large enough improvements in either transit or driving travel times to any one neighborhood increases income segregation.

Note that while these results show the effect of transport improvements in a given neighborhood, their insights also apply to improvements spanning the entire transport network where one neighborhood (and mode) improves disproportionately more.

Akbar (2024*a*) offers a more complete characterization of the conditions under which transit improvements lead to higher income segregation.

Finally, the impact of transportation on segregation depends on the distribution of idiosyncratic neighborhood preferences $\bar{\xi}$. Stronger attachments to one's current neighborhood limit relocation in response to improved travel times or rising housing prices. This weakens the link between transportation improvements and segregation.

We discuss how these results connect to the empirical evidence in Section 3.4 below.

3.3 *Welfare*

We now quantify how changes in travel time from $\tau \equiv \{\tau_1^d, \tau_1^t, \tau_2^d, \tau_2^t\}$ to $\tau' \equiv \{\tau_1'^d, \tau_1'^t, \tau_2'^d, \tau_2'^t\}$ affect welfare. We define welfare changes as the compensating variation in income, $CV_g(\bar{\xi}_i)$, needed for household of type g to maintain the same level of utility as before the travel time change:

$$CV_g(\bar{\xi}_i; \tau, \tau') = -h \cdot (p'_{n'} - p_n) - \big(C_{gn'}(\tau') - C_{gn}(\tau)\big) + (\xi_{in'} - \xi_{in}) \tag{8}$$

where p'_n is the price at which the housing market in neighborhood n is cleared at the new travel times τ'. Note that the original residential neighborhood $n \equiv n^\star(w_g; \tau)$ of the household may differ from their residential neighborhood $n' \equiv n^\star(w_g; \tau')$ after the travel time change. So, the change in welfare depends on changes in housing prices and travel times, but also on the household's latent neighborhood preferences ξ_{in} dictating where they reside initially and whether they relocate.

3.3.1 *Welfare gains depend on mode usage and residential location*

We first consider welfare changes for households who do not relocate ($n = n'$). Those households with larger reductions in aggregate travel costs C gain more. Because housing prices capitalize average gains, households with smaller reductions are worse off. Whether high- or low-income households benefit most again depends on whether transit times improve or driving times improve.

Proposition 2. Suppose transit is slow enough relative to driving. For households who remain in the same neighborhood, marginal improvements in:

1. their neighborhood's driving travel time:
    - increase their welfare if they are high-income, and
    - decrease their welfare if they are low-income.
2. their neighborhood's transit travel time:
    - increase their welfare if they are low-income, and
    - decrease their welfare if they are high-income.
3. travel time (by either mode) to the neighborhood they do not reside in:
    - increase the welfare of both high- and low-income households

The third statement of Proposition 2 follows from the fact that even if a neighborhood's own travel times do not improve, housing prices there fall as demand shifts toward the neighborhood that does benefit. Residents therefore gain in absolute welfare from lower housing costs, though their relative welfare may be lower than that of households who reside in the neighborhood with improved travel times.

3.3.2 *Welfare gains depend on ease of relocating*

We now consider welfare changes for households who relocate. Relocation allows households to benefit from travel time improvements in another neighborhood. Stronger idiosyncratic attachments raise relocation costs, so households with strong attachment to their

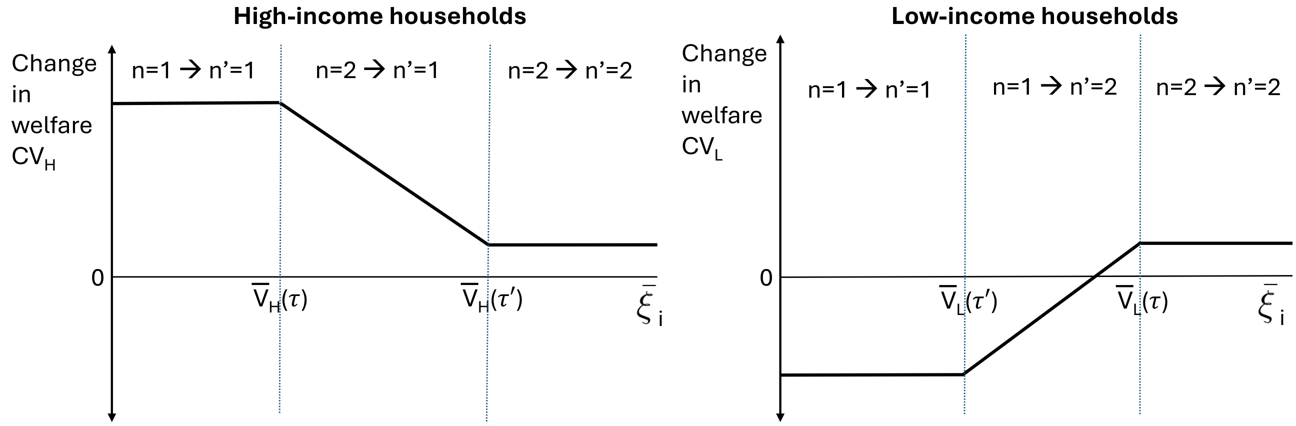

Figure 1: Change in welfare from improving driving travel time in neighborhood 1 as a function of $\bar{\xi}_i$, the household's idiosyncratic preference for neighborhood 2 over 1. Households with $\bar{\xi}_i \leq \bar{V}_g$ reside in neighborhood 1 and households with $\bar{\xi}_i > \bar{V}_g$ reside in neighborhood 2. Households with $\bar{\xi}$ between the dotted vertical lines relocate when the travel time improvement shifts $\bar{V}_g$ from $\bar{V}_g(\tau)$ to $\bar{V}_g(\tau')$.

original neighborhood benefit less from such improvements than households with lower relocation costs.

Figure 1 shows how welfare gains from improving driving times to neighborhood 1 vary with both income and relative idiosyncratic attachment to neighborhood 2 ($\bar{\xi}_i$). On the left of the figure ($\bar{\xi}_i = 0$), preference for neighborhood 1 is strongest. As $\bar{\xi}_i$ increases moving to the right, this preference weakens and gives way to preference for neighborhood 2. Recall that a household of type g resides in neighborhood 1 if and only if $\bar{\xi}_i \leq \bar{V}_g$. A reduction in driving times τ_1^d increases $\bar{V}_H$ and decreases $\bar{V}_L$, leading some high-income households to relocate to neighborhood 1 and some low-income households to relocate out of neighborhood 1.[16] The weaker a mover's attachment to their original neighborhood, the larger are their welfare gains (or the smaller their losses). Households with sufficiently strong attachment to their original neighborhood remain there and experience the welfare changes described earlier in Proposition 2. We show in the Appendix that movers benefit more (or lose less) than non-movers from either favorable transportation improvements in a different neighborhood or unfavorable transportation improvements in own neighborhood. [17]

[16] While Figure 1 illustrates an improvement in driving times, an improvement in transit times in neighborhood 1 would instead produce welfare gains that increase in $\bar{\xi}_i$ for high-income households and decrease in $\bar{\xi}_i$ for low-income households. In other words, some low-income households would locate to neighborhood 1 while some high-income households would relocate out of neighborhood 1.

[17] Our model allows the distribution F_g of households' attachment to their original neighborhood (i.e., their relocation costs) to vary by type. So, for example, if low-income households typically have higher relocation costs than high-income households, they may lose more from driving improvements in the low-income neighborhood than high-income households would from transit improvements in the high-income neighborhood.

3.3.3 *Welfare gains depend on location of transportation improvements*

Because relocation costs prevent some households from moving, they cannot take advantage of improvements in other neighborhoods. They also cannot avoid unfavorable effects in their own neighborhood, such as low-income people who rarely drive being hurt by rising house prices from lower driving times. The average distributional impact of a transport improvement therefore depends on where it is built.

Proposition 3. High-income households, on average, benefit more from driving and lose more from transit improvements in the high-income neighborhood. Low-income households, on average, benefit more from transit and lose more from driving improvements in the low-income neighborhood.

So as long as relocation is possible but costly, building transportation improvements where their primary users are concentrated increases segregation (see Corollary 1) but also raises the welfare of the targeted income group.

3.4 *Discussion*

The model rationalizes several empirical patterns from Section 2. It predicts that low-income households, who have a lower value of travel time, use transit more, and that the gap in transit use between low- and high-income households gets wider as driving gets faster than transit (Equation 2). This is consistent with the mode shares in Table 1 and Table A.2. The gap in bus use between low- and high-income travelers is wider in Atlanta, where driving is fast relative to transit, than in New York, where the gap in travel times is smaller.[18]

In the model, the direction of segregation depends on who uses the mode and where it is built. It predicts that when transit is slow relative to driving, transit improvements increase the share of low-income households in the affected neighborhood, while driving improvements increase the share of high-income households (Proposition 1). Segregation rises when each mode is improved where its primary users already live (Corollary 1), though a sufficiently large improvement by any mode would raise it regardless, by attracting high-income households (Remark 2). The evidence from Section 2, however, suggests most transit projects fall short of this last case: poverty rises near new U.S. bus stations. Instead, the dominant pattern matches the Corollary: new bus stations concentrate poverty in low-income areas, and the IHS drew richer households to higher-income suburbs. When richer households are more likely to ride transit, as in some developing countries, the prediction

[18] We do not see this pattern for Atlanta in Table 1 because transit use is very limited among both high- and low-income travelers in the metropolitan area. In contexts where transit is more prevalent - for example, in the three New York vs Atlanta comparisons shown in Table A.2 of the Appendix (city only, commute only, and CTPP commute data) - the gap in bus use between low- and high-income travelers is wider in Atlanta than in New York.

reverses, and new transit draws higher-income residents into poorer neighborhoods, as Balboni *et al.* (2025) document in Dar es Salaam.

Turning to welfare, the model predicts that each income group benefits most when improvements target the neighborhoods where that group is concentrated, and that the group which does not use the improved mode loses through higher housing prices (Propositions 2 and 3). These directional predictions match the findings of much richer quantitative spatial models applied to specific cities. Weiwu (2024) finds that the IHS raised welfare for White residents and reduced it for Black residents, consistent with highway improvements in suburban areas where richer, car-owning households lived. Tsivanidis (2023) and Warnes (2024) find broadly shared BRT gains in Bogotá and Buenos Aires, consistent with mixed ridership and wide spatial coverage. Our model captures these broad patterns with only two neighborhoods and two income groups, suggesting that its three forces, mode use, project location, and the ability to relocate, are first-order in shaping distributional outcomes.[19]

There are also features of the data that our model does not capture but could accommodate with simple extensions. Relocation costs, for instance, are often asymmetric. During the construction of the IHS, redlining prevented Black residents from leaving neighborhoods the highways had degraded. Our baseline segregation results (Corollary 1) assume both income groups draw neighborhood preferences from the same distribution, but allowing type-specific distributions ($F_H \neq F_L$) could generate higher segregation and higher inequality simultaneously, as Weiwu (2024) documents.

A second limitation is the assumption of fixed housing supply. Tsivanidis (2023) estimates that allowing more housing near Bogotá's BRT stations would have raised welfare, which suggests that supply responses near new infrastructure matter for both welfare and segregation.

4. Conclusion

Our paper shows that simple factors help anticipate the impact of transportation improvements on location choices and welfare across income groups: who uses the mode, where the improvement is located, and how easily people can move. Projects that serve a specific group in a specific area, such as large parts of the Interstate Highway Systems and many new bus routes, tend to raise segregation and inequality. Projects with broader use and wider coverage, such as BRT in developing countries, likely generate more modest segregation effects and broader welfare gains.

People's ability to move in response to better travel access depends on other policies, including land use regulation. Allowing multi-family housing near new infrastructure,

[19]While a richer multi-neighborhood model would allow more flexibility in capturing more complex patterns of income sorting and travel mode choices in real cities, such a theoretical framework would require more restrictive assumptions on how locations differ and would have insights that are less generalizable.

for example, increases the chances that poorer households share in the benefits. Since governments often use transportation projects to advance broader objectives, the political economy of project design, placement, and land use regulation remains an understudied research area (Glaeser and Ponzetto, 2018).

New data and methods also open other avenues for research on distributional impacts. Detailed geocoded panel data now allow researchers to track household location choices by income, and quantitative spatial models can measure welfare in general equilibrium. Extending these models to incorporate trip chaining, as in Miyauchi, Nakajima, and Redding (2025), could clarify whether differences in travel patterns between the rich and the poor have first-order welfare implications. These same tools can also inform current policy debates, for example by studying who gains when traffic lanes are removed to create walkable areas or bike lanes.

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Appendix A. Data construction

1 Transportation modes of the rich and the poor

The analysis of modal shares by income group reported in Tables 1 and A.2 draws from three data sources: the 2017 National Household Travel Survey (NHTS; U.S. Department of Transportation 2017), Warnes (2024), and the Census Transportation Planning Products (CTPP). Table A.1 shows how we harmonize transportation modes into five categories (Car/Motorcycle, Bus, Subway, Walking/Bicycle, and Other).

National Household Travel Survey (NHTS 2017)

For the modal shares reported in column 1 to 4 of Table 1, we create metropolitan statistical areas for New York–Newark–Jersey City, NY–NJ–PA (`https://data.census.gov/profile/New_York-Newark-Jersey_City,_NY-NJ_Metro_Area?g=310XX00US35620`, retrieved 23 September 2025) and Atlanta–Sandy Springs–Roswell (`https://censusreporter.org/profiles/31000US12060-atlanta-sandy-springs-roswell-ga-metro-area/`, retrieved 23 September 2025).[20] We assign each trip in the NHTS 2017 data to one of the five modal groups based on the TRPTRANS variable. Households with income below $75,000 are classified as low-income, while households with income above this threshold are classified as high-income. We compute aggregate modal shares within an income group by weighting each trip by individuals aged 18 or older using the "Final trip weight" provided in the NHTS.

We also construct two additional trip samples reported in columns 1 to 8 of Table A.2. For the city-only results, we restrict to counties within the city proper (Bronx, Brooklyn, Manhattan, Queens, and Staten Island for New York City and Fulton and DeKalb counties for the city of Atlanta). For the commute-only results, we use the WHYTO variable to select trips whose destination is "work".

[20]This geographic matching requires the confidential geo-coded version of the NHTS. We thank Gilles Duranton, who has access to it, for producing these results.

Warnes (2024)

The modal shares reported in columns 5 and 6 of Table 1, from the metropolitan region of Buenos Aires, are those reported in Table I of Warnes (2024), based on the 2010 "Encuesta de Movilidad Domiciliaria" for people with and without a post-secondary education who are 18 or older.

Census Transportation Planning Products (CTPP)

As an alternative source of commute modal shares reported in columns 9 to 12 of table A.2, we use 2017-2021 CTPP Table B103203 (Household Income in the Past 12 Months by Means of Transportation to Work) for the cities of New York and Atlanta. Households with income below $75,000 are classified as low-income, while households with income above this threshold are classified as high-income. We compute modal shares as the share of commutes by each mode relative to the total number of commutes.

Table A.1: Harmonization of transportation modes across data sources

Harmonized Mode	**NHTS 2017**	**Warnes (2024)**	**CTPP**
Car / Motorcycle	Car, SUV, Van, Pickup truck; Motorcycle/Moped; RV (motor home, ATV, snowmobile); Taxi/limo (incl. Uber/Lyft); Rental car (incl. Zipcar/Car2Go)	Car/Motorcycle; Taxi	Car, truck, or van (drove alone, 2-person carpool, 3+ person carpool); Taxicab, motorcycle, or other means
Bus	School bus; Public or commuter bus; Private / Charter / Tour / Shuttle bus	Bus	Bus
Subway	Subway / elevated / light rail / streetcar	Subway	Subway or elevated rail; Light rail; Streetcar or trolley
Walking / Bicycle	Walk; Bicycle	Walk; Bicycle	Bicycle; Walked
Other	Golf cart/ Segway; Paratransit/Dial-a-ride; Amtrak / Commuter rail; Airplane; Boat / ferry / water taxi; Something else	Train; Other	Long-distance train; Commuter rail; Ferryboat

Table A.2: Mode Share by City and Income Group - City Only (%)

	NHTS City Only				NHTS City Only, Commute Only				CTPP City Only, Commute Only			
	Atlanta		New York		Atlanta		New York		Atlanta		New York	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mode	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Car/Motorcycle	77.3	81.6	26.0	33.7	76.7	83.3	25.8	22.0	77.6	88.3	27.8	34.6
Bus	7.2	0.6	10.8	4.1	9.3	0.8	14.2	4.6	10.4	2.6	14.3	9.1
Subway	1.6	1.4	16.3	18.6	4.3	2.8	34.5	38.4	5.5	4.0	43.1	43.2
Walking/Bicycle	12.5	15.4	45.1	41.8	8.1	11.7	23.7	32.9	6.1	5.0	13.4	11.3
Other	1.3	1.1	1.8	1.8	1.5	1.4	1.8	2.1	0.4	0.1	1.5	1.8

Notes: Columns 1-8 use data from the National Household Travel Survey 2017 to report shares of trips by transportation mode within the city limits of Atlanta and New York, for households with income above and below $75,000. Columns 1-4 sample all trips. Columns 5-8 restrict to trips whose destination is "work." Columns 9-12 use data from the Census Transportation Planning Products 2017-2021 for the same cities and income groups, restricted to commute trips. Columns 1-8 cover adults aged 18 and over; columns 9-12 cover adults aged 16 and over.

Appendix B. Model derivations

1 Travel costs

Households face the following aggregate travel cost across all trips q from their neighborhood:

$$\begin{aligned} C_{gn} &\equiv \int_{\gamma_q} \tilde{C}_{gnq}(m^\star) \cdot d\Psi(\gamma_q) \\ &= \Psi(\bar{\gamma}_{gn}) \cdot (\beta_g \cdot \tau_n^t + \kappa^t) + [1 - \Psi(\bar{\gamma}_{gn})] \cdot (\beta_g \cdot \tau_n^d + \kappa^d) - \int_{\bar{\gamma}_{gn}}^{+\infty} \gamma_q \cdot d\Psi(\gamma_q). \end{aligned}$$

Let $\psi(\gamma)$ denote the probability density of γ. Then the marginal cost of higher transit travel times is:

$$\begin{aligned} \frac{dC_{gn}}{d\tau_n^t} &= \frac{d\Psi(\bar{\gamma}_{gn})}{d\tau_n^t} \cdot \Big[(\beta_g \cdot \tau_n^t + \kappa^t) - (\beta_g \cdot \tau_n^d + \kappa^d) \Big] + \beta_g \cdot \Psi(\bar{\gamma}_{gn}) - \beta_g \cdot \bar{\gamma}_{gn} \cdot \psi(\bar{\gamma}_{gn}) \\ &= \beta_g \cdot \bar{\gamma}_{gn} \cdot \psi(\bar{\gamma}_{gn}) + \beta_g \cdot \Psi(\bar{\gamma}_{gn}) - \beta_g \cdot \bar{\gamma}_{gn} \cdot \psi(\bar{\gamma}_{gn}) \\ &= \beta_g \cdot \Psi(\bar{\gamma}_{gn}). \end{aligned} \tag{B1}$$

Similarly, the marginal cost of higher driving travel times is:

$$\frac{dC_{gn}}{d\tau_n^d} = \beta_g \cdot [1 - \Psi(\bar{\gamma}_{gn})]. \tag{B2}$$

2 Residential location sorting

2.1 Housing price effects of changes in travel times

Let $\Delta p \equiv p_1 - p_2$ denote the housing price in neighborhood 1 relative to the housing price in neighborhood 2. Using the implicit function theorem on the housing market clearing condition in equation 6:

$$\frac{d\Delta p}{d\tau_n^m} = -\left[\Lambda \cdot \frac{\partial \bar{F}_L}{\partial \tau_n^m} + (1-\Lambda) \cdot \frac{\partial \bar{F}_H}{\partial \tau_n^m} \right] \cdot \left[\Lambda \cdot \frac{\partial \bar{F}_L}{\partial \Delta p} + (1-\Lambda) \cdot \frac{\partial \bar{F}_H}{\partial \Delta p} \right]^{-1}.$$

We know from Equation 5 that

$$\frac{\partial \bar{F}_g}{\partial \tau_n^m} = \frac{\partial F(V_{g1} - V_{g2})}{\partial \tau_n^m} = (1 - 2\mathbb{I}[n=2]) \cdot f \cdot \frac{\partial V_{gn}}{\partial \tau_n^m} = -f \cdot (1 - 2\mathbb{I}[n=2]) \cdot \frac{dC_{gn}}{d\tau_n^m}$$

where $\mathbb{I}[X]$ is an indicator function that equals 1 if condition X is true and 0 otherwise, and $\frac{\partial \bar{F}_g}{\partial \Delta p} = f$. Plugging these into the expression for $\frac{d\Delta p}{d\tau_n^m}$ above, we get:

$$\begin{aligned} \frac{d\Delta p}{d\tau_n^m} &= (1 - 2\mathbb{I}[n=2]) \cdot \left[\Lambda \cdot \frac{dC_{Ln}}{d\tau_n^m} + (1-\Lambda) \cdot \frac{dC_{Hn}}{d\tau_n^m} \right] \cdot \Big[\Lambda + (1-\Lambda) \Big]^{-1} \\ &= (1 - 2\mathbb{I}[n=2]) \cdot \left[\Lambda \cdot \frac{dC_{Ln}}{d\tau_n^m} + (1-\Lambda) \cdot \frac{dC_{Hn}}{d\tau_n^m} \right]. \end{aligned} \tag{B3}$$

Note that

$$\frac{d\Delta p}{d\tau_n^m} = \frac{d\Delta p}{dp_1} \cdot \frac{dp_1}{d\tau_n^m} = \frac{d\Delta p}{dp_2} \cdot \frac{dp_2}{d\tau_n^m}$$

So

$$\frac{dp_1}{d\tau_n^m} = -\frac{1}{h} \cdot \frac{d\Delta p}{d\tau_n^m} \text{ and } \frac{dp_2}{d\tau_n^m} = \frac{1}{h} \cdot \frac{d\Delta p}{d\tau_n^m} \tag{B4}$$

2.2 *Neighborhood sorting effects of changes in travel times*

Lemma 1. Decreasing travel time to a neighborhood n increases its share of type g households if and only if:

$$\frac{dC_{gn}}{d\tau_n^m} > \frac{dC_{g'n}}{d\tau_n^m} \text{ for } g' \neq g.$$

Proof We know from Equation 7 that decreasing travel time to a neighborhood increases its share of type g households if and only if

$$\begin{aligned} \frac{d\bar{F}_g}{d\tau_n^m} < 0 \Leftrightarrow & \frac{dC_{gn}}{d\tau_n^m} > -h \cdot \frac{dp_n}{d\tau_n^m} \\ \Leftrightarrow & \frac{dC_{gn}}{d\tau_n^m} > \Lambda \cdot \frac{dC_{Ln}}{d\tau_n^m} + (1-\Lambda) \cdot \frac{dC_{Hn}}{d\tau_n^m} \end{aligned}$$

where the inequality in the second line follows from Equations B3 and B4. So

$$\begin{aligned} \frac{d\bar{F}_L}{d\tau_n^m} < 0 \Leftrightarrow \frac{dC_{Ln}}{d\tau_n^m} > \frac{dC_{Hn}}{d\tau_n^m} \\ \text{and } \frac{d\bar{F}_H}{d\tau_n^m} < 0 \Leftrightarrow \frac{dC_{Hn}}{d\tau_n^m} > \frac{dC_{Ln}}{d\tau_n^m}. \end{aligned} \tag{B5}$$

□

2.3 *Proof of Proposition 1*

Proposition 1 states: *Marginal improvements in:*

- *driving time τ_n^d increases the neighborhood's share of high-income households.*
- *transit time τ_n^t increases the neighborhood's share of low-income households if and only if transit is slow enough relative to driving.*

Proof First, consider changes in driving travel times. We know from Lemma 1 and Equation B2 that

$$\frac{d\bar{F}_L}{d\tau_n^d} > 0 \text{ and } \frac{d\bar{F}_H}{d\tau_n^d} < 0 \Leftrightarrow \beta_L \cdot [1 - \Psi(\bar{\gamma}_{Ln})] < \beta_H \cdot [1 - \Psi(\bar{\gamma}_{Hn})].$$

Since β is larger and $\bar{\gamma}$ is smaller for high-income households, improving driving travel times increases the share of high-income households (and decreases the share of low-income households) in the neighborhood.

Similarly, for transit travel time changes, we know from Equation B1 that

$$\frac{d\bar{F}_L}{d\tau_n^t} < 0 \text{ and } \frac{d\bar{F}_H}{d\tau_n^t} > 0 \Leftrightarrow \beta_L \cdot \Psi(\bar{\gamma}_{Ln}) > \beta_H \cdot \Psi(\bar{\gamma}_{Hn}).$$

In this case, given the value of travel time (β_H and β_L) and the baseline transit ridership of each household type, improving transit travel times increases the share of low-income households in the neighborhood if and only if

$$\frac{\beta_H}{\beta_L} < \frac{\Psi(\bar{\gamma}_{Ln})}{\Psi(\bar{\gamma}_{Hn})}.$$

We know from Equation 2 that the ratio of low- to high-income transit ridership is increasing in the difference in travel times between driving and transit ($\tau_n^d - \tau_n^t$). When transit is slow enough, the baseline transit ridership $\Psi(\bar{\gamma}_{Hn})$ of high-income households is small enough that improving transit travel times increases the share of low-income households in the neighborhood. Otherwise, transit time improvements would increase the neighborhood share of high-income households (like driving time improvements).

□

3 Segregation

Since the idiosyncratic preferences over neighborhoods are drawn from a uniform distribution with probability density f_g over its support, our measure of segregation can be rewritten as:

$$\begin{aligned} S &= \left| f_H \cdot (V_{H1} - V_{H2}) - f_L \cdot (V_{L1} - V_{L2}) \right| \\ &= \left| f_H \cdot (C_{H2} - C_{H1}) - f_L \cdot (C_{L2} - C_{L1}) \right|. \end{aligned}$$

Note that segregation is proportional to the difference in relative travel costs.

3.1 Proof of Corollary 1

Corollary 1 states: *Suppose idiosyncratic preferences ξ of both high- and low-income households are drawn from the same distribution ($F = F_H = F_L$). When transit is slow enough relative to driving, marginal improvements in:*

1. *driving time to the high-income neighborhood or transit time to the low-income neighborhood increases income segregation.*

2. *driving time to the low-income neighborhood or transit time to the high-income neighborhood decreases income segregation.*

Proof Consider the derivative of S with respect to travel time:

$$\frac{dS}{d\tau_n^m} = (1 - 2\mathbb{I}[\bar{F}_H < \bar{F}_L]) \cdot (1 - 2\mathbb{I}[n = 1]) \cdot \left(f_H \cdot \frac{dC_{Hn}}{d\tau_n^m} - f_L \cdot \frac{dC_{Ln}}{d\tau_n^m} \right)$$

and

$$\left(f_H \cdot \frac{dC_{Hn}}{d\tau_n^m} - f_L \cdot \frac{dC_{Ln}}{d\tau_n^m} \right) = \begin{cases} f_H \cdot \beta_H \cdot [1 - \Psi(\bar{\gamma}_{Hn})] - f_L \cdot \beta_L \cdot [1 - \Psi(\bar{\gamma}_{Ln})] & \text{for } m = d \\ f_H \cdot \beta_H \cdot \Psi(\bar{\gamma}_{Hn}) - f_L \cdot \beta_L \cdot \Psi(\bar{\gamma}_{Ln}) & \text{for } m = t \end{cases}$$

First, consider changes in driving travel times. Since we assumed that idiosyncratic preferences for high- and low-income households are drawn from the same distribution ($f_H = f_L$), we know that $f_H \cdot \beta_H \cdot [1 - \Psi(\bar{\gamma}_{Hn})] > f_L \cdot \beta_L \cdot [1 - \Psi(\bar{\gamma}_{Ln})]$. So, driving time improvements increase segregation ($dS/d\tau_n^d < 0$) if and only if either:

- $n = 1$ and $\bar{F}_L < \bar{F}_H$ (neighborhood 1 has more high-income households), or
- $n = 2$ and $\bar{F}_L > \bar{F}_H$ (neighborhood 2 has more high-income households)

In other words, marginal improvements in driving time to the high-income neighborhood increase segregation. Equivalently, marginal improvements in driving time to the low-income neighborhood decrease segregation.

On the other hand, transit travel time improvements increase segregation if and only if one of the following holds true:

1. transit improvement in low-income neighborhood ($n = 1$, $\bar{F}_L > \bar{F}_H$ OR $n = 2$, $\bar{F}_L < \bar{F}_H$) and transit is sufficiently slow ($f_H \cdot \beta_H \cdot \Psi(\bar{\gamma}_{Hn}) < f_L \cdot \beta_L \cdot \Psi(\bar{\gamma}_{Ln})$)
2. transit improvement in high-income neighborhood ($n = 1$, $\bar{F}_L < \bar{F}_H$ OR $n = 2$, $\bar{F}_L > \bar{F}_H$) and transit is sufficiently fast ($f_H \cdot \beta_H \cdot \Psi(\bar{\gamma}_{Hn}) > f_L \cdot \beta_L \cdot \Psi(\bar{\gamma}_{Ln})$)

□

4 Welfare

4.1 Welfare gains for neighborhood stayers (Proof of Proposition 2)

Proposition 2 states: *Suppose transit is slow enough relative to driving. For households who remain in the same neighborhood, marginal improvements in:*

1. *their neighborhood's driving travel time:*
   - *increase their welfare if they are high-income, and*
   - *decrease their welfare if they are low-income.*
2. *their neighborhood's transit travel time:*
   - *increase their welfare if they are low-income, and*
   - *decrease their welfare if they are high-income.*
3. *travel time (by either mode) to the neighborhood they do not reside in:*
   - *increase the welfare of both high- and low-income households*

Proof Based on Equation 8, for households who do not move neighborhoods ($n = n'$), the change in welfare is:

$$CV_g(\bar{\xi}_i, \tau, \tau') = -h \cdot (p'_n - p_n) - \big(C_{gn}(\tau') - C_{gn}(\tau)\big).$$

Following a marginal travel time improvement on mode m,

$$\begin{aligned} CV_g > 0 \Leftrightarrow & \frac{dC_{gn}}{d\tau_n^m} > -h \cdot \frac{dp_n}{d\tau_n^m} \\ \Leftrightarrow & \frac{dC_{gn}}{d\tau_n^m} > \Lambda \cdot \frac{dC_{Ln}}{d\tau_n^m} + (1-\Lambda) \cdot \frac{dC_{Hn}}{d\tau_n^m} \end{aligned}$$

where the inequality in the second line follows from Equations B3 and B4 (just as in Section 2.2). So

$$\begin{aligned} CV_L > 0 \Leftrightarrow \frac{dC_{Ln}}{d\tau_n^m} > \frac{dC_{Hn}}{d\tau_n^m} \\ \text{and } CV_H > 0 \Leftrightarrow \frac{dC_{Hn}}{d\tau_n^m} > \frac{dC_{Ln}}{d\tau_n^m}. \end{aligned} \tag{B6}$$

Note the resemblance between equations B5 and B6. The travel time improvements that benefit the type g stayers in a neighborhood are also the ones that increase the share of type g households in the neighborhood. So we can re-apply the logic of the proof of Proposition 1.

First, consider improvements in driving travel times ($\tau_n'^d < \tau_n^d, \tau_n'^t = \tau_n^t$). We know from Equations B6 and B2 that

$$CV_H > 0 \text{ and } CV_L < 0 \Leftrightarrow \beta_L \cdot [1 - \Psi(\bar{\gamma}_{Ln})] < \beta_H \cdot [1 - \Psi(\bar{\gamma}_{Hn})].$$

Since β is larger and $\bar{\gamma}$ is smaller for high-income households, improving driving travel times always increases the welfare of high-income stayers (and decreases the welfare of low-income stayers) in the neighborhood.

Similarly, for transit travel time improvements ($\tau_n'^d = \tau_n^d, \tau_n'^t < \tau_n^t$), we know from Equation B1 that

$$CV_H < 0 \text{ and } CV_L > 0 \Leftrightarrow \beta_L \cdot \Psi(\bar{\gamma}_{Ln}) > \beta_H \cdot \Psi(\bar{\gamma}_{Hn}).$$

In this case, improving transit travel times benefits low-income stayers in the neighborhood as long as transit is slow enough (and the transit ridership $\Psi(\bar{\gamma}_{Hn})$ of high-income households small enough) that

$$\frac{\beta_H}{\beta_L} < \frac{\Psi(\bar{\gamma}_{Ln})}{\Psi(\bar{\gamma}_{Hn})}.$$

Finally, for travel time improvements in neighborhoods where the households do not reside (and will not relocate to), there are no changes in travel costs but lower housing prices (see Section 2.1). This leads to higher absolute welfare for both high- and low-income stayers in the neighborhood. □

4.2 Welfare gains for neighborhood movers

Lemma 2. Suppose transit is sufficiently slow relative to driving. The change in welfare CV_g from improving:

1. transit time in neighborhood 1 or driving time in neighborhood 2 is
   - (weakly) decreasing in $\bar{\xi}_i$ for low-income households
   - (weakly) increasing in $\bar{\xi}_i$ for high-income households
2. driving time in neighborhood 1 or transit time in neighborhood 2 is
   - (weakly) increasing in $\bar{\xi}_i$ for low-income households
   - (weakly) decreasing in $\bar{\xi}_i$ for high-income households

Proof First, for households who do not move neighborhoods ($n = n'$), their welfare change CV_g does not depend on their idiosyncratic neighborhood preferences $\bar{\xi}_i$. So, $\frac{\partial CV_g}{\partial \bar{\xi}_i} = 0$ for them.

For households who do move neighborhoods ($n \neq n'$) when travel time τ_1^m decreases in neighborhood 1, their change in welfare depends on costs that are invariant across households of a given type and on idiosyncratic neighborhood preferences:

$$(\xi_{in'} - \xi_{in}) = \begin{cases} -\bar{\xi}_i & \text{if } n = 2 \text{ and } n' = 1 \\ +\bar{\xi}_i & \text{if } n = 1 \text{ and } n' = 2 \end{cases}$$

We know from Proposition 1 that when either τ_1^d or τ_2^t decreases, some high-income households move to neighborhood 1 ($n' = 1, n = 2$) and some low-income households move to neighborhood 2 ($n' = 2, n = 1$). So, welfare change is decreasing in $\bar{\xi}_i$ for high-income households and increasing in $\bar{\xi}_i$ for low-income households.

Similarly, when either τ_1^t or τ_2^d decreases, some low-income households move to neighborhood 1 ($n' = 1, n = 2$) and some high-income households move to neighborhood 2 ($n' = 2, n = 1$). So, welfare change is decreasing in $\bar{\xi}_i$ for low-income households and increasing in $\bar{\xi}_i$ for high-income households. $\square$

4.3 *Expected welfare gains by location of transportation improvement (Proof of Proposition 3)*

Proposition 3 states: *High-income households, on average, benefit more from driving and lose more from transit improvements in the high-income neighborhood. Low-income households, on average, benefit more from transit and lose more from driving improvements in the low-income neighborhood.*

Proof Without loss of generality, suppose neighborhood 1 has a larger share of high-income households and neighborhood 2 has a larger share of low-income households. Recall that a household of type g resides in neighborhood 1 if and only if its idiosyncratic preference for neighborhood 2 over 1 is low: $\bar{\xi}_i \leq \bar{V}_g$. So, when CV_g is increasing in $\bar{\xi}$, stayers in neighborhood 2 (highest $\bar{\xi}_i$) benefit more than movers to neighborhood 2, who benefit more than stayers in neighborhood 1 (lowest $\bar{\xi}_i$). On the other hand, when CV_g is decreasing in $\bar{\xi}$, stayers in neighborhood 1 benefit more than movers to neighborhood 1, who benefit more than stayers in neighborhood 2.

So, Lemma 2 implies that improving driving travel time in neighborhood 1 benefits high-income stayers in neighborhood 1 more than high-income movers to neighborhood 1. Whereas, the exact opposite is true for improving driving time in neighborhood 2: high-income movers to neighborhood 2 benefit more than high-income stayers in neighborhood 1. Given neighborhood 1 already has a larger share of high-income households, on aggregate, high-income households benefit more from driving time improvements in neighborhood 1 than in neighborhood 2.

Lemma 2 also implies that improving driving travel time in neighborhood 1 benefits low-income stayers in neighborhood 2 more than low-income movers to neighborhood 2.

Whereas, the exact opposite is true for improving driving time in neighborhood 2: low-income movers to neighborhood 1 benefit more than low-income stayers in neighborhood 2 (who experience a decrease in welfare). Given neighborhood 2 has a larger share of low-income households to begin with, low-income households lose more on aggregate from driving time improvements in neighborhood 2 than in neighborhood 1.

Analogous arguments hold for transit time improvements. □

5 *Model generalization: Exogenous local amenities*

In this section, we consider a generalization of the model where neighborhoods may differ on other characteristics besides travel times and housing prices. We show that insights from our simpler model still apply.

5.1 *Setup*

Suppose households now face the following utility function:

$$U_g(x; \xi_{in}, \beta_g) = x + A_{gn} + \xi_{in}$$

where $A_{gn} \equiv A(a_{gn}, C_{gn})$ includes the household's aggregate travel cost C_{gn} as well as their preferences over other neighborhood amenities a_{gn}. Assume A is a continuously differentiable function and households experience a constant marginal disutility c when their travel costs increase and, as before, no direct disutility from travel cost changes for other households or in other neighborhoods:

$$\frac{dA_{gn}}{dC_{gn}} = c < 0 \text{ and } \frac{dA_{gn}}{dC_{g'n'}} = 0 \text{ for } (g', n') \neq (g, n). \tag{B7}$$

Note that our baseline model is a special case with $A_{gn} = -C_{gn}$ and $c = -1$. We further assume that travel times only affect local amenities through their effect on household travel costs:

$$\frac{dA_{gn}}{d\tau_n^m} = \frac{dA_{gn}}{dC_{gn}} \cdot \frac{dC_{gn}}{d\tau_n^m} = c \cdot \frac{dC_{gn}}{d\tau_n^m}. \tag{B8}$$

We will relax this assumption shortly.

Households are subject to the same budget constraint as before (as in Equation 3) and thus face the following indirect utility function:

$$V_{gn} + \xi_{in} \equiv w_g - h \cdot p_n + A_{gn} + \xi_{in}.$$

5.2 *Sorting, segregation and welfare*

All our results on segregation and welfare from the baseline model still hold. This is because the marginal effect of travel times on A_{gn}, and hence on housing prices p_n, is just $-c$ times what it was in the baseline model.[21]

For our segregation results, note that travel time improvements increase the share of type g households in the neighborhood when:

$$\begin{aligned}\frac{d\bar{F}_g}{d\tau_n^m} < 0 \Leftrightarrow & \frac{dA_{gn}}{d\tau_n^m} < h \cdot \frac{dp_n}{d\tau_n^m} \\ & \Leftrightarrow -c \cdot \frac{dC_{gn}}{d\tau_n^m} > -h \cdot \frac{dp_n}{d\tau_n^m}.\end{aligned}$$

The rest of the proof of Lemma 1 proceeds as in Appendix B.2.2. The proof of Proposition 1 follows easily. Once again assuming a uniform distribution of idiosyncratic preferences ξ_{in} over neighborhoods, our measure of segregation can be rewritten as:

$$S = \left| f_H \cdot (A_{H1} - A_{H2}) - f_L \cdot (A_{L1} - A_{L2}) \right|$$

where A_{gn} is replaced by $-C_{gn}$ in our baseline model. Then, it follows from Equation B8 that $dS/d\tau_n^m$ is just $-c$ times what it was in the baseline model and Corollary 1 still holds (see proof in Appendix B.3.1).

For our welfare results, note that for those who stay in the same neighborhood, travel time improvements increase welfare when:

$$\begin{aligned}CV_g > 0 \Leftrightarrow & \frac{dA_{gn}}{d\tau_n^m} < h \cdot \frac{dp_n}{d\tau_n^m} \\ & \Leftrightarrow -c \cdot \frac{dC_{gn}}{d\tau_n^m} > -h \cdot \frac{dp_n}{d\tau_n^m}.\end{aligned}$$

The rest of the proof of Proposition 2 proceeds as in Appendix B.4.1 while the proofs of Lemma 2 and Proposition 3 remain unchanged.

6 *Model generalization: Endogenous local amenities*

In this section, we allow changes in travel times to also affect local amenities. For example, a new highway connection could replace space for a park or introduce new businesses to the neighborhood.

[21] In particular, the following expression now replaces Equation B3 in depicting the capitalization of travel times into neighborhood housing price differences:

$$\frac{d\Delta p}{d\tau_n^m} = -c \cdot (1 - 2\mathbb{I}[n=2]) \cdot \left[\Lambda \cdot \frac{dC_{Ln}}{d\tau_n^m} + (1 - \Lambda) \cdot \frac{dC_{Hn}}{d\tau_n^m} \right].$$

6.1 Setup

We model amenity endogeneity by replacing our assumption in Equation B8 with the following:

$$\begin{aligned}\frac{dA_{gn}}{d\tau_n^m} &= \frac{dA_{gn}}{dC_{gn}} \cdot \frac{dC_{gn}}{d\tau_n^m} + \frac{dA_{gn}}{da_{gn}} \cdot \frac{da_{gn}}{d\tau_n^m} \\ &= c \cdot \frac{dC_{gn}}{d\tau_n^m} + \alpha_g^m\end{aligned} \tag{B9}$$

where the first additive component is the direct effect on travel costs and the second component α_g^m is the effect on local amenities, which could be either positive or negative. We allow this effect to vary by travel mode to reflect the fact that the local externalities of new driving infrastructure can differ from those of new mass transit infrastructure. We also allow this effect to vary across household types. If the amenity gains do not differ across household types ($\alpha_H^m = \alpha_L^m$), then they would not change how household types sort across locations or which type benefits more from the transport improvement.

Note that the baseline model already includes an endogenous amenity in the form of housing prices, which can capitalize the effects of other amenities.[22] The following expression now replaces Equation B3 in depicting the capitalization of travel times, as well as resulting amenity changes, into neighborhood housing price differences:

$$\frac{d\Delta p}{d\tau_n^m} = -(1 - 2\mathbb{I}[n=2]) \cdot \left[c \cdot \left(\Lambda \cdot \frac{dC_{Ln}}{d\tau_n^m} + (1-\Lambda) \cdot \frac{dC_{Hn}}{d\tau_n^m}\right) + \Lambda \cdot \alpha_L^m + (1-\Lambda) \cdot \alpha_H^m\right]. \tag{B10}$$

6.2 Location sorting and segregation

Decreasing travel time to a neighborhood n increases its share of type g households if and only if

$$\begin{aligned}\frac{d\bar{F}_g}{d\tau_n^m} < 0 \Leftrightarrow & \frac{dA_{gn}}{d\tau_n^m} < h \cdot \frac{dp_n}{d\tau_n^m} \\ & \Leftrightarrow -c \cdot \frac{dC_{gn}}{d\tau_n^m} - \alpha_g^m > -h \cdot \frac{dp_n}{d\tau_n^m}\end{aligned}$$

which, together with Equations B10 and B4, implies:

$$\begin{aligned}\frac{d\bar{F}_L}{d\tau_n^m} < 0 &\Leftrightarrow \frac{dC_{Ln}}{d\tau_n^m} + \alpha_L^m > \frac{dC_{Hn}}{d\tau_n^m} + \alpha_H^m \\ \text{and } \frac{d\bar{F}_H}{d\tau_n^m} < 0 &\Leftrightarrow \frac{dC_{Hn}}{d\tau_n^m} + \alpha_H^m > \frac{dC_{Ln}}{d\tau_n^m} + \alpha_L^m.\end{aligned} \tag{B11}$$

[22] However, unlike the endogenous amenity in this model extension, housing prices are the same for all residents.

Relative to the baseline model, household location sorting now also depends on how the amenity gains (α_g^m) compare for the two household types and not just which household type has the higher time cost savings. So, if driving time improvements introduce larger amenity gains for higher-income households ($\alpha_H^d > \alpha_L^d$), then they increase the neighborhood's share of high-income households. On the other hand, if driving time improvements introduce larger amenity gains for lower-income households ($\alpha_L^d > \alpha_H^d$), then they increase the neighborhood's share of high-income households only if the relative travel cost savings exceed the relative amenity gains:

$$\frac{d\bar{F}_H}{d\tau_n^d} < 0 \Leftrightarrow \frac{dC_{Hn}}{d\tau_n^d} - \frac{dC_{Ln}}{d\tau_n^d} > \alpha_L^d - \alpha_H^d.$$

Similarly, because transit improvements improve travel cost savings more for low-income households, they increase the neighborhood's share of low-income households if the associated amenity gains are also larger for low-income households. But if the amenity gains from improved transit are larger for high-income households, then the effect on the neighborhood's income composition depends on how the travel cost savings compare to the amenity gains from the transit improvement. The implications for income segregation are now also accordingly more nuanced.

6.3 *Welfare*

For those who stay in the same neighborhood, travel time improvements increase welfare when:

$$\begin{aligned} CV_g > 0 \Leftrightarrow & \frac{dA_{gn}}{d\tau_n^m} < h \cdot \frac{dp_n}{d\tau_n^m} \\ & \Leftrightarrow - c \cdot \frac{dC_{gn}}{d\tau_n^m} - \alpha_g^m > -h \cdot \frac{dp_n}{d\tau_n^m} \end{aligned}$$

which, together with Equations B10 and B4, implies:

$$\begin{aligned} CV_L > 0 \Leftrightarrow \frac{dC_{Ln}}{d\tau_n^m} + \alpha_L^m > \frac{dC_{Hn}}{d\tau_n^m} + \alpha_H^m \\ \text{and } CV_H > 0 \Leftrightarrow \frac{dC_{Hn}}{d\tau_n^m} + \alpha_H^m > \frac{dC_{Ln}}{d\tau_n^m} + \alpha_L^m. \end{aligned} \tag{B12}$$

Note the similarity to Equation B11. Welfare gains depend on both travel cost savings and amenity gains, and the same conditions that increase the share of a household type in the neighborhood with improved travel times also leads to positive welfare gains from the improvement. Driving time improvements need not benefit higher-income residents more if the associated amenity gains are larger for lower-income residents. Similarly, transit time improvements need not benefit lower-income residents more if the associated amenity gains are larger for higher-income residents. These nuances also carry over to our other results on welfare.