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The Cost and Affordability Paradox of Transit-Oriented Development: A Comparison of Housing and Transportation Costs Across Transit-Oriented Development, Hybrid and Transit-Adjacent Development Station Typologies

John L. Renne^a , Tara Tolford^b, Shima Hamidi^c  and Reid Ewing^d

^aSchool of Urban and Regional Planning and Center for Urban and Environmental Solutions, Florida Atlantic University, Boca Raton, USA ; ^bMerritt C. Becker Jr. Transportation Institute University of New Orleans, LA, USA;

^cDepartment of Planning and Landscape Architecture and Institute of Urban Studies, University of Texas at Arlington, USA; ^dDepartment of City and Metropolitan Planning and Metropolitan Research Center, University of Utah, Salt Lake City, USA

ABSTRACT

This study presents a comparison of housing and transportation costs (H+T) in 4,399 fixed-route transit station areas across the United States. Each station area is classified as a transit-oriented development (TOD), hybrid, or transit-adjacent development (TAD) based on walkability and housing density targets. Station areas with a Walk Score of 70 or greater and a gross housing density of 8 units per acre or more are classified as TOD. Station areas that meet just one of these criteria are classified as hybrids, and those that do not meet either of these criteria are categorized as TAD. The findings reveal a paradox that whereas TOD are more expensive places to buy and rent housing, they are more affordable than hybrids and TAD because the lower cost of transportation offsets housing costs. We argue that policies to increase the density and walkability of hybrid and TAD station areas, which account for two thirds of all station areas across the United States, should be a top priority for both housing and transportation officials.

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Housing cost; location; affordability; transit; development; TOD

Transit-oriented development (TOD) has become a popular strategy advocated by planners and developers to encourage location affordability, also known as location efficiency. Holtzclaw, Clear, Dittmar, Goldstein, and Haas (2002) examined neighborhoods across the regions of Chicago, Illinois; Los Angeles, California; and San Francisco, California, and found that households drove less and owned fewer automobiles in neighborhoods with more density, a greater mix of land uses, more walkability, and better public transit accessibility. The location-efficient mortgage (LEM) and smart-commute mortgage programs offered by Fannie Mae, which date back to 1999, formally recognized transportation savings because of high-quality transit access and high population density as a valid reason to allow households to borrow more for mortgages than typical lending standards. Ultimately, low demand from borrowers resulted in the discontinuance of these programs, which stemmed from implementation problems and competitive terms from other loan program (Chatman & Voorhoeve, 2010). However, the concept of location affordability remains of interest to the federal government, as exemplified by the release of the Location Affordability portal and the Location Affordability Index (LAI) (U.S. Department of Housing and Urban Development, n.d.) jointly by the U.S. Department of Housing and Urban Development (HUD) and the U.S. Department of Transportation (DOT).

As TOD becomes a more popular planning strategy to achieve a greater degree of location affordability, it has also come under fire among housing affordability activists in response to the higher costs of housing in TOD. However, much of the reaction has been visceral, based on the sticker-shock of rental and for-sale prices in walkable, mixed-use, and transit-served communities. For example, a group in San Francisco's Mission District proposed a moratorium on the construction of new market rate housing to "save the soul of [the] neighborhood" (Wildermuth, 2015). Opponents from a housing coalition stated that a moratorium would just exacerbate housing costs, if housing production supply were not able to keep pace with demand.

This study is part of a larger, emerging area of research on location affordability. This article complements others in this special issue and recently published by *Housing Policy Debate* that delve deeper into the theory and literature on housing affordability and location efficiency, but a brief summary of these debates will help in understanding how this article fits into the larger debates. In summary, the HUD ratio approach assumes that households should not spend more than 30% of their gross income on housing (HUD 2006). However, many households drive to qualify, meaning they often take on long commutes to afford their mortgage or rent. Research examining the effects of distance on rent prices dates back to the early 1800s (von Thunen, 1826; Alonso, 1960), but has only recently become a serious part of examining households' ability to afford housing and transportation. Stone (1993) introduced the residual income approach, which examines the remaining income after housing expenses. The Center for Neighborhood Technology (CNT) and the Center for Transit-Oriented Development released the Housing + Transportation (H+T) Index in 2006 and argued that households should not exceed a 45% threshold, which was a more robust measure because many households that spend less than 30% of their income on housing exceed the recommended 15% on transportation (thus exceeding 45%). In a separate study published in this Journal we examined HUD Section 8 voucher recipients and found that recipients in sprawling metropolitan regions and neighborhoods characterized as automobile oriented spent a significantly larger share of their income on transportation (Hamidi, Ewing, & Renne, 2016).

In light of these debates, this article examines how housing and transportation costs vary in nearly 4,400 fixed-route transit station areas across 39 regions in the United States, and whether households that live in TOD exhibit lower transportation costs compared with households that live in station areas which are not TOD. This study defines TOD based on minimum thresholds for walkability and housing density. Stations that had a Walk Score of 70 or greater and a gross housing density of 8 units per acre were categorized as TOD. Stations that met only one of these criteria were categorized as hybrids, and stations that met neither of these criteria were categorized as transit-adjacent developments (TAD). We focus on how the combined share of housing and transportation costs for a household varies by TOD typology. We then examine how neighborhood- and regional-level characteristics impact household transportation budgets. Specifically, this study examines the following research questions:

1. How do housing and transportation costs vary across station areas, by TOD typology?
2. Which variables are significantly associated with reduced household transportation costs within the context of fixed-route transit stations nested within regions?

A variety of data are used to answer these research questions, as discussed in the Methodology section. In attempting to answer these questions we hope to shed light on the debate between higher costs of housing in TOD versus the location affordability savings afforded to households in such locations. Is there a paradox that more expensive housing in TOD is offset by transportation savings?

Literature

In recent years, scholars have defined *housing affordability* based on a residual income approach: "Affordability expresses the challenge each household faces in balancing the cost of its actual or potential housing, on the one hand, and its nonhousing expenditures, on the other, within the constraints of its income" (Stone, 2006, p. 151). The tradeoff between housing and transportation costs date back to the foundations of suburbia and the concept of *drive until you qualify*. Massive investments and federal

subsidies in both highways and mass-produced housing enabled legions of Americans to flee central cities for the opportunity of homeownership (DiMento & Ellis, 2013; Rose & Mohl, 2012; Wells, 2012).

The CNT and Center for Transit-Oriented Development released the H+T Index along with the report *The Affordability Index: A New Tool for Measuring the True Affordability of a Housing Choice* (2006). They argued that transportation costs should be considered in housing affordability, and that neighborhood characteristics, such as density, convenient access to amenities, walkability, and transit access and service are important factors overlooked in national housing policy debates. HUD continued to build upon this work with the release of LAI, noted above. The H+T Index and LAI have been important tools for a growing national policy focus on encouraging denser, mixed-use, walkable communities developed around transit nodes—otherwise known as TOD.

Peter Calthorpe, an architect and urban designer, first coined the term transit-oriented development in 1993 in his book *the Next American Metropolis*. In the 1990s, scholars Michael Bernick and Robert Cervero in the United States, Peter Newman and Jeffrey Kenworthy in Australia, and Luca Bertolini in Europe were among the first to study the concept (Bernick & Cervero, 1996; Newman & Kenworthy, 1999; Bertolini & Spit, 1998). In the 2000s, TOD became an increasingly popular model for urban planning, promoted by professional nonprofits including Reconnecting America's Center for Transit-Oriented Development, the Congress for the New Urbanism, Smart Growth America, and the Urban Land Institute (Center for Transit-Oriented Development, 2004). In the postrecession economy, TOD seems to be growing even more in popularity among urban planners, developers, and transit agencies interested in transit-supportive land uses. However, evidence is mounting that housing in TOD is mostly targeted to the luxury market or subsidized affordable market, but is often out of reach for average Americans. Yet the literature has been underdeveloped with regards to understanding whether transportation savings of TOD residents offset higher housing costs.

The debate about expensive housing and TOD is becoming more common across the United States. From the demand side, shifting housing preferences, especially among the millennial generation, might result in a significant undersupply of housing in walkable and transit-served neighborhoods. Estimates for the total population that want to live in walkable, transit-served communities range from 30% to 50% of the entire population (Leinberger, 2009; Nelson, 2013). More than half of the American population and 63% of the millennial generation would like to access work without an automobile, and more than half of the population report that walkability is a top priority when considering where to live (Urban Land Institute, 2015).

With regard to supply, in 2010 about 5% of the American population (17 million) lived within a half-mile of the 4,400 fixed-route transit stations (Renne, 2013) compared with 63 million jobs (48% of all jobs in the nation) in these same locations. The oversupply of jobs in comparison with housing creates pressure on the housing market among people willing to pay for such accessible housing. On the other hand, the fact that so many jobs are within walking distance to fixed-route transit stations creates an opportunity to direct new housing in these locations.

According to the literature, 8 units to the acre (gross density or 4,000 housing units within a half-mile of a station) is approximately the minimum density necessary to support transit ridership (Messenger & Ewing, 1996; Newman & Kenworthy, 2006). Thus, given the large investment to build rail infrastructure, it would only make sense that station areas should achieve such a density to generate transit trips, but zoning in many municipalities needs to be rewritten to allow for higher densities and mixed-use neighborhoods (Levine, 2006). Only 36% of all stations areas achieved a density of 8 units per acre but if all stations were built out to this minimum density threshold, housing supply would only be able to accommodate 11% of the American population by 2050 (Renne, 2013). Given practical planning realities, it is unlikely that most of the underdeveloped station areas will suddenly become a TOD given a number of barriers, including NIMBYism (Not in My Backyard) against new housing; competing demand for land within station areas for transit park-and-rides and commercial space; and inferior locations of many stations, including freight rail and/or highway corridors, within regional housing markets.

Given high levels of demand and limited opportunities for new housing supply, fear of gentrification in walkable, transit-served communities, including TOD, is a legitimate concern (Rayle, 2015). However,

existing research has been inadequate to even establish a baseline of existing conditions to benchmark future changes. One of the reasons is a lack of clarity in defining TOD.

TOD and Affordability

As a leader in urban planning and design practice and a founder of the Congress for the New Urbanism, when Calthorpe first introduced the term TOD into the modern lexicon of urban planning literature he deliberately connected the concept to a focus on pedestrianization, affordability, and environmental stewardship. Regarding affordability, Calthorpe argued that TOD would be more affordable for working families because they would not have to rely as much on automobile transportation (Calthorpe, 1993).

The affordability of TOD relates to the so-called D variables. Cervero and Kockelman (1997) introduced the concept of the three Ds, which included density, diversity (land use mix), and design (walkability), which was later extended to seven Ds, which added destination accessibility (a measure of regional accessibility), distance to transit, demand management, and demographics (Ewing & Cervero, 2001, 2010). These factors have been found to be statistically significant in influencing travel behavior across more than 200 studies (Ewing & Cervero, 2010). The Ds relate primarily to transportation affordability, a component of H+T affordability. Neighborhoods that have better D values generate lower vehicle miles traveled (VMT) and more walk and transit trips (Ewing & Cervero, 2010), thus reducing household transportation expenditures. Higher density may also reduce housing costs, as the price of land is amortized over more units.

What does this have to do with TOD? TOD are dense, mixed-use, pedestrian-friendly developments close to transit stations (Cervero et al., 2004). Thus, the D variables work to reduce transportation costs for residents of TOD, and may also reduce housing costs.

Cervero et al. (2004) identified about 100 TOD across the United States that were self-reported through a national survey of stakeholders. Renne (2009b) argues that the perspective of what constitutes a successful TOD varies based on the stakeholder, since different groups have different goals and objectives. For example, transit agencies seek to maximize transit use, whereas local governments might be more interested in economic development. Such objectives could color how one defines TOD. But density, mixed use, pedestrian friendliness, and proximity to transit seem basic to the concept under anyone's definition.

TOD Versus TAD

In the 2000s, several studies identified the difference between TOD and TAD, the latter identifying station areas that are near fixed-route transit stations but are characterized by low-density, auto-dominated places (Dittmar & Poticha, 2004; Belzer & Autler, 2002; Cervero, Ferrell, & Murphy, 2002; Renne, 2009a). This approach is related to defining TOD based on typologies and performance-based definitions. Dittmar and Poticha (2004) proposed that TOD "should be reserved to refer to projects that achieve five main goals: location efficiency, rich mix of choices, value capture, place making, [and] resolution of the tension between node and place" (p. 22). They then propose a typology that includes urban downtowns, urban neighborhoods, suburban town centers, suburban neighborhoods, neighborhood transit zones, and commuter towns. They provided a table that summarizes the type of land-use mix, density, housing types, scale, regional connectivity, transit modes, and frequencies for each typology.

Reconnecting America's Center for Transit-Oriented Development published a number of reports that sought to define and promote the concept of TOD in the United States, including *Hidden in Plain Sight: Capturing the Demand for Housing Near Transit* (2004) and the *Performance-Based [TOD] Typology Guidebook* (Austin et al., 2010). The latter report suggested that all station areas should be categorized with respect to VMT, and compared VMT along a spectrum that included residential-focused places, employment-focused places, and balanced places. Other studies to propose TOD typologies include Reusser, Loukopoulos, Stauffacher, and Scholz (2008), who applied Bertolini's node and place classification system to all stations in Switzerland. Zemp, Stauffacher, Lang, and Scholz (2011) and Kamruzzaman, Baker, Washington, and Turrell (2014) each utilized a complex multivariate cluster analysis to classify

Table 1. Classification of station areas by transit-oriented development (TOD) typology and region.

		TOD	Hybrids	TAD	Total
Albuquerque, NM	Count	0	3	10	13
	% within region	0	23.1	76.9	100
Atlanta, GA	Count	2	15	24	41
	% within region	4.9	36.6	58.5	100
Austin, TX	Count	0	2	7	9
	% within region	0	22.2	77.8	100
Baltimore, MD	Count	19	7	41	67
	% within region	28.4	10.4	61.2	100
Boston, MA	Count	116	56	150	322
	% within region	36.0	17.4	46.6	100
Buffalo, NY	Count	1	13	5	19
	% within region	5.3	68.4	26.3	100
Charlotte, NC	Count	0	7	8	15
	% within region	0	46.7	53.3	100
Chicago, IL	Count	109	90	198	397
	% within region	27.5	22.7	49.9	100
Cleveland, OH	Count	6	34	70	110
	% within region	5.5	30.9	63.6	100
Dallas, TX	Count	20	23	51	94
	% within region	21.3	24.5	54.3	100
Denver, CO	Count	21	18	15	54
	% within region	38.9	33.3	27.8	100
Detroit, MI	Count	0	12	0	12
	% within region	0	100.0	0	100
Eugene, OR	Count	0	9	19	28
	% within region	0	32.1	67.9	100
Harrisburg, PA	Count	0	3	2	5
	% within region	0	60.0	40.0	100
Houston, TX	Count	0	9	7	16
	% within region	0	56.3	43.8	100
Jacksonville, FL	Count	0	6	2	8
	% within region	0	75.0	25.0	100
Kansas City, KS	Count	0	34	21	55
	% within region	0	61.8	38.2	100
Las Vegas, NV	Count	0	13	41	54
	% within region	0	24.1	75.9	100
Little Rock, AK	Count	0	13	0	13
	% within region	0	100	0	100
Los Angeles, CA	Count	26	39	86	151
	% within region	17.2	25.8	57.0	100
Memphis, TN	Count	0	18	5	23
	% within region	0	78.3	21.7	100
Miami, FL	Count	25	11	31	67
	% within region	37.3	16.4	46.3	100
Minneapolis–St. Paul, MN	Count	3	6	16	25
	% within region	12.0	24.0	64.0	100
Nashville, TN	Count	0	1	5	6
	% within region	0	16.7	83.3	100
New Orleans, LA	Count	15	72	10	97
	% within region	15.5	74.2	10.3	100
New York, NY	Count	468	128	130	726
	% within region	65	18	18	100
Norfolk, VA	Count	40	86	113	239
	% within region	16.7	36.0	47.3	100
Philadelphia, PA	Count	223	147	240	610
	% within region	36.6	24.1	39.3	100
Phoenix, AR	Count	0	16	16	32
	% within region	0	50.0	50.0	100
Pittsburgh, PA	Count	1	19	66	86
	% within region	1.2	22.1	76.7	100
Portland, OR	Count	59	42	40	141
	% within region	41.8	29.8	28.4	100
Sacramento, CA	Count	4	28	29	61
	% within region	6.6	45.9	47.5	100

(Continued)

Table 1. (Continued).

		TOD	Hybrids	TAD	Total
Salt Lake City, UT	Count	1	13	34	48
	% within region	2.1	27.1	70.8	100
San Diego, CA	Count	14	22	45	81
	% within region	17.3	27.2	55.6	100
San Francisco, CA	Count	225	69	83	377
	% within region	59.7	18.3	22.0	100
Seattle, WA	Count	17	27	26	70
	% within region	24.3	38.6	37.1	100
St. Louis, MO	Count	1	31	53	85
	% within region	1.2	36.5	62.4	100
Tampa, FL	Count	0	6	5	11
	% within region	0	54.5	45.5	100
Washington, DC	Count	27	32	72	131
	% within region	20.6	24.4	55.0	100
All regions	Count	1,443	1,180	1,776	4,399
	% within region	32.8	26.8	40.4	100

Note. TAD = transit-adjacent developments.

TOD station typology; however, neither of these studies was conducted in the United States. This study builds on Renne and Ewing's (2013) work, which was the only study found that classifies all fixed-route transit stations across the United States as a TOD, hybrid, or TAD utilizing a simple approach based on density and walkability, as described in the Methods below (see Table 1).

Data, Methodology, and Limitations

This study draws upon national geospatial data for an area representing a half-mile radius from nearly 4,400 fixed-route transit stations across 39 metropolitan areas in the United States. This section highlights the unit of analysis and classifying station areas into typologies, variables used in this study, the methods to answer the research questions, and the limitations of the study.

Unit of Analysis and Classifying Station Areas Into Typologies

This study examines the entire station area that is located a half-mile around each fixed-route transit station. This constitutes 4,399 stations across 39 metropolitan areas in the United States. The data represent aggregate areas so anyone interpreting the results must keep in mind aggregation bias, and the ecological fallacy and spatial autocorrelation present in geographic analyses of this nature. Spatial autocorrelation is accounted for based on the multilevel modeling (MLM) analysis. In sum, however, this represents the best attempt to collect and use secondary data representing fixed-route transit stations for most stations across the entire United States. Despite the limitations, few studies have analyzed similar data at a national scale.

As noted above, this article defines TOD based on minimum thresholds for walkability and housing density. Stations that had a Walk Score of 70 or greater and a gross housing density of 8 units per acre were categorized as TOD. Stations that met only one of these criteria were categorized as hybrids, and stations that met neither of these criteria were categorized as TAD. As shown in Table 1, based on this approach, 1,776 (40.4%) of station areas across the United States were classified as TAD, 1,180 (26.8%) were hybrids, and 1,443 (32.8%) were TOD. Table 1 also reports the share of each category for each of the 39 regions in the study.

Variables

Using a geographic information system (GIS), we aggregated data from the U.S. Census Bureau (n.d.), the National TOD Database (n.d.), which includes the H+T Index, the U.S. Environmental Protection Agency (EPA; 2013) Smart Location Database, HUD LAI (n.d.), Walk Score (n.d.) and Zillow Real Estate Research (n.d.). Table 2 lists the variables collected in this study.

Table 2. List of variables and data sources for multilevel modeling.

Variable name	Description	Source
LAIHT	Modeled housing and transportation costs as a percentage of income	HUD LAI
LAIHOUSING	Modeled housing costs as a percentage of income	HUD LAI
LAITRANS	Modeled transportation costs as a percentage of income	HUD LAI
DENSITY	Gross housing density	National TOD Database
INCOME	Median household income	National TOD Database
TRANSITFREQ	Aggregate frequency of transit service	GTFS/EPA Smart Location Database
WALKSCORE	Walk Score rating	Walk Score
TOTALPOP	Total population of station area	National TOD Database
TOTALJOB	Total number of jobs in station area	National TOD Database
JOBSPOPBAL	Jobs–population balance	Calculated by authors using LED from National TOD Database
ENTROPY	Entropy measure of mixed land uses	Calculated by authors LED from National TOD Database
DISTCBD	Distance to CBD	Calculated by authors in GIS
DETACHED	Percentage detached single-family homes	HUD LAI
COMMUTEDIST	Median commute distance	HUD LAI
RETAIL	Retail access index	HUD LAI
WHITE	Share of White households	National TOD Database
BLACK	Share of Black households	National TOD Database
NONWHITE	Share of non-White households	National TOD Database
HISPANIC	Share of Hispanic households	National TOD Database
LRT_STREET	Dummy variable for light rail or streetcar station	National TOD Database
CRAIL	Dummy variable for commuter rail	National TOD Database
HRAIL	Dummy variable for heavy rail/subway station	National TOD Database
BRT	Dummy variable for bus or rapid transit station	National TOD Database
FERRY	Dummy variable for ferry station	National TOD Database
TODINDEX	TOD have greater than 70 Walk Score and 8 housing units per acre. TAD have neither, and hybrids meet one of these criteria	Calculated by authors

Note. HUD = U.S. Department of Housing and Urban Development; LAI = Location Affordability Index; TOD = transit-oriented development; GTFS = Google Transit Service Feed; EPA = Environmental Protection Agency; LED = Location Employment Dynamics; CBD = central business district; GIS = geographic information system; TAD = transit-adjacent development.

Our dependent variables are estimated housing and transportation costs (LAIHT, LAIHOUSING, and LAITRANS) as a percentage of household income, as reported by HUD LAI (Version 2 data used; U.S. Department of Housing & Urban Development, [n.d.](#)).

Gross housing density, median household income, the share of transit and walk commuting were each downloaded from the National TOD Database, which is based on U.S. Census Bureau data from 2010 and the 2005–2009 American Community Survey ([n.d.](#)). Transit frequencies were obtained from the EPA Smart Location Database, which is based on the Google Transit Service Feed (GTFS).

Walk Score data were calculated for the station point as the average of census tracts in which their centroid is located within the half-mile station area. Because these were highly correlated and the average calculation had more missing data, we chose to use the Walk Score rating for the station point.

Jobs–population balance and land-use entropy, which are index ratings of the degree of mixed land uses, were calculated by the authors using the Location Employment Dynamics (LED) data reported in the National TOD Database.¹ The distance to the central business district (CBD) was calculated by the authors in GIS.

The HUD LAI database included the percentage of single-family detached homes, the median commute distance, and a retail access index. The racial and ethnic demographics were downloaded from the National TOD Database. Dummy variables were included from the same database for the type of transit at the station, which includes light rail or streetcar, commuter rail, heavy rail or subway, bus rapid transit, and ferry.

Finally, the change in home values from January 2007 to August 2014 was downloaded and calculated from the Zillow Real Estate Index based on all types of for-sale homes.

It is important to note that some of the variables were calculated based on different methodologies, which could introduce bias into this study. All of the data from the National TOD Database were downloaded based on the half-mile radius of the station. This database uses special software to calculate

proportional weighted variables. For most of the variables using the LAI data, we used the data from the centroids of the block groups that were within a half-mile area of the station. In some cases the centroids fell outside the half-mile area; thus, in those instances, the block groups were selected that intersected with the half-mile buffer. The zip-code level is the smallest geographic area that could be used for Zillow data, so the change in home values is reported for the zip code that the station exists within. There are also many nuances in the collection of the original data by the U.S. Census Bureau, HUD, Google Transit, Zillow, and others, which are too numerous to describe in this article.

Methods

The first research question (*How do housing and transportation costs vary across station areas, by TOD typology?*) is addressed through the use of a typology that classifies all stations based on thresholds of walkability and household density, as discussed above. A comparison of means test was performed to compare indicators of the built environment, income and housing tenure, jobs, employment, transportation indicators, demographics, home and rent values, and location affordability metrics for LAI across station typologies.

To illustrate the cost of housing, we also examined the station area by zip code, which was the smallest applicable unit of geography available using Zillow data. Station areas are much smaller than zip codes; however, the results presented below show strong discrimination among TOD, hybrids and TAD with regards to home values and rental prices. These data are longitudinal and show trends over time. Again, such data at the station-area level are not available on a national scale. We debated even reporting these results because of the geographic scale problem, but feel that such information sheds important light on the topic. Moreover, some public housing authorities, including Dallas, are using zip codes as a basis for distributing rental vouchers. The innovative program, endorsed by HUD, allows subsidies to be calculated by zip code (Horner, 2010). This allows lower income residents to afford housing in more expensive neighborhoods, such as TOD. If such a program becomes widespread, the zip code could become an important unit of geography for research on location affordability.

The second research question (*Which variables are significantly associated with reduced household transportation costs within the context of fixed-route transit stations nested within regions?*) was addressed using two methods, including factor analysis and MLM. Data reduction techniques, also known as factor analysis, were conducted in SPSS, including principal component analysis (PCA) and principal axis factoring (PAF). The results of the PAF run are presented below to shed light on the associations among variables of the built environment, employment, travel behavior, demographics, and household costs. PAF is considered more reliable than PCA because the latter assumes that the entire variance in any given variable is described by all of the variables in the model (i.e., initial communalities are set to 1.0), whereas PAF relaxes that assumption and thus is more realistic. Whereas PCA is commonly used in the urban planning field, PAF is the most commonly used method of factor analysis (Warner, 2007).

MLM is a statistical technique becoming more popular in the urban planning and transportation literature. MLM partitions variance between the station precincts and regional levels and then, insofar as is possible, explains variance at each level using variables specific to that level. MLM accounts for the fact that stations are nested within regions and share the characteristics of the region, violating the independence assumption of ordinary least squares (OLS) regression. Because it overcomes this serious limitation of OLS, MLM has long been used in fields such as education and public health to analyze nested data. MLM is just beginning to be used in planning research (Ewing et al., 2011; Ewing, Greenwald, Zhang, Bogaerts, & Greene, 2013).

In this study, LAITRANS (modeled transportation costs as a percentage of income) was the dependent variable in the MLM model. The reason we chose this variable as opposed to the combined cost of housing and transportation is because the foci of this study are the locational neighborhood and regional characteristics and the possible cost savings they represent to households. We were mainly interested in knowing the significance of variables, such as density, distance to the CBD, transit service frequency, and the rating of each station on the TOD–TAD spectrum, along with socioeconomic

Table 3. Median household income and housing tenure.

Station typology	Median HH income (\$)	Percentage renters
TAD	63,848	45
Hybrid	52,724	63
TOD	55,032	72

Note. HH = household; TAD = transit-adjacent development; TOD = transit-oriented development.

variables. Transit network accessibility only varies at the regional level; thus, the MLM model was the most appropriate for the purpose of this study. In sum, all of the variables in this model are useful in explaining variations in household transportation cost expenditures based on the different attributes of the regions and the neighborhoods surrounding each station.

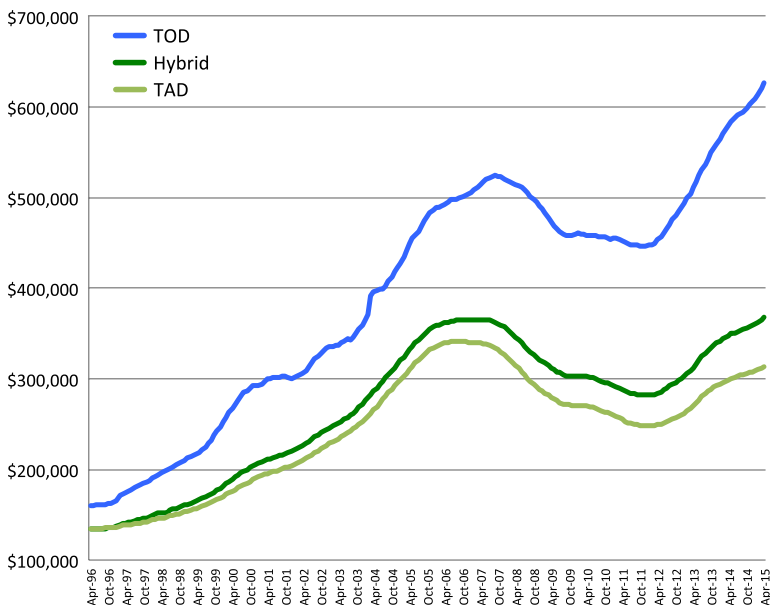
Results

This section first presents the results of the analysis on housing costs followed by a discussion of H+T affordability. Each section compares station areas by TOD typology. Next, the findings from the factor analysis are presented, followed by those from the MLM, which help to shed light on which variables are significantly associated with reduced household costs within the context of fixed-route transit stations nested within regions.

Housing Costs by TOD Typology

Table 3 shows a mean comparison of median household income and housing tenure in TOD compared with hybrids and TAD. TOD have lower median household incomes compared with TAD, and a higher share of renters compared with all other typologies.

Figures 1 and 2 report home and rent values in TOD compared with TAD and hybrid station areas. The data were obtained from Zillow Real Estate Research. The data in Figure 1 show more home value growth in TOD station areas compared with other categories. TOD home values grew 2.9 times versus 1.74 times in hybrids and 1.34 times in TAD. Because of data limitations, this included 830 TOD station

**Figure 1.** Average Zillow home value index by station typology, 1996–2015.

Note. TAD = transit-adjacent development. TOD = transit-oriented development. Calculated by the authors from Zillow data.

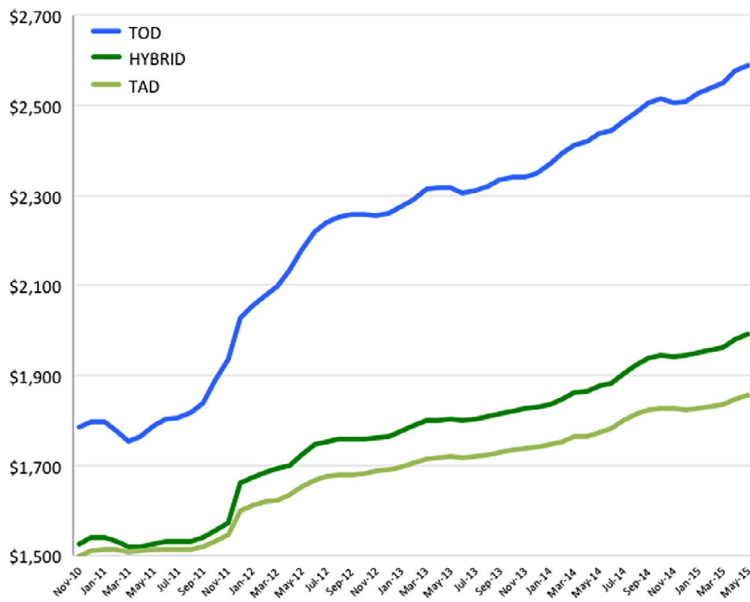


Figure 2. Average Zillow rent index by station typology, 2010–2015.
Note. TAD = transit-adjacent development. TOD = transit-oriented development. Calculated by the authors from Zillow data.

areas, 1,077 hybrid station areas and 1,057 TAD. It is important to note that the LAI H+T affordability metrics (see Table 4) were based on the 2008–2012 American Community Survey (n.d.) data, and thus would not capture the recent growth in home values since the most recent economic recovery period that started in 2012.

Figure 2 reports rental price data, which Zillow has collected since 2010. The data also show significant growth in apartment prices in TOD compared with other station typologies, with a 45% growth in TOD compared with a 31% growth in hybrids and a 24% growth in TAD over the period. Again, the data shown here are more recent data compared with the LAI H+T data, which predate the period of this analysis. Certainly, one limitation of the LAI data used in this study is that it has quickly become outdated in a national housing market that is constantly changing.

H+T Affordability by TOD Typology

The results confirm one of the paradoxes identified in this article—whereas housing in TOD station areas is marginally more expensive, the cost of transportation is lower and thus the total H+T costs are lower. Table 4 shows that TOD households spend the largest share of their income on housing, at 29% compared with 28% in TAD and 27% in hybrids. Transportation costs in TOD are the lowest at 14%, compared with 19% and 17% for TAD and hybrids, respectively. Thus, total H+T costs in TOD are 4% lower at 43% compared with TAD (47%), and 1% lower than hybrids (44%).

Table 4. Location Affordability Index (LAI) housing and transportation affordability in transit-adjacent developments (TAD), hybrids, and transit-oriented developments (TOD).

TOD typology	LAI H+T (%)	LAI housing (%)	LAI trans (%)
TAD (1,774 stations)	47	28	19
Hybrid (1,180 stations)	44	27	17
TOD (1,443 stations)	43	29	14

Table 5. Principal axis factor loadings.

Variable	Factor 1	Factor 2	Factor 3	Factor 4
LAIHOUSING			Positive	Positive
LAITRANS	Negative			Positive
HOMEVALUE	Positive	Negative		
DENSITY	Positive		Positive	
INCOME		Negative	Positive	
VEHICLEOWN	Negative			
TRANSIT	Positive		Positive	
BLACK		Positive		
HISPANIC		Positive		
NONWHITE	Positive	Positive		
LRT_STREET			Negative	Positive
CRAIL	Negative			
HRAIL	Positive		Positive	
JOBSPOPBAL		Positive	Positive	
DISTCBD	Negative			
ENTROPY				
TRANSITFREQ	Positive		Negative	
WALK	Positive	Negative		
WALKSCORE	Positive			
DETACHED	Negative			
RETAIL	Positive		Negative	
TODINDEX	Positive			

Factor Analysis Results

The next step of the analysis was to test the correlations among the variables in our PAF model. The four factors shown in Table 5 account for 54% of variance across all variables shown in the model based on the extraction sums of squared loadings.

Factor 1 reported that TOD station areas are correlated with lower household transportation costs. TOD have seen a positive change in home values. The factor is correlated with higher housing density and higher shares of transit commuting in comparison with all other fixed-route transit stations across the nation. This factor reported correlation with higher shares of non-White station areas along heavy rail (also known as subway or metro area rail systems). This factor is negatively associated with commuter rail station areas. The factor includes station areas that are closer to the CBD, and have higher transit frequencies, higher shares of walking to work, higher Walk Scores, more multifamily homes, and a higher rating on the retail access index.

Factor 2 did not report any loadings for housing or transportation costs. This factor mainly describes station areas that have shown a decrease in property values, and have lower incomes, higher shares of Black, Hispanic and non-White residents. Despite having a balance between jobs and population, these are locations with lower Walk Scores.

Factor 3 reveals that station areas that have higher housing costs are also likely to be places with higher densities, higher incomes, and higher transit commuting not located along light rail transit (LRT) or streetcar corridors, but associated with heavy rail stations. These locations have more of a balance between jobs and population, but they do not have frequent transit service and they score lower on the retail access index.

Finally, Factor 4 includes station areas that have both high housing and transportation costs and are associated with LRT or streetcar corridors.

Multilevel Model Results

As shown in Table 6, the results reveal that at the regional level (Level 2) the share of population living within a half-mile of all fixed-route transit stations has a negative impact on household transportation costs. The *p* value of this variable was not strong, but the limited number of regions resulted in 33 degrees of freedom, which could be a factor in the *p* value of .014.

Table 6. Multilevel modeling results.

Variable	Coefficient	SE	t ratio	df	p value
INTERCEPT	17.045	.767	22.223	33	<.001
Level 2					
POP_SHARE	−10.158	3.902	−2.603	33	.014
Level 1					
TOTALPOP	−.000017	.000006	−2.792	4,303	.005
TOTALJOB	−.000006	.000001	−4.524	4,303	<.001
INCOME	.000035	.000009	3.638	4,303	<.001
BLACK	1.490091	.558311	2.669	4,303	.008
DISTCBD	.074534	.012722	5.859	4,303	<.001
TRANSITFREQ	−.002329	.000439	−5.306	4,303	<.001
TODINDEX	−.810417	.264713	−3.016	4,303	.002

Note. *df* = degrees of freedom. *SE* = standard error. Outcome variable: LAITRANS.

Pseudo R^2 = .08135.

At the station-area level (Level 1), the total population of the station area, the total number of jobs in the station area, transit frequency, and TOD stations all had a negative relationship with household transportation costs. Household income, areas with higher share of Black residents, and places farther from the CBD had a positive relationship with household transportation costs.

We report this model with a pseudo R^2 of 0.08 which is relatively low. Pseudo R^2 in MLM are not equivalent to R^2 in OLS regression, and should not be interpreted the same way. The pseudo R^2 is calculated by dividing the value of the log-likelihood function of the model by the log-likelihood function of the null model and subtracting from 1.0. The pseudo R^2 bears some resemblance to the statistic used to test the hypothesis that all coefficients in the model are zero, but there is no construction by which it is a measure of how well the model predicts the outcome variable in the way that R^2 does in conventional regression analysis. We have shown the pseudo R^2 because other articles in the planning field that use MLM also report the pseudo R^2 . Therefore, this study can be compared with other published articles in the field that also utilize MLM (Ewing et al., 2014).

For comparison purposes, the authors ran a linear regression with LAITRANS as the dependent variable and BLACK (.545), DISTCBD (.041), HRAIL (−1.351), TRANSITFREQ (−.003), TOTALPOP (−4.812E-005) and TODINDEX (−1.171) as independent variables (the values in the parentheses above are the unstandardized beta values). For this regression model, the R^2 was 0.351.

Discussion

This article sought to answer two research questions to shed light on costs and affordability for households living in TOD. We defined TOD as station areas within a half-mile of a fixed-route transit station that have a Walk Score greater than 70 and a gross housing density greater than 8 units to the acre. Based on these criteria, 1,443 stations representing 33% of all stations across 39 regions were identified as TOD.

We discovered that the LAI H+T data have quickly become outdated when looking at the rapidly increasing costs of housing and rent in TOD station areas, based on monthly Zillow data. The LAI data from HUD are based on the 2008–2012 American Community Survey data and describe a snapshot in the past that does not exist in the current housing market. In addition to securing more current market data, future studies should also seek to compare fixed-route transit station areas with areas not directly served by fixed-route transit to test for the effect of access to fixed-route transit on H+T costs.

Nevertheless, this article was still able to examine the relationships and correlations between variables using factor analysis and MLM modeling. Presumably, despite the limited supply of TOD housing, which is driving up costs and likely decreasing affordability, the relationships among variables should provide insights for future planners, policymakers, financiers, developers, and future TOD residents.

The MLM model examined the variation in transportation costs, not housing costs. We do not expect the relationships among household transportation costs to vary based on fluctuations in the housing market. Based on the findings, we summarize the effects as follows:

1. TOD Effect—TOD station areas, which are characterized by having a gross housing density of more than 8 units per acre and a Walk Score of greater than 70, were significantly associated with lower levels of household transportation spending.
2. Transit frequency effect—station areas with higher levels of transit frequency are significantly associated with lower transportation spending.
3. Downtown effect—stations closer to the CBD are significantly associated with lower levels of transportation spending.
4. Density/intensity effect—station areas that have more people and higher job density are associated with lower transportation spending.
5. Income effect—station areas that are characterized by higher levels of income are associated with a higher percentage of household income spent on transportation.
6. Race effect—station areas that have higher shares of African Americans are associated with a higher percentage of household spending on transportation. This could be due to the type of vehicles that African Americans typically own and drive. For many African Americans, owning a car has become a powerful social status symbol (Gilroy, 2001). Another study found that among vehicle owners, African Americans spend around 12% more on vehicles than comparable Whites (Kerwin, Hurst, & Roussanov, 2009).
7. Network effect—the data also revealed that regions with a larger share of the population living within the half-mile catchment of all stations were more likely to have lower percentages of household transportation spending. This is independent of the built-environment characteristics of the station area.

Given that these effects are mostly independent, combined effects could be quite powerful and could help guide planners, policymakers, and developers in prioritizing which station areas could be ripe for TOD. For example, boosting densities, increasing walkability, increasing transit service, and promoting affordable housing can have multiplicative effects. Extending new rail lines to job and population centers could also have powerful transportation cost-saving impacts on households living across the entire network.

So what is the cost and affordability paradox of TOD? Whereas costs for housing in TOD appear to be skyrocketing, the share of transportation costs should remain consistently low as a percentage of income in comparison with non-TOD areas. Data show that around the year 2010, the combined cost of H+T in TOD was more competitive than in hybrids and TAD, but since 2012, the housing market in TOD appears to be accelerating faster than in the other typologies.

Such high desirability to live in TOD is an indication that the housing market is failing to deliver new housing in most station areas, which have densities that are not even transit supportive at 8 units to the acre. If America fails to deliver new housing in TOD, prices will continue to escalate as demand outpaces supply. If demand continues to outpace supply, affordable housing in TOD is likely to dwindle, resulting in gentrification of TOD neighborhoods. Policies targeted at both increasing the total supply of housing and providing affordable options are necessary. A number of methods could achieve more affordable housing near rail stations, including affordable housing land acquisition funds; directing local, state, and federal subsidies to support TOD that include some component of affordable housing; and inclusionary housing policies.

Two thirds of fixed-route transit station areas across the United States fail to meet a minimum density threshold of 8 units to the acre, so there is potential to convert more TAD and hybrids into TOD. Christopher Wells noted in *Car Country* (2012) that specific policies in the post-WWII era enabled massive suburban growth. In addition to massive highway building, the Federal Housing Administration provided mortgage insurance to underwrite the cost of new housing developments. At the same time, the Veterans Administration provided over 10 million loans for new housing. Finally, Congress changed

the depreciation rate of commercial real estate, which fueled new shopping malls in the suburbs. Wells argues that this suite of policies was not haphazard but coordinated to enable the massive growth of suburbia across the United States.

Perhaps housing and transportation policymakers need to coordinate once again to ensure that new housing is built in locations where fixed-route transit lines already exist or are being constructed. This article shows that whereas transportation costs in TOD are affordable, the housing market in TOD is quickly escalating. Unless policies are implemented soon to bolster densities in underutilized fixed-route transit station areas, the limited amount of housing in TOD is likely to continue to be priced out of the reach of average Americans.

Note

1. $\text{JOBSPOPBAL} = 1 - [\text{ABS}(\text{employment} - 0.2 * \text{population}) / (\text{employment} + 0.2 * \text{population})]$; ABS is the absolute value of the expression in parentheses. The value 0.2, representing a balance of employment and population, was found through trial and error to maximize the explanatory power of the variable (see Ewing et al., 2011). Entropy is the share of jobs in a particular sector compared with the share of jobs across all sectors. A value of 1.0 represents balanced land uses, and a value of 0 represents unbalanced land uses.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Notes on Contributors

John L. Renne, PhD, AICP, is the director of the Center for Urban and Environmental Solutions and an associate professor in the School of Urban and Regional Planning at Florida Atlantic University. He is also an honorary research associate at Oxford University. He is the chair of the Transportation and Land Development Committee for the Transportation Research Board and he serves on the editorial board of *Housing Policy Debate*. His research focuses on urban planning and policy for resilient, livable and sustainable communities with a focus on land use and sustainable transportation systems, as well as disaster recovery and preparedness.

Tara Tolford, AICP, is a research associate with the Merritt C. Becker Jr. University of New Orleans Transportation Institute. She is responsible for leading all bicycle and pedestrian-related programs and research activities. She also manages projects in smart growth and economic development. Tara's research interests include transportation resilience, active transportation policy and infrastructure design, bicycle and pedestrian data collection and analysis, transit-related economic development, and regional transportation planning.

Shima Hamidi, PhD, is an assistant professor of planning in the College of Architecture, Planning and Public Affairs at the University of Texas at Arlington, and director of the Institute of Urban Studies. Her research focuses on urban sprawl and its environmental, economic, social, and public health impacts. She also has published extensively on transportation, housing affordability, urban design, and walkability.

Reid Ewing, PhD, is a professor of city and metropolitan planning at the University of Utah. He is chair of the Department of City and Metropolitan Planning and director of the PhD program and Metropolitan Research Center at the university. He is also the associate editor of the *Journal of the American Planning Association*, and columnist for *Planning* magazine, writing the bimonthly column "Research You Can Use." His research focuses on the interaction of land use and transportation.

ORCID

John L. Renne  <http://orcid.org/0000-0002-1554-7557>

Shima Hamidi  <http://orcid.org/0000-0001-6717-5700>

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