Master's Thesis

Impact of regional transportation investments on property values: Phase 1 Sunrail and I-4 Ultimate in Central Florida

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Abstract

The capitalization of accessibility benefits from new transportation investments into property values has long been drawn attention from planning researchers. This study aims to add to the existing literature more recent evidence on the impact of the commuter rail service on local property prices. Phase 1 Sunrail commuter rail system, opened in May 2014 in the Greater Orlando area, Florida is considered. Developing multilevel hedonic price models with DID specifications, this study analyzes prices of single-family houses within a 1-mile catchment area of Sunrail stations before and after the key implementation phases: announcement, FFGA & construction, and operation. The variation in the effect on sale prices over each phase is studied for three station types (Downtown, Hospital Campus, and Suburban) which are defined based on contextual differences between stations and commuting patterns of Sunrail riders.

This study also examines the individual and cumulative effects of multiple transportation interventions coexisting spatially and temporally. After the start of Phase 1 Sunrail operation, FDOT initiated multi-year construction of the 21-mile stretch of Interstate-4 known as the I-4 Ultimate Project. Given the spatial proximity of Phase 1 Sunrail and I-4 Ultimate to each other and their concurrent implementation, disamenity effects of I-4 Ultimate construction on sale prices of single-family houses are analyzed in combination with accessibility benefits of Phase 1 Sunrail in the area shared by both transport interventions.

The findings show that single-family houses located within the 1-mile treatment zone are sold consistently at a premium of 5.4%-7.1% depending on the implementation phase of Sunrail service. The highest housing value uplift occurred after the project was announced and during its construction years. Moreover, it was found that the positive impact of Phase 1 Sunrail is not typical for every station as the largest premiums are concentrated around Downtown and Hospital Campus stations whereas houses near suburban stations did not show statistically significant findings. The results also suggest that nuisance from I-4 Ultimate was not a decisive factor for property owners in the overlapping zone as there was no significant price change found among houses in this zone.

The findings of this study hold an important value for transport policy-making including the importance of considering property premiums at stages preceding transit service opening for value capture programs and benefit-cost analysis. Moreover, this study raises the importance of

considering the non-uniform distribution of property premiums that provides a roadmap for planners for understanding how individual transit stations perform in terms of generating local property value uplift. Finally, it also provides an example policy-makers could use to evaluate the cumulative effects of multiple transportation interventions, co-existing in space and time, on the local property market.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

The last few decades witnessed a nationwide interest among the state and local governments in investing in non-motorized modes across the US cities to address the auto-related issues of excessive traffic congestion and carbon gas emissions. Public transit investments are believed to yield a wide array of benefits to urban citizens of economic and environmental nature encouraging these citizens to use an alternative to a private car to get around the city while commuting for their respective work and non-work destinations (Cervero et al., 2002; Mohammad et al., 2013). However, substantial capital subsidies are involved in the construction and operation of public transit systems. To gain public support for these massive infrastructure projects, planners and policy-makers justify these subsidies by demonstrating the potential for new transit service to translate into contributions to local revenue streams such as the increase in nearby property values following the opening of this service.

Many previous studies attempted to estimate the impact of transit investments, namely, rail systems on various real-estate markets with more focusing on single-family houses and less on multi-family and commercial development (Cao and Lou, 2017; Chatman, Tulach, and Kim, 2010; Ke and Gkritza, 2019; McMillen and McDonald, 2004). The consensus can be seen among the studies concerning the impact of accessibility benefits, brought by rail systems, on property prices: houses are generally sold at a premium in the proximity to these systems. Most of these works primarily addressed either the light or heavy rail transit (LRT or HRT) systems whereas only a limited scope examined the capitalization effects of commuter rail service. Despite lacking studies, it is believed that the commuter rail causes a higher property value uplift compared to more common LRT systems (Cervero and Duncan, 2002; Higgins and Kanaroglou, 2016).

The cross-sectional hedonic price models with one-year data are often applied for analyzing the impact of rail investments on property values. Studies that applied the before-after analysis tend to focus solely on price effects after the start of the rail service operation potentially overlooking the value uplift before the opening of the service. This might undervalue the overall value uplift from new transit service as other implementation phases such as announcement and construction of the rail service are not analyzed (Cao and Lou, 2017).

Numerous studies also highlighted how contextual differences of individual stations affect the ability of proximity to these stations to generate property premiums. Generally, these studies focused on the presence of TOD attributes in station areas as the main factor contributing to the increase in local property values (Atkinson-Palombo, 2010; Duncan, 2011; Higgins and Kanaroglou, 2017; Kahn, 2007; Lieske et al., 2019; Mathur and Ferrell, 2013). Findings show that areas adjacent to transit stations which are also characterized as pedestrian-oriented, mixed-use, and walk-and-ride are likely to attract higher property premiums compared to those with low-dense residential development, poor walkability, and a park-and-ride facility.

The development of the regional transportation infrastructure is a dynamic process as continuous improvements and additions to the infrastructure are made by local transport authorities. By now, only a single study has raised the importance to model the effects of several transportation interventions that overlap spatially and occur either sequentially or simultaneously (Bardaka, Delgado, and Florax, 2019). This is particularly relevant when the effects of the transportation system are considered over longer time frames during which additional interventions to the system are likely to take place.

Moreover, there were very few studies that combined the effects of different transportation infrastructure types on property values (Seo, Golub, and Kuby, 2014; Seo et al., 2018). The access to the transportation infrastructure such as rail and highway might be valued differently by an individual who is willing to buy a nearby property since the nature of the amenity (i.e. accessibility) and disamenity effects, including noise, traffic, and air pollution, can differ for rail and highway.

This study aims to examine how the improved accessibility to commuter rail affects the willingness of local property owners to buy a house close to a station filling the gap in recent literature on this rail transit type. The recent Phase 1 Sunrail commuter rail system that has started its service in May 2014 in the Greater Orlando area, Florida is considered. Applying a quasi-experimental econometric approach known as difference-in-differences (DID) and hedonic price models, this study estimates the impact of Phase 1 Sunrail on sale prices of single-family houses in proximity to rail stations. The timing of property premiums is analyzed by taking into account Sunrail's capitalization effects before the opening of the service: during its announcement and FFGA & construction phases.

A contribution of this study is that it also addresses how capitalization effects of transit service vary with station area context. Phase 1 Sunrail stations are divided into three main types – Downtown, Hospital Campus, and Suburban – based on key contextual differences between stations and how these differences shape commuting patterns of Sunrail riders. As shown later, property premiums are not distributed uniformly along a rail line as they might concentrate only around certain stations compared to the rest of the line where houses in proximity to stations might be sold at a discount. By estimating and comparing the change in sale prices of single-family houses near three different station types at each implementation phase of Phase 1 Sunrail, this study offers a more detailed look on how residents might value differently the access to certain individual stations over time.

Moreover, this study makes a contribution by analyzing the individual and cumulative effects of multiple sequential transportation interventions that overlap spatially. In 2015, FDOT initiated the multi-year I-4 Ultimate Project to reconstruct the 21-mile stretch of Interstate-4 corridor passing along the Sunrail line, aiming at improving regional connectivity and traffic safety. The I-4 Ultimate's construction potentially causes a nuisance, such as traffic congestion and noise, on residents living close to the I-4 corridor thus affecting a potential buyer's willingness to pay a premium for a house. The property values of single-family houses, located near the I-4 corridor, are examined separately as well as in combination with potential accessibility benefits of Sunrail by focusing on houses in the overlapping area of both transport interventions.

II. LITERATURE REVIEW

The theoretical foundation of the past studies focusing on the impact of rail transit on the property values dates back to the location theory of the monocentric model developed by Alonso (1964), Muth (1969), and Mills (1972). According to this theory, different land uses compete with one another for more accessible locations to CBD based on their bid rent curves that define the maximum amount of rent each land use is willing to pay for having access to a given location (Alonso, 1964; Muth, 1969; Mills, 1972). Each land use type raises its bid for access to this location until the accessibility benefits in the form of transportation cost savings, brought by this location, are fully capitalized into the property values. As a result, most of the capitalization studies generally rest on the fundamental idea that property owners will try to outbid one another to gain the accessibility benefits, offered by a transit service, by competing for a finite supply of parcels that are located close to a station.

Since the bid-rent theory was proposed, the extensive literature has been produced to demonstrate how public transit systems affect the nearby property values (Atkinson-Palombo, 2010; Cervero & Duncan, 2002; Cervero, 2004; Chatman et al., 2012; 12. Duncan, 2011; Golub et al., 2012; Guo, 2016; Hess and Almeida, 2007; Knaap et al., 2001, McMillen & McDonald, 2004; Weinberger; 2001). To have a systematic look at the findings of many capitalization studies which differ in a spatial context, time frame, transit type, and research design, several recent meta-studies have been produced which showed that the majority of these works confirm the positive effects of the proximity to a rail system on property values with most concentrating their attention on single-family residential development (Debrezion, 2007; Mohammad, 2013; Hamidi, 2016; Higgins and Kanaroglou, 2016).

The meta-studies also clearly display that most of the previous works on the impact of rail investments on property values have predominantly focused on LRT or HRT as the transit type while those on commuter rail are dated and recently under-represented. They also demonstrate commuter rail systems are assumed to entail higher value uplift potentially attributed to their larger service coverage areas and higher speeds as opposed to other transit types (Debrezion, 2007). Overall, the scope of studies, reviewed here, are limited to the past works which address, specifically, commuter rail service or considered to be methodologically or context relevant.

In one of the earlier attempts, Cervero and Duncan have conducted a cross-sectional study where they showed that within a quarter-mile distance from the commuter rail station both single-family and multi-family houses in Santa Clara, CA have experienced a $4 per square feet premium (2002a). In the following study, they estimated a hedonic price model indicating a much larger value uplift for commercial properties within a quarter-mile from commuter stations compared to ones located within the same proximity from LRT stations (Cervero and Duncan, 2002b).

However, earlier studies such as described above mainly applied cross-sectional analysis which does not account for intertemporal changes in property values located within a station area and does not allow to isolate transit proximity effects (Ko and Cao, 2013). Some recent works have performed a more sophisticated analysis employing longitudinal and quasi-experimental approaches to estimate property premiums before and after the start of the rail service. (Atkinson-Palombo, 2010; Cao and Porter-Nelson, 2016). However, these studies are likely to overlook the property value uplift which can occur even before the opening of the service leading to an underestimation of accessibility benefits brought by the rail investments (Cao and Lou, 2018; Devaux, Dube, and Apparicio, 2017; Ke and Gkritza, 2019).

In an earlier attempt to account for property premiums before the commencement of rail service, Knaap along with Ding and Hopkins (2001) revealed that amid the plan announcement for the LRT in Portland, OR vacant residential parcels, located no farther than half-mile from a station, experienced 36% increase in their sales prices whereas for parcels within a mile distance prices were only 9% higher. This study was one of the cases to apply the DID approach in the hedonic price model to estimate a change in property values before and after a certain point in time even though the model they built did not include the temporal variable for the post-announcement period or time fixed effects to control for global trends in sales prices changes.

Later, McMillen and McDonald (2004) examined the effect of the heavy rail Midway Line in Chicago, IL on values of the single-family houses between 1983 and 1999. Alternative to the DID model, they applied the repeat-sales method which allows for considering properties that were sold more than once in the four-time intervals. Creating interaction terms between the temporal variable for each time interval and the distance to a station, they found that being located closer to Midway Line positively affected prices of single-family houses and these positive effects are estimated not only during the service operation but after the project was announced and underwent construction indicating the possibility for the property value uplift as a result of the service anticipation.

Golub, Guhathakurta, and Sollapuram (2012) applied the DID model to examine how different stages of LRT service completion in Phoenix, AZ affected property values of real-estate markets including single-family and multi-family houses, commercial development as well as vacant lands. Dividing the study period into four subperiods (conception, planning, construction, and operation) and calculating distance to each station, they constructed interaction terms between each subperiod and distance to LRT showing the presence of price premiums for single-family houses closer to stations. Mixed results in terms of their significance were found for other types of properties. This study also tried to address the potential nuisance effects, produced by being in the immediate proximity to the LRT track, on property values with most findings no statistically significant.

Ke and Gkritza (2019) examined how the LRT system impacted single-family housing values in Charlotte-Mecklenburg, NC during the system's announcement and operations phases. Applying a quasi-experimental spatial econometric approach, this study found that prices per square feet of houses, located closer to proposed LRT stations, grew after the official announcement of the project revealing the importance of estimating a value uplift before opening. On the contrary, following the start of LRT service, houses were valued more if they were located farther away from a station. This can be explained by residents' anticipation of potential nuisance effects (e.g. noise pollution, increased traffic, and an influx of strangers) in locations closer to LRT. However, this study is not without limitations including the use of prices per square feet rather than actual sales prices and missing key controls for location and neighborhood characteristics affecting residents' willingness to buy a house such as the distance to CBD and income.

More recent work by Mathur (2020) analyzed sales of single-family houses and condominium/townhouses within two miles from the Warm Springs (WS) BART Station in Fremont, CA between 2000 and 2018. Unlike most studies on LRT that focus on properties within a half-mile, this study defines rather a broader station area of two miles arguing that heavy and commuter rail services impact property values on a larger geographic area. Mathur divided a study period into five subperiods of interest where each one marked an important project implementation stage. He found for most subperiods single-family housing values experienced an increase of 10-

15% within two miles from WS BART station even before the service opening. Mathur was also one of the first to utilize the value capture tool for funding mass transit projects: he estimated the total housing value increment enough to cover five times the costs of the WS BART project.

Similarly, the most relevant work to the current study, done by Duncan et al. (2020), also focuses on property value and tax value increments of properties, located within the half-mile of individual stations of Sunrail Phase 1 commuter rail service in Greater Orlando Area, FL during the eleven-year study period (2007–2017). Employing a relatively simple paired case-study approach, this study showed that the operation of new Sunrail service possibly spurred the new mixed-use TOD and construction of multi-family units around individual stations yielding an incremental gain in station area property values of more than $1.3 billion. Comparatively, a tax revenue increment of $2.63 million was estimated for station areas.

Overall, property value and tax revenue increments within station areas demonstrated that Sunrail commuter rail positively affects local property values and tax revenues in a relatively short time. However, as the authors pointed out themselves, a more accurate estimation of Sunrail effects on property prices requires a more sophisticated statistical analysis that controls for other characteristics contributing to a potential value uplift. To account for other factors affecting property values, a methodology such as the hedonic price model, imposing both controls and fixed effects, is needed.

The capitalization effects of transit investments are also hypothesized to vary depending on the context of the station area. Previous studies mainly attribute the contextual differences between stations to how well a transit station incorporates the transit-oriented development (TOD) elements (Atkinson-Palombo, 2010; Duncan, 2011; Higgins and Kanaroglou, 2017; Kahn, 2007; Lieske et al., 2019; Mathur and Ferrell, 2013). According to these studies, areas featuring TOD characteristics such as high levels of transit accessibility, high-density mixed-use development, and pedestrian-friendly environment, not having a park-and-ride facility are assumed to concentrate the highest property premiums.

In his study on gentrification levels in TOD communities of 14 US cities with rail transit expansions from 1970 to 2000, Kahn (2007) argues that walk-and-ride (WAR) and park-and-ride (WAR) station types distinguished by whether or not they have access to a parking lot affect local communities differently. He hypothesized that living near WAR station areas were more likely to offer a new urbanist lifestyle involving walking to a station whereas PAR communities experienced noise, exacerbated traffic, and, generally, poorer quality of life. Overall, findings by Kahn showed housing prices increased around WAR stations as opposed to no changes in prices in PAR station areas. However, in US cities like Boston, he found housing prices decreased near PAR stations.

Atkinson-Palombo (2010) estimated the effects of the accessibility to LRT and transit-oriented overlay zoning on prices of single-family houses and condos in different neighborhood types in Phoenix, Arizona. Based on the land-use mix, two neighborhood types were defined: amenity-dominated mixed-use neighborhoods, largely WAR communities, and primarily residential neighborhoods, mostly PAR communities. Single-family houses and condos were found to be sold at a premium of 6% and 17% respectively in amenity-dominated mixed-use neighborhoods near WAR stations with overlay zoning boosting a premium for condos to 37%. In residential neighborhoods near PAR stations, there was no price change for single-family houses and a 13% decrease in prices of condos attributed to noise, traffic, and congestion due to a parking lot.

Duncan (2011) explores the impact of the TOD on prices of condominiums in San Diego, CA. Here, TOD is represented through the synergistic relationship between proximity to trolley stations and pedestrian environment. Duncan found that condo prices witnessed a substantially higher premium near a rail station if it is located in a pedestrian-oriented environment. However, condos within a station area characterized as auto-oriented and barely walkable were sold at a discount. The findings demonstrate the ability of station proximity to generate property premiums is conditional on the quality of the pedestrian environment around a station.

More recent work by Higgins and Kanaroglou (2017) examined how the proximity to different station types, varying in terms of the local TOD context, affects the land value uplift (LVU) of single-family houses in the Toronto region, Canada. Four types of stations were specified depending on the degree of existing TOD elements, measured by transit accessibility, development density, land-use mix, and walkability. The authors confirm that LVU effects are heterogenous and conditional on the station context. The findings are rather mixed as LVU is consistently higher but declines quickly in suburban TOD stations compared to more urban stations experiencing a marginal LVU with a larger impact area. They also found no LVU effects for station areas exhibiting the highest levels of TOD. These findings were explained by a complex interaction between TOD and the single-family housing market.

As was noted earlier, in certain instances, accessibility benefits, brought by new transportation infrastructure, could be outweighed by negative externalities associated with being located closer to this infrastructure that results in the discount of property prices. Several studies specifically addressed both amenity and disamenity effects of rail service and highway on property values of single-family houses as well as commercial properties (Kilpatrick, 2007; Seo, Golub, and Kuby, 2014; Seo et al., 2018).

Focusing on 1,321 sales transactions of single-family houses in Seattle, WA between 2002 and 2005, Kilpatrick (2007) attempted to isolate and discern the negative externalities from being located within a one-mile proximity zone from Interstate 90 corridor on property values. Using the OLS estimators with hedonic price modeling, he found that sales prices of single-family houses appear to grow as the distance from the I-90 corridor increases and this negative effect on sales prices continues up to 300 feet. However, as Kilpatrick explains himself, this study poses a limitation for causal inferences since it is yet to be verified whether accessibility benefits of I-90 are robust given it presents the only connection between CBD and suburbs and no other alternative rail transit option is offered for local people.

Another study was done by Seo, Golub, and Kuby (2014) which was focused on amenity and disamenity effects of two different transportation infrastructures, namely LRT and highway, on property values of single-family detached homes in 2009 in Phoenix, AZ. This study assumes that accessibility benefits (amenity) of both LRT and highway are likely to be found at nodes (i.e. LRT stations and highway exits) whereas negative externalities (disamenity) should be detected in the immediate proximity from both rail and highway links and nodes. Multiple-distance bands rather than actual distance from LRT and highway is applied to capture the distance decay of amenity and disamenity effects. They found single-family houses have higher property values if they are located closer to both LRT and highway nodes with shorter-range distance-decay disamenity effects whereas the findings for the distance from highway and LRT links lacked statistical significance. They also inferred that positive amenity effects for highway exits extend further than for LRT stations.

However, the work by Seo, Golub, and Kuby (2014) has its shortcomings that offer room for further research. Even though it might be considered beyond the scope of the study, it did not estimate combined amenity and disamenity effects of LRT and highway on property values in a single model. This can be done by looking specifically at overlapping proximity zones where properties can benefit from accessibility to both LRT stations and highway exits simultaneously. Moreover, this study follows a cross-sectional research design by analyzing one-year data which makes it hard to infer whether positive effects on property values are directly caused by better access to both highway and LRT making the findings less conclusive. The quasi-experimental econometric analysis should be carried out to compare property values before and after a transportation intervention was made affecting the level of access to highway or rail service.

Bardaka, Delgado, and Florax (2019) present rather a rare attempt in the literature to examine potentially reinforcing effects of multiple transportation interventions located in vicinity to each other. Specifically, this study designs DID models using spatial econometrics and a sequential treatment approach to investigate multiple transportation interventions caused by the opening of the LRT system in 1994 (first treatment) in Denver, CO that was consequently expanded between 2000 - 2006 (second treatment). Direct, indirect, and total average causal effects of sequential and spatially overlapping LRT interventions on three main outcomes - median household income, educational attainment, and median housing values – serving as indicators for neighborhood gentrification are estimated. For detailed findings refer to the study by Bardaka, Delgado, and Florax (2019). Overall, this work offers a useful framework for analyzing concurrent transportation interventions in spatial and temporal scales.

This study examines the impact of Phase 1 Sunrail commuter service on sale prices of single-family houses in proximity to stations. It seeks to make a contribution to the above-described literature in the following ways: (1) provide evidence for regional variation in housing premiums with contextual differences between station types (2) build upon the framework, proposed by Bardaka, Delgado, and Florax (2019), to present the first capitalization study that addresses individual and cumulative effects of multiple transportation interventions coexisting spatially and temporally. The latter contribution is made by considering how disamenity effects, generated by the multi-year construction of I-4 Ultimate, potentially offset the accessibility benefits, brought by Sunrail, for single-family houses located in the area impacted by both transportation interventions. The secondary contributions involve adding more recent work about the effects of commuter rail on property prices and examining the value uplift from improved accessibility to Sunrail before service completion.

III. METHODOLOGY

3.1 Study Area: Phase 1 Sunrail Project

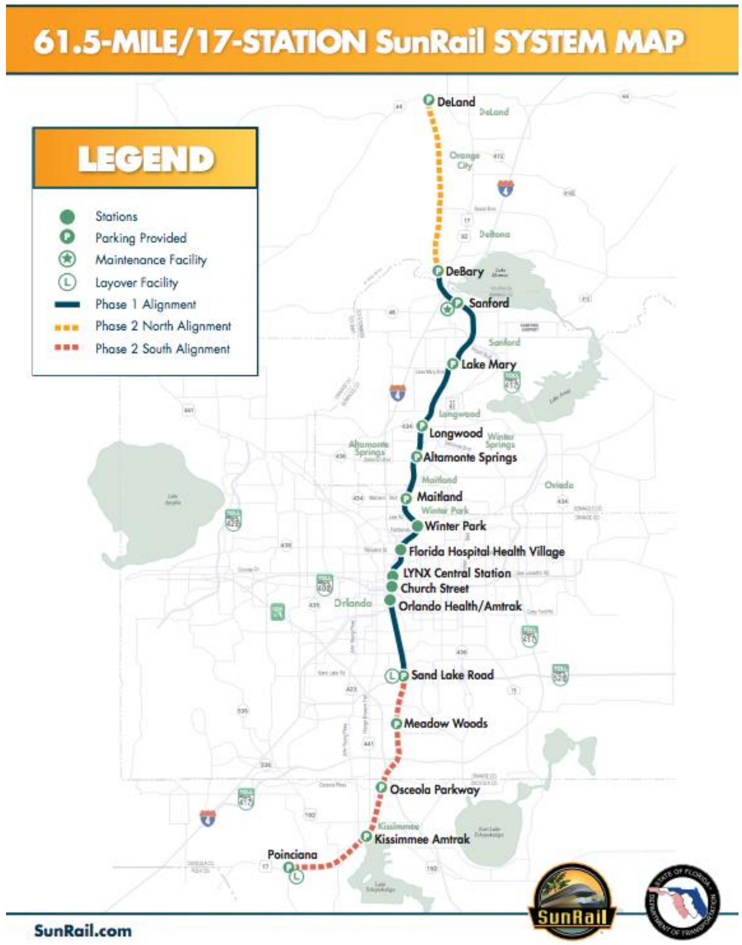

Figure 1. Sunrail Commuter System Map (Source: Florida DOT)

Sunrail is Florida's second major commuter rail system since the opening of Tri-Rail in South Florida. Being located in the Orlando metropolitan area, it spans 48.9 miles from DeBary (northern terminus) to Poinciana (southern terminus) along a former CSX Transportation railroad right-of-way connecting Downtown Orlando with suburbs and urban centers of four counties: Volusia, Seminole, Orange, and Osceola (Figure 1). The capital cost of the transit projects is estimated at \$357.2 million with an average cost per mile of \$11.2 million. Sunrail commuter system was primarily built to offer a reliable non-motorized alternative for commuting across the region of

Central Florida and alleviate considerable traffic congestion, particularly, on the busiest Interstate-4 corridor that runs along the Sunrail line.

The Sunrail commuter system was implemented in two phases. Opened on May 1, 2014, Phase 1 includes 12 stations that are connected by the 32-mile long track running north-south through boundaries of Volusia, Seminole and Orange counties between Debary and Sand Lake Road. The further system expansion of 17 miles toward a southern region, known as Phase 2 South, was completed in July 2018 providing access to Sunrail on four additional stations in Osceola county. The system extension of 13 miles north from the City of DeBary to the DeLand Amtrak station was also planned but given the lack of necessary funds, the project was not completed.

Providing weekday service each day, Sunrail is the only transit option for residents to commute in a north-south direction as the local bus transit system, LYNX, mostly plays the complementary role of offering the east-west access to Sunrail at each station expanding the service area of the commuter service (DOT, 2019). Additionally, the Downtown Orlando stations (LYNX and Church Street) are also integrated with the LYMMO BRT system that serves an entire downtown area and allows to freely transfer to and from Sunrail stations. However, given that most stations are placed in suburbs, characterized by medium to low development density and limited bus service coverage, they are equipped with the park-and-ride system leading to most Sunrail passengers arriving at stations by car. As it is explained later, the above-mentioned factors influenced to a certain extent the selection of the station catchment area size.

Sunrail's average daily ridership as of April 2019 is 6,371 trips doubling the monthly trips in its first year of its operation (slightly over 3,000) suggesting that more residents are inclined to use the Sunrail commuter service. Most of these trips originate in suburban stations from where residents commute to their job destinations in Downtown Orlando arriving at LYNX and Church Street stations as well as in more urban stations of Florida Hospital and Orlando Health (DOT, 2019). The latter two stations are located close to the medical centers, including AdventHealth which is considered as one of the largest regional employers in Central Florida. Based on suggestive travel patterns of Sunrail commuters, stations in downtown and near hospital campuses will be examined apart from the rest of suburban stations.

The focus of this study is to examine the impact of Phase 1 Sunrail stations (from Debary to Sand Lake Road) on property values of nearby single-family houses. The capitalization effects of Phase 2 Sunrail stations are a subject for future research. Since this study hypothesizes the property value uplift before the start of service operation, the timeline of the Sunrail Phase 1 project completion is explained in Figure 2.

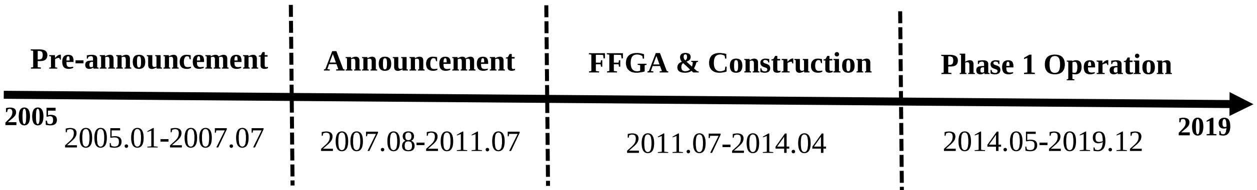

Figure 2. Timeline of Phase 1 Sunrail project completion

Pre-announcement phase (2005.01 – 2007.07): Between 2005 and 2007, the regional transportation authority of Central Florida was in serious talks about the future construction of the commuter rail system. In 2005, regional LRT plans considered Central Florida Commuter Rail Transit number one transportation funding priority (Tampa Bay Transportation Management Area Leadership Group, 2015). In 2006, FDOT was in the process to devise various plans with a specific focus on the CSX rail corridor as the future location for a commuter rail system.

Announcement phase (2007.08 – 2011.07): In July 2007, the officials of four counties and the city of Orlando reached an agreement to approve the Sunrail commuter system which marked the first serious step toward the implementation of the transit project. A few months later, CSX has agreed to sell the rights for tracks and right of way to FDOT. However, during the 2008 legislative session, the agreement was rejected on the grounds of liability and indemnification concerns. In April 2009, the bill to kick off Sunrail's construction failed again to secure support despite the approval of the project by FTA to enter into the final engineering and design stage a year earlier. Only in December 2009, the bill was finally approved by the Florida State legislature. Although the project was supported by senators, Amtrak and Sunrail disputed over liability obligations which prevented proceeding with the acquisition of CSX tracks. This dispute was eventually settled in December 2010. In January 2011, the state governor suspended the Sunrail project to review its financial feasibility who has finally approved the project later that year.

FFGA and Construction phase (2011.07-2014.04): On July 15, 2011, the Phase 1 Federal Funding Grant Agreement (FFGA), worth of $357.4 million, was signed that is viewed to be a crucial step in the Sunrail planning process and signifies the commitment by FTA for completing the commuter transit project (Cao and Lou, 2017). The groundbreaking event took place on January 27, 2012, commemorating the official start of the Phase 1 Sunrail construction. During the construction process, the entire commuter rail line was double-tracked, a total of 12 stations with a new Operations Control Center and Vehicle Storage & Maintenance Facility were built.

Phase 1 Operation phase (2014.05-2019.12): The Sunrail commuter service was officially commenced on May 1, 2014, providing the first reliable regional rail transit connection for the local population of Central Florida in modern history. Since its opening, several important additions were made to the service: mid-day and late-night trains were introduced as well as Saturday service was offered which boosted significantly the Sunrail ridership years onward.

3.2 Study Area: I-4 Ultimate Project

I-4 is Florida's interstate highway running 133 miles southwest-northeast concurrent with State Road 400 (SR 400). Constructed in the late 50s, the I-4 represents a key transportation connection starting at a western terminus of an interchange with I-275 in Tampa passing through suburbs of the Greater Orlando Area (e.g. Sanford, Maitland, and Winter Park) as well as Downtown Orlando and eventually terminating an eastern junction with I-95 in Daytona Beach (Figure 3).

On February 18, 2015, the FDOT officials and state governor held a groundbreaking ceremony marking the start of the $2.3 billion I-4 Ultimate Project focusing on rebuilding the 21-mile stretch of I-4 corridor from Kirkman Road (exit 75) in Orlando, Orange County to SR 434 (exit 94) in Longwood, Seminole County (Figure 3). Going down in Florida history as the largest infrastructure project, the I-4 Ultimate will result in notable improvements to the I-4 corridor: four variable-toll express lanes will be introduced, general-use lanes will be reconstructed, 15 major interchanges will be reconfigured, and over 120 bridges will be added or replaced. The I-4 Ultimate is projected to be completed in 2021 meaning that one of the busiest regional freeways is closed for, at least, six years.

Throughout the process of I-4 Ultimate implementation, there were several reports by news media outlets highlighting the overall discontent of local citizens with the nuisance produced from the construction of the project as well as excessive traffic congestion encountered by drivers using the I-4 corridor regularly for regional mobility. Recently, due to continuous delays and closures in the construction process, FDOT decided to postpone the completion of the I-4 Ultimate for an additional six months.

Figure 3. I-4 Ultimate Project Map (Source: www.i4ultimate.com)

3.3 Research Design

a. Sunrail's impact on prices of single-family houses

This study employs the data on sales transactions and property characteristics between 2005 and 2019 to examine the impact of Phase 1 Sunrail commuter service on property values of single-family family houses within the one-mile catchment area of each Sunrail station comprising the treatment zone (Figure 4). The dummy variable is created for parcels located within the treatment zone of one mile. The properties sold within the treatment zone are compared to the control zone which is represented by houses located between one and five miles to the Sunrail station. The distance from each property to the Sunrail station is calculated using the ArcGIS tool for computing the straight-line or euclidean distance.

The choice of the 1-mile station catchment area is justified by the assumption that the commuter rail is believed to influence property values on a larger geographic scope as opposed to LRT service which was a subject for most capitalization studies in the last two decades (Debrezion, 2007; Higgins and Kanaroglou, 2016; Mathur, 2020). Unlike most LRT systems in the US cities that generally carry fewer passengers and have a smaller coverage area, Sunrail runs through a larger part of the Central Florida region, serving as the main rail connection for people in municipalities of four counties. Therefore, the one-mile catchment area of Sunrail stations appears to be a reasonable way to define the size of the treatment zone that helps to avoid potentially underestimating Sunrail's effects on local property prices.

This study hypothesizes that the increase in property prices in response to the new Sunrail service takes place before the opening of the service. To test this hypothesis, the fifteen-year study period is divided into four subperiods according to the Sunrail project details explained earlier: January 2005– July 2007, August 2007 – July 2011, July 2011-April 2014, and May 2014 – December 2019. January 2005 – July 2007 is used as the pre-announcement phase when the first talks began about the future construction of the commuter rail system in the region. The August 2007 – July 2011 is the announcement phase during which the Sunrail's project was approved by all four counties, Florida's state legislature and the state governor. The subperiod of July 2011 – April 2014 is when FFGA was signed by FTA and major construction occurred. May 2014 – December 2019 is the Sunrail service operation phase. The dummy variable indicating each subperiod of interest is created. Finally, to estimate the impact of Sunrail service on property prices, interaction terms between a dummy variable for each subperiod and a dummy variable for properties sold within a 1-mile treatment zone are created.

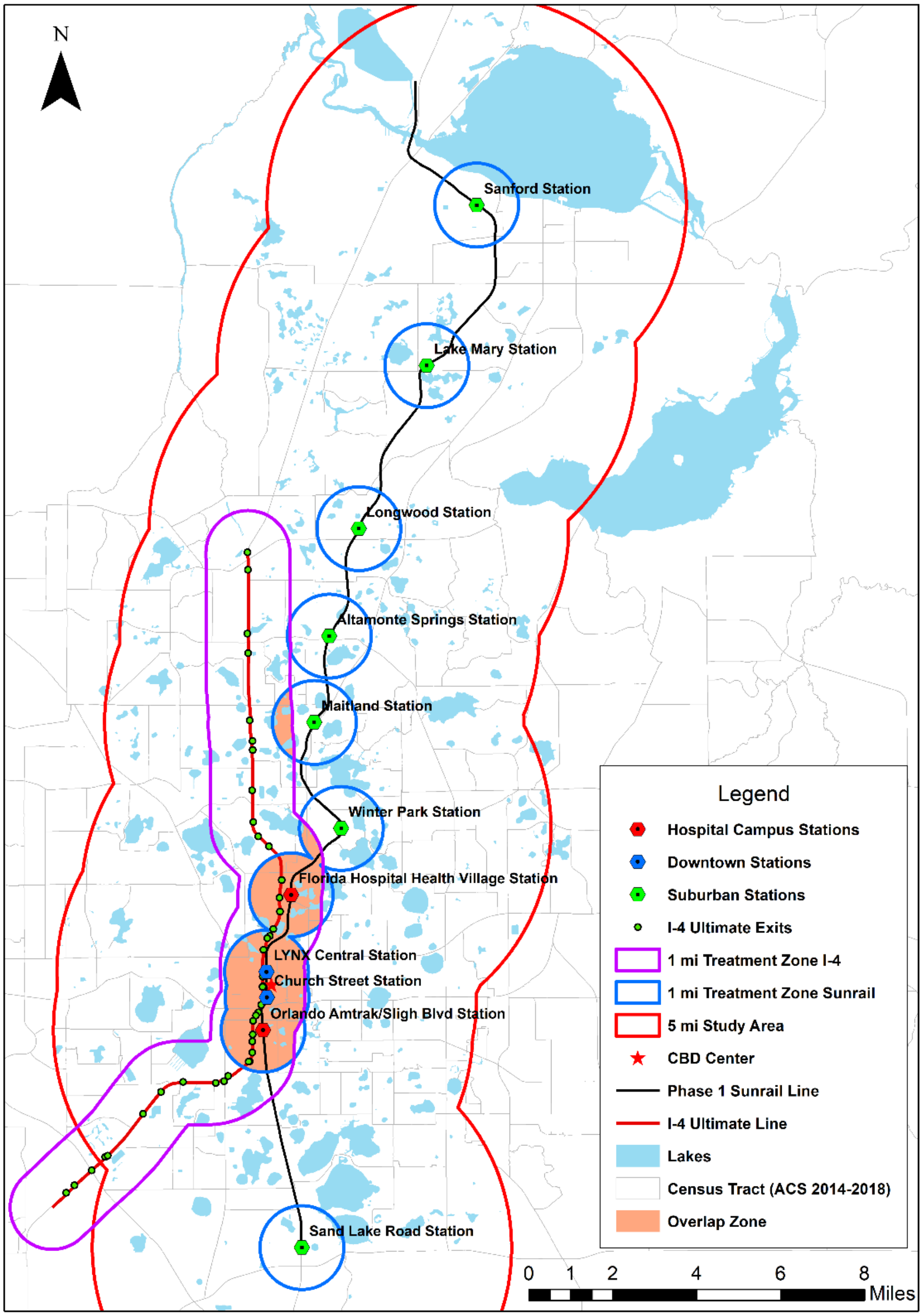

Figure 4. Map of the Study Area

b. Variation of Sunrail's impact on prices of single-family houses by station type

As was mentioned earlier, individual Sunrail stations are separated into three main station types: Suburban, Hospital Campus/Urban Center, and Downtown stations. The full data sample is divided based on these station types. The typology of stations was focused on contextual differences between station areas: Downtown and, to a lesser extent, Hospital Campus station areas are characterized as pedestrian-oriented, high dense, mixed-use, walk-and-ride whereas Suburban station areas are auto-oriented with low-density residential uses and park-and-ride facilities. Downtown stations are also integrated with the LYMMO BRT system that offers an effective first/last-mile solution for Sunrail riders other than walking to a station who reside in neighborhoods served by LYMMO system.

These contextual differences of station types, defined in the study, are further amplified by numerous revitalization projects in neighborhoods around Downtown and Hospital Campus stations which might further attract the attention of potential home buyers. One of these projects is Creative Village TOD in Paramore neighborhood west to LYNX station which "brings residents new educational and job training opportunities, housing options across a wide range of income levels and room for businesses to start and grow" (Orlando.gov).

Moreover, commuting patterns of Sunrail riders play a role in defining station types as most of them commute to job destinations in Downtown and Hospital Campus stations. The former stations are located in immediate proximity to Orlando CBD with a profusion of job opportunities whereas medical facilities near latter stations are a workplace for many among the local population. As a result, the heterogeneous context and development initiatives focused on specific station areas as well as commuting patterns of Sunrail users urged the need to analyze separately the effect of Phase 1 Sunrail on sale price of single-family houses around three station types.

c. Cumulative effects of I-4 Ultimate and Sunrail on prices of single-family houses

This study also aims to examine how property prices of single-family houses were affected by multiple transportation interventions, specifically, the I-4 Ultimate and Phase 1 Sunrail which overlap spatially and occur sequentially one after another (Figure 4). The property prices of single-family houses, located within one mile from the segment of the I-4 corridor, undergoing a multi-year reconstruction, are hypothesized to be affected by the nuisance from the construction work and intensified traffic congestion resulting from the closure of this segment. A dummy variable for single-family houses sold within the one-mile treatment zone is created. The selection of the size for the I-4 treatment zone was mainly influenced by the previous work by Kilpatrick (2007) who also applied the one-mile proximity zone for analyzing the impact of negative externalities from being located close to Interstate 90 corridor on property values.

Next, to evaluate how the I-4 Ultimate shaped the property prices, the study period after Sunrail service began its operation is divided into two subperiods before and after the reference time point signifying the start of I-4 Ultimate construction, February 18, 2015. As a result, two subperiods are considered: May 2014 – February 2015, and February 2015 – December 2019. The first subperiod of May 2014 – February 2015 is the pre-construction period of the I-4 Ultimate project when the project was planned and designed, and it was also the first operation year of Phase 1 Sunrail. The second subperiod of February 2015 – December 2019 marks the start of I-4 Ultimate project construction and continuation of Sunrail service operation. A dummy variable is created for each subperiod of interest.

To estimate the individual effect of I-4 Ultimate on property prices, dummy variables for the pre-announcement, announcement and FFGA & construction phases of the Sunrail project, described in the previous section, as well as pre-construction and construction phases of I-4 Ultimate are multiplied with a dummy variable, indicating properties sold within a 1-mile treatment zone from the I4 corridor. This creates interaction terms between each respective phase and I-4 treatment zone.

To account for the cumulative effects of both transportation interventions on single-family housing values, the dummy variable is assigned to houses located in the area where the two-mile treatment zone of Sunrail and one-mile zone of I-4 Ultimate overlap in space. The overlap zone allows us to isolate and analyze properties affected by both Sunrail service (treatment 1) and I-4 Ultimate (treatment 2). Interaction terms between a dummy variable of the overlap zone and a dummy variable for each subperiod of interest are created. The interaction term between the overlap zone and I-4 construction phase is of particular importance given that the focus of the analysis is to infer whether the multi-year construction of I-4 Ultimate Project engenders disamenity effects for properties, located no farther than 1 mile from the highway corridor, which also benefit from the accessibility to Sunrail stations.

3.4 Data

The parcel-level data for sales of single-family houses between 2005 and 2019 was obtained from the property appraiser offices of two counties (Orange and Seminole) comprising the entire study area. The house sale transactions of Volusia county were not included in the analysis due to missing data for important structural attributes such as the number of bathrooms in the house. The unit of analysis is a parcel of the single-family house. The raw data included property characteristics such as lot size, living area, actual and estimated years when the house was built, number of bedrooms and bathrooms in the house, the DOR use of the parcel, the date of the most recent sale in the "mm/dd/yyyy" format, and the actual sale price.

Next, the sales dataset was thoroughly cleaned to avoid any existing data errors: (1) observations with missing sale prices or sale dates were removed, (2) observations with a missing actual year built were removed, (3) observations with an estimated or actual year built later than a year a house was sold were removed, (4) observations with zero lot size, living area, bedrooms, and bathrooms were removed. To prevent potential effects of outliers, observations, indicating houses with more than 6 bedrooms and 4 bathrooms, as well as the top and bottom percentiles of actual sale prices, lot size, and living area were dropped. This resulted in the final sample size of 54,588 observations. The sale prices were also normalized to the US dollars in 2019 using the quarterly all-transactions HPI index for Orlando-Kissimmee-Sanford MSA provided by FRED Economic Data.

Employing ArcGIS tools, several locational characteristics were added to the initial sales dataset which might affect the property prices including the straight-line distance from each house to the nearest commercial development, nearest neighborhood park, nearest school or college, nearest hospital (due to the presence of major medical centers close to Sunrail stations), nearest highway road, nearest bus stop, and whether a property is located within 100 meters from the lake. Using US Census Bureau ACS 5-year estimates (2014-2018), the census tract data were also included to take into account neighborhood characteristics such as the median household income, population density, calculated the number of per square kilometer, and proportions of African-American and Hispanic populations. In addition, using LEHD Origin-Destination Employment Statistics

(LODES) data for 2017, the job density was calculated as the number of jobs available in a census tract per square kilometer.

3.5 Model Specification

The hedonic price model is commonly applied to estimate the impact of rail investments on property values. Developed by Rosen (1974), this model assumes the price of a house is determined by the implicit prices of its internal and external attributes including the structural characteristics (e.g. lot size, living area, number of bedrooms and bathrooms, age of the house, whether a house is a townhome or duplex), locational characteristics (e.g. proximity to commercial uses, park, schools/colleges, hospital, highway, bus stop, and lakes), and neighborhood characteristics (median income, population and densities, and racial composition). Therefore, the following notation (1) can be used to outline the hedonic price model more intuitively:

$$P = f\ (S, L, N, Treat)\ (1)\ ,$$

where *P* is the HPI-adjusted sales price of a single-family house, *S* contains a set of structural characteristics, *L* includes a set of locational characteristics, *N* comprises a set of neighborhood characteristics, and *Treat* is a dummy variable indicating whether a house is located within a certain distance threshold from transportation intervention under analysis.

The multilevel regression model is used for estimating the baseline hedonic price model. The decision to choose the multilevel model was made based on the indication of the presence of the unobserved spatial heterogeneity between individual parcels. These parcels at a lower level are believed to be nested at a higher level which is the census tract in this study. The simple OLS models are not suitable for taking into account the spatial variability in the sample which might lead to the overestimation of coefficients. As a result, the two-level regression model is established with level 1 of individual single-family house parcels aggregated at level 2 by census tract:

$$L1: Y_{ij} = \beta_{0j} + \sum_{n=1}^{N} \beta_{nj} X_{ij} + r_{ij}\ (2)$$

$$L2: \beta_{nj} = \gamma_{n0} + \sum_{m=1}^{M} \gamma_{nm} W_{mj} + u_{nj}$$

$$Y_{ij} = \gamma_0 + \sum_{n=1}^{I} \gamma_n X_{nij} + u_{0j} + \sum_{n=1}^{N} u_{nj} X_{nij} + r_{ij}$$

Where Y_{ij} is the log-transformed HPI-adjusted sale price of a single-family house i at level 1 located in a census tract j (level 2). β_{0j} is the intercept of the sale price in a census tract j, X_{ij} is the level 1 explanatory variable (structural and locational characteristics) of a house i in a census tract j and N, n, M, m serve as parameters. β_{nj} stands for the regression coefficient of the relationship between level 1 explanatory variables and sale price in a census tract j and r_{ij} is a random error coefficient at level 1. γ_{n0} is the overall intercept, γ_{nm} is the regression coefficient of the relationship between level 2 explanatory variables (neighborhood characteristics) and sale price, W_{mj} is level 2 explanatory variable, u_{nj} means a random error coefficient at level 2. $\gamma_0 + \sum_{n=1}^{I} \gamma_n X_{nij}$ is the FE of the model and $u_{0j} + \sum_{n=1}^{N} u_{nj} X_{nij} + r_{ij}$ is RE of the model.

The multilevel hedonic price model also follows the quasi-experimental research design through the addition of DID specifications since the objective of this study is to examine whether sale prices within the 1-mile treatment zone are affected by the Sunrail service over time (particularly in its announcement, construction, and operation phases). Therefore, DID specifications are used which include dummy variables for each subperiod of interest (Sunrail's announcement, FFGA & construction, and operation) and their interaction terms with the *Treat₁* variable. In addition, dummy variables for months are included to control for unobserved time trends in the data.

The baseline estimation equation can be expressed below (3):

$$lnP_{it} = \beta_0 + \beta_1 Treat_{1i} + \beta_2 A_t + \beta_3 C_t + \beta_4 O_t + \beta_5 (Treat_1 * A)_{it} + \beta_6 (Treat_1 * C)_{it} + \beta_7 (Treat_1 * O)_{it} + \beta_8 X_i + \sum \gamma_k \, month_k + \varepsilon_{it} \quad (3)$$

lnP_{it} is the dependent variable in the form of the log-transformed HPI-adjusted sale price of the house i at a time point t. β_0 is the constant, β_1 is the coefficient of $Treat_{1i}$, indicating a house i within a 1-mile treatment zone, β_2 is the coefficient of A_t signifying a sale at a time point t after the Sunrail's announcement was made, β_3 is the coefficient of C_t signaling a sale at a time point t during Sunrail's construction, β_4 is the coefficient of O_t indicating a sale at a time point t after Sunrail's opening, β_5 is the coefficient of $(Treat_1 * A)_{1it}$ which shows a house i sold within a treatment zone at a time point t during the announcement phase, β_6 is the coefficient of

$(Treat_1 * C)_{1it}$ indicating a house i sold within a treatment zone at a time point t during the FFGA and construction phase, β_7 is the coefficient of $(Treat_1 * O)_{1it}$ indicating a house i sold within a treatment zone at a time point t during the operation phase, β_4 is the coefficient of X_i indicating structural, neighborhood, and locational characteristics of a house i, $\sum \gamma_k \, month_k$ is the notation for monthly trend variable, and ε_{it} is the error term. The single-family houses sold in the control zone between 2 and 5 miles in the pre-announcement phase are used as the reference group for analysis.

Evaluating the results of Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC) for models of linear, semi-log, and log-log functional forms, the log-log model was selected. Besides a sales price, control variables for the structural, neighborhood, and locational characteristics, potentially exhibiting non-linear relationships were also log-transformed.

To examine the individual effects of I-4 Ultimate on sale prices of single-family houses, located within a 1-mile distance from the segment of the I-4 corridor under construction, the estimation equation (3) was derived:

$$lnP_{it} = \beta_0 + \beta_1 Treat_{2i} + \beta_2 A_t + \beta_3 C_t + \beta_4 PreI4_t + \beta_5 I4con_t + \beta_6 (Treat_2 * A)_{it} + \beta_7 (Treat_2 * C)_{it} + \beta_8 (Treat_2 * PreI4)_{it} + \beta_9 (Treat_2 * I4con)_{it} + \beta_{10} X_i + \sum \gamma_k \, month_k + \varepsilon_{it} \quad (4)$$

As compared to the equation (4), β_4 is the coefficient of $PreI4_t$ indicating a sale at a time point t during the first year of Sunrail's operation as well as a planning and design phase of I-4 Ultimate, β_5 is the coefficient of $I4con_t$ indicating a sale at a time point t after the start of the I-4 Ultimate construction, β_8 is the coefficient of $(Treat_2 * PreI4)_{it}$ indicating a house i sold within a treatment zone at a time point t during the pre-construction phase of I-4, β_9 is the coefficient of $(Treat_2 * I4con)_{it}$ signifying a house i sold within a treatment zone at a time point t during the I-4 Ultimate construction phase. For the rest of the variables, the coefficients are interpreted similarly to equation (2). The reference group contains single-family houses, sold during the pre-announcement phase, outside of the I-4 treatment zone but within the 5 miles from Phase 1 Sunrail.

Finally, to analyze how single-family housing prices were affected by both Sunrail service (*Treat*$_1$) and I-4 Ultimate (*Treat*$_2$), the sequential treatment DID specification should be added to the baseline model to include the cumulative effects of both transportation interventions shown in the equation (4):

$$lnP_{it} = \beta_0 + \beta_1 Treat_{1i} + \beta_2 Treat_{2i} + \beta_3 (Treat_1 * Treat_2)_i + \beta_4 A_t + \beta_5 C_t + \beta_6 PreI4_t + \beta_7 I4con_t + \beta_8 (Treat_1 * A)_{it} + \beta_9 (Treat_1 * C)_{it} + \beta_{10} (Treat_1 * PreI4)_{it} + \beta_{11} (Treat_1 * I4con)_{it} + \beta_{12} (Treat_2 * A)_{it} + \beta_{13} (Treat_2 * C)_{it} + \beta_{14} (Treat_2 * PreI4)_{it} + \beta_{15} (Treat_2 * I4con)_{it} + \beta_{16} (Treat_1 * Treat_2 * A)_{it} + \beta_{17} (Treat_1 * Treat_2 * C)_{it} + \beta_{18} (Treat_1 * Treat_2 * PreI4)_{it} + \beta_{19} (Treat_1 * Treat_2 * I4con)_{it} + \beta_{20} X_i + \sum \gamma_k \, month_k + \varepsilon_{it} \quad (5)$$

The equation (4) includes both $Treat_1$ and $Treat_2$ in a single model along with all coefficients of interaction terms for both treatments as specified in the equations (3) and (4). It is important to note that $Treat_1$ and $Treat_2$ do not include observations in the overlapping zone. β_3 is the coefficient of $(Treat_1 * Treat_2)_i$ indicating a house i sold within the overlap zone of Sunrail's 2-mile station catchment area and I-4 Ultimate's 1-mile proximity zone. $(Treat_1 * Treat_2)_i$ interact with each subperiod of interest: $A_t, C_t, PreI4_t, and\ I4con_t$. β_{19} is a coefficient of particular interest in the model since it signifies the disamenity effects of the I-4 Ultimate Project's construction on sale prices of single-family houses which also benefit from the improved transit accessibility from the Sunrail's operation. The reference group for this model is comprised of houses located outside of the treatment zones for both transportation interventions which were sold in the pre-announcement phase.

IV. RESULTS

4.1 Descriptive Statistics

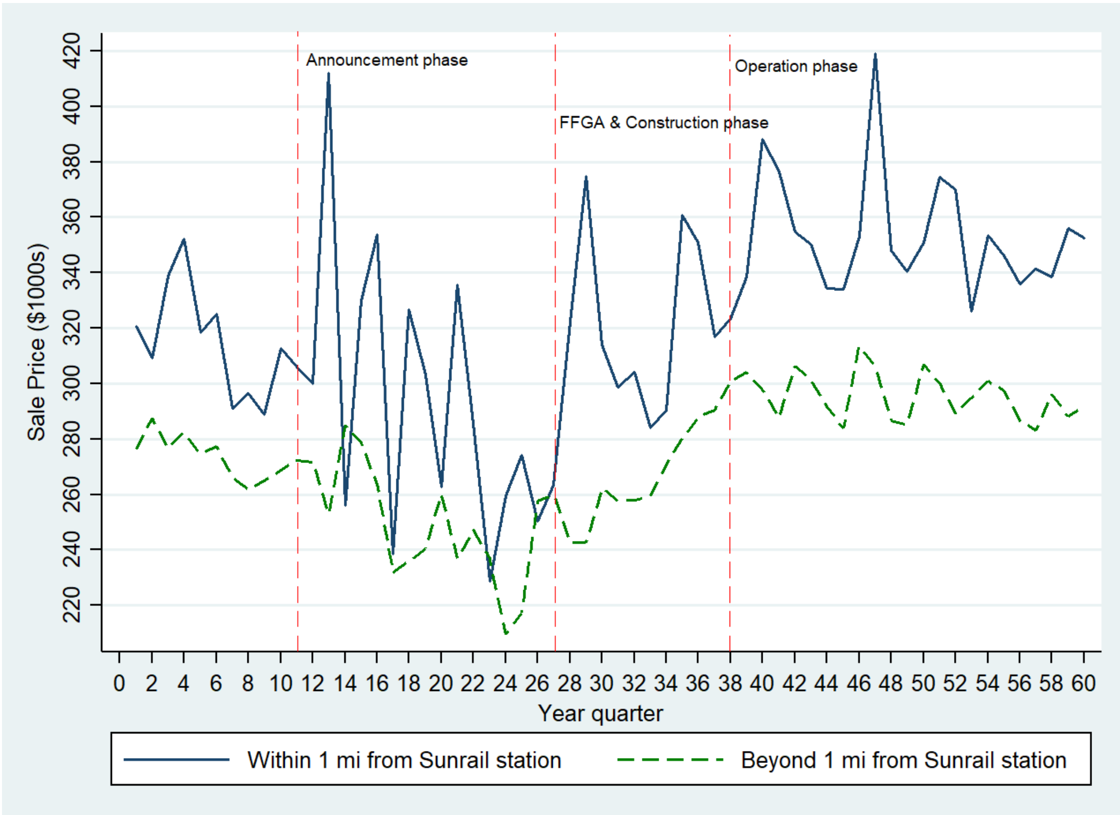

Figure 5. Temporal changes of sale price (2019 $s) in treatment and control zones

Figure 5 shows how HPI-adjusted sale prices of single-family houses changed over the fifteen-year study period in the 1-mile treatment zone from Sunrail station as compared to the control zone comprised of houses between 1 and 5 miles from the station. The red dash lines indicate important time points during the study period: announcement, FFGA and construction, and operation phases. According to Figure 5, sale prices of single-family houses were consistently higher in the treatment zone as opposed to the control zone in the pre-announcement phase. After the Sunrail's project was announced, however, there was a downward trend in fluctuations of sale prices for both zones that is likely attributed to the Great Recession of 2008 as Florida was among states the housing market of which hit hardest by the crisis. From the third quarter of 2011, coinciding with the start of the FFGA and construction phase, sale prices of houses within a treatment zone recovered at a higher rate relative to the control zone. This trend continued during

Phase 1 Sunrail's operation phase as the gap between prices in treatment and control zones appeared to get wider.

Table 1. Descriptive statistics of the study area

	Variable	Mean	Std. Dev.	Min	Max
	Sale price in 2019 $s	288,947	167,696	24,654	1,571,345
	Ln (sale price in 2019 $s)	12.42	0.58	10.11	14.27
Structural Characteristics	Lot size (sq.ft)	9509.51	7199.5	1045.4	63772.09
	Living area (sq.ft)	1818.98	665.17	805	4419
	Bedrooms	3.2	0.72	1	6
	Bathrooms	2.22	0.67	1	4
	Age of the house (years)	27	18	0	119
	Townhome	0.14	0.34	0	1
	Duplex	0.01	0.11	0	1
Locational Characteristics	Distance to nearest commercial (mi)	0.37	0.26	0	1.624
	Distance to nearest park (mi)	1.585	1.025	0.007	5.869
	Distance to nearest school/college (mi)	1.001	0.705	0.013	4.657
	Distance to nearest hospital (mi)	3.73	1.595	0.069	7.563
	Distance to nearest bus stop (mi)	0.574	0.528	0.008	2.659
	Distance to nearest highway (mi)	0.646	0.491	0.011	2.677
	Houses within 100 m of a lake	0.08	0.28	0	1
Neighborhood Characteristics	Median household income ($)	62,624	22,220	21,279	171,000
	Population density (per sq.km)	1,339.53	724.49	90.58	4,558.76
	Job density (per sq.km)	598.32	791.57	23.66	5,698.25
	Percent Black	0.15	0.19	0	0.99
	Percent Hispanic	0.14	0	0.71	
Time Variables	Announcement phase	0.12	0.33	0	1
	FFGA & construction phase	0.13	0.34	0	1
	Operation phase	0.61	0.49	0	1
	N	**54,588**			

Table 1 demonstrates descriptive statistics for the entire study area which is comprised of 55,588 observations. It includes a full list of structural, locational, and neighborhood characteristics controlled in the regression models. However, as shown later in the results of the models, most of these control variables are log-transformed due to non-linearity they might exhibit. This was confirmed by the performance of the log-log model compared to other functional forms based on

AIC and BIC values. After the rigorous data cleaning process, described in the previous section, the average sale price of a single-family house is equal to $288,947 for the entire study area.

Table 2. Descriptive statistics of treatment and control zones (Phase 1 Sunrail)

		Treatment		**Control**	
	Variable	Mean	Std.Dev.	Mean	Std.Dev.
Structural Characteristics	Sale price in 2019 $s	336,596	208,861	283,608	161,563
	Ln (sale price in 2019 $s)	12.54	0.63	12.4	0.57
	Lot size (sq.ft)	9,035.97	5,996.59	9,562.46	7,320.19
	Living area (sq.ft)	1,803.83	672.32	1,820.68	664.36
	Bedrooms	3.09	0.75	3.21	0.72
	Bathrooms	2.13	0.73	2.23	0.66
	Age of the house (years)	28	18	26	18
	Townhome	0.09	0.29	0.14	0.35
	Duplex	0.01	0.08	0.01	0.11
Locational Characteristics	Distance to nearest commercial (mi)	0.251	0.181	0.383	0.264
	Distance to nearest park (mi)	0.774	0.511	1.676	1.028
	Distance to nearest school/college (mi)	0.642	0.33	1.042	0.724
	Distance to nearest hospital (mi)	3.45	1.687	3.761	1.581
	Distance to nearest bus stop (mi)	0.305	0.216	0.605	0.544
	Distance to nearest highway (mi)	0.338	0.224	0.681	0.5
	Houses within 100 m of a lake	0.11	0.31	0.08	0.27
Neighborhood Characteristics	Median household income ($)	64,538	20,614	62,410	22,383
	Population density (per sq.km)	1,366.68	534.08	1,336.48	742.75
	Job density (per sq.km)	1,376.94	1,523.34	511.05	600.99
	Percent Black	0.11	0.14	0.16	0.19
	Percent Hispanic	0.17	0.08	0.24	0.14
Time Variables	Announcement phase	0.11	0.31	0.12	0.33
	FFGA & construction phase	0.13	0.33	0.13	0.34
	Operation phase	0.63	0.48	0.6	0.49
	N	**5,502**		**49,086**	

Table 2 compares the characteristics of Phase 1 Sunrail treatment and control zones. The treatment zone includes 5,502 observations compared to 49,086 observations in the control zone. Overall, it appears to be both treatment and control zones share similar characteristics. However, as observed in Figure 4, it also shows that sale prices of houses within the 1-mile catchment area of Sunrail stations were on average higher as opposed to the control zone by approximately $50,000 over the study period. Additionally, neighborhoods with a higher number of jobs, lower proportions of African-Americans and Hispanics, and are located within a 1-mile distance from Sunrail stations compared to the rest of the study area.

Table 3. Descriptive statistics of the study area by station type (Phase 1 Sunrail)

		Suburban	**Hospital Campus**	**Downtown**
	Variable	Mean	Mean	Mean
Structural Characteristics	Sale price in 2019 $s	285,130	304,412	285,052
	Ln (sale price in 2019 $s)	12.41	12.46	12.35
	Lot size (sq.ft)	9,851.14	8,693.15	8,616.92
	Living area (sq.ft)	1,890.51	1,678.33	1,566.14
	Bedrooms	3.26	3.08	2.97
	Bathrooms	2.32	2.02	1.90
	Age of the house (years)	26	28	32
	Townhome	0.16	0.07	0.07
	Duplex	0.01	0.02	0.02
Locational Characteristics	Distance to nearest commercial (mi)	0.419	0.268	0.202
	Distance to nearest park (mi)	1.817	0.991	1.067
	Distance to nearest school/college (mi)	0.962	1.205	0.866
	Distance to nearest hospital (mi)	3.399	4.333	5.000
	Distance to nearest bus stop (mi)	0.724	0.219	0.179
	Distance to nearest highway (mi)	0.689	0.627	0.350
	Houses within 100 m of a lake	0.07	0.13	0.07
Neighborhood Characteristics	Median household income ($)	65,879	57,046	49,328
	Population density (per sq.km)	1,126.44	1,887.23	1,811.22
	Job density (per sq.km)	475.68	859.43	988.22
	Percent Black	0.12	0.23	0.23
	Percent Hispanic	0.23	0.19	0.28
Time Variables	Announcement phase	0.13	0.12	0.10
	FFGA & construction phase	0.14	0.13	0.11
	Operation phase	0.62	0.58	0.59
	N	**38,804**	**10,832**	**4,952**

Table 3 describes the characteristics of the study are by station type (suburban, downtown, and hospital campus). The standard deviation, min, and max values are not shown to present descriptive statistics more concisely. As was noted in the Phase 1 Sunrail Case Study section, travel patterns of Sunrail commuters suggest that certain stations attract more trips than others as passengers largely commute for work from suburbs to either LYNX and Church Street stations in Downtown Orlando or Florida Hospital and Orlando Health stations where large-scale hospital facilities, serving as major regional employers, are located. Table 3 compares the characteristics of houses by station type which shows most single-family houses are predominantly located closer to suburban stations (38,804) followed by hospital campus (10,832) and downtown stations (4,952). The highest mean sale price is found in hospital campus station areas. The median household income is the highest in neighborhoods close to suburban stations of Sunrail which also have the lowest proportion of Black Americans compared to other station types. As expected, the average population and job densities of suburban stations are significantly lower relative to downtown and more urban stations.

Table 4. Descriptive statistics of treatment and control zones (I-4 Ultimate)

		Treatment		**Control**	
	Variable	Mean	Std. Dev.	Mean	Std. Dev.
Structural Characteristics	Sale price in 2019 $s	343,633	192,870	281,160	162,307
	Ln (sale price in 2019 $s)	12.59	0.60	12.39	0.58
	Lot size (sq.ft)	10,051.24	7,383.05	9,432.21	7,169.74
	Living area (sq.ft)	1,861.57	693.88	1,812.91	660.77
	Bedrooms	3.15	0.74	3.20	0.72
	Bathrooms	2.14	0.71	2.24	0.66
	Age of the house (years)	30	17	26	18
	Townhome	0.10	0.29	0.14	0.35
	Duplex	0.004	0.06	0.01	0.12
Locational Characteristics	Distance to nearest commercial (mi)	0.233	0.152	0.389	0.266
	Distance to nearest park (mi)	0.871	0.519	1.686	1.039
	Distance to nearest school/college (mi)	0.815	0.447	1.028	0.730
	Distance to nearest hospital (mi)	3.771	1.486	3.724	1.610
	Distance to nearest bus stop (mi)	0.280	0.212	0.616	0.546
	Distance to nearest highway (mi)	0.324	0.206	0.692	0.502
	Houses within 100 m of a lake	0.12	0.33	0.08	0.27
Neighborhood Characteristics	Median household income ($)	62,385	20,336	62,659	22,476
	Population density (per sq. km)	1,556.33	577.12	1,308.64	737.95
	Job density (per sq. km)	1,402.31	1,472.82	483.80	549.29
	Percent Black	0.15	0.22	0.15	0.18
	Percent Hispanic	0.18	0.10	0.24	0.14

Time Variables	Announcement phase	0.12	0.32	0.12	0.33
	FFGA & construction phase	0.15	0.36	0.13	0.34
	Pre-construction I-4 phase	0.06	0.23	0.05	0.22
	Construction I-4 phase	0.53	0.50	0.55	0.50
	N	**6,806**		**47,782**	

Table 4 shows the descriptive statistics for the treatment and control zones for I-4 Ultimate. The 1-mile zone from the I-4 corridor under a multi-year construction is comprised of 6,806 observations compared to 47,782 observations in the control zone. From Table 4, it can be seen that single-family houses within both treatment and control zones share relatively similar attributes. However, houses within a 1-mile distance from the I-4 Ultimate appear to have considerably higher prices on average compared to those farther than 1 mile.

Table 5. Frequency of interactions terms

Variable	Frequency	Percent
1 mi Sunrail * Announcement	344	0.63
1 mi Sunrail * FFGA & Construction	421	0.77
1 mi Sunrail * Operation	3,441	6.3
1 mi Sunrail * I-4 Pre-construction	164	0.3
1 mi Sunrail * I-4 Construction	1,758	3.22
1 mi I-4 Ultimate * Announcement	540	0.99
1 mi I-4 Ultimate * FFGA & Construction	762	1.4
1 mi I-4 Ultimate * I-4 Pre-construction	260	0.48
1 mi I-4 Ultimate * I-4 Construction	2,207	4.04
Overlap * Announcement	263	0.48
Overlap * FFGA & Construction	285	0.52
Overlap * I-4 Pre-construction	134	0.25
Overlap * I-4 Construction	1,369	2.51
Observations	55,588	

Table 5 shows the frequency of all interaction terms included in the regression models. These interactions terms, indicating whether a single-family house is located within a given treatment zone during a given phase, are of particular interest in the analysis. The analysis of the models, described in the next section, is performed using the Stata version 13.0 software.

4.2 Baseline DID Model Results for Phase 1 Sunrail

Table 6. DID Model Results for Phase 1 Sunrail

	Dependent variable	Ln of Sale price (2019 $s)	Coefficient	p-value
	Fixed effects			
Level 1	Time variables	Announcement	-0.0204	
			(0.056)	
		FFGA & Construction	0.0179	
			(0.024)	
		Operation	0.1160	***
			(0.022)	
	Treatment zone	1 mi Sunrail station	-0.0635	***
			(0.013)	
	Interaction terms	1 mi Sunrail * Announcement	**0.0689**	*******
			(0.017)	
		1 mi Sunrail * FFGA-Construction	**0.0706**	*******
			(0.016)	
		1 mi Sunrail * Operation	**0.054**	*******
			(0.013)	
	Structural characteristics	Ln of Lot Size	0.107	***
			(0.004)	
		Ln of Living Area	0.679	***
			(0.008)	
		Age of the house	-0.0131	***
			(0.000)	
		Age of the house (squared)	0.0001	***
			(0.000)	
		Bedrooms	-0.0063	*
			(0.003)	
		Bathrooms	0.0620	***
			(0.003)	
		Townhome	-0.0636	***
			(0.006)	
		Duplex	-0.1437	***
			(0.013)	
	Locational characteristics	Houses within 100 m from a lake	0.0590	***
			(0.005)	
		Ln of distance to nearest commercial	0.0155	***
			(0.002)	
		Ln of distance to nearest park	0.0088	*

			(0.003)	
		Ln of distance to nearest school	0.0109	***
			(0.003)	
		Ln of distance to nearest hospital	-0.0296	***
			(0.007)	
		Ln of distance to nearest highway	0.0110	***
			(0.002)	
		Ln of distance to nearest bus stop	0.0159	***
			(0.002)	
Level 2	Neighborhood characteristics	Ln of median household income	0.214	***
			(0.063)	
		Ln of population density	0.113	***
			(0.024)	
		Ln of job density	0.0721	***
			(0.013)	
		Percent Black	-0.762	***
			(0.100)	
		Percent Hispanic	-0.491	***
			(0.117)	
	Monthly trend variable	Monthly dummy	Yes	
		Intercept	3.2989	***
			(0.8068)	
Level 1	**Random effects**	Intercept	-1.688	***
			(0.056)	
		N	54,588	
Level 2		Intercept	-1.234	***
			(0.003)	
		N groups	179	
		ICC	0.2873	
		AIC	21,415.2	
		BIC	23,259.1	

Standard errors in parentheses: * p<0.1, ** p<0.05, *** p<0.01

Unit change in IV = exp(b – 1/2*se^2) – 1

Table 6 shows the baseline multilevel DID model results for Phase 1 Sunrail. Applying the chi-square likelihood-ratio test, AIC and BIC tests to assess the overall model fit, the model in Table 6 was concluded to perform the best. The coefficients of dummy variables in the model are interpreted as a unit change using the formula: $\exp(b – 1/2*se^2) – 1$. A more detailed look at the calculation of these estimates can be found in studies by Immergluck (2009) and Kennedy (1981).

Overall, most of the control variables in the level 1 of the model that are statistically significant at 5% have expected signs: with the increase in the living area, lot size, and the number of bathrooms the sale price of the single-family house increases too. Meanwhile, the housing price falls as the number of bedrooms and the age of the house increase. The counterintuitive sign of the variable for bedrooms might be explained by the strong correlation with variables for living area and number of bathrooms which showed sizable positive coefficients. If the house is classified as a townhouse or a duplex, it is sold at a lower price.

Moreover, a house is sold at a premium if it is located closer to a hospital potentially pointing at the value of the accessibility to medical centers such as AdventHealth viewed as major employers in the region. Sale prices are also higher for houses within 100 m from a lake. In contrast, houses located closer to commercial uses, bus stops, and highway roads are sold at a discount which can be explained by residents having negative sentiments about nuisance these locations create including high noise, crime, and air pollution levels. The unexpected sign was found for the nearest schools or colleges and parks: if the house is located closer to either school/college or park it has a lower price.

The level 2 variables generally show expected signs and are statistically significant at a 5% level: the sale prices are higher for houses in neighborhoods with higher median household income, population density, and job density. Meanwhile, if a house is located in neighborhoods with a higher share of African Americans and Hispanic populations it is sold at a lower price.

From Table 6, it can be seen that over the study period, the sale price of the house was generally lower within a 1-mile treatment zone compared to the rest of the study area by 6.3%. Moreover, during the announcement phase, houses in the entire study area were sold at a lower price compared to houses in the pre-announcement phase whereas they were sold at a premium in the FFGA-construction and operation phases of Phase 1 Sunrail. However, due to the inclusion of the monthly fixed effects, only the coefficient of the operation phase is statistically significant.

Most importantly, the coefficients of interaction terms show the statistically significant positive effect of Sunrail service on housing prices within a 1-mile treatment zone at each respective phase. Relative to houses sold between 1 and 5 miles from Sunrail station in the pre-announcement phase, those, located within a treatment zone, had a higher sale price by 6.9% after Sunrail was announced, 7.1% during Sunrail's construction, and 5.4% after Sunrail's opening. These findings indicate that higher price premiums occurred after the Phase 1 Sunrail was announced and after FFGA was signed and construction kicked off compared to more moderate premiums during Sunrail's operations years.

4.3 DID Model Results for Phase 1 Sunrail by Station Type

Table 7 demonstrates multi-level DID model results for Phase 1 Sunrail by station type. Compared to baseline results in Table 6 which showed the overall positive impact of Sunrail, there was no price change for houses within a 1-mile treatment zone from a suburban station with coefficients of interaction terms lacking statistical significance. However, the statistically significant increase in prices was found for houses in the treatment zone of Hospital Campus stations at each phase – 16.5% in the announcement, 16.4% in the FFGA & construction, 10.6% in the operation phases – compared to the reference group. Even a higher spike of sale prices was shown for houses within 1 mile to Downtown stations: houses were sold at a premium of 23.8% after service was announced, 26.3% after the FFGA agreement and construction start, and 11.3% after service opening.

Table 7. DID Model Results for Phase 1 Sunrail by Station Type

	Dependent variable	Ln of Sale price (2019 $s)	Suburban		Hospital Campus		Downtown	
	Fixed effects							
Level 1	Time variables	Announcement	-0.0377		0.0586		-0.2723	***
			(0.096)		(0.182)		(0.088)	
		FFGA & Construction	0.0365		-0.1004	*	-0.1315	*
			(0.031)		(0.041)		(0.077)	
		Operation	0.1603	***	0.0092		0.1225	*
			(0.027)		(0.039)		(0.070)	
	Treatment zone	1 mi of Sunrail station	-0.0647	***	-0.0158		-0.1611	***
			(0.018)		(0.019)		(0.038)	
	Interaction terms	1 mi Sunrail * Announcement	**0.0027**		**0.1650**	***	**0.2382**	***
			(0.024)		**(0.024)**		**(0.051)**	
		1 mi Sunrail * FFGA & Construction	**0.0062**		**0.1638**	***	**0.2634**	***
			(0.023)		**(0.024)**		**(0.048)**	
		1 mi Sunrail * Operation	**0.0298**		**0.1061**	***	**0.1134**	***
			(0.018)		**(0.018)**		**(0.034)**	

	Structural characteristics	Ln of Lot Size	0.107	***	0.136	***	0.113	***
			(0.004)		(0.008)		(0.013)	
		Ln of Living Area	0.640	***	0.608	***	0.824	***
			(0.010)		(0.013)		(0.021)	
		Age of the house	-0.0145	***	-0.0098	***	-0.0074	***
			(0.000)		(0.001)		(0.001)	
		Age of the house (squared)	0.0001	***	0.00004	***	-0.00002	
			(0.000)		(0.000)		(0.000)	
		Bedrooms	0.0113	***	-0.0048		-0.0675	***
			(0.003)		(0.005)		(0.008)	
		Bathrooms	0.0603	***	0.0728	***	0.0711	***
			(0.004)		(0.006)		(0.010)	
		Townhome	-0.0668	***	-0.062	***	-0.1170	***
			(0.007)		(0.017)		(0.028)	
		Duplex	-0.1291	***	-0.143	***	-0.1669	***
			(0.020)		(0.018)		(0.033)	
	Locational characteristics	Houses within 100 m from a lake	0.0507	***	0.064	***	0.0112	
			(0.006)		(0.008)		(0.017)	
		Ln of distance to nearest commercial	0.0151	***	0.0337	***	-0.0078	
			(0.003)		(0.004)		(0.008)	
		Ln of distance to nearest park	-0.0037		0.0165	***	-0.0504	***
			(0.005)		(0.006)		(0.012)	
		Ln of distance to nearest school	-0.0009		0.0672	***	0.0951	***
			(0.003)		(0.008)		(0.012)	
		Ln of distance to nearest hospital	-0.0309	***	0.0203		0.509	***
			(0.007)		(0.030)		(0.110)	
		Ln of distance to nearest highway	0.0161	***	0.0309	***	-0.0065	
			(0.003)		(0.005)		(0.008)	
		Ln of distance to nearest bus stop	0.0048		0.0281	***	0.0656	***
			(0.003)		(0.004)		(0.008)	
Level 2	Neighborhood characteristics	Ln of median household income	0.352	***	0.0292		-0.220	*
			(0.067)		(0.124)		(0.117)	
		Ln of population density	0.108	***	0.0875		0.0111	
			(0.026)		(0.060)		(0.049)	
		Ln of job density	0.0648	***	0.0944	***	0.0741	***
			(0.015)		(0.024)		(0.027)	

		Percent Black	-0.838	***	-0.994	***	-1.521	***
			(0.137)		(0.162)		(0.162)	
		Percent Hispanic	-0.259	*	-0.748	***	-1.046	***
			(0.124)		(0.215)		(0.195)	
	Monthly trend variable	Monthly dummy	Yes		Yes		Yes	
		Intercept	1.981	*	5.796	***	7.433	***
			(0.856)		(1.548)		(1.418)	
Level 1	**Random effects**	Intercept	-1.766	***	-1.786	***	-2.163	***
			(0.068)		(0.103)		(0.160)	
		N	38,804		10,832		4,952	
Level 2		Intercept	-1.211	***	-1.420	***	-1.228	***
			(0.004)		(0.007)		(0.010)	
		N groups	125		58		27	
		ICC	0.248		0.324		0.134	
		AIC	17024.6		606.7		2379.5	
		BIC	18797.8		2115.8		3720.0	

Standard errors in parentheses: * p<0.1, ** p<0.05, *** p<0.01

Unit change in IV = exp(b – 1/2*se^2) – 1

Comparing findings from Tables 6 and 7, it seems evident that the rise in sale prices found in a baseline model was primarily attributed to houses near Hospital Campus stations, including Florida Hospital Health Village and Orlando Health, and Downtown Orlando stations such as LYNX Central and Church Street. On the contrary, houses in proximity to suburban stations did not experience any price changes during each respective phase.

4.4 DID Model Results for I-4 Ultimate

Table 8. DID Model Results for I-4 Ultimate

	Dependent variable	Ln of Sale price (2019 $s)	Coefficient	p-value
Level 1	**Fixed effects**			
	Time variables	Announcement	-0.0204	
			(0.056)	
		FFGA & Construction	-0.0181	
			(0.024)	
		I-4 Pre-construction	-0.0917	***
			(0.035)	
		I-4 Construction	0.1272	***
			(0.021)	
	Treatment zone	1 mi of I-4 Ultimate	0.0560	***
			(0.012)	

	Interaction terms	1 mi I-4 Ultimate * Announcement	**0.0173**	
			(0.015)	
		1 mi I-4 Ultimate * FFGA & Construction	**0.0570**	*******
			(0.014)	
		1 mi I-4 Ultimate * I-4 Pre-construction	**0.0399**	*****
			(0.019)	
		1 mi I-4 Ultimate * I-4 Construction	**-0.0109**	
			(0.011)	
	Structural characteristics	Ln of Lot Size	0.107	***
			(0.004)	
		Ln of Living Area	0.675	***
			(0.008)	
		Age of the house	-0.0132	***
			(0.000)	
		Age of the house (squared)	0.00009	***
			(0.000)	
		Bedrooms	-0.0061	*
			(0.003)	
		Bathrooms	0.0624	***
			(0.003)	
		Townhome	-0.0629	***
			(0.006)	
		Duplex	-0.1437	***
			(0.013)	
	Locational characteristics	Houses within 100 m from a lake	0.0595	***
			(0.005)	
		Ln of distance to nearest commercial	0.0159	***
			(0.002)	
		Ln of distance to nearest park	0.0087	
			(0.003)	
		Ln of distance to nearest school	0.0116	***
			(0.003)	
		Ln of distance to nearest hospital	-0.0365	***
			(0.007)	
		Ln of distance to nearest highway	0.0139	***
			(0.002)	
		Ln of distance to nearest bus stop	0.0164	***
			(0.002)	
Level 2	Neighborhood characteristics	Ln of median household income	0.218	***
			(0.063)	

		Ln of population density	0.110	***
			(0.024)	
		Ln of job density	0.0643	***
			(0.013)	
		Percent Black	-0.763	***
			(0.100)	
		Percent Hispanic	-0.452	***
			(0.117)	
	Monthly trend variable	Monthly dummy	Yes	
		Intercept	3.334	***
			(0.804)	
Level 1	**Random effects**	Intercept	-1.691	***
			(0.056)	
		N	54,588	
Level 2		Intercept	-1.234	***
			(0.003)	
		N groups	179	
		ICC	0.2873	
		AIC	21336.6	
		BIC	23198.3	

Standard errors in parentheses: * p<0.1, ** p<0.05, *** p<0.01

Unit change in IV = exp(b – 1/2*se^2) – 1

Table 8 shows multi-level DID Model Results for I-4 Ultimate. Single-family houses, located within a 1-mile proximity zone to the segment of the I-4 corridor currently undergoing multi-year construction, were sold at a premium of 1.7% after the announcement about Sunrail was made, however, the coefficient falls short in terms of its statistical significance. During FFGA and construction, a statistically significant value uplift of 5.7% was found among houses in the 1-mile distance from I-4 Ultimate. In the first year of Sunrail's operation, also marked by the planning and design of the I-4 Ultimate project, sale prices of houses in the treatment zone were higher by 4% relative to the reference group (significant at 10% level).

However, after the start of the I-4 Ultimate construction, single-family houses within 1 mile from I-4 Ultimate were sold at a discount of 1.1% which is not statistically significant. Given that a 1-mile treatment zone of I-4 Ultimate is largely comprised of houses, also located in proximity to Sunrail's Downtown and Hospital Campus stations which showed sizeable price increases, this finding might point at the possibility for the disamenity effect of I-4 Ultimate on sale prices of houses shared by both transportation intervention zones.

4.5 Combined DID Model Results for Phase 1 Sunrail and I-4 Ultimate

Table 9 provides the combined multi-level DID model results for Phase 1 Sunrail and I-4 Ultimate. The findings are interpreted relative to the reference group comprised of houses outside of the 1-mile treatment zones of Sunrail stations and I-4 Ultimate sold in the pre-announcement phase. Table 9 indicates that after combining the effects of both transportation interventions in a single model, the increase in sale prices of houses within 1 mile of Sunrail stations, only exposed to Phase 1 Sunrail, was overall less pronounced compared to the individual impact of the service in the baseline model in Table 6. However, after I-4 Ultimate construction began, houses near Sunrail stations only were sold at a premium of 6.8%.

A similar pattern was observed for prices of houses located within a 1-mile proximity zone of I-4 Ultimate with lower values across interaction terms as compared to individual model results in Table 8. However, in the combined DID model, houses, only exposed to I-4 Ultimate, were sold at a discount of 2.5% within 1 mile to the highway corridor after the start of the construction, potentially signalizing the individual disamenity effect produced by I-4 Ultimate. The coefficient is statistically significant at the 10% level.

Table 9. Combined DID Model Results for Sunrail and I-4 Ultimate

	Dependent variable	Ln of Sale price (2019 $s)	Coefficient	p-value
Level 1	**Fixed effects**			
	Time variables	Announcement	-0.0166	
			(0.056)	
		FFGA & Construction	-0.02	
			(0.024)	
		I-4 Pre-construction	-0.0916	***
			(0.035)	
		I-4 Construction	0.1194	***
			(0.022)	
	Treatment zone	1 mi of Sunrail station	-0.0702	***
			(0.017)	
		1 mi of I-4 Ultimate	0.0808	***
			(0.014)	
		Overlap	-0.0054	

		(0.018)	
Interaction terms	1 mi Sunrail * Announcement	0.0487	*
		(0.023)	
	1 mi Sunrail * FFGA & Construction	0.0480	*
		(0.022)	
	1 mi Sunrail * Pre-construction I-4	0.0377	
		(0.028)	
	1 mi Sunrail * I-4 Construction	0.0681	***
		(0.017)	
	1 mi I-4 Ultimate * Announcement	-0.0177	
		(0.018)	
	1 mi I-4 Ultimate * FFGA & Construction	0.0312	*
		(0.018)	
	1 mi I-4 Ultimate * I-4 Pre-construction	0.0084	
		(0.023)	
	1 mi I-4 Ultimate * I-4 Construction	**-0.0251**	*****
		(0.014)	
	Overlap * Announcement	**0.0885**	*******
		(0.024)	
	Overlap * FFGA & Construction	**0.1104**	*******
		(0.023)	
	Overlap * I-4 Pre-construction	**0.0995**	*******
		(0.030)	
	Overlap * I-4 Construction	**0.0206**	
		(0.017)	
Structural characteristics	Ln of Lot Size	0.107	***
		(0.004)	
	Ln of Living Area	0.676	***
		(0.008)	
	Age of the house	-0.0132	***
		(0.000)	
	Age of the house (squared)	0.0001	***
		(0.000)	
	Bedrooms	-0.0064	*
		(0.003)	
	Bathrooms	0.0622	***
		(0.003)	
	Townhome	-0.0645	***
		(0.006)	
	Duplex	-0.1437	***
		(0.013)	

	Locational characteristics	Houses within 100 m from a lake	0.0596	***
			(0.005)	
		Ln of distance to nearest commercial	0.0167	***
			(0.002)	
		Ln of distance to nearest park	0.0073	*
			(0.003)	
		Ln of distance to nearest school	0.0102	***
			(0.003)	
		Ln of distance to nearest hospital	-0.0357	***
			(0.007)	
		Ln of distance to nearest highway	0.0128	***
			(0.002)	
		Ln of distance to nearest bus stop	0.0163	***
			(0.002)	
Level 2	Neighborhood characteristics	Ln of median household income	0.219	***
			(0.063)	
		Ln of population density	0.110	***
			(0.024)	
		Ln of job density	0.0659	***
			(0.013)	
		Percent Black	-0.766	***
			(0.100)	
		Percent Hispanic	-0.462	***
			(0.117)	
	Monthly trend variable	Monthly dummy	Yes	
		Intercept	3.320	***
			(0.809)	
Level 1	**Random effects**	Intercept	-1.684	***
			(0.056)	
		N	54,588	
Level 2		Intercept	-1.235	***
			(0.003)	
		N groups	179	
		ICC	0.2891	
		AIC	21312.1	
		BIC	23262.9	

Standard errors in parentheses: * $p<0.1$, ** $p<0.05$, *** $p<0.01$

Unit change in IV = exp(b – 1/2*se^2) – 1

Findings of particular interest here are focused on the overlapping zone of Phase 1 Sunrail and I-4 Ultimate. Table 9 indicates that houses within the overlapping zone of both transportation interventions were sold at a premium during each respective phase. After Phase 1 Sunrail was announced, a premium of 8.8% was found among houses in the overlapping zone followed by even a higher premium of 11% during the FFGA and construction phase. In the first year of Sunrail's operation when the I-4 Ultimate project was planned and designed, housing prices increased by 9.9% in the overlapping zone. However, after the I-4 Ultimate construction kicked off, a value uplift of 2.1% was found for single-family houses in the overlapping area which is not statistically significant. Overall, these findings suggest that the substantial positive effect of Phase 1 Sunrail on housing prices in the common area of both transportation interventions sustained throughout each phase but became insignificant and reduced in its magnitude after the start of I-4 Ultimate suggesting the potential presence of nuisance from continuous construction.

V. DISCUSSION

This study examined the capitalization effects of transportation interventions, including Phase 1 Sunrail and I-4 Ultimate, on sale prices of single-family houses in the proximity to these interventions over the 15-year study period of 2005-2019. These capitalization effects were studied before and after the key implementation phases of both transportation interventions.

Applying the multilevel hedonic price model with DID specifications, the findings of this study confirm the hypothesis on the value uplift of single-family houses close to Sunrail service before its opening. A total of 5.4%-7.1% increase (Table 6) was found for housing prices within a 1-mile treatment zone of Sunrail stations in each given phase – announcement, FFGA & construction, and operation – suggesting that property owners are generally willing to pay a premium to benefit from the improved accessibility to regional rail transit service. These results also confirm the capitalization impact of the commuter system on a larger geographic scope not limited to the immediate station proximity thresholds used in most LRT-focused studies.

Findings of the value uplift before service completion (Table 6) also show that houses in the 1-mile treatment zone were sold at the lowest premium after the Phase 1 Sunrail began its operation whereas higher premiums were observed after the transit project was formally announced and in the following phase marked by FFGA and start of construction. This can be explained by the property market speculators who in anticipation of the service decided to purchase a house in proximity to a station that led to the highest price increase in both the announcement and FFGA-construction phases of Sunrail implementation. These findings provide the evidence for the existing announcement and anticipation effects of Phase 1 Sunrail which should be taken into account when assessing the overall value generated from the service. Following the start of the service operation, houses in the treatment zone of Sunrail stations continued to be sold at a slightly lower premium.

Moreover, analyzing the effects of Phase 1 Sunrail by station type (Table 7), no statistically significant price changes were found for houses near suburban stations during each implementation phase. This contrasts with the overall increase in sale prices found in the baseline DID model results. However, the findings also indicate that houses, located in the proximity to the Downtown Orlando and Hospital Campus stations, had the highest price spike, particularly, before the start of Sunrail service operation. According to these findings, it can be inferred that the overall positive effect of Sunrail on property prices is not distributed uniformly across all stations as houses near Downtown Orlando and Hospital Campus stations appear to be primary contributors for Sunrail's accessibility benefits to translate into higher housing prices.

The reason for housing premiums to concentrate around these stations can be found in context-related or outside economic factors some of which could also be interpreted as the byproduct of the Sunrail service arrival. Downtown stations such as LYNX Central and Church Street are well-connected with fair-free LYMMO BRT service and LYNX bus system providing more convenient access for residents, who live beyond the walkable distance, to reach Sunrail stations. This might encourage residents to buy a house farther from a station but still be able to enjoy accessibility benefits brought by Sunrail service.

Another contributing factor can be that the area around Downtown and Hospital Campus station areas are viewed as urbanized, highly dense, pedestrian-oriented, and with a considerable mix of uses as opposed to generally auto-oriented Suburban station areas with medium-to-low density, strip residential development, and park-and-ride facilities. The review of previous works showed that houses in proximity to a transit station were sold at a significantly higher premium if this station exhibits TOD characteristics including the presence of a walkable environment and mixed-use development. The same studies also report how properties in station areas with poor connectivity and low mix of uses, centered around transit riders driving to a station, did not experience any price changes or were sold at a discount.

Moreover, the last decade saw a spur of redevelopment initiatives, some of which are TOD-related, around station areas in Downtown Orlando. The Parramore Comprehensive Plan was designed as a part of the HUD Sustainable Communities Regional Planning Grant to revitalize a neighborhood with concentrated poverty to the west of Church Street Station (Kim, 2017). This plan includes education initiatives such as the opening of the Academic Center for Excellence K-8 school, UCF Downtown Campus and vocational training centers, the extension of LYMMO service to Parramore residents, and construction of multiple mixed-income housing units (Orlando.gov). The Creative Village TOD to the north of Parramore near LYNX Station is a new mixed-use development that adds more educational and job opportunities as well as a variety of affordable housing options and will become future headquarters for Electronic Arts, Inc. (EA) (Orlando.gov).

Meanwhile, Florida Hospital and Orlando Health station areas also benefited from substantial development investments such as the implementation of the South Downtown Vision Plan. Benefiting from the $1 billion investment, this plan is focused on redeveloping neighborhoods near the Orlando Health station and turning them into vibrant, mixed-use, and well-connected areas (Orlando.gov). As a part of this plan, several important projects including the construction of Heart Hospital and Sodo mixed-use district were completed.

All of these factors including contextual differences and redevelopment projects might also play a role in the growth in housing prices around Downtown and Hospital Campus stations. However, it is not to say that suburban station areas completely lacked similar development initiatives as a more detailed look at the heterogeneous context of individual suburban stations should be done which might reveal that proximity to certain stations in suburbs also generated property premiums.

The DID model results for individual effects of I-4 Ultimate on sale prices of houses within a 1-mile proximity zone (Table 8) show a statistically significant premium of 3.9% – 5.7% for Sunrail FFGA-construction and pre-construction I-4 phases. However, since the I-4 Ultimate multi-year construction was given a green light, the sign of the relationship became negative indicating a price decrease for houses within a 1-mile distance from the I-4 corridor even though it was short of statistical significance. This finding might implicitly indicate disamenity effects of I-4 Ultimate which caused negative sentiments of residents about buying a house close to I-4 construction making the positive effect of accessibility benefits of Sunrail on property prices insignificant. This conclusion rests on the fact that the I-4 Ultimate 1-mile zone includes mostly houses close to Downtown and Hospital Campus stations where the highest value uplift from Sunrail service was concentrated.

To consider explicitly the individual and cumulative effects of both transportation interventions, the combined DID model was developed (Table 9). The findings confirm the possible disamenity effects of I-4 Ultimate as the houses, only exposed to I-4 Ultimate and located outside of the Sunrail treatment zone, were sold at a discount of 2.5% after the construction started. However, houses located in the overlapping zone of Phase 1 Sunrail and I-4 Ultimate were steadily sold at a premium before the start of I-4 Ultimate. However, during I-4 construction, the sale prices of houses in the overlapping area did not show any significant price changes possibly meaning that the disamenity effects of I-4 Ultimate are not pronounced enough to cause the negative effect on housing prices.

The latter finding can be explained in two ways. On the one hand, any nuisance potentially caused by the construction of I-4 Ultimate does not appear to be a decisive factor for property owners on whether or not to purchase a house as long as they can benefit from the improved accessibility to Sunrail stations. If anything, the shutdown of the I-4 corridor for construction caused excessive traffic congestion on the key transportation connection in the north-south direction making the lives of local drivers, commuting in this direction on daily basis, a lot harder. This might have encouraged them to seek alternative ways to commute potentially opting to use Sunrail commuter service since it provides the only reliable rail transit service following a north-south route parallel to the I-4 segment under construction, as it can be seen from Figures 3 and 4. This might have resulted in their decision to move closer to a station location by purchasing a house nearby as they need to find rather a long-term solution for their regular commutes for years ahead given the duration of I-4 Ultimate construction.

Another factor might be the highway configurations, as hypothesized by Seo and Golub (2014), that might shape how the proximity to highway infrastructure affect property prices. Using Google Street view, it was verified that most of the I-4 corridor segment under construction is above-grade or, in other words, represented by elevated roads. Given that the I-4 Ultimate construction did not take place on the on-ground level, the nuisance it caused such as noise and air pollution might not have been sufficiently pronounced to have a negative impact on local housing prices.

Moreover, from the methodological perspective, the selection of the treatment zone size of I-4 Ultimate might also affect the results of the combined DID model. Seo and Golub (2014) argue that the disamenity effect is limited to the immediate proximity to the highway link (around 300-350 m) whereas Kilpatrick (2007) found the negative effect on sale prices maintaining up to 300 ft. Limiting a proximity zone closer to the I-4 corridor under construction might lead to detecting more pronounced disamenity effects of I-4 Ultimate.

On the other hand, as was mentioned earlier, a large number of houses in the overlapping zone are located in proximity to Downtown and Hospital Campus stations which showed the highest concentration of property premiums during each implementation phase of Sunrail service. Specifically, a premium of 11% was found within the 1-mile distance of these stations after the start of Phase 1 Sunrail operation coinciding with the I-4 Ultimate construction period. Meanwhile, the combined DID model results demonstrate a 2.1% increase in sale prices lacking statistical significance in the overlapping zone where most of the houses near Downtown and Hospital Campus stations fell into. The comparison of these findings might implicitly suggest that the disamenity effects of I-4 Ultimate existed in the overlapping zone, reducing the magnitude of the increase in sale prices brought by the arrival of Sunrail service, but, again, it was not sufficiently strong to offset the value of accessibility benefits from Sunrail.

VI. CONCLUSION

The impact of transportations investments on property values in the US cities has been widely addressed by planning researchers over the last three decades. The contribution of this study to the existing literature is the following: first, it offers more recent evidence on capitalization effects of the commuter rail service on local property prices; second, it further proves the importance of analyzing property value uplift before the opening of transit service, stressed in previous works; third, it addresses variation in capitalization effects of transit service with station area context; forth, it presents the first attempt in the literature to examine individual and cumulative effects of multiple transportation interventions, coexisting spatially and temporally, on the local housing market.

This study shows that Phase 1 Sunrail has an overall positive effect on sale prices of single-family houses located in proximity to stations. It was found that this effect stretches as far as 1 mile from stations and occurs even before the start of Sunrail service operation with the highest value uplift taken place after service announcement and during construction years. Moreover, it was found that the positive impact of Phase 1 Sunrail is not uniformly distributed across the line as houses around Downtown and Hospital Campus stations have drawn the largest premiums as opposed to those near suburban stations with no effect on prices.

Analyzing the combined effects of Phase 1 Sunrail and I-4 Ultimate on sale prices of single-family houses, this study demonstrates that disamenity effects of the I-4 Ultimate construction were not pronounced enough to make houses sell at a discount in the area, shared by both transportation interventions, as findings suggest no significant price changes after the start of I-4 Ultimate. Factors including the importance of Sunrail service as a long-term solution for regular commutes of residents struggling to use the I-4 corridor closed for a multi-year construction, the above-grade configuration of I-4 roads, and methodological selection of the proximity zone of I-4 Ultimate were suggested to play a role in undetected disamenity effects.

Future research should consider extending this study by examining the capitalization effects of Phase 2 Sunrail before and after the start of its operation. The proposed framework here to analyze the individual and cumulative effects of multiple transportation interventions can also be applied for systems that expand over time such as the Sunrail service by focusing, in particular, on the combined effects of Phases 1 and 2 on local property prices. The impact of Sunrail service on other property markets including multi-family housing units and commercial establishments should also be examined as both types of development are highly present in proximity to Sunrail stations and not frequently discussed in capitalization studies. Moreover, potential signs of gentrification and displacement of low-income residents in neighborhoods around Sunrail stations should be explored given numerous revitalization projects targeting these neighborhoods. Finally, a more in-depth typology with controlling for existing pedestrian- and transit-oriented features should be considered for analyzing contextual heterogeneity between suburban stations as certain stations are more predisposed to TOD than others.

This study has a few important policy implications. The findings set an example of how the property premiums from new transportation investments can be vastly undervalued if they are analyzed only during service operation years. To capture all monetary benefits from these investments is crucial for policy-makers in their efforts to conduct VC and benefit-cost analysis of the project such as Phase 1 Sunrail which requires immense capital subsidies for its construction and operation. Moreover, it offers evidence for possible non-uniform distribution of property premiums planners can use to target station areas demanding TOD design improvements that increase the value of accessibility benefits of these station areas. This study also shows policy-makers how to evaluate cumulative effects of multiple transportation interventions, co-existing in space and time, on the local property market making it important to understand how new additions to this infrastructure impact the existing one. Finally, this study is relevant to housing affordability issues as higher rental rates and taxes may lead to gentrification and displacement of low-income residents.

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