Rebecca Santiago

March 2017

The Role of Urban Infrastructure in Supporting Transit-Oriented Development

HDR, Inc.

Abstract

Of the many challenges cities face, congestion and air quality are two interrelated issues that despite technological improvements in vehicle emissions standards and engine efficiency, continue to worsen. Of the strategies attempting to reduce automobile dependency, a popular approach adopted by cities is the concept of transit-oriented development (TOD). The strategy aims to better integrate land use and transportation planning, and is often characterized by a mix of land uses, high density, and proximity to quality public transit. While practitioners and academics argue the economic and environmental benefits of TOD, there are several examples along the Valley Metro light rail corridor where the strategy appears to be failing to attract people, businesses, and ultimately transit riders. The purpose of this study is to explore how urban infrastructure characteristics, specifically transportation connectivity, urban design, and land use interact to support light rail ridership.

The study utilizes a rendition of sustainability's triple-bottom-line framework, wherein economic, environmental, and social elements are represented as criteria in the transportation, land use, and urban design analysis of six Valley Metro light rail stations. Each element has supporting criteria that are ranked relative to the other stations under analysis, culminating in overall TOD scores for each station. The number of TOD projects and ridership trends are also compared, and in combination with the evaluation of urban infrastructure elements, the results suggest the importance of transportation connectivity, pedestrian-scale infrastructure, a sense of place, and employment centers for TOD stations to yield high ridership. Findings are analyzed through a sustainability lens resulting in the proposal of strategic solutions for improving TOD planning methods.

Table of Contents

Introduction

Urban Form, Transportation, and Sustainable Development

The relationship between land use and transportation shapes cities; it plays a fundamental role in where people live, where businesses are located, and how people navigate between places. Historically, transportation technologies drive land use and urban form. The earliest cities developed around walking and resulted in compact mixed-use environments. City boundaries expanded with the introduction of horses and carriages; expanded further with streetcars, trolleys, and trains; and expanded even greater with the introduction of the automobile.

Many western American cities, including Phoenix, Arizona, developed in the age of the automobile. In combination with reactionary zoning, the advent of the automobile led to the epitome of suburban sprawl. Now, decades after these cities have taken form, society is starting to understand the ramifications of how highways divide communities, congestion leads to air pollution and increased anxiety, grey infrastructure effects hydrological systems and impedes on natural ecosystems, and how sedentary lifestyles impact health. Moreover, a significant impact of sprawl stems from the transportation technology that supports it – personal automobiles. In 2014, greenhouse gas (GHG) emissions from light-duty vehicles accounted for 19% of United States' total GHG emissions, with the entire transportation industry accounting for 26% of total emissions (Salon, 2015; "Sources of Greenhouse Gas Emissions", 2014), making the industry a major target for improvement. Technological solutions such as "improved vehicle and system efficiency together with an expanded role for low carbon fuels are important strategies to meet [climate change] challenges. Absent an enormous leap forward in low-carbon transportation technologies, however, successfully reducing transport emissions will require individuals to reduce the amount that they drive" (Salon, 2015). So the question stands, how do we reduce sprawl and the amount individuals drive?

Efforts to counteract the development mistakes of the last half century promote the idea of "sustainable development". The term was popularized by the landmark 1987 Brundtland Report, which defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). The definition's ambiguity provides flexibility for interpretation, enabling diversity in proposed solutions on how sustainable development should manifest. Though sustainable development has yet to refine to a commonly accepted definition since the concept's inception thirty years ago, several characteristics of what planners and city officials envision and strive for in achieving sustainable developments have culminated into a planning strategy known as transit-oriented development (TOD).

TOD promotes high density, walkable, transit-oriented living and working environments. While the concept is a revitalization of older planning practices, "Peter Calthorpe codified the concept of Transit-Oriented Development (TOD) in the late 1980's and…TOD became a fixture of modern planning when Calthorpe published "'The New American Metropolis' in 1993" (Carlton, 2007). The ultimate goals of the strategy are to reduce automobile dependence and provide environments that offer daily amenities and necessities within walking distance or a short bike or transit ride. As such, TOD is founded on the idea that creating livable environments depends directly on the aforementioned

relationship between land use and transportation. Research to date backs these efforts and provides "concrete evidence that supports the expected relationships between built environment characteristics and driving. As alternatives to solo driving become available, people drive less. As driving becomes more expensive and less convenient, people drive less. As trip destinations and origins move closer together, people drive less" (Salon, 2015). As such, TOD is a highly sought after solution for its positive reinforcing relationship of transit that serves dense environments, which in turn increases demand for better transit service, which consequently increases ridership, which then increases demand for locations near transit, and so on.

Despite the growing understanding of the relationship between urban form and travel behavior, there is much more to examine as the practice of TOD unfolds. Notably, the mixed-use element of TOD has no one-size-fits-all ratio of housing, retail, and commercial, but is deemed critically important for providing the transit-supportive environment necessary for increasing transit ridership and decreasing automobile trips. Literature on TOD implementation strategies also point to the role of urban design in creating pedestrian-oriented, walkable environments around the transit station (The City of Phoenix, 2016; *"Transit-Oriented Development and Putting People First*", 2015; *"Transit-Oriented Development (TOD)"*, 2013). Yet the context dependent nature of TOD yields varying levels of "success" across systems and even within a system ("success" is defined below in the Methodology section). It is the intent of this project to explore how the elements of urban infrastructure, specifically transportation connectivity, urban design, and land use interact to support light rail ridership. As a cross-disciplinary study, this project aims to identify gaps in the current TOD model advocated for by urban planning professionals and academics, and to provide recommendations for improving the model based on sustainability principles.

Context

Phoenix, Arizona is infamous for its sprawling urban environment. The city spans 517 square miles, with the larger metropolitan area (including cities such as Glendale, Tempe, Mesa, Scottsdale) spanning over 2,000 square miles ("Fun Facts: VisitPhoenix.com", 2017). The city has experienced significant growth over the past several decades and is expected to continue growing, with U.S. Census estimates projecting an increase in metropolitan area population from the existing 1.5 million people to 6.3 million by 2030 ("Population estimates, July 1, 2015", 2017; "Why Phoenix? — Growth Nation", 2017). Of the growth management challenges Phoenix faces, housing and infrastructure are of primary concern. As of 2011, single-detached units comprised 67.8% of the region's housing stock (American Housing Survey, 2011), and the housing market is expected to stay strong for the foreseeable future (Sunnucks, 2016). The expanding development of single-family houses and sprawling environment make Phoenicians incredibly car dependent; about 87 percent of workers (580,000 people) take a light-duty vehicle (sedan or station wagon (non-SUV or truck)) to their job and only 3.6 percent take transit ("Commuting Characteristics by Sex: 2011-2015 American Community Survey 5-Year Estimates", 2015). For comparison, the national percentage of workers who drive or take transit to work is 76.4 and 5.2, respectively (McKenzie, 2013).

Like many cities across the U.S., to address its sprawling environment, reduce congestion, and bring life back to the central business district (CBD), the City of Phoenix turned to improved public transit as a solution. In 2004 Maricopa County voters approved

Proposition 400, a half-cent sales-tax dedicated to funding transit, freeways, and streets. Transit received one-third of the funds to support "regional bus services and high-capacity transit services such as light rail, bus rapid transit and streetcar…the half-cent sales tax, along with federal matching funds and other funding sources, is projected to provide $6.9 billion in public transportation improvements through 2026" (Valley Metro, 2016). The Proposition played an essential role in funding the 20-mile long original light rail alignment, which was constructed over the 2005-2008 timeframe and began operation in December 2008. In 2015, two extensions on either end of the alignment brought the total length of the line to 26.3 miles. Moreover, in 2015, the City of Phoenix passed Proposition 104, "a comprehensive transportation package that will expand bus and light rail and fix aging streets... Funds generated will triple light rail miles, increase bus routes and frequency, increase Dial-a-Ride service as well as build over 1,000 miles of new bike lanes…" (Beaubien, 2016). Also referred to as the Transportation Plan 2050 (T2050), the increase from a .4 cent sales tax to .7 cent sales tax has secured funding for transportation projects for the next 35 years. Though the system currently consists of 35 stations located in the cities of Phoenix, Tempe, and Mesa, the revenue sources will help fund seven light-rail extensions to create a 66-mile regional rail system by 2034.

The dedication to public transit improvements is complemented by smart growth efforts such as TOD Overlays, the Walkable Urban Code, the Tree and Shade Master Plan, and the Green Construction Code. The City of Phoenix also collaborated with the U.S. Department of Housing and Urban Development, Arizona State University, St. Luke's Health Initiatives and local organizations to develop Reinvent PHX, a document that "created action plans for districts along the light rail system. The plans establish a community-based vision for the future and identify investment strategies to improve the quality of life for all residents. ("Reinvent PHX", 2016). Together these efforts are expected to improve TOD activity and create sustainable communities along the Valley Metro rail system.

These strategies are a dramatic shift from development trends in Phoenix over the past fifty years, and while they are significantly more comprehensive and forward thinking than previously, TOD performance around stations on the light rail alignment varies considerably. In exploring urban infrastructure elements around the study stations, this paper aims to understand what factors contribute to successful TOD (measured by light rail ridership performance and number of new development projects) and propose strategies for more sustainable TOD efforts.

Literature Review

Overview

It is widely recognized by environmentalists, city planners, and academics alike that the sprawling development pattern which dominated the last half century is no longer a suitable model for growth moving forward. Recognition of the land use impacts and resource demands sprawl development has on the environment, as well as changing demographic, travel, and work trends has shifted thinking about future urban forms.

Much of literature on sustainable development strategies is nested in transportation planning efforts, with experts explaining how "sustainable transportation requires higher-density land use patterns that accommodate alternative modes, and that cities with high-density neighbourhoods developed around passenger rail transit system are the most sustainable model for urban areas" (Litman & Burwell, 2006). Similarly, Duany puts forth

that sustainable development equates to communities wherein individuals live within "a 5-minute walk to most everyday activities" (2000). Together, these ideas have culminated into the practice of transit-oriented development (TOD), which, as the name suggests, is development focused around a transit station or along a transit corridor. The primary motives for TOD are to reduce automobile dependency and associated greenhouse gas emissions, increase resource efficiency by reducing land use demands, and spur economic development. The Sustainable Cities Institute notes TOD is often characterized by:

1. A mix of [land] uses
2. Moderate to high density
3. Pedestrian orientation/connectivity
4. Transportation choices
5. Reduced parking
6. High quality design ("Transit- Oriented Development (TOD)", 2013)

The literature reviewed aligns with these characteristics, but at varying degrees of emphasis. As such, the literature review is organized to demonstrate the prevalence of TOD in planning agencies and government entities, highlight the emphasis on economic and environmental benefits, showcase the role of urban design and its tie to social considerations of TOD, and provide reasons to question how TOD is currently implemented.

TOD - The Growing Market

In the decades following the Brundtland report, cities and transit agencies have adopted policies and strategic programs for implementing TOD. Of the top ten most populated jurisdictions according to 2015 U.S. Census estimates, every city listed had at least one agency with a TOD policy or strategic program (Appendix A). Adopted documents include everything from TOD overlays, sustainability goals, action plans, design guidelines, TOD planning toolkits, and case study examples. The depth and quality of the documents varies, but the emphasis on creating mixed-use, dense developments around transit stations has clearly gained significant support from public and private entities. Additionally, a range of evidence suggests the demand for TOD will continue to increase due to changing demographic trends, most notably the aging Baby Boomer population and decreasing licensure rates (Golub & Kuby, 2015).

As noted in the City of Phoenix Reinvent PHX plan, "In 2011, the oldest Baby Boomers began turning 65, beginning a wave that will continue steadily through 2030. This two decade-long event will equate to an average of 10,000 people turning 65 – about the size of Sedona – every day for 19 years" (2016). In an age of independence, retirees will be looking for ways to stay socially active, and will come to rely more on alternative transportation modes as their ability to operate an automobile deteriorates. Additionally, a 2015 study by Kuby and Golub found "the decline in licensure rates for the younger cohorts is significant; typical 20 to 24 year-olds today are 15% less likely to have driver's licenses than the same age group 30 years ago" (2015). Whether individuals are just significantly delaying getting a license has yet to be seen, but "the national TOD real estate market strengthened over the past decade and demographic trends point to a significant growth in demand in the coming years" (City of Phoenix, 2016). Thus, the aging Baby Boomer population and declining licensure rates are nonetheless an opportunity to create communities with lasting impacts on social interaction and daily mobility.

Moreover, cities are pushing for TOD and alternative modes of transportation as they struggle to manage congestion, meet air quality standards, manage limited resources, and overall become more sustainable. Much of the literature focused on this aspect of TOD is discussed in the following section.

Economic and Environmental Benefits

While changing demographics are important, there are arguably two primary reasons for encouraging TOD in cities. The first relates to easing traffic congestion by creating environments that reduce or eliminate the need of an automobile. Greenhouse gas (GHG) emissions from transportation accounted for over a quarter of total U.S. GHG emissions in 2014 ("Sources of Greenhouse Gas Emissions", 2014), so reducing automobile use is seen as a key way to help cities achieve air quality standards mandated by the Clean Air Act of 1970. As Johnston explains, "the Clean Air Act of 1970 required all states to adopt a State Implementation Plan (SIP) that includes an emissions inventory for each region in the state and a plan for attainment of all ambient federal air quality standards" (2004). And while higher vehicle emissions standards themselves have significantly contributed to improved air quality, increasing vehicle-miles traveled (VMT) and the growing number of cars on the road are exacerbating congestion problems, thereby negating nearly all improvements made to vehicle emission standards (Parry, Walls, & Harrington, 2007; Cervero & Duncan, 2008; Gomez-Ibanez, 1999).

Cities consequently have transformed transportation strategies "from adding road and transit capacity to also managing travel demand, connecting modes, and reducing emissions" (Johnston, 2004). Nationwide efforts in transportation planning have shifted from, "focusing on improving capacity and service...to [bringing] a critical mass to the service areas" (Livable Centers Study, 2010). Cities thus began better integrating transportation and land-use planning strategies to foster dense and diverse environments that are more transit supportive. As such, TOD helps reduce automobile travel by "(1) bringing origins and destinations closer together, thus reducing trip distances and durations; (2) inducing people to walk, bike, or ride public transit in lieu of driving (in part due to the shorter distances involved); and (3) eliminating or shortening vehicle trips by capturing travelers at new, more convenient destinations." (Cervero & Duncan, 2008). The City of Phoenix TOD Overlay perhaps best exemplifies how cities perceive the strategy to work, noting the purpose of the overlay is to "encourage an appropriate mixture and density of activity around transit stations to increase ridership along the [Valley Metro] Light Rail Corridor and promote alternative modes of transportation to the automobile. The secondary purpose of the [TOD] is to decrease auto-dependency, and mitigate the effects of congestion and pollution" (City Clerk's Office, 2016). The defining mixed land-use and high density characteristics of TOD consequently provide the built environment and critical mass of people necessary to support transit, thereby removing automobiles from the roads and reducing GHG emissions.

The second primary argument for TOD results from the economic benefits of the strategy. Improving public transit and creating dense, mixed-use environments can strengthen local economies by improving access to jobs, and cutting transportation costs and time spent on commuting. In turn, families have more money to spend locally at restaurants, shops, and activity centers (("Benefits of Transit-Oriented Development – Planning for Complete Communities in Delaware", n.d.; Center for Transit-Oriented Development, 2011; "Transit- Oriented Development (TOD)", 2013; "Transit-Oriented Development and Putting

People First", 2015). As Litman and Burwell observe, people who live and work in TOD communities "tend to own fewer vehicles, drive less, and rely more on alternative modes. The greatest mode shift is not from automobile to public transit, it is to walking... In total, residents of neighborhoods with good transit and mixed land use drive less than half as much on average as residents elsewhere" (2006). The shift to walking is important for local economies, as street-lined shops benefit from increased pedestrian traffic supported by walkable environments.

Regional Benefits

- Increases regional mobility
- Provides travel options
- Keeps region competitive
- Encourages development and redevelopment
- Helps create more walkable, sustainable communities
- Enhances quality of life

Rail System Features

- 26 miles, 35 stations
- Operates 7 days a week, 20+ hours a day
- 12-minute peak frequency

Total Development Along Light Rail (Phoenix, Mesa, Tempe)
Recently Completed and Under Construction Projects
(2005-Present)*

Number of Projects	260
Capital Investment - Private	$6.7 billion
Capital Investment - Public	$2.2 billion
Total Investment	$8.9 billion
Square Feet Commercial	15.8 million
Square Feet Public	1 million
Square Feet Education	5 million
Square Feet Residential	19.1 million
# Residential Units	17,540
# Affordable Units	1,702
# Hotel Rooms	3,208

*Figures shown above are for the initial 20 miles of Valley Metro Rail.

Figure 1: TOD economic benefits promotional document.

Research also shows that TOD can increase land values, and "building a regional TOD network increases access to jobs, housing and services around stations, allowing each place to thrive" (Center for Transit-Oriented Development, 2011). Many agencies document development investments in TOD locations, reporting the number of housing units, and square footage of retail and office available. For example, since the start of construction on the Valley Metro system in 2005, the agency calculates a total of $8.9 billion in investment near light rail stops (Figure 1) (*"Providing Public Transportation Alternatives for the Greater Phoenix Metro Area", 2017*). Although the relationship between property values and TOD is fairly well understood, it is less clear how much local businesses benefit from the TOD model of development. With the observed increase in property values and rents, it is possible that local businesses may be hurt or displaced by TOD efforts, though literature on this was sparse. And though the Center for Transit-Oriented Development (2011) and the Housing and Transportation Index ("H+T Fact Sheets: True Affordability and Location Efficiency", n.d.) have shown the savings people incur from commuting, the literature reviewed provided little to no quantifiable examples of the money going back into local businesses.

Lastly, cities save money by encouraging compact development, as it is more efficient to supply, operate, and maintain utilities, emergency services, and other infrastructure in dense urban areas. A study by the Halifax Regional Municipality found "the most sprawling areas impose three times the annual cost per household as the most compact areas. For hard infrastructure like water, sewers, and roads, the high cost of sprawl is even more stark — 'ten times the cost of other patterns' over the lifecycle of the investment" (2005). These tremendous savings that can incur from providing utilities and infrastructure in more compact developments can be reinvested in schools, businesses, technological improvements, and other infrastructure investments that enhance the community and make it a more desirable place to live and/or locate a business.

<u>Social Benefits and the Role of Urban Design</u>

Due to the intimate relationship between land use planning and transportation planning, many of the social benefits of TOD stem from the benefits rooted in transportation

improvements. Cervero and Kockelman explain, "an expected outcome of degenerating trips and weaning people from their cars, proponents hope, will be a lessening of the negative consequences of an automobile-oriented society – namely, reductions in air pollution, fossil fuel consumption, and class and social segregation" (1997). In providing transportation alternatives supportive of active lifestyles, that create a sense of place, and boost economic activity, TOD can consequently have a social impact as well.

While not to belabor the transportation aspect of TOD, it is a fundamental aspect of the development model that needs to operate efficiently and effectively for environmental, economic, and social benefits to actualize. As Johnston notes, "accessibility is simply access to activities, which is what the traveler is seeking. Travel is primarily a means to get to activities, such as work, shopping, or visiting friends... So we can increase accessibility with a policy for higher density mixed-use land centers, by themselves or with better transit" (2004). Increased mobility thus leads to increased accessibility, which can reduce class and social segregation by providing new opportunities to economic and educational advancement. Class and social barriers can also be negated by creating social spaces near TOD, such as parks and plazas, where daily interaction with others can help build civic pride and social cohesion (Project for Public Spaces, 2009).

An additional social benefit of TOD comes from the efforts to regain a sense of place and balanced urban systems. For example, Litman and Burwell elaborate on the concept of "liveability", writing:

> Community liveability is sensitive to the quality of the public realm (public spaces where people can interact), of which the street system is a major component. This suggests that creating a more attractive, interactive, pedestrian-friendly streetscape, and other policies that encourage non-motorized transport, may be important for sustainable development. (2006)

The subject's growing literature, and implementation strategies' focus on urban design and its influence on social interaction and behavior, suggests an evolving understanding of the importance of pedestrian-oriented design and spaces in TODs.

Despite the benefits outlined above, the overall prevalence of social gains compared to economic and environmental benefits highlights a gap between planning theory and practice. The social ties to TOD are secondhand to larger objectives, and the variation in TOD activity on the Valley Metro light rail alignment could stem from the way urban design is used (or not) to support communities. In this way, TOD planning and implementation strategies are crucial for engaging existing communities and ensuring that TOD projects meet the needs of those that live there. Of the many social impacts that need additional research, exploring how an organic or in-organic implementation process influences TOD should be explored.

Reasons to be Wary

The literature reviewed repeatedly circled around the fact that "sustainable transportation requires higher-density land use patterns that accommodate alternative modes, and that cities with high-density neighbourhoods developed around passenger rail transit system are the most sustainable model for urban areas" (Litman & Burwell, 2006). The intent of this paper is not to explore the impact of sustainable transportation efforts, but rather to question the larger TOD model currently supporting those efforts. The literature clearly demonstrates that the current TOD model is synonymous with mixed-use

development (Cervero & Duncan, 2008; Center for Transit-Oriented Development, 2011; Litman, 2009; "Transit- Oriented Development (TOD)", 2013), and as Cervero and Duncan observe, "putting jobs and retail shops in close proximity to housing can substantially reduce motorized travel, [but] it says little about which forms of balance and mix yield the greatest dividends" (2008). The proportion of each use is hardly given, largely because of the context-dependent nature of community needs, regional real estate markets, and financial investments available. Yet with TOD and "mixed-use" becoming synonymous, TOD complexes often take the shape of "mixed-use" buildings, "...defined as housing over retail" (Center for Transit-Oriented Development, 2011). This model of TOD/mixed-use is evident in the repetitive complexes sprouting up nationwide along rail systems (Figure 2).

Figure 2: Transit-oriented developments

Left: Dallas (Clower, Bomba, Wilson-Chavez, & Gray, 2014) Center: Phoenix (Santiago, 2017) Right: Atlanta ("Transit Oriented Atlanta: A Strategy for Advancing Transit-Oriented Development", n.d.)

Evolving research on the relationship between land use and transportation behavior supports a different model of TOD planning. Most notably, a growing understanding of the role of commercial land uses and access to jobs suggests a need to re-evaluate the push for retail in the TOD equation. For example, while Cervero and Duncan note "the question of whether built environments significantly shape travel behavior is hardly a settled question," their research shows, "access to jobs reduces vehicle miles of travel 72.5% more than access to shopping and services" (2008). Additionally, the Center for Transit-Oriented Development found, "the work trip accounts for nearly 60 percent of transit trips and studies show that concentrating employment near transit is more closely associated with higher ridership than housing, increasing jobs near transit should be a priority" (2011). And while some cities, such as Phoenix and Houston, have used an urbanist-type approach to regional planning by determining recommendations based on station area typology, most cities adopt blanket TOD policies and strategies that do little to customize solutions and development objectives for different environs.

Despite the economic benefits of TOD and push for mixed land use, the variation in investment and ridership activity at stations along the Valley Metro light rail line tell a different story about the urban form of TOD that supports transit ridership. In conjunction with the literature review, a case study of six Valley Metro light rail stations was undertaken to examine factors contributing to the success or underperformance of TOD.

Methodology

For this project, I considered TOD in the general sense of the term, as any area within a half-mile radius of a public transit station, in this case, a rail station. A half-mile radius is the transportation industry standard for the area a station serves and was chosen for this

analysis as well (Duany, 2000; The City of Phoenix, 2016; Valley Metro, 2016). Six stations were selected for analysis based on average daily boardings and the number of TOD projects around the station, specifically projects that were developed after the alignment started construction in 2005. Based on these metrics, 2 well-performing TOD stations, 2 under-performing TOD stations, and 2 well-performing stations that are in largely auto-oriented centers were selected. The stations in the auto-oriented districts were selected to understand what factors are influencing ridership in areas that are not transit-oriented. The six stations analyzed by category are:

1. Well-performing TOD:
    a. Roosevelt/Central Avenue
    b. 1st Ave./Jefferson and Washington/Central Avenue
2. Underperforming TOD:
    a. Encanto Park
    b. 12th St./Washington and 12th St./Jefferson
3. Auto-oriented Centers:
    a. Camelback/Central Avenue
    b. Priest Dr./Washington

Due to the one-way street configuration along Washington and Jefferson streets, stations are split to match the direction of traffic. As such, 12th/Jefferson and 12th/Washington were analyzed as one station area for this study because they serve the same location. Stations at 1st Ave./Jefferson and Washington/Central were also analyzed as one station area. End-of-line stations were omitted from analysis due to the larger ridership catchment area. Additionally, all the stations examined are in the City of Phoenix for consistency as far as policy and implementation strategies, except for Priest/Washington. While Priest/Washington is technically in Tempe, the station is positioned on the Phoenix-Tempe border and was nonetheless selected because of its high ridership in an auto-oriented area.

Stations were evaluated on several criteria that can generally be grouped into three overarching categories: transportation, urban design, and land use. Criteria were selected based on their connection to TOD elements prevalent in the literature and agency documents. The criteria and data supporting each category is outlined below and discussed in detail in the Station Profiles located in Appendix B.

Transportation

Two factors were included in the transportation score: light rail ridership and overall transit connectivity. Average daily boardings (Monday-Friday) in 2016 (the average of each month's average daily boardings) was calculated for each station and used for the light rail ridership comparison. Only boardings were examined so this is not representative of all station activity (people de-boarding were not included); however, transit agencies typically report data either by daily boardings or monthly boardings. Daily boardings were used as it is a more manageable number to comprehend. The data for the ridership comparison was drawn from Valley Metro's 2016 Monthly Ridership Reports. The transit connectivity score is the sum of the relative rankings for each of the following elements: the number of bus stops, bus routes, bus service type, and perpendicular running routes within the half-mile station buffer. The transit score was developed specifically for this study and used data from

Valley Metro's 2017 GIS shapefiles. The transit score was weighted twice as much as ridership because an increase in connectivity makes station areas more accessible.

Urban Design

Each station area's walk score, bike score, sense of place score, number of TOD projects, and total investment dollars contributed to the urban design evaluation. The walk score and bike score, gathered from Walkscore.com, were included in the urban design instead of the transportation score because they feature pedestrian-scale infrastructure. Walkscore.com evaluates walkability and bike-ability by looking at the density of amenities and quality of pedestrian infrastructure (length of blocks, connectivity, etc.) surrounding a selected location and is a commonly referenced source for homebuyers, businesses, real estate agents, and real estate developers.

The researcher used a "Transit-Oriented Development (TOD) Field Audit Worksheet" developed by the Professor Jason Kelley at the School of Geographical Sciences and Urban Planning at Arizona State University (Appendix C) to measure sense of place. Sense of place is "a unique collection of qualities and characteristics – visual, cultural, social, and environmental – that provide meaning to a location. Sense of place is what makes one city or town different from another, but sense of place is also what makes our physical surroundings worth caring about" (Hsiao, 2012). The audit works to measure the quality of urban design and pedestrian-orientation features that are central to creating a sense of place, such as accessibility/connectivity, employment and residential density, diversity and land uses, design, and parking orientation. Four questions from the audit were omitted; an explanation for why is provided next to the question in the audit worksheet in the appendix. An hour was spent at each study station and the researcher's evaluation was based on the areas visited within that timeframe.

The number of TOD projects and total investment dollars were gathered from the Valley Metro Economic Development Database (in-house) and are nested under the urban design evaluation. Investments within a half-mile of light rail stations since 2005 are considered transit-oriented. As such, investment dollars were included with the assumption that developments used TOD urban design principles. Station area investment was consolidated from private, public, and transportation investments into an overall value.

Land Use Characteristics

Population density, employment density, and the number of new parking stalls (associated with *new* TOD projects) were criteria included in the land use evaluation. Population density and employment density were calculated in ArcGIS using 2014 American Community Survey (ACS) data. While the percentage of land use types (2012 MAG data) within each station area was also qualitatively evaluated, population and employment density provide an objective comparison of activity around stations. Population density was weighted twice as much as the other values because of the literature's emphasis on high population density to support TOD and transit ridership. Data on the number of new parking stalls was gathered from the Valley Metro Economic Development Database and is included in the land use evaluation because transit-oriented projects should have few parking stalls to discourage driving and encourage transit use.

Data Analysis

Land use, employment and population density, and transportation connectivity around stations were analyzed using ArcGIS. Data was clipped to select all information within a half-mile buffer of the station area, and data was weighed to reflect the proportion of the Census Block or Tract in the study area. The maps developed are provided in Appendix D, and while the visuals tell a compelling story of connectivity and density, data from the maps was inputted into Excel for a quantifiable analysis.

The researcher used a relative ranking approach, wherein each criterion under analysis was evaluated relative to its performance to the other study stations. Overall, the final evaluation matrix included the 2016 average daily light rail boardings, transit score, walk score, bike score, sense of place score, population density, employment density, number of TOD projects since 2005, total investment dollars, and the amount of new parking for each station (full table in Appendix E). Factors were ranked based on values from highest to lowest, except for parking where the lowest number of new parking was assigned the best score. Having six study stations equated to a relative ranking system between 1 and 6, with 1 indicating the top performing station and 6 indicating the worst performing station. For stations that scored equally in a category, the stations received the same ranking and the subsequent rank was skipped. For example, the downtown stations (1st Ave./Jefferson, Washington/Central) and Priest/Washington both had the fourth best bike score. The fifth best ranking was omitted and Central/Camelback station, which had the worst bike score, was ranked sixth. Once total scores for each category were tabulated, they were weighed equally out of a maximum score of 36. Table 1 contains the final values and is presented and discussed further in the Findings section below.

Findings

The relationship between transportation, urban design, and land use is dynamic and complex, but the evaluation of criteria outlined in this study provides insight on how these elements interact to support TOD. Table 1 is a summary of scores assigned to each station based on the criteria outlined above. As mentioned, lower scores equate to better connected or better designed areas, and more transit supportive land uses. Scores for each urban infrastructure element were weighted equally and the maximum (worst) score for any category is 36. Consequently, the worst Overall TOD Score a station could possibly receive is 108. The table is discussed below in conjunction with observations made when conducting the field audit.

Table 1: Summary Table of Relative Rankings

	Transportation	Urban Design	Land Use	Overall TOD Score
Central Ave/Camelback	30	27	16.5	73.5
Encanto/Central Ave	28	20	21	69
Roosevelt/Central	12	11	19.5	42.5
1st Ave./Jefferson & Washington/Central	6	10	22.5	38.5
12th St./Jefferson & 12th St./Washington	22	24	18	64
Priest Dr./Washington	28	32	28.5	88.5

Network Connectivity (*Transportation*)

The variation in transportation scores reveal the differences in transportation network connectivity. Stations that scored well (low values) had the greatest number of bus stops, intersecting bus routes, and key local bus service routes (which have the highest frequency service). In well performing areas, bus routes serve regional and local destinations, and are interlined (overlap) to enhance connectivity and accessibility. The findings consequently suggest that when public transit service complements itself by providing various types of interconnected service, station locations perform better.

Available Groundwork (*Urban Design*)

The study also shows that urban design has a powerful impact on the overall TOD score. The sense of place field audit was especially powerful for the analysis by confirming the ranking of the other urban design criteria. The importance of urban design supports the existing literature that TOD should focus on pedestrian-oriented features that make walking and biking in the area a safe and desirable alternative to driving. Additionally, while data on existing parking was unfortunately not available, parking orientation was a primary component of the sense of place evaluation. Not surprisingly, Camelback/Central and Priest/Washington, the two auto-oriented stations, had the worst sense of place scores, as well as worst overall urban design scores, largely because swaths of surface parking lots are barriers to safe and connected pedestrian infrastructure.

Notably, the results of the urban design evaluation suggest that station area performance depends heavily on the pedestrian-scale infrastructure and sense of place. As land use and transportation have a dependent and dynamic relationship, the City of Phoenix should continue to advance its efforts for improving pedestrian infrastructure. Providing the groundwork for walkability and bikeability can spur development, which itself should be required to contribute to the sense of place (again creating a positive feedback loop between land use and transportation investment).

Emphasize Provision of Transit Services to Job Centers (*Land Use Characteristics*)

The larger variation in transportation and urban design scores compared to land use scores suggests that criteria included in those categories play a more significant role in the total TOD scores' variation. However, stations with a concentration of commercial/office land-use, and therefore high-employment densities, exhibit significantly higher ridership, which calls into question the emphasis on the mixed land use element of TOD outlined by the literature and encouraged by cities and planning agencies. In fact, results from this study support the growing body of literature on the importance of nodal employment centers near transit locations. Results also align with findings from the Valley Metro's Origins and Destination Survey, which found 39% of its transit riders are work commuters (2016). Though ridership activity at the Encanto station contradicts this, employment density near the station is skewed by the distribution of employment centers within the half-mile buffer, which are in closer proximity to the Thomas Rd. and McDowell Rd. stations. Notably, the transportation score for Encanto is poor, again suggesting the importance of network connectivity for TOD performance. A further examination of employment density at station areas along the entire alignment could confirm this finding.

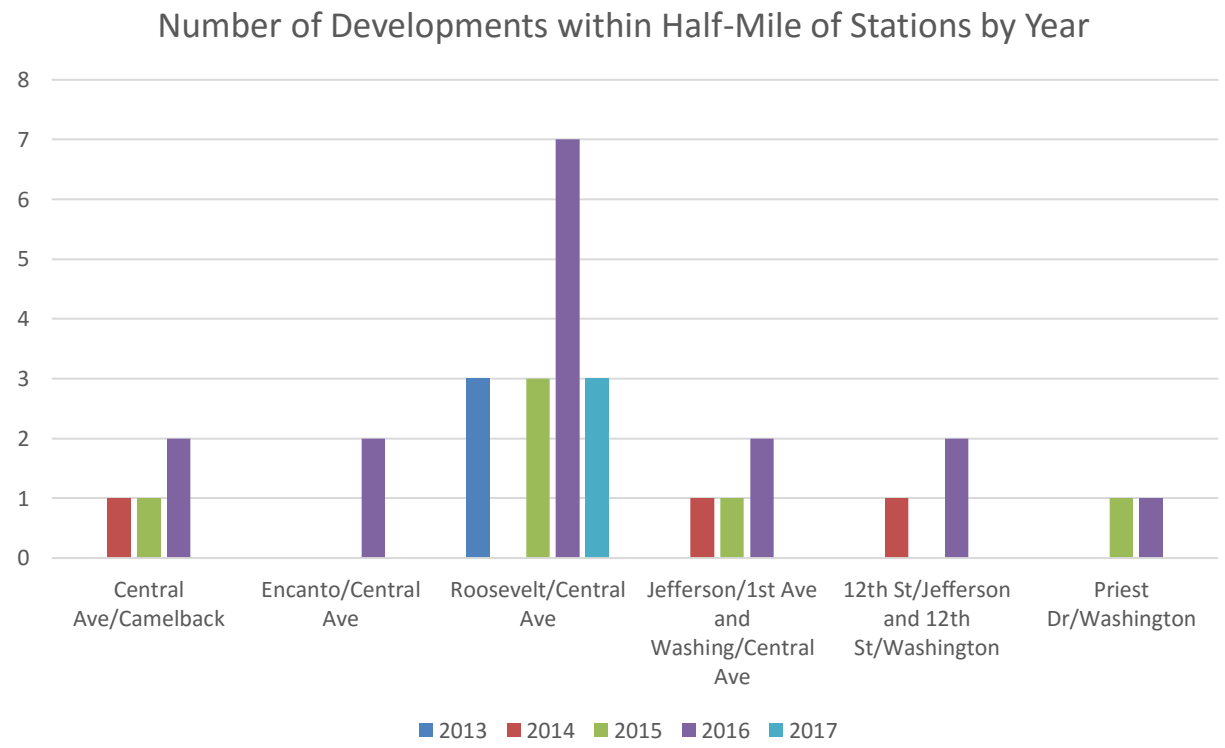
Ridership and New Developments

Though a comprehensive longitudinal analysis of the criterion is beyond the scope of this project, a comparison of the number of development projects and ridership trends between 2013 and 2016 was explored to gauge how developments impact ridership (ridership data prior to 2013 was reported in a different method that made comparing beyond that year a challenge).

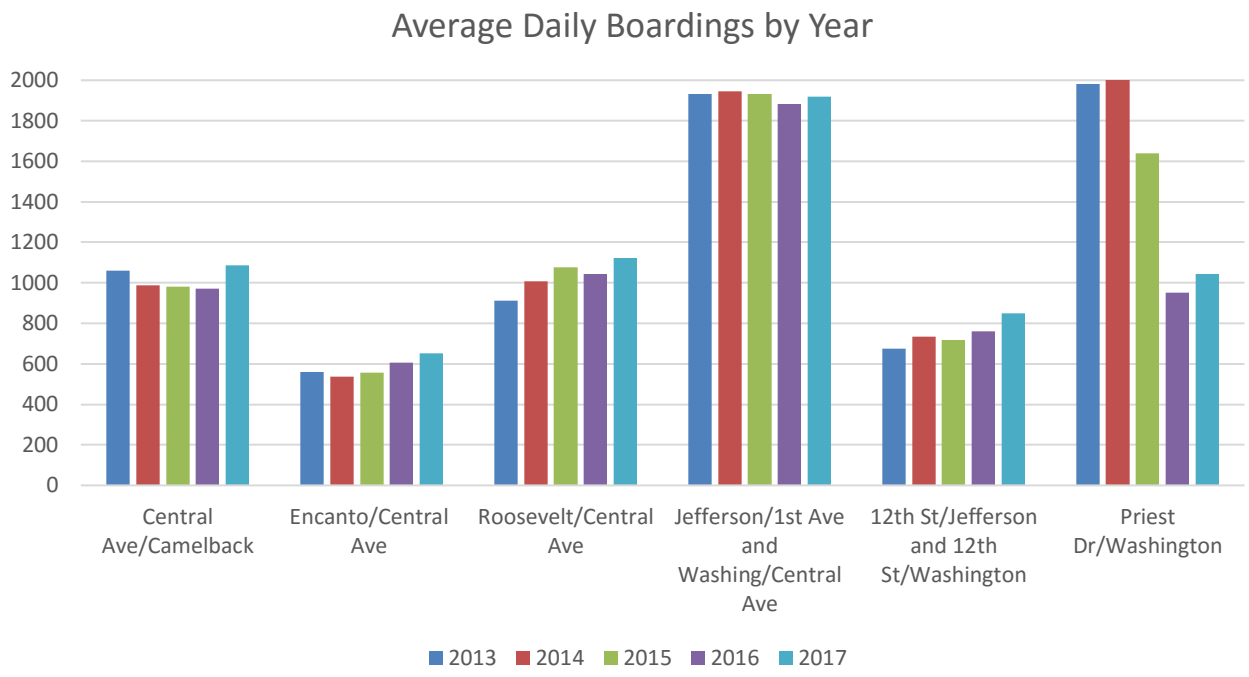
Each year's average daily boardings for weekdays were calculated by averaging the average daily ridership of each month within the year. Weekday ridership is defined as Monday-Friday. Weekends were excluded due to differences in travel behavior on Saturdays and Sundays. Graphs depicting the number of TOD projects and ridership trends are presented on the following page.

While the other elements discussed throughout this paper obviously factor in development siting decisions and transportation behavior, there is a clear positive correlation between the number of developments and ridership trends, specifically at the Roosevelt/Central station. Encanto and the 12th Street stations also show a positive correlation between the number of developments and ridership, but the change is smaller since there have been fewer projects and the projects also only recently opened. Notably, 1st Ave./Jefferson and Washington/Central serve the CBD and as the area is already a densely populated and active employment center, the impact on ridership has been minimal since four new developments occurred since 2013.

Graph 1: TOD projects completed by year.



Graph 2: Average daily boardings for weekdays (Monday-Friday) by year.



Transit-Oriented vs. Transit-Convenient Development

Tying these findings together, zoning codes, overlays, implementation plans, and other policies/strategies should be enhanced to ensure new developments are actually *transit-oriented* and not just *transit-convenient.* Most importantly, parking at new developments should be reduced to minimize competition between driving and transit. For example, though the area the value encompasses is unclear, "Downtown Phoenix boasts more than 25,000 parking spaces, making it a very car-friendly city center" ("Downtown Phoenix Map, Parking and More", n.d.). The addition of nearly 4,000 parking stalls in the 1st Ave./Jefferson and Washington/Central study area only further facilitates car culture and works against the transit supportive goals of TOD. Reducing parking supply and providing connected and well-designed alternative transportation infrastructure, especially near employment centers, can in turn improve ridership.

Considerations Moving Forward

Given the findings, four recommendations are put forth:

1. ***Improve the transportation network and serve job centers.*** As the Network Connectivity analysis suggests, an enhanced public transit network is a strong indicator for healthy TOD. Transit networks should specifically be enhanced to intersect and interline to provide a robust and redundant system with different service options. Furthermore, examining TOD with both regional and community level lens can help identify entertainment and more importantly, employment centers the network should focus on. Using a regional lens is important for improving the distribution of nodal developments along the alignment, and the community lens is

necessary for ensuring TOD efforts are appropriate for the area. Transportation planning efforts should thus emphasize serving job centers, and land use planning/development efforts should focus more on design (and less on diversifying land use). Important to the success of this recommendation is looking beyond the quarter-mile or half-mile radius of station area planning that is often put forth by the literature and agencies.

2. ***Focus on pedestrians.*** TOD areas should provide the appropriate pedestrian-scale infrastructure and features that contribute to a sense of place (building facades and setbacks, landmarks, smaller building signs, rear parking, etc.). Like the transportation network, sidewalks and bike lanes also require connectivity to the surrounding communities. Looking beyond the quarter or half-mile radius will help in creating an attractive walkable/bike-able environments beyond the immediate station area. Additionally, parking policies and strategies should complement transit ridership improvement efforts by reducing supply and increasing costs, thereby deterring automobile use.
3. ***Serve the community.*** Linking the first two recommendations together, developments must actively engage the streetscape and contribute/reflect the surrounding community. Community engagement plans should be created to help develop visions and implementation strategies for how TOD can best serve surrounding communities. Such an effort has been completed as part of the Reinvent PHX plan, which created 5-year Action Plans for five districts along the light rail (Appendix F). This effort should be expanded upon and utilized for new stations.
4. ***Develop metrics of success.*** Based on recommendations 1-3, TOD objectives should vary by station. While all should aim to increase transit ridership, a specific set of additional metrics should be developed to monitor progress of the station area towards achieving selected TOD objectives. Examples of metrics include community happiness, small business growth, percentage of residents involved in the planning process, number of vehicles per household, and/or household vehicle miles traveled, amongst others. Adopting a sustainability framework will help cities and transportation agencies with the implementation and evaluation of TOD.

Client Deliverables

This study was conducted to assist HDR in understanding what TOD principles support light rail ridership. Station profiles (Appendix B) for each study station were created to provide a description of station characteristics. The profiles can be used as a launching pad for reiterating the primary goals of TOD and discussing with key stakeholders the need to rethink the strategies utilized to accomplish those goals.

Study Limitations

This study examined elements of urban infrastructure of the researcher's choosing and as such could be expanded to include any number of additional elements. The data on the selected elements came from reliable sources, yet as with any research project, gaps in datasets limit the analysis to a certain extent. For example, the MAG GIS shapefile for employment only counted employers with five or more employees. In places with significant amounts of commercial or retail space, excluding this category could omit numerous small businesses and consequently affect the overall employment density. There were also data

gaps related to bicycle connectivity. In addition to only having access to nine-year old bike route data, information on GR:D activity, the bikeshare system in Phoenix, was unavailable. Lastly, a ratio of the station areas' population to parking stalls would have been a stronger measure for how auto-accommodating station areas are, but the parking data required for that analysis was not available.

More significantly, differences in the relative scores are not reflective of the variation in data values. For example, there could be a significant difference in population density between the first and second ranked stations, but stations 2-6 could have relatively similar population densities. The relative ranking system thus removes the naturally occurring weight between station area characteristics. Additionally, the sense of place score is a subjective evaluation, and while the researcher attempted to be as methodical as possible, different scores could be produced if another researcher were to explore the area.

Other limitations stem from software/data restrictions. GIS is a powerful tool, but it can only manipulate the data at the level at which it is imported. Consequently, sources like ACS population data that is available at the Census Tract level must be considered with a grain of salt because the clipped data, while weighted to reflect the proportion in the study area, could incorrectly reflect the actual population of that section of the Census Tract. A final caveat to the analysis is that data from Walkscore.com is based on characteristics within a quarter-mile radius of the selected site, whereas all other analysis occurs within a half-mile radius of the stations.

Finally, the findings from this study are also not statistically significant; however, the study provides avenues and potential frameworks for more rigorous statistical analysis. In particular, a regression model or correlation analysis could be developed to test the significance of the selected criteria on light rail ridership.

Conclusion

Urban environments are complex systems and must be examined holistically to understand how social, economic, and built environment forces interact to influence travel behavior. This study specifically looked at the role transportation connectivity, urban design, and land use have on light rail ridership, but in a larger context works to contribute to the understanding of sustainable development efforts aimed at reducing automobile dependency and infrastructure demands (miles of roads, distribution of utilities, etc.). The findings suggest TOD implementation strategies should be revisited to bring clarity to TOD objectives and ensure that development plans work to achieve those objectives. If TOD is intended to reduce automobile use, then developments need to provide less parking, more pedestrian-oriented infrastructure, and connections to multiple forms of transit services. TOD should be examined from a regional and micro scale context to distribute employment centers in certain locations and maintain community character in others. Findings also support the literature that transportation networks should focus more on serving employment centers and focus less on providing ground-floor retail.

Efforts from the Reinvent PHX plan utilize a more sustainability-oriented approach to station area planning, but may still have misguided efforts, as the plan promotes "a concentration of retail, employment and other day to-day destinations within quarter-mile of light rail stations in order to maximize convenient access" (The City of Phoenix, 2016). Using the findings from this study as a foundation, Valley Metro, the City of Phoenix, MAG, and other large stakeholders should develop metrics for TOD success, and invest in the

regular monitoring of transit activity as certain types of TOD projects come online. This can help the region better understand if its larger social, environmental, and economic objectives are being actualized. Additionally, major stakeholders should engage in anticipatory thinking about the future of the region; what industries are being promoted? What environmental challenges may constrain growth? How are social groups being supported? Anticipatory and systems thinking can help Valley Metro, Phoenix, MAG, and other municipalities develop a diverse set of solutions to accommodate the different lifestyles people want to live. While suburban lifestyles should not be excluded, the region needs to find effective incentives to densify and pursue infill development if they hope to reduce automobile trips and increase public transportation ridership.

Future Directions

This study only scratches the surface of analyzing the extent to which certain TOD principles support transit ridership. An obvious study that would help support (or debunk) the findings of this study would be a more extensive historical examination of ridership trends, specifically before and after the opening of a TOD project. Ridership on other modes of public transit that serve light rail station areas would also strengthen a ridership analysis.

More generally, research exploring social aspects of TOD needs to expand. The researcher attempted to explore a social dimension of TOD by looking at housing affordability around stations, but complications in the available data inhibited a proper evaluation of the study areas. In addition to a demographic analysis of station areas, other ways to evaluate the social sustainability of TOD could be to examine the level of community participation in project implementation, the presence of public services, or the level of pedestrian activity (and purpose). There is also research on environmental consciousness and green behavior, though the nexus between green ideology, transportation and the built environment is only limited explored. As Kahn and Morris note, "efforts to build and market more compact communities, improve transit ridership, or promote more fuel-efficient autos may founder if citizens are apathetic about environmental issues or if they do not translate their environmental concerns into concrete green behaviors" (2009). As such, exploring the attitudes and travel behaviors of residents living near rail could shed light on strategies for improving transit ridership.

This study can also be supported by a review of policies (e.g. parking minimums vs. maximums, height restrictions, etc.) and implementation strategies (civic engagement) around stations or even between different projects. Another comparative analysis could be between TOD performance at stations created before and after the Reinvent PHX strategy was adopted. The study could be further expanded to compare policies and strategies for station areas in different jurisdictions as well.

Finally, the initial observation that inspired this study were vacant retail locations along the alignment. Though leasing data was not obtainable for this study, a comparison of leasing rates around TOD could reveal drastic differences in rates that affect business siting decisions. Similarly, a regional analysis looking at market saturation of certain developments (specifically the mixed-use 4-story apartment complex with ground floor retail) could potentially uncover the true demand for such mixed-use developments.

Appendices

Appendix A: Table of top ten largest cities and associated TOD documents. The table is not a complete list of all TOD policies, strategies, or documents in each city.

City*	Agency	Document or Description	Link
New York	Metropolitan Transportation Authority	Smart Growth/TOD	http://web.mta.info/sustainability/index.html?c=SmartGrowth
	Metropolitan Transportation Authority	Smart Growth/TOD	http://web.mta.info/sustainability/pdf/MTA%20Smart%20Growth-TOD%2010%2029%2008.pdf
	New York and Connecticut Sustainable Communities	Sustainable Communities	http://www.sustainablenyct.org/projects/
	New York City Mayor's Office of Sustainability	New York City's Roadmap to 80X50	http://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/New%20York%20City's%20Roadmap%20to%2080%20x%2050_Final.pdf
	Regional Plan Association	Transit-Oriented Development	http://www.rpa.org/programs/transit-oriented-development
Los Angeles	LA Metro/CTOD	Creating Successful Transit-Oriented Districts in Los Angeles; A Citywide Toolkit for Achieving Regional Goals	http://ctod.org/pdfs/2010LATOD.pdf
	City of Los Angeles	Developing and Implementing the City of Los Angeles' Transit Corridors Strategy: Coordinated Action toward a Transit-Oriented Metropolis	http://planning.lacity.org/policyinitiatives/TransitOrientedDistrictPlanning/LATransitCorridorsStrategy_WhitePaper%20Final%20(2012-10-01)%20Carlton.pdf
	LA Metro	Transit Supportive Planning	https://www.metro.net/projects/tod/
	LA Metro	Transit Supportive Planning Toolkit	https://www.metro.net/projects/tod-toolkit/
Chicago	Chicago Metropolitan Agency for Planning	Transit-Oriented Development	http://www.cmap.illinois.gov/about/2040/supporting-materials/process-archive/strategy-papers/urban-design/tod
	Regional Transportation Authority	Transit-Oriented Development	http://www.rtachicago.org/plans-programs/guides-resources/transit-oriented-development

	Center for Neighborhood Technology	Transit-Oriented Development in the Chicago Region: Efficient and Resilient Communities for the 21st Century	http://www.cnt.org/sites/default/files/publications/CNT_TODInChicagoRegion.pdf
Houston	ICF International	Building Houston's Competitive Edge: Transit-Oriented Development fro the Ensemble/HCC Station	https://www.epa.gov/sites/production/files/documents/houston.pdf
	Houston Metro	Transit-Oriented Development Goals and Strategies	http://www.ridemetro.org/Pages/JointDevelopmentGuidelines.aspx
	Livable Centers Studies	Several Studies for TOD	http://www.houstontx.gov/planning/transportation/LivableCenter.html
	City of Houston	City of Houston Economic Development Programs	http://www.houstontx.gov/council/k/summit2014/cohecodev.pdf
Philadelphia	SEPTA	Sep-Tainable: the Route to Regional Sustainability	http://www.septa.org/sustain/pdf/septainable11.pdf
	City of Philadelphia	TOD Overlay District Code	http://phillycode.org/14-513/
	Neighborhoods Now	Transit-Oriented Development in Philadelphia: Using a proven strategy to create more vibrant, livable neighborhoods.	http://www.fltod.com/research/tod_planning_and_fbc_outside_florida/muncipalities/philadephia/transit_oriented_development_in_philadelphia.pdf
Phoenix	City of Phoenix	Reinvent PHX	https://www.phoenix.gov/pddsite/Documents/pdd_pz_pdf_00380.pdf
	City of Phoenix	Walkable Urban Code	https://www.phoenix.gov/pdd/pz/walkable-urban-code
	City of Phoenix	Uptown TOD Policy Plan	https://www.phoenix.gov/pddsite/Documents/ReinventPHX%20UPTOWN%20TOD%20Policy%20Plan%208.5X11.pdf
	City of Phoenix	Eastlake-Garfield TOD Overlay Rezoning Map**	https://www.phoenix.gov/pddsite/Documents/Eastlake-Garfield%20TOD%20Rezoning%20Boundary%20Map.pdf
	Valley Metro	Transit Oriented Development and Proposition 207 in Metropolitan Phoenix	http://www.valleymetro.org/images/uploads/lightrail_publications/FINAL-REPORT-TOD-and-Prop-207-in-AZ.pdf
	Valley Metro	TOD Overview and Station Profiles	http://www.valleymetro.org/projects_and_planning/transit_oriented_development
	Valley Metro	TOD Strategy	http://www.valleymetro.org/projects_and_planning/transit_oriented_development_policy/

San Antonio	City of San Antonio	Mission Verde: Building a 21st Economy	https://sanantonio.gov/Portals/0/Files/Sustainability/MissionVerdeSustainabilityPlan.pdf
	City of San Antonio	City Code	https://webapps1.sanantonio.gov/archivedagendas/CC02011/5$lg01!.PDF
San Diego	SANDAG	Regional Transit Oriented Development Strategy	http://www.sandag.org/index.asp?classid=12&projectid=500&fuseaction=projects.detail
	City of San Diego	Transit-Oriented Development Design Guidelines	https://www.sandiego.gov/sites/default/files/legacy/planning/documents/pdf/trans/todguide.pdf
	Metropolitan Transit System (MTS)	Policies and Procedures	https://www.sdmts.com/sites/default/files/POLICY.39.TRANSIT%20LAND%20USE%20PLANNING%20COORD.pdf
Dallas	City of Dallas	Transit-Oriented Development	https://www.google.com/webhp?sourceid=chrome-instant&ion=1&espv=2&ie=UTF-8#q=dallas+tod
	DART	Transit Oriented Development Policy and Guidelines	https://www.dart.org/about/todpolicy.asp
	DART	Transit-Oriented Development Guidelines: Promoting TOD around DART Transit Facilities	https://www.dart.org/economicdevelopment/DARTTODGuidelines2008.pdf
San Jose	Valley Transportation Authority (VTA)	Transit-Oriented Development Program	http://www.vta.org/projects-and-programs/Programs/Projects-Studies-and-Programs-TransitOriented-Development-TOD-Program
	Metropolitan Transportation Commission	Transit-Oriented Development	http://mtc.ca.gov/our-work/plans-projects/focused-growth-livable-communities/transit-oriented-development
	City of San Jose	Diridon Station Area Planning	http://www.sanjoseca.gov/DocumentCenter/View/33058

City size based on 2014 Census Data - cities (not metro areas) with populations of 1 million or more (https://www.census.gov/content/dam/Census/newsroom/releases/2015/cb15-89_graphic.jpg)

*Cities organized in descending order based on size.
**Other station area TOD plans available at: https://www.phoenix.gov/pdd/pz/walkable-urban-code

Appendix B: Station Profiles (Client Deliverables) – Please attached PDF.

Appendix C: Field Audit Worksheet

PUP 430—Transit-Oriented Development (TOD) Field Audit Worksheet

	Section 1: Accessibility/Connectivity		
	Description	Observation	Comments/Notes
1	Are physical or psychological barriers present within the ¼ mile station area that could reduce willingness to walk?	Yes No Some Areas	
2	Are blocks within the station area short and walkable?	Yes No Some Areas	
3	Are the streets within the station area frequent and interconnected?	Yes No Some Areas	
4	Are continuous and direct pedestrian connections to the station available from all locations within the area?	Yes No Some Areas	
5	Are bike lanes or paths provided that connect the station with the nearby area, as well as neighboring communities?	Yes No Some Areas	
6	Are convenient transfers to other forms of transit available within the immediate station area?	Yes No Some Areas	
	Section 2: Employment & Residential Density		
1	Are employment land uses dense enough to achieve the appropriate unit/acre ratio for the station area setting?	Yes No Some Areas	
2	Are residential land uses dense enough to achieve appropriate unit/acre ratio for the station area setting?	Yes No Some Areas	
3	Is the Floor Area Ration (FAR) of employment and residential uses appropriate for the station area setting?	Yes No Some Areas	Omitted – Beyond the level of detail of this project.
	Section 3: Diversity of Land Uses		
1	Are land uses within ¼ mile station area "transit supportive"?	Yes No Some Areas	
2	Are land uses within the ¼ mile station area "complimentary"?	Yes No Some Areas	
3	Are land uses within the station area "high activity"?	Yes No Some Areas	
4	Are vertical mixed use development developments present in the station area?	Yes No Some Areas	
5	Is the amount of total area devoted to residential uses appropriate for the station area setting?	Yes No Some Areas	
6	Is the amount of total area devoted to employment uses appropriate for the station area setting?	Yes No Some Areas	
7	Is the amount of total area devoted to retail/service uses appropriate for the station area setting?	Yes No Some Areas	
8	Are the retail/service uses concentrated within the immediate vicinity of the transit station?	Yes No Some Areas	
9	Is the amount of total area devoted to public/civic space appropriate for the station area setting?	Yes No Some Areas	
	Section 4: Design		
1	Are vehicular and pedestrian functions well-separated?	Yes No Some Areas	
2	Do building setbacks and heights provide "visual closure" to the streets in the station area?	Yes No Some Areas	
3	Are sightlines down streets interrupted with interesting features or landmarks?	Yes No Some Areas	

4	Are comfortable and appealing public spaces provided?	Yes No Some Areas	
5	Do public art or other landmarks provide interest and sense of place?	Yes No Some Areas	
6	Are buildings within the station area "ground-floor oriented"?	Yes No Some Areas	
7	Do unobstructed ground-floor windows cover 40% of building lengths in the station area?	Yes No Some Areas	
8	Does landscaping help provide a pleasant and comfortable environment in the station area?	Yes No Some Areas	
9	Are "all-season design" strategies incorporated into pedestrian spaces in the area to enhance comfort?	Yes No Some Areas	Omitted – Phoenix doesn't have drastic seasonal changes. Shading could be the only possible criteria to replace this, but the researcher considered shading as part of question 8 in this section (Design).
10	Is "human-scale" lighting available to enhance the feeling of safety and security in the station area?	Yes No Some Areas	Omitted – Research was conducted during the day.
11	Is signage coherent and "human-scale" to enhance the pedestrian environment?	Yes No Some Areas	
12	Does the design of bicycle facilities in the station area provide cyclists with a safe and secure environment?	Yes No Some Areas	
13	Does the design of the light rail station provide a pleasant, comfortable, and safe environment for transit users?	Yes No Some Areas	Omitted – Stations are generally uniformly designed and would receive the same score. The researcher also understands that the sense of safety related to the light rail extends beyond the station (e.g. into the vehicles themselves).
	Section 5: Parking		
1	Are parking costs in the study area appropriately high as to discourage automobile use?	Yes No Some Areas	
2	Are surface parking lots located behind or between buildings, rather than in front, to encourage pedestrian access?	Yes No Some Areas	
3	Are buildings "clustered" near intersections to provide easy pedestrian access, rather than isolated across parking lots?	Yes No Some Areas	
4	Are parking lots shared by different business and/or is district parking provided?	Yes No Some Areas	
5	Does on-street parking provide accessibility, as well as vehicular-pedestrian separation?	Yes No Some Areas	
6	Do parking structures contain retail or other uses on the ground floor?	Yes No Some Areas	
7	Are park-and-ride lots located in a way that takes minimal space and does not interfere with TOD potential?	Yes No Some Areas	
8	Is adequate and secure bicycle parking provided?	Yes No Some Areas	
	Section 6: Other Important Considerations		
1	Is readily developable (or re-developable) and suitable land available in the station area vicinity?	Yes No Some Areas	
2	Do the characteristics and health of economic activity in the station area vicinity support potential transit-oriented development?	Yes No Some Areas	

Appendix D: Station Area Maps – Please see attached PDF.

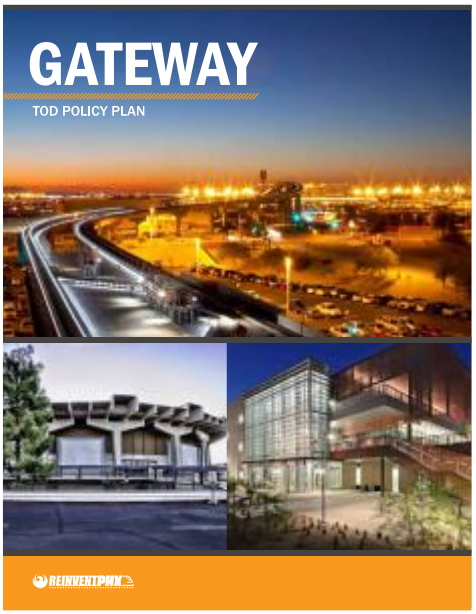
Appendix E: Raw rankings for given criteria.

Categories not converted to common denominator. *Weighted score.

	Criteria	Central Ave & Camelback	Encanto & Central Ave	Roosevelt & Central	1st Ave/Jefferson & Washington/Central	12th/Jefferson & 12th/Washington	Priest Dr/Washington
Transportation	Light Rail Average Daily Boardings	3	6	2	1	5	4
	Transit Score*	12	8	4	2	6	10
	Transportation Total	**15**	**14**	**6**	**3**	**11**	**14**
Urban Design	Walk Score	3	4	2	1	5	6
	Bike Score	6	3	2	4	1	4
	Sense of Place	5	3	2	1	4	6
	# of TOD Projects	3	4	1	2	6	4
	Total Investment	10	6	4	2	8	12
	Urban Design Total	**27**	**20**	**11**	**10**	**24**	**32**
Land Use	Population Density (2014)*	2	10	4	8	6	12
	Employment Density (2014)	6	2	4	1	5	3
	New Parking	3	2	5	6	1	4
	Land Use Total	**11**	**14**	**13**	**15**	**12**	**19**

Appendix F: Reinvent PHX District Action Plans

All district plans available at: https://www.phoenix.gov/pdd/topics/reinvent-phx



Acknowledgements

I would like to express sincere gratitude to the client, Scott Miller, for encouraging the project and providing support and guidance throughout the course of the study. A team of planners and engineers at Valley Metro and HDR also deserve thanks for helping me gather data, troubleshoot complications, and for being a sounding board as I dug through the abundance of data and ideas related to this project. Thank you, Melissa, Cavan, Josh, Kyle, and Alec. A special thank you to Joe, who regularly helped with GIS and made analysis of the data significantly easier, and Jessica who helped edit and review the work.

References

American Housing Survey. (2011). *2011 Housing Profile: Phoenix-Mesa-Scottsdale, AZ*. U.S. Census Bureau. Retrieved from https://www.census.gov/prod/2013pubs/ahs11-21.pdf

Beaubien, J. (2016). *Phoenix Votes Yes on Proposition 104 Transportation Package*. *Ability360*. Retrieved 10 February 2017, from http://ability360.org/news/advocacy-news/phoenix-proposition-104-transportation

Benefits of Transit-Oriented Development – Planning for Complete Communities in Delaware. *Completecommunitiesde.org*. Retrieved 14 January 2017, from http://www.completecommunitiesde.org/planning/complete-streets/tod-benefits/

Center for Transit-Oriented Development. (2011). Station Area Planning; How to Make Great Transit-Oriented Places (pp. 1-28). Reconnecting America and Center for Transit-Oriented Development. Retrieved from http://www.reconnectingamerica.org/resource-center/browse-research/2011/tod-204-planning-for-tod-at-the-regional-scale/

Cervero, Robert; & Duncan, Michael. (2008). Which Reduces Vehicle Travel More: Jobs-Housing Balance or Retail-Housing Mixing?. *University of California Transportation Center*. UC Berkeley: University of California Transportation Center. Retrieved from: http://escholarship.org/uc/item/1s110395

Cervero, R.; & Kockelman, K, (1997). Travel Demand and the 3Ds: Density, Diversity, and Design. Transportation Research Part D: Transport and Environment, Volume 2, Issue 3, p. 199-219.

City Clerk's Office. (2016). *662 Interim Transit-Oriented Zoning Overlay District One (TOD-1)*. Phoenix, AZ: City of Phoenix.

Clower, T., Bomba, M., Wilson-Chavez, O., & Gray, M. (2014). *Development Impacts of the Dallas Area Rapid Transit Light Rail System*. Center for Economic Development and Research. Retrieved from http://www.dart.org/about/economicdevelopment/developmentalimpactjanuary2014.asp

Commuting Characteristics by Sex: 2011-2015 American Community Survey 5-Year Estimates. (2015). *American Fact Finder*. Retrieved 19 March 2017, from https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF

Downtown Phoenix Map, Parking and More. *Downtown Phoenix Inc.*. Retrieved 28 March 2017, from http://dtphx.org/things-to-do/getting-around/

Duany, Andres. (2000). Suburban Nation: The Rise of Sprawl and the Decline of the American Dream. New York: North Point Press.

Fun Facts: VisitPhoenix.com. (2017). *Visitphoenix.com*. Retrieved 19 March 2017, from https://www.visitphoenix.com/media/media-kit/fun-facts/

Golub, A. & Kuby, M. 2015. Transportation and Arizona. Retrieved August 30, 2015, from http://www.aztownhall.org/Resources/Documents/106%20background%20report%20web%20final.pdf

Gomez-Ibanez, J. (1999). *Essays in Transportation Economics and Policy* (1st ed., pp. 224-250). Washington: Brookings Institution Press.

H+T Fact Sheets: True Affordability and Location Efficiency. *H+T Affordability Index*. Retrieved 3 April 2017, from http://htaindex.cnt.org/fact-sheets/?focus=cbsa&gid=313

Halifax Regional Municipality. (2005). *Settlement Pattern and Form with Service Cost Analysis*. Halifax, Nova Scotia. Retrieved from http://usa.streetsblog.org/wp-content/uploads/sites/5/2015/03/Halifax-data.pdf

Hsiao, A. (2012). *Why Sense of Place is Worth Caring About*. *Planetizen*. Retrieved 20 March 2017, from https://www.planetizen.com/node/56165

Johnston, R. (2004). The Urban Transportation Planning Process. In S. Hanson & G. Giuliano, *The Geography of Urban Transportation* (3rd ed., pp. 115-140). Guilford Publications, Incorporated.

Kahn, M., & Morris, E. (2009). Walking the Walk: The Association Between Community Environmentalism and Green Travel Behavior. *Journal Of The American Planning Association*, *75*(4), 389-405. http://dx.doi.org/10.1080/01944360903082290

Litman, T. (2009). *Comprehensive Evaluation of Transit Oriented Development Benefits*. *Planetizen: The independent resource for people passionate about planning and related fields*. Retrieved 18 February 2017, from https://www.planetizen.com/node/39133

Litman, T. & Burwell, D. (2006). Issues in sustainable transportation. *International Journal of Global Environmental Issues*, *6*(4), 331. http://dx.doi.org/10.1504/ijgenvi.2006.010889

Livable Centers Study. (2010). *Ensemble/HCC Livable Centers Study*. Houston-Galveston. Retrieved from http://videos.h-gac.com/ce/livablecenters/city_of_houston_midtown_livable_centers_study.pdf

McKenzie, B. (2013). *Who Drives to Work? Commuting by Automobile in the United States: 2013*. American Community Survey. Retrieved from https://www.census.gov/hhes/commuting/files/2014/acs-32.pdf

Parry, Ian, Margaret Walls and Winston Harrington. 2007. "Automobile Externalities and Policies." *Journal of Economic Literature*, 45(2): 373-399.

Population estimates, July 1, 2015. (2017). *United States Census Bureau*. Retrieved 19 March 2017, from https://www.census.gov/quickfacts/table/PST045215/0455000

Project for Public Spaces. (2009). *10 Benefits of Creating Good Public Spaces - Project for Public Spaces*. *Project for Public Spaces*. Retrieved 20 January 2017, from https://www.pps.org/reference/10benefits/

Providing Public Transportation Alternatives for the Greater Phoenix Metro Area. (2017). Valleymetro.org. Retrieved 29 January 2017, from http://www.valleymetro.org/publications_reports/economic_highlights

Reinvent PHX: Transit Oriented Development Strategic Policy Framework. (2016). (pp. 6-21). *City of Phoenix*. Retrieved 6 November 2016, from https://www.phoenix.gov/pdd/topics/reinvent-phx

Sources of Greenhouse Gas Emissions. (2014). *United States Environmental Protection Agency*. Retrieved 19 March 2017, from https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

Salon, D. (2015). *The Effect of Land Use Policies and Infrastructure Investments on How Much We Drive: A Practitioner's Guide to the Literature*. National Center for Sustainable Transportation.

Sunnucks, M. (2016). *Phoenix projected as number one US housing market for 2017*. *Phoenix Business Journal*. Retrieved 19 March 2017, from http://www.bizjournals.com/phoenix/news/2016/11/30/phoenix-projected-as-number-one-us-housing-market.html

The City of Phoenix. (2016). *Reinvent Phoenix* (pp. 2-21). Phoenix, AZ.

Transit Oriented Atlanta: A Strategy for Advancing Transit-Oriented Development. City of Atlanta.

Transit- Oriented Development (TOD). (2013). *Sustainablecitiesinstitute.org*. Retrieved 10 March 2017, from http://www.sustainablecitiesinstitute.org/topics/land-use-and-planning/transit-oriented-development-(tod)

Transit-Oriented Development and Putting People First. (2015). *Sustainablecitiescollective.com*. Retrieved 18 February 2017, from http://www.sustainablecitiescollective.com/wricities/1084724/how-transit-oriented-development-benefits-local-economies

Valley Metro. (2016). *Valley Metro Rider Profile 2015 Origin and Destination Survey*. Retrieved from http://www.valleymetro.org/images/uploads/projects/2015_OD_Survery_Infographic.pdf

Valley Metro. (2016). *Valley Metro System Fact Sheet* (pp. 1-2). Phoenix, AZ. Retrieved from http://www.valleymetro.org/images/uploads/RPT2411-opt.pdf

Why Phoenix? — Growth Nation. (2017). *Growth Nation*. Retrieved 19 March 2017, from http://growthnation.com/azigg/why-phoenix/

World Commission on Environment and Development. (1987). *Our common future*. Oxford: Oxford University Press.