POLICY BRIEF

Transit-Oriented Development

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Program Description

This project reviews and summarizes empirical evidence for a selection of transportation and land use policies, infrastructure investments, demand management programs, and pricing policies for reducing vehicle miles traveled (VMT) and greenhouse gas (GHG) emissions. The project explicitly considers social equity (fairness that accounts for differences in opportunity) and justice (equity of social systems) for the strategies and their outcomes. Each brief identifies the best available evidence in the peer-reviewed academic literature and has detailed discussions of study selection and methodological issues.

VMT and GHG emissions reduction is shown by effect size, defined as the amount of change in VMT (or other measures of travel behavior) per unit of the strategy, e.g., a unit increase in density. Effect sizes can be used to predict the outcome of a proposed policy or strategy. They can be in absolute terms (e.g., VMT reduced), but are more commonly in relative terms (e.g., percent VMT reduced). Relative effect sizes are often reported as the percent change in the outcome divided by the percent change in the strategy, also called an elasticity.

Summary

Strategy Description

Transit-oriented development (TOD), has been defined as "a compact, mixed-use community, centered around a transit station that - by design - invites residents, workers, and shoppers to drive their cars less and ride mass transit more" (Bernick and Cervero, 1997). While TOD zones are often considered to refer to the areas surrounding transit stations, such as within a half-mile radius, some scholars distinguish between TOD zones that contain certain land use characteristics, particularly compact, mixed-use, and pedestrian-friendly development, as distinct from transit-*adjacent* development (TAD) that "lacks any functional connectivity to transit, whether in terms of land-use composition, means of station access, or site design" (TCRP, 2002).

While TOD is most commonly considered at a neighborhood scale, some scholars have sought to expand the concept to transit corridors or even full metro regions; for example, Bertolini et al. (2012) called TOD "an approach to station area projects which reaches further than single-locations, and aims at the re-centering of entire urban regions around transport by rail and away from the car."

Behavioral Effect Size

While a huge amount of empirical research has examined transportation-land use interactions, most does not distinguish travel behavior in TOD versus non-TOD zones, and surprisingly few studies have examined TOD effects on vehicle miles traveled (VMT), the main impact considered in this policy brief. Instead, the most common focus for TOD research has been on mode choice, trip generation, and parking rates. Studies generally find that TOD residents are more likely to use sustainable modes, such as public transit and active transportation, and to own fewer vehicles and take fewer and shorter auto trips than residents of conventional low-density suburban areas (Park et al., 2018a and b; Ibraeva et al, 2020; Chi and Lee, 2024; Sabouri et al., 2024).

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Recent TOD research examining VMT effects, including in California, finds that TOD residents have substantially lower VMT per household than non-TOD residents, falling between 28% and 41% lower (see the section "Relationship of Vehicle Miles Traveled and Transit-Oriented Development" on pp. 12–14).

The effects of TOD on travel behavior do not rely only or even primarily on transit use. TOD-transit interactions can be synergistic and mutually supportive; when transit provides better accessibility and network connectivity, it supports TOD with features, such as more compact and mixed land uses in close proximity, that help further reduce the need to drive through mode-switching and shorter vehicle trips (Gallivan et al., 2015). Whether such development actually occurs near transit stops depends on multiple factors, including public regulation (e.g., much land located near transit is zoned to permit only single-family residential development).

Some research has aimed to carefully parse travel impacts for TODs, defined not just as any areas near transit access, but rather as transit-proximate areas with high density, walkability, and land use mix, while also controlling for "self-selection" effects – the propensity for people to choose a residence that supports their travel preferences. One recent study (Park et al., 2018a), with results shown in the section "Relationship of Vehicle Miles Traveled and Transit-Oriented Development" (pp. 12–14), examined travel outcomes, including VMT, in station areas in eight US metropolitan areas categorized as TODs, TADs, and hybrid areas, based on travel survey data collected between 2006 and 2012. The study found that TOD residents walk and take transit substantially more often, while driving less, than TAD residents, after controlling for household factors (size, number of workers, and income), distance to the nearest transit station, regional job accessibility and regional location, and self-selection. TOD residents were found to generate 39% less VMT than TAD residents. More detail on the study findings is provided later in the report.

Despite their observed greater use of sustainable transportation modes, TOD residents, on average, remain car dependent for some types of trips, particularly non-work trips. A California study found that private vehicle mode share was approximately 2.7 times greater than public transportation for work trips (71.6% vs. 26.5%), but the disparity increased notably to 10.7 times higher (87.5% vs. 8.2%) for non-commuting trips (Lund et al., 2004; Lund et al., 2006).

Some scholars contend that region-scale analysis better captures the synergic reliance between TOD and transit than localized analysis can do, given that most trips extend beyond the borders of small areas (Ibraeva et al., 2020). TOD development in multiple transit station areas supports transit use by putting more trip origins (e.g., homes) and destinations (e.g., workplaces, schools, and shops) in closer proximity to transit. In turn, transit enables density by reducing the need to use and store cars.

Considering transit-land use interactions at a regional scale can highlight sustainability benefits (Sabouri et al., 2024). One study (Gallivan et al., 2015) of more than 300 US urbanized areas in 2010 found that greater compactness of development was associated with more transit service, and compared to a hypothetical (counter-factual) "non-transit" condition, the observed greater compactness produced an aggregate 8% reduction of VMT. This land use effect amplified the direct benefits of higher transit service levels on VMT reduction by a ratio (a.k.a. multiplier) of 4:1. In a similar study using disaggregated built-environment data measures in conjunction with household travel survey data from 28 diverse US regions, Sabouri et al. (2024) found that the multiplier for VMT reduction attributable to land use, working in conjunction with transit service levels observed, ranged from 6.1 to 9.5 for the regions sampled, with a median of 6.6. Essentially, the VMT reduction patterns observed in transit-rich regions were attributed primarily to associated land uses favoring density and their effect on travel variables other than transit passenger miles, in particular more walk trips and shorter auto trips.

Land use multiplier studies of this sort underscore the importance of considering TOD as more than just a set of characteristics of any single neighborhood. As Cervero and Gorham (1995) noted, "The form of the macro-region may be too auto-dependent for the micro-pattern of any particular neighborhood to matter. Islands of neotraditional development in a sea of freeway-oriented suburbs will do little to change fundamental commuting habits."

The wider-than-local synergy needed between transit and TOD is captured in a widely cited conceptual typology for considering TOD effectiveness developed by Bertolini (1996, 1999), called the "node-place" model. This conceptual framework considers TOD zones along two axes, one representing the accessibility attributes of a transit station considered as a "node" (describing the variety and frequency of transit supply, and the connectivity afforded to desirable destinations at a wider-than-local scale), while the other axis considers the station area as a "place" (describing the local functional mix, compactness, and walkability of the station area). Historical assessment of effective transit planning processes underscores the value of concerted and coordinated corridor-scale planning of both land use and transit provision (Suzuki et al., 2013; Nasri and Zhang, 2019; Ibraeva et al., 2020).

Co-benefits and Synergies

Co-benefits and potential synergies of TOD strategies pertain to public health (e.g., from more active travel), economic efficiency/productivity (from greater accessibility provided for more groups of people), and community vibrancy (from greater proximity of desirable destinations). Studies corroborating such synergies include two by Frederick et al. (2018a and b) which found correlations in 148 mid-sized US cities between multimodal travel patterns and better health outcomes including longer lifespan and reduced obesity, as well as lower income inequality by race and sex.

Various strategies support TOD-transit synergies. Pricing policies, such as for parking, can help reduce auto-dependency, as can transportation demand management strategies, such as employer-provided transit subsidies and carpooling. Additionally, zoning, permitting, and financing strategies to promote compact mixed-use development, reduce parking requirements, and support affordable housing near transit can help make TOD more viable and equitable.

Given the rapid proliferation of new mobility modes, such as ride-hailing services (e.g., Uber and Lyft), the integration of these services with TOD and transit needs to be considered (Chi and Lee, 2024). Shared mobility—allowing short-term access to convenient shared modes including vehicles, bicycles, or scooters—could help address "first mile-last mile" needs for transit users and at least partially replace the role of private vehicles for non-commuting trips. However, concerted policy support will be essential to ensure that shared mobility enhances, rather than substitutes for, transit use.

Equity Considerations

Some research indicates that low-income households benefit expenditure-wise from living in TODs, even though TOD housing tends to be higher-priced. That is because lower transportation costs in TOD zones generally outweigh higher housing costs, such that lower-income households can end up better off in terms of combined costs (Renne et al., 2016).

As market demand has grown for compact, multi-unit homes near transit, coinciding with California's worsening housing affordability crisis, concerns have arisen in many TOD locales about gentrification leading to displacement of existing low-income residents.

A considerable amount of research indicates that gentrification in TOD zones – the introduction of market rate up-scale development into lower-income neighborhoods located near transit access – does not, on average, lead to displacement of existing residents, and often instead results in lower rents (Asquith et al., 2019; Mast, 2019; Phillips et al., 2021). Some California studies corroborate this finding (Chapple et al., 2017; Chapple and Zuk, 2020; Chatman et al., 2019).

Such research findings are unlikely to allay all worries about loss of local control and uncertainty about impacts from new TOD development, given that average impacts across metro areas do not guarantee similar impacts in a particular neighborhood. Various anti-displacement policies, such as renter protections, inclusionary housing requirements, and density bonus programs, are needed to ensure that displacement is avoided. More public funding for affordable multi-family housing is also needed to fully manifest equitable TOD ("e-TOD"), aligning sustainability goals for equity, the environment, and economic well-being.

Some researchers have examined TOD housing and transportation expenditures by income group to explore implications for VMT reduction. Chatman et al. (2019) and Boarnet et al. (2020) evaluated how VMT and transit trips vary with income and rail transit access by neighborhood type in California's four largest metropolitan areas, finding that, for households with similar incomes living near rail vs. not-near rail, the difference in nominal VMT and transit mode share of TOD vs. non-TOD residents was generally greater for higher-income than lower-income households. This finding led the scholars to conclude that, with appropriate protections put in place for providing and maintaining affordable housing, the most promising strategy for fostering VMT-reducing TOD could be to support not just mixed-use but mixed-income neighborhoods, because locating higher-income housing near transit can produce significant VMT reduction benefits.

Strategy Description

Peter Calthorpe first conceptualized "transit-oriented development" (TOD) in his book *The Next American Metropolis* as a "mixed-use community within average 2000-foot [600m, .37 mile] walking distance of a transit stop and core commercial area; TODs mix residential, retail, office, open space, and public uses in a walkable environment, making it convenient for residents and employees to travel by transit, bicycle, foot, or car" (Calthorpe, 1993; Ibraeva et al., 2020). Various other definitions have been offered, generally emphasizing the interaction of land use with sustainable transportation modes. Thomas and Bertolini (2017) defined TOD as "land-use and transportation *planning* [emphasis added] that makes cycling, walking, and transit use convenient and desirable, and that maximizes the efficiency of existing public transit services by focusing development around public stations, stops, and exchanges." Land use characteristics associated with TOD include, in particular, compact, mixed-use, and pedestrian-friendly development.

The TOD concept has gained substantial attention from scholars and planning practitioners especially in the US and Europe, as it is deemed to support multiple environmental, social, health, and economic benefits (Ibraeva et al., 2020). However, as TOD has been examined and pursued in practice, diverse outcomes have been observed. TOD faces various implementation challenges including high investment costs, land assembly challenges, and difficulty in achieving cooperation and coordination among involved stakeholders (ibid).

Some practitioners distinguish TOD from transit-*adjacent* development (TAD), with the latter characterized as development which "lacks any functional connectivity to transit, whether in terms of land-use composition, means of station access, or site design" (TCRP, 2002). The TOD/TAD distinction reflects the fact that many highly urban areas contain substantial shares of land located near transit that is zoned for single-family development; for example, in California localities, about two-thirds of land is zoned for single-family housing, and less than one quarter for multifamily housing, even in central cities (Mawhorter et al., 2018).

As the cited TOD definitions indicate, TOD has been most often associated with *neighborhood-scale* built-environment factors, especially density, land use diversity, and pedestrian-friendly design (street connectivity), in areas in walking distance to transit. Bernick and Cervero (1997) specified a half-mile buffer zone around a transit station as the appropriate walkshed associated with transit access, and they defined TOD as "a compact, mixed use community, centered around a transit station that - by design - invites residents, workers, and shoppers to drive their cars less and ride mass transit more." Research studies since then generally define the TOD boundary as the area within 0.25 mile (about 0.4km) to 1 mile (about 1.6km) or a 10- to 15-minute walk time from a transit station (Ibraeva et al., 2020).

Many studies define TOD simply based on the proximity to a transit station, but some also employ land use factors, especially density, land use diversity, and street connectivity, to define and classify TODs. Studies that distinguish TOD from TAD tend to use either scoring systems for these land use factors, or, increasingly, cluster analysis as a way to distinguish station areas based on actual observed differences.

Some scholars have sought to expand the TOD concept to a wider-than-local scale to account for conditions operating at a regional or sub-regional (e.g., transit corridor) level. So, for example, Bertolini et al. (2012) called TOD "an approach to station area projects which reaches further than single locations, and aims at the re-centering of entire urban regions around transport by rail and away from the car." Cervero and Gorham (1995) observed that compact and dense developments could be expected to produce only minor effects on travel behavior if they are not properly incorporated into a wider regional transport network.

A widely-cited TOD analytical typology, which recognizes the importance of wider-than-local transit network accessibility effects, is the node-place model, developed by Bertolini (1996, 1999). This typology employs two axes, one representing the accessibility attributes of a transit station considered as a "node" (describing the variety and frequency of transit supply, and the connectivity afforded to desirable destinations at a wider-than-local scale), while the other axis considers the station area as a "place" (describing the local functional mix of the station area).

Strategy Effect

While a huge amount of empirical research has examined transport-land use interactions, most does not distinguish travel behavior in TOD versus non-TOD zones (Chi and Lee, 2024). Instead, the most common approach has been to examine the impact on travel behavior across all urban space of observed neighborhood-scale variation in built-environment characteristics commonly called the "5 D's" – development density, diversity of land uses, street design, distance to transit, and destination accessibility — without explicitly distinguishing results separately for TOD versus non-TOD locations. One study that did parse the relative influence of the different neighborhood-scale D-variables on travel behavior specifically for TOD residents found that, among residents of rail-based station areas in 8 US metropolitan areas, automobile use was most strongly associated with land-use diversity, street network design, and regional job accessibility; transit use with transit availability, land-use diversity, whether the station had heavy rail (instead of commuter rail), and regional job accessibility; and walking with job accessibility, transit availability, land-use diversity, and street network design (Park et al., 2018b). The weakest influence among station-area environment factors was density.

Another variable, namely parking provision, has recently gained more attention in terms of influence on travel behavior in TOD zones. Chatman (2013) found in a study of catchment areas surrounding 10 railway stations in New Jersey that parking availability, both on- and off-street, was among the strongest influences on the probability of car ownership and car commuting. Commuting by car was 60% lower in station areas with limited parking supply compared to other non-TOD sites. Several other factors were also significant, including level of bus service, size and tenure of housing, numbers of jobs, residents, and stores within walking distance, proximity to downtown, and subregional employment density; however, proximity to rail access was not influential after controlling for the other factors tested.

Surprisingly few studies examining TOD effects on travel behavior have focused on VMT. Instead, the most common focus has been on mode choice, trip generation, and parking rates (Ibraeva et al, 2020; Chi and Lee, 2024). The research has generally employed cross-sectional analysis comparing TODs and non-TODs at one point in time. Most studies have found that TOD residents are more likely to use sustainable modes, such as public transit and active transportation, and to own fewer vehicles and take fewer and shorter auto trips than residents of conventional low-density suburban areas (Park et al., 2018a and b; Ibraeva et al, 2020; Chi and Lee, 2024; Sabouri et al., 2024). Most of the research has focused on commuting behavior (Ibraeva et al, 2020; Chi and Lee, 2024).

Another common focus in studies of TOD has been on real-estate prices, which have often been found to command a price premium compared to non-TOD areas, reflecting the market value of accessibility and amenity benefits conveyed by transit access and walkability. TOD price premiums observed in California have ranged from 11 to 15% (Duncan, 2011; Mathur and Ferrell, 2013).

Behavioral Effect Size

Research generally finds that TOD residents are less vehicle dependent than non-TOD residents, which translates to lower VMT. Across multiple studies, TOD residents have been found to have a vehicle mode share that is 30% to 90% lower than non-TOD residents (Chi and Lee, 2024).

Recent TOD research examining VMT effects, including in California, finds a substantial average difference in VMT per household between TOD residents and others, with VMT between 28% and 41% lower for TOD households compared to non-TOD households (see the section “Relationship of Vehicle Miles Traveled and Transit-Oriented Development” on pp. 12–14). TOD residents’ lower VMT holds even after controlling for “self-selection” – the propensity of people to choose a residential location that caters to their travel preferences (see results for Park et al., 2018a, in the section “Relationship of Vehicle Miles Traveled and Transit-Oriented Development” on pp. 12–14).

Research that identifies TOD zones simply as a function of the proximity of urban land to transit (e.g., land within a half-mile radius of a transit station) fails to fully capture TOD effects. The Park et al. study (2018a) addresses this concern by examining various travel outcomes, including VMT and auto, transit, and walk trips, in different types of transit station areas in eight US metropolitan areas, based on travel survey data collected between 2006 and 2012. The study used cluster analysis to classify 549 existing station areas as TOD, TAD, or hybrid types, with the TOD and hybrid types containing 306 and 1,876 households, respectively, while the TAD type had 251 households. The TAD cluster exhibited relatively low density, diversity, and intersection density, while the TOD cluster had the opposite; the hybrid cluster had low density and intersection density, but very high land use diversity. Households living in TADs tended to be more affluent, to own more cars, and to be larger and more auto-oriented than their counterparts in TODs, according to the study. Using propensity score matching to control for self-selection, the study found that TOD residents walk and take transit substantially more often, while driving less, than TAD residents, after controlling for household factors (size, number of workers, and income), as well as distance to the nearest transit station, regional job accessibility, and regional location. TOD residents generated 39% less VMT than TAD residents, aligning with their fewer auto trips (35% reduction) (see the section “Relationship of Vehicle Miles Traveled and Transit-Oriented Development” on pp. 12–14). In addition, after propensity score matching, the average TOD household took 0.74 more transit trips daily (or 148% higher) than the average TAD household. Likewise, the average TOD household took 1.89 more walk trips daily (or 110% higher) than a TAD household, and both differences were statistically significant.

Despite their observed greater preference for sustainable transportation modes, TOD residents, on average, remain car dependent for some types of trips. They use public transportation more frequently for commuting than non-work trips, and tend to retain their vehicles to use for non-commuting trip purposes (Lund et al., 2004, 2006; Cervero and Arrington, 2008; Langlois et al., 2015). Land use features of TOD appear to be more effective in influencing shorter distance non-work travel choices, as a dense mix of uses and amenities surrounding a transit station can encourage less driving and more non-motorized travel. A California study found that private vehicle mode share was approximately 2.7 times greater than public transportation for work trips (71.6% vs. 26.5%), but the disparity increased notably to 10.7 times higher (87.5% vs. 8.2%) for non-commuting trips (Lund et al., 2004; Lund et al., 2006).

Longitudinal TOD studies are relatively rare (Chi and Lee, 2024). Renne (2005) tracked long-term trends in commuting travel and vehicle ownership in 103 TOD precincts across the US from 1970 to 2000, and found that over the 30-year period, the transit mode share for commuting trips among TOD residents increased by 1.6% (from 15.1% in 1970 to 16.7% in 2000), whereas it decreased by 11.9% (from 19% to 7.1%) in surrounding areas. While the share of walking and cycling to work was declining nationally, the degree of decline was less significant in TODs.

Findings from studies that examine travel mode changes using retrospective surveys are also noteworthy. For example, after having relocated to California TODs, residents were found to have reduced their average VMT by 42% (Cervero, 2007). Another study conducted in Portland found that upon moving to a TOD, 19% of commuters switched to transit as their primary mode, while 4% did the opposite (Dill, 2008).

Creating TOD can take a long time. Focusing on the Portland metropolitan area, Dong (2016) examined changes in land use associated with suburban metro stations in a buffer of approximately 400 meters from stations for the period between 2004 and 2014, differentiating between stations opened before 2004 (mature stations) and newly opened stations. A 7% increase in the housing stock during the period was concentrated around mature stations and 95% of this increase came from multifamily homes. Using a regression model, the author concluded that a 10% rise in ridership was correlated with 12% more dwellings every two years.

Considering TOD-transit synergies using a wider-than-local lens

The effects of TOD on travel behavior do not rely only or even primarily on transit use. Effective TOD-transit interactions are synergistic and mutually supportive; when transit provides better accessibility and network connectivity, it supports TOD development with features, such as mix of uses in close proximity, that help further reduce the need to drive through mode-switching to active transport and through shorter vehicle trips (Gallivan et al., 2015).

Various scholars contend that region-scale analysis better captures the synergic reliance of TOD and transit than localized analysis can do, given that most trips extend beyond the borders of small neighborhood areas (Ibraeva et al., 2020). TOD-like built environment (BE) characteristics present across multiple station areas enable transit use, by putting more trip origins (e.g., homes) and destinations (e.g., workplaces, schools, and shops) in closer proximity to transit access. In turn, transit enables density by reducing the need to use and store cars.

Considering such transit-land use interactions at a regional scale can highlight sustainability benefits (Sabouri et al., 2024). Some analysts have considered how BE characteristics co-vary with transit provision by region as a means to estimate over-time cumulative evolution of transit-land use interdependencies and their effect on trip-making and VMT. One study (Gallivan et al., 2015) found across more than 300 US urbanized areas in 2010 that greater compactness of development was associated with more transit service, with substantial consequences for VMT; compared to a hypothetical (counter-factual) “non-transit” condition, the compactness of development associated with observed transit service levels produced an aggregate 8% reduction of VMT, with benefits varying substantially by urban area, ranging from a 1% to a 21% reduction in VMT compared to the hypothetical no-transit scenario. The impact attributed to land use amplified the direct benefits of higher transit service levels by a ratio of 4:1. Without transit systems to support compact development (and vice versa, based on their coterminous presence), according to the study, gross population densities in the US overall would be 27% lower.

Sabouri et al. (2024) completed an even more extensive study of the same type using disaggregated trip and built-environment data measures in conjunction with a huge sample of household travel survey data from 28 diverse US regions. The authors found that the multiplier for VMT reduction attributable to land use, working in conjunction with transit service levels observed, ranged from 6.1 to 9.5 for the regions sampled, with a median of 6.6. Considering all households and regions simultaneously, the average transit land-use multiplier was 7.4. In the most transit-rich regions, the VMT effect was exerted primarily through land uses favoring density and the effect on travel variables other than transit passenger miles, in particular more walk trips and shorter auto trips.

Land use multiplier studies of this sort underscore the importance of considering TOD in a wider framework than just the immediate neighborhood of residence. Scholars increasingly recognize the importance of considering the aggregate effect of the whole metropolitan built environment pattern, including transit network connectivity, on travel behavior, rather than just examining neighborhood-by-neighborhood variation in land use conditions (Ibraeva et al., 2020). As Cervero and Gorham (1995) noted, “The form of the macro-region may be too auto-dependent for the micro-pattern of any particular neighborhood to matter. Islands of neotraditional development in a sea of freeway-oriented suburbs will do little to change fundamental commuting habits.”

Historical assessment of effective TOD-transit planning coordination underscores this message. Even in the age of automobility, some metro areas have been able, through concerted and coordinated corridor-scale planning undertaken over decades, to limit suburban sprawl, avoid segregated land uses, and reduce auto dependence. For example, Copenhagen and Stockholm have achieved high transit mode shares by targeting urban growth along rail corridors, supported through strategies including public land acquisition and mixed-use zoning (Suzuki et al., 2013; Ibraeva et al., 2020).

Some empirical studies support the value of corridor planning for promoting transit-land use synergies. Nasri and Zhang (2019) found that the probability of choosing transit and non-motorized modes was higher for trips that both originated and ended in TOD areas in the Washington, D.C. area, with the magnitude of this effect larger at the trip origin than at the destination. Thus, higher residential and employment densities at both trip ends can reduce auto use in favor of transit and non-motorized modes. This finding corroborates the argument by Bernick and Cervero (1997) that “transit villages” work best as high-density clusters along a rail line, resembling "pearls on a necklace" that interact in a coordinated fashion (Bernick and Cervero, 1997; Suzuki et al., 2013). As Bertolini argued, transit station areas need to function effectively as both nodes and places to substantially alter outcomes.

Co-benefits and Synergies

Co-benefits and potential synergies of TOD strategies pertain to public health (e.g., from more active travel), economic efficiency/productivity (from more efficient means of accessibility), and community vibrancy (from greater proximity of desirable destinations). Studies that corroborate such synergies include two by Frederick et al. (2018a and b) which found correlations in 148 mid-sized US cities between multimodal travel patterns and better health outcomes including longer lifespan and reduced obesity, as well as lower income inequality by race and sex.

Given the rapid proliferation of new mobility modes such as ride-hailing services (e.g., Uber and Lyft), the potential for integration of these services with TOD and transit needs to be considered (Chi and Lee, 2024). Fixed public transportation services may not fully satisfy the diverse travel needs of TOD residents, and shared mobility allows short-term access to convenient shared modes including vehicles, bicycles, or scooters, without ownership (ibid). Shared mobility could help address "first mile-last mile" needs for transit users and at least partially replace the role of private vehicles for non-commuting trips.

Some research indicates that auto-centric shared mobility, such as car sharing, is more popular for non-commuting trips than commutes (Jiao et al., 2020). For short-distance trips, bike or scooter sharing could be an effective replacement, especially if supported by parking policies. Shared mobility could expand the transit catchment area as a first and last mile facilitator (ibid). However, concerted policy support will be essential to ensure that shared mobility enhances, rather than substitutes for, transit use.

A variety of additional strategies can help support TOD-transit synergies. Pricing policies, such as for parking, coupled with transportation demand management strategies, such as employer-provided transit subsidies and carpooling, can help reduce auto-dependency for TOD residents. Additionally, zoning, permitting, and financing strategies to promote compact mixed-use development, reduce parking requirements, and provide affordable housing near transit, can help make TOD more viable and equitable.

Equity Considerations

Some research indicates that low-income households benefit expenditure-wise from living in TODs, even though TOD housing tends to be higher-priced, because lower transport costs in TOD zones can outweigh higher housing costs, meaning that lower-income households can end up better off in terms of combined costs. Renne et al. (2016) compared housing and transport expenditures for TOD and TAD residents in 4,399 fixed-route transit station areas across the United States during the years from 1996 to 2015. They found that home values and rents in TOD zones, defined as having a gross housing density of more than 8 units per acre and a Walk Score of greater than 70, were higher than in TAD areas, with the price disparity increasing over time. Meanwhile, average household income in TOD areas was lower than in TAD areas and the proportion of renters was higher, but transportation costs in TOD areas were lower (at approximately 14% of income, compared to 19% in TAD areas). TOD residents spent around 29% of income on housing against 28% in TADs, but they ended up better off in terms of combined costs, on average.

Some more recent studies confirm the general finding that transportation cost savings of TOD residents can offset their higher housing costs, but the benefits are attenuated for very low-income TOD residents. In a study of urbanized portions of 27 US metropolitan areas with intra-urban rail service, Singer (2021) confirms Renne's finding that transit-rich neighborhoods are more affordable than auto-oriented ones, mainly due to lower transportation costs. However, only a small share of neighborhoods and housing units across both TOD and non-TOD areas studied were found to be affordable to very low-income households. Makarewicz et al. (2020) reached a similar conclusion in a study using block group-level data from the 2015 Panel Study of Income Dynamics. Testing a model with and without car ownership, they found that about half of the savings from living in accessible urban locations was due to differences in car ownership rates. Residents in each of five income groups living in accessible areas were found to enjoy statistically significant and meaningful average transportation cost savings, and for four of the income groups, these savings offset higher housing costs, resulting in lower combined average housing and transportation costs (H + T) as a percentage of income, compared to others. However, this offset effect did not hold for the lowest income category (less than 35% of the area median income).

As market demand has grown for compact, multi-unit homes near transit, alongside California's worsening housing affordability crisis, concerns have risen about gentrification leading to displacement of existing low-income residents of TOD zones. Research on the California housing market indicates that the state's acute housing affordability problems have resulted primarily from a housing under-supply problem – from the failure of new housing production to keep up with demand – and new housing supply, in TOD zones and elsewhere, can reduce pressure on the market and thereby reduce overall housing prices (LAO, 2015). Many research studies and meta-analyses confirm that more housing supply at the city and regional scales, even when offered at higher price points, reduces overall housing prices (Gyourko and Molloy, 2015; Zuk and Chapple, 2016; Been et al., 2019; Phillips et al., 2021; Chatman et al., 2023). Research further indicates that pervasive single-family zoning in California, including near transit, has served to constrain housing supply and to raise prices (Glaeser and Gyourko, 2002; Quigley and Raphael, 2005; Saiz, 2010; Jackson, 2016).

Meanwhile, a considerable amount of research also indicates that gentrification in TOD zones – the introduction of market rate up-scale development into lower-income neighborhoods located near transit access – does not, on average, lead to displacement of existing residents, and often instead results in lower rents (Asquith et al., 2019; Mast, 2019; Phillips et al., 2021). Some California studies corroborate this finding. Research on the San Francisco Bay and Los Angeles regions showed that neighborhoods with fixed-rail transit (i.e., TOD zones) that experienced gentrification (influx of wealthier, more highly educated, and more white residents) from 1990 to 2013 did not, on average, see displacement (the loss of affordable housing or low income households from the TOD zones) (Chapple et al., 2017). Chapple and Zuk (2020) found that about 10% of Bay Area Census tracts gentrified between 1990 and 2000 and about the same share between 2000 and 2013, and about half of the gentrified tracts were located in TOD zones (areas within one-half mile of a fixed-rail transit station). But for core city TODs, individuals in poverty moved in at higher rates than higher-income in-movers, although the same was not true for non-core city TODs.

Parallel findings come from a study by Chatman et al (2019), which found, in examining population changes in California's four largest metro areas between 1990 and 2013, that census tracts located near rail transit did not lose low-income residents overall, even when gaining high-income ones.

Such research findings are unlikely to allay all worries about loss of local control and uncertainty about impacts from new TOD development, given that average impacts across metro areas do not guarantee specific impacts in a particular neighborhood. To prevent displacement, deliberate efforts are needed to protect and increase affordable housing, such as through renter protections, inclusionary housing requirements, and density bonus programs. More public funding for affordable multi-family housing is also needed to fully manifest equitable TOD ("e-TOD"), aligning sustainability and equity goals (Chapple & Loukaitou-Sideris, 2019).

At the same time, effective TOD planning should work to ensure that existing community members directly benefit from increased transportation investments and associated neighborhood change (Chapple & Loukaitou-Sideris, 2019). State policies to induce more housing production, especially when they affect local zoning, may be more effective if they accommodate and integrate elements of local control and discretion to allow for effective tailoring of wider-than-local objectives to local conditions. One TOD strategy considered useful by many localities is to develop Specific Plans, i.e., neighborhood plans, that stipulate standards for factors including density, mix of uses, parking requirements, and urban design (Chatman et al., 2023). Although Specific Plans are usually expensive and time consuming for a city to develop, the benefits can also be substantial, both in facilitating streamlining of development approvals and also in addressing neighborhood priorities and concerns (ibid).

Some researchers have further examined TOD housing and transport patterns by income group to explore implications for VMT reduction. Lower-income households contribute to sustainable transportation benefits of TODs, because they use transit and other sustainable modes more often, meaning they produce less VMT, than higher-income households. However, that does not mean that introduction of new low-income housing in TOD zones can be automatically considered a better strategy for reducing VMT than introduction of market-rate housing. Chatman et al. (2019) and Boarnet et al. (2020) evaluated how VMT and transit trips vary with income and rail transit access by neighborhood type in California's four largest metropolitan areas, finding that, for households with similar incomes living near rail vs. not-near rail, the difference in nominal VMT and transit mode share between TOD vs. non-TOD residents was generally greater for higher-income than lower-income households, and particularly so for neighborhoods dense with both jobs and population. Lower-income households drive less and take transit more, but the greater TOD-vs-non-TOD difference in VMT and mode choice for higher-income households means that locating higher-income housing near transit can produce greater VMT reduction benefits overall.

This finding led the scholars to conclude that, with appropriate protections put in place for generating and maintaining affordable housing, the most promising strategy for fostering VMT-reducing TOD could be to support not just mixed-use but mixed-income neighborhoods. Chatman et al (2019) concluded that adding new market-rate housing units, without displacing existing residents, should be expected to reduce vehicle use, whereas restricting new housing near transit to affordable development alone would likely reduce overall housing supply, thus resulting in higher VMT and higher overall housing prices, in comparison to a broader effort to increase housing supply in TODs.

Confidence in Evidence Quality

The findings reported in the section "Relationship of Vehicle Miles Traveled and Transit-Oriented Development" (pp. 12–14) come from recent, high-quality studies with large sample sizes and controls employed for characteristics of households and travelers. Two of the studies (from Chatman et al., 2019 and Boarnet et al., 2020) employ recent high-quality travel survey data from California, and the studies find similar results for VMT by household income level when using the same dataset (the California Household Travel Survey).

Meanwhile, the study by Park et al. (2018a) indicates that with good demographic and socioeconomic controls, self-selection bias may not pose a major hurdle to establishing viable results for VMT estimation; the authors' propensity score matching technique, used to control for self-selection, indicates that built environment conditions explained the majority of observed differences in TOD-versus-TAD outcomes, in most cases. The Park study also confirms, however, that studies which lump together and consider all land area within a given radius of a transit station as TOD (rather than distinguishing TOD from TAD) mask considerable differences in outcomes for TOD vs. TAD vs. hybrid zones.

Relationship of Vehicle Miles Traveled and Transit-Oriented Development

See the references section of this report to find full references for the studies with the findings reported below.

Boarnet et al., 2020

Dependent variable/measure: Household VMT

Survey data location & year; number of observations: California Household Travel Survey (CHTS) data from 2010–2012 for 23,534 households in California's four largest metro areas

Specification of TOD/non-TOD, and for outcomes listed, TOD/Non-TOD comparison: TOD = < half-mile distance band from 461 heavy and light rail stations

Control for self-selection? No

Table 1. Results from Boarnet et al., 2020

Household Income	\$0–25K	\$25–50K	\$50–100K	\$100 K+	All Incomes
Percentage lower HH VMT	−46%	−26%	−32%	−30%	−35%

Chatman et al., 2019

Dependent variable/measure: Household VMT

Survey data location & year; number of observations: 2010-2012 CHTS and 2009 Nationwide Household Travel Survey data, for California's four largest metro areas

Specification of TOD/non-TOD, and for outcomes listed, TOD/Non-TOD comparison: TOD = < half-mile band from 765 passenger rail stations in the four metro areas

Of the 16,575 households in the NHTS data, 847 were within 1/2 mile of a passenger rail station. Of the 25,246 households in the CHTS data, 2,263 were within 1/2 mile of a rail station.

Control for self-selection? No

Table 2. Results from Chatman et al., 2019

Data source	Outcome variable	Household Income				All households
		\$0-50K	\$50-75K	\$75-100K	\$100K+	
NHTS 2009	VMT inside rail station area	31.1	49.0	49.7	60.9	41.9
	VMT outside rail station area	37.8	55.9	71.2	79.9	57.9
	% lower VMT for TOD vs. non-TOD by income group	-18%	-12%	-30%	-24%	-28%
CHTS 2010-2012	VMT inside rail station area	16.8	28.1	29.8	35.2	25.6
	VMT outside rail station area	26.7	39.0	45.9	55.6	43.7
	% lower VMT for TOD vs. non-TOD by income group	-37%	-28%	-35%	-37%	-41%

Nasri and Zhang, 2014

Survey data location & year; number of observations: Household travel survey data for 2007-2008; Washington, DC, 10,000 households; Baltimore, MD, 4,000 households

Specification of TOD/non-TOD, and for outcomes listed, TOD/Non-TOD comparison: TOD= < 0.5 mi from heavy rail transit, PLUS residential or employment density >= metropolitan average, mixed-use level >= 0.30 (according to an entropy measure); non-TOD = other

Control for self-selection? No

Table 3. Results from Nasri and Zhang, 2014

Outcome variable	TOD/non-TOD Washington DC	TOD/non-TOD Baltimore, MD
Household VMT for all trip types	38% lower	21% lower
% all trips by transit/walk/bike	36%/13%	22%/18%
% all trips made by auto	62%/83%	74%/79%
% work trips made by transit/walk/bike	45%/21%	21%/25%
% non-work trips made by transit/walk/bike	33%/11%	24%/16%
% of work trips made by auto	54%/78%	74%/73%
% of non-work trips made by auto	65%/84%	74%/80%

Park et al., 2018a

Survey data location & year; number of observations: Household travel surveys conducted between 2006 and 2012 in Boston, Portland, Miami, Minneapolis-St. Paul, Atlanta, Denver, Salt Lake City, and Seattle; 549 TODs identified, with data for 2,433 households (HHs)

Specification of TOD/non-TOD, and for outcomes listed, TOD/Non-TOD comparison: Station areas drawn at 1/2-mile buffer in network distance from each heavy or light rail station. Cluster analysis uses activity density, land use diversity, and street network design to classify station area types as TOD, hybrid, and TAD.

Control for self-selection? Yes, using propensity score matching for TOD vs. hybrid and TAD

Table 4. Results from Park et al (2018a) that were not controlled for self-selection

Sample characteristics by station area type	# of stations	HH sample size	Daily HH VMT	Daily HH auto trips	Daily HH transit trips	Daily HH walk trips
TAD	107	251	21.23	6.06	0.72	1.91
Hybrid	382	1,876	15.44	4.93	1.47	3.89
TOD	60	306	8.61	2.04	1.35	4.81
Total	549	2,433	15.18	4.68	1.37	3.8

Table 5. Results from Park et al (2018a) that were controlled for self-selection

ATE = average treatment effects of station area type computed as the mean travel factors of the matched TOD households versus those of the matched TAD households.

Outcome variable	ATE mean for TAD house-holds	ATE mean TOD vs. TAD	Observed difference TOD vs. TAD	Self-selection controlled difference	Ratio of difference from built enviro (not from self-selection) to observed difference
VMT	14.18	-39%	-6.34	-5.49	0.87
Auto trips	4.06	-35%	-4.02	-1.44	0.36
Transit trips	0.50	148%	0.64	0.74	1.16
Walk trips	1.72	110%	2.86	1.89	0.66

N = 564 (unmatched), 108 (matched)

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