CONNECTIVITY ORDINANCES IN OREGON MUNICIPALITIES

IMPACTS OF STREET LAYOUT REGULATION IN RESIDENTIAL SUBDIVISIONS

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Table of Contents

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If you have questions about this research or would like to discuss my findings, feel free to contact me at brandonrjpike@gmail.com.

ABSTRACT

Street connectivity ordinances influence development practices and the built environment within cities, dictating street layout for the foreseeable future. Cities in Oregon, a state with a robust statewide planning program and stated goals which include urban growth boundaries that regulate development in urban areas, utilize a number of strategies to regulate street layout and connectivity. This study examines both the effects those strategies have had on the built environment and how effective or ineffective they have been over time in three Oregon cities: Beaverton, Bend, and Hillsboro. Bend adopted new connectivity ordinances in 2006, offering a chance to research street connectivity before and after that point. This study's findings indicate that, after adoption, Bend's new ordinances worked to moderately increase intersection density, one of the most widely-used metrics for measuring street connectivity. This occurred alongside intersection density levels which decreased in the other two cities over the study period. This study also addresses the greater context of what those policies and their outcomes mean to urban areas and their residents long-term. Finally, the study presents a handful of other findings that appeared in the research related to transit and street connectivity, as well as zoning and street connectivity.

KEYWORDS

Street connectivity; block size; urban mobility; street network; street layout; active transportation; walkability

CHAPTER 1: INTRODUCTION & PREVIOUS STUDY

PURPOSE

Street connectivity influences active transportation levels in residential neighborhoods (Berrigan, Pickle, and Dill, 2010), which, in turn, influences greenhouse gas emissions (GHGs) in urban areas. Street connectivity also impacts transit availability and access to social services (Badia, Estrada, & Robusté, 2016). Neighborhoods with low levels of street connectivity have also been shown to lead to populations that lead more sedentary lifestyles than neighborhoods with street networks that have high connectivity, translating into additional health problems for those populations (Koohsari, et al. 2017).

Oregon cities remain among the top housing-constrained cities in the US, with some real estate firms placing Portland and Eugene in the 10 cities with the highest housing shortages (Pan, 2017). This occurs while Oregon maintains high growth rates compared to the US as a whole (US Census, 2017; Population Research Center, 2017), and added over 310,000 people between 2010 and 2017—an 8.1 percent increase (State of Oregon, 2017). The form that additional development takes, then, will have lasting affects in the region for a growing number of people.

The State of Oregon has an active interest in limiting suburban sprawl with their use of urban growth boundaries; accordingly, it is important that policy-makers and planners in the state know what their decisions lead to in terms of residential development and viable transportation infrastructure for all types of travel. As more people move into the region, cities and neighborhoods that have high street connectivity will benefit economically due to their ability to support flexible uses and nearby destinations (Ellickson, 2012). Additionally, efficient use of space is likely a top priority for cities who have seen rapid growth and increased traffic.

In light of these long-term environmental, social, economic, and public health-related factors that are related to street connectivity, studies which examine policies that influence connectivity of city streets are valuable to professionals in a variety of fields, from city planning, transportation engineering, and public administration to private developers and affordable housing advocates. Knowing more about the long-term effects of connectivity ordinances can allow policy makers to make more informed decisions regarding future development.

PREVIOUS STUDY

This section summarizes findings of literature related to street connectivity. As previously mentioned, past research points to a number of benefits that arise from areas with well-connected street systems, such as public health and equity, and environmental, economic, and transportation-related impacts.

Some existing literature focuses on street connectivity as it relates to social equity. Van der Kloof, Bastiaanssen, and Martens (2014) found that, while bicycle access can increase mobility of those most likely to experience transport-related social exclusion and accessibility barriers, it does not necessarily translate to users who are able to access the services they need. They conclude that having the proper infrastructure in place can help bridge that gap. High levels of street connectivity, then, can increase access to services for the most vulnerable members of society. Areas with high levels of street connectivity can also help lower obesity rates for vulnerable populations (Wang, Wen, and Xu, 2013).

One particular marginalized group that can benefit from well-connected street layouts are people with disabilities. Those with mobility and visual impairments often rely on public transportation for their daily transport. Public transit systems are usually more economically viable and better able to serve their citizens in areas with high street connectivity (Badia, Estrada, and Robusté, 2016). Once people with mobility and visual impairments arrive in their destination's immediate area, they deserve infrastructure that safely supports them, such as well-maintained sidewalks, and audible and tactile cues at crosswalks. Thompson (2013) found that maintaining the infrastructure in neighborhoods with traditional development and well-connected streets is significantly cheaper for municipalities over time. All this suggests that people with disabilities stand to benefit from having neighborhoods with well-connected street networks, and that those neighborhoods are more affordable to maintain over time.

Well-connected street layouts also lead to more available destinations within walking distance (Koohsari, et al., 2017; Ozbil, Peponis, and Stone, 2011). One of the key benefits of a well-connected street layout, then, is the increased appeal of walking and bicycling for transport, which becomes easier since travel distances are shorter and routes tend to be less complicated in terms of wayfinding (Kulash, Anglin, and Marks, 1990).

Along with pedestrian and bicycle-related impacts, street connectivity influences transit access and viability. Partially as a result of the drop in fuel prices and recent increased usage of ride-hailing technologies like Uber and Lyft, major transit agencies are having to rethink their routes to remain viable and better serve their constituents (Gunda & Atluri, 2017), especially those who traditionally have not had the level of transit service of cities such as New York City or Chicago. Badia, Estrada, and Robusté (2016) found that neighborhoods with grid patterns (and, consequently, more connected street networks), were more likely to experience success when redesigning their bus networks. Similarly, in order for a corridor to support transit, it should have at least eight housing units per acre (Dunham-Jones and Williamson, 2009). Since traditional development and traditional street patterns often leads to higher housing units per acre, areas of new development that boast higher street connectivity can lead to higher housing density, creating more areas that can support transit.

The environmental impacts related to street connectivity stem from the lower vehicle miles travelled (VMT) that results from cities with high connectivity (Koohsari, Owen, Cerin, Giles-Corti, & Sugiyama, 2016). Street networks that provide more direct paths between destinations lead to shorter trips, and, therefore, fewer GHGs released into the atmosphere (2016).

Finally, measuring street connectivity can prove challenging. Within the literature, it is often measured using the street connectivity index or intersection density, which is calculated by dividing the number of intersections in a location by its area unit (Tresidder, 2005; Handy, Patterson, and Butler 2003). Additionally, there are metrics that gauge walkability, such as the Pedestrian Catchment Area (PCA) and the Center for Disease Control and Prevention's Walkability Audit—the latter being an qualitative analysis of street features, while the former creates a buffer around a given point, and uses network analysis to record nodes and length of street segments.

Tresidder (2005) presents a variety of connectivity metrics, including intersection density, street density, connected node ratio (CNR), average block length, and the Gamma and Alpha indices. With the data available and the scope of this study, it was decided intersection density would be the most appropriate and efficient metric available for analysis.

BACKGROUND

In light of increased research related to the benefits of well-connected street networks, many cities have begun adopting connectivity ordinances in recent years that require developers to meet minimum standards for things like block length and perimeter size (Stangl, 2015). Of the three study cities (see *Methodology*), Beaverton and Hillsboro have had some form of connectivity ordinances in their codes since at least the early 1990s. Bend adopted block length and block perimeter size ordinances in late 2006. This provides windows in which to examine street connectivity in Bend both before and after they adopted connectivity ordinances, while comparing those results with the same analyses of Beaverton and Hillsboro, whose ordinances remained the same during the study's timeframe. Accordingly, this timeframe is broken into two 10-year periods: 1997 to 2006, and 2007 to 2016.

Bend adopted block length and block perimeter size ordinances in late 2006. To measure the impact of those ordinances, this study looks at development in two windows of time: ten years before and ten years after were put into place.

Urban growth boundaries (UGBs) were instituted by the Oregon State legislature in 1973, stemming from the landmark land-use legislation SB 100. Since that time, various state agencies have played roles in limiting development to urban areas in the state, as opposed to developing on fertile agriculture land far away from urban centers. This is worth noting, as research has shown UGBs can limit the amount of suburban development that occurs altogether (Song & Knaap, 2004), and, in turn, UGBs can influence the street layout of new development.

Rather than strictly limiting development to achieve a certain level of street connectivity, cities often regulate other aspects of street layout and design in order to influence connectivity (Duany and Talen, 2002). These policies, often called connectivity ordinances, which can also have the intended effect of providing sufficient emergency vehicle access, often include regulations of block length, block perimeter size, and the presence and/or length of cul-de-sacs.

In order to understand how connectivity ordinances influence the built environment in Oregon cities, this study aims to answer the following questions.

RESEARCH QUESTIONS

Have Bend's street connectivity ordinances in residential subdivisions led to an increase in street connectivity? And, more broadly, what effects have these ordinances had on the built environment in Oregon cities?

CHAPTER 2: METHODOLOGY

ANSWERING THE RESEARCH QUESTION

The broad goal of this study is to explore the effectiveness of street connectivity policies in Oregon. To narrow the scope, the 10 largest Oregon cities by 2016 population were selected (Population Research Center, 2017), then cities of a similar size which saw increases in population during the same periods were chosen (see appendix I). This produced a group of four Oregon cities: Beaverton, Bend, Hillsboro, and Medford. Finally, the goal was to examine cities which took different approaches to regulating street connectivity in recent decades. Hillsboro appeared to take the most stringent approach, Beaverton the least, and Bend and Medford, who take relatively similar approaches, fell somewhere in the middle, with their block length and cul-de-sac regulations being virtually identical. Medford did not have their data collected in a way that worked in the study's analysis, and since their approach to regulating street connectivity is similar to Bend, they were omitted from the final study group. Table 1 shows a brief summary of these cities' street connectivity ordinances. See appendix C for a detailed list of the study cities' connectivity ordinances.

It should first be noted that, while the policies examined in this study are commonly found in other Oregon cities' development codes, there are other types of street connectivity policies that may be more effective. For various reasons—they may be considered too drastic or too hindering to development in some cities, for instance—these policies are not as common as the policies analyzed in this study. Perhaps the most obvious approach to maintaining a certain level of street connectivity in new development is to require developers to build a street network that adheres to a street connectivity level of a certain value, or, more simply, to adhere to a grid layout. Further study could to be conducted to discover why exactly cities hesitate to establish such policies outside central business districts (see *Future Research* section), though it is not hard to imagine the potential public pushback that could occur if attempts were made to limit residential development in such ways. With that in mind, the following paragraph summarizes the general connectivity ordinances found across the state.

There are three main types of policies related to street connectivity commonly found in development codes, with any combination of the three in a given city's code, plus other less common ordinances. First, cities can regulate block length and block perimeter size. They tend to have different requirements depending on the type of zoning in place—commercial, residential, and industrial, for example. For the purposes of this study, only residential block length requirements were examined. This is because other types of zones, such as commercial and industrial, have widely-varying ordinances which are often different than residential zones. The decision was made to focus solely on residential areas so that valid comparisons could be made. Second, cities can regulate cul-de-sacs—namely, whether they are permitted and/or their length. Third, cities can regulate new subdivisions based on their internal street connections to existing development. This can be implemented in a variety of ways, as cities can be as strict or as lenient as they wish to be. For example, Hillsboro requires developers to outline how their development will connect to existing streets, and deviation from a well-connected network requires a comprehensive explanation from the developer for why that layout is needed. Beaverton, on the other hand, only requires developers to include an accessway for pedestrians and bicyclists between their development if block lengths exceed 600 feet.

Portland and Eugene, two of Oregon's three largest cities, employ a handful of perhaps more stringent methods in regulating street connectivity. Instead of focusing on those cities' methods for regulating street connectivity, which have both been well-researched (Tresidder, 2005; Handy, Paterson, and Butler, 2003; Metropolitan Service District, Street Design Work Team, et al., 1997), it was decided that this study would examine how small to mid-sized cities in Oregon regulate street connectivity. This is in hopes that similarly-sized cities that are facing an increase in development activity could be able to use the information presented in this study to make informed decisions regarding connectivity ordinance adoption.

Table 1 | Summary of Street Connectivity Ordinances by City

	Beaverton	Bend	Hillsboro
Block Length	600*	660	530 to 600**
Block Perimeter	None	2000	1800 to 2750**
Cul-de-Sacs	Accessway may be required	Discouraged	Discouraged
Cul-de-Sac: Length	None	None	450

Connectivity Analysis Required?	No	No	Yes
* See appendix C for exceptions ** Depending on proximity to transit infrastructure			

The process of isolating cities in Oregon that saw development during the same eras was intended to control for market forces that affect street connectivity—in other words, subdivisions built during the 1950s, for instance, tend to have different street layouts than those from the 1980s, oftentimes without the influence of street connectivity policies (Handy, Paterson, and Butler, 2003). This process isolated three cities that took different approaches to street connectivity in new residential development, with the intent to show how effective each city's approach has been over time.

The years examined in this study are 1997 to 2017—ten years before and ten years after there were changes in Bend's development codes related to connectivity ordinances. Both Beaverton and Hillsboro's ordinances have remained the same over the study period, both implementing their policies prior to 1997. Beaverton and Hillsboro, then, provide a control group for observing changes in Bend street connectivity over this time period.

MEASUREMENT & DATA

Street connectivity analysis for the three study cities was conducted in two ways:

1. Conducting a policy review, which examined the ordinances related to cul-de-sacs, block lengths, and block perimeter sizes in the three cities, and
2. Measuring intersection density.

The policy review revealed that, as previously stated, Hillsboro had the strictest connectivity ordinances over the study period, while Bend's ordinances (adopted 2006) were moderately strict, and Beaverton's were the least strict. Along with stricter ordinances related to block length, perimeter, and cul-de-sacs than the other cities, Hillsboro also requires developers to submit what they call a connectivity analysis for developments with proposed internal streets (see table 1). This adds another level of oversight by the City, which is likely resource-intensive for both the developer and the planning agency to prepare and review, respectively.

Next, data was obtained in order to measure the effectiveness of the ordinances over time—data such as subdivisions, zoning, and city limits from the appropriate city, county, and regional government agencies. This allowed for the ability to examine each subdivision in the study cities, as well as what land use zone it belonged to and when it was developed.

The next step involved locating each intersection in the study cities. Using street layer data from the State of Oregon, line intersection analysis was performed, producing nodes at each street intersection and intersections between streets and paths. During intersection density analysis, roundabouts were treated as a standard single intersection. The only exception was if the center of the roundabout contained a destination with access points (see Compass Park in Bend for an example). Next, the street connectivity was measured inside subdivisions that fell within the bounds of the study's timeline.

Some judgement was required when sifting through the subdivision data. This study intended to examine street connectivity of *typical* residential subdivisions, so certain parcels and developments were eliminated from the analysis, such as the Broken Top Club golf course neighborhood and Mount Bachelor Village Resort on the western edge of Bend. While zoned single-family (RS) and platted within the timeframe of the study's bounds, those uses necessitate entirely different street layouts than standard residential neighborhoods and are outright prohibited in many residential zones. This decision was to allow for this study to be applied to a typical residential neighborhood. Other than a small handful of similar situations, every residential subdivision platted between 1997 and 2016 for Beaverton, Bend, and Hillsboro were included in the study.

Additionally, partitions and small subdivisions that did not include new street creation were excluded from the study, unless they were part of a larger subdivision taking place over time. This was accomplished through data analysis that required partitions and small subdivisions to meet two criteria in order to be included in the study:

1. The partition or small subdivision's name needed to closely match that of the larger subdivision—"Arbor Roses" and "Arbor Roses No.2", for an example.
2. The partition or small subdivision needed to lie directly adjacent to the larger subdivision.

The data from all three cities needed significant attention, as duplicate subdivisions needed to be deleted or consolidated. Consideration was taken for when the area was originally platted, so that each subdivision was placed into the year it was first on record as being platted with Washington County (for Beaverton and Hillsboro) or Deschutes County (for Bend).

This process of filtering the data created a grouping of all residential subdivisions in the study cities which occurred between 1997 and 2016, did not occur within the larger bounds of a golf course or resort-type development, and included the creation of streets.

COMMUNITY PROFILES

Summary

Two United States Censuses were conducted during this study's timeframe, occurring during the fourth year of both 10-year periods of the study—the 2000 Census during the 1997-2006 period and the 2010 Census during the 2007-2016 period. This provides detailed snapshots in data form of Oregon, Beaverton, Bend, and Hillsboro during the study. See appendix H.

All study cities saw considerable population and housing growth over the study period, but Bend's growth was most pronounced. The following subsections summarize changes in the cities and Oregon as a whole over the study's timeline.

Note: All data presented in this section are from the 2000 and 2010 US Census and the 2012-2016 American Community Survey 5-Year Estimates, unless otherwise noted.

Housing

Between 2000 and 2016, Beaverton added around 7,700 housing units, increasing 19.3 percent from 32,500 to 40,267. Bend saw the highest rate of housing growth and added close to 15,000 units, increasing from 22,507 to 37,406—just shy of a 40 percent increase in total units over a 16-year period. Hillsboro added over 11,000 units, going from 27,211 to 38,495—a 29.3 percent increase. Table 2 summarizes the change in housing units over time for the study cities.

Table 2 | Change in Housing Units Over Time

	Oregon	Beaverton	Bend	Hillsboro
2000	1,452,709	32,500	22,507	27,211
2010	1,675,562	39,500	36,110	35,487
2016 (Estimate)	1,706,290	40,267	37,406	38,495
Percent Change	14.9%	19.3%	39.8%	29.3%

Income

Hillsboro residents make around $10,000 to $17,000 more per year than Beaverton, Bend, and Oregon residents as a whole (see table 3). However, the median home price in Hillsboro is at least $30,000 less than Beaverton or Bend, and $3,500 more than Oregon as a whole. Consequently, while Beaverton and Bend's ratio of income to median home price were both around 20 percent in 2016, Hillsboro's was just over 29 percent. This shows that Hillsboro residents must spend less on their housing all while making more per year than Beaverton or Bend residents.

Table 3 | Income & Housing Statistics

	Oregon	Beaverton	Bend	Hillsboro
Median Household Income				
2000	$40,916	$47,863	$40,857	$51,737
2010	$49,260	$54,885	$53,006	$60,695
2016 (Estimate)	$53,270	$59,620	$55,625	$70,180
Percent Change				
Median Home Price	$237,300	$286,200	$271,300	$240,800
Ratio of Income to Median Home Price (2016)	22.4%	20.8%	20.5%	29.1%

Sources: US Census: Selected Economic Characteristics; Livability.com

LIMITATIONS

Criticisms of using intersection density to gauge street connectivity and walkability exist (Haynie, 2016; Knight & Marshall, 2015). However, it remains perhaps the most widely-used method of measuring connectivity, since the scale at which it can be conducted is vast compared with analyses that are site-by-site based, for instance, and is less time-intensive than other large-scale connectivity metrics. The following paragraph explores some of the key criticisms of intersection density analysis.

When using intersection density to measure street connectivity, one concern stems from the fact that new developments cannot entirely claim responsibility for intersections along routes that already exist. Unless it is a greenfield development with no existing street network, developers are likely to need to include one or more existing streets in their plans. In other words, it does not make sense to judge a new development by the streets or roads that already may exist within or adjacent to its bounds due to preexisting infrastructure. While not the developer's choice in design, existing streets in the development instantly have a guaranteed length of roadway, plus whatever new streets the development includes. This potentially increases the likelihood for developments to include more intersections. However, this criticism, while worth noting, is often rebuffed by researchers (Tresidder, 2005) since developers are still chiefly responsible for the development's final layout of new streets within the mandates of the regulatory agencies. Additionally, the argument can be made that this potential conflict is cancelled out through regulation, as rules for access and easements are the same regardless of if the current developer has to design around existing street infrastructure or if they have an empty parcel of land (assuming, of course, that they are in the same jurisdiction in either scenario).

One potential limitation to this project is the scale at which development occurred during the study's timeframe. While research is limited on the subject (Morris, 2009), larger developments tend to have different street layouts than small developments, often due to the flexibility in design and layout that comes with developing larger pieces of land. In light of the 2007-2008 economic recession which affected housing development considerably in US cities, it could be posited that street connectivity in Beaverton, Bend, and Hillsboro post-2008 was affected by economic factors as well as the connectivity ordinances in place. To see the drastic changes in the number and sizes of residential subdivision developments in the study cities before and after the Recession, see "Effects of 2007-2008 Financial Crisis on Oregon Residential Development" in *Findings*. Consequently, along with connectivity ordinances, this drop in development activity could have played a role in these cities' street connectivity levels over the study period.

There is a key distinction to make between street connectivity and walkability and other forms of active transportation. Not all neighborhoods with high levels of intersection density or, more broadly, street connectivity, will be conducive to active transportation. While street connectivity paves the way for that to be possible, the proper infrastructure, such as sidewalks, streetlights, and bike lanes, need to be in place for a neighborhood to be walkable and bike-friendly. A neighborhood with very high street connectivity yet lacking adequate sidewalk or bicycle infrastructure, will not encourage active modes of transportation. Further analysis that includes sidewalk and bicycle lane data—if available—could help correct for this (see *Future Research*).

Finally, the data used in the study had its own limitations, as certain adjustments and calculations needed to be made for each city, including that of subdivision size in the case of Hillsboro and Beaverton. While these calculations were checked for accuracy and confirmed to be within 0.01 acres of actual size, this should be noted.

CHAPTER 3: FINDINGS

FINDINGS SUMMARY

This chapter presents the findings of the study. A brief summary is listed below:

- Bend's connectivity ordinances adopted in 2006 seem to have increased intersection density in the second 10-year period. See *Connectivity Ordinances & Intersection Density.*
- Hillsboro's stricter connectivity ordinances have not led to significantly higher levels of intersection density citywide. See *Connectivity Ordinances & Intersection Density*.
- Cities with more high density zoning did not have higher intersection density over the second 10-year period. See *Land Use Zoning & Street Connectivity*.
- While Hillsboro's ordinances that aim to increase street connectivity in areas close to the MAX light rail corridor have influenced some areas with high connectivity—notably the Orenco new urbanist transit-oriented development (TOD)—this study found numerous examples of developments outside the MAX transit stop buffer zone that achieved the same or even higher levels of intersection density. See *Street Connectivity & Transit*.
- Beaverton's ordinance that encourages mid-block accessways may have led to development with high internal street connectivity but low external street connectivity (Song and Knaap, 2004). See *Connectivity Ordinances & Intersection Density*.
- The connectivity analysis Hillsboro requires developers to complete does not appear to have led to significantly higher levels of external street connections (Song and Knaap, 2004). See *Connectivity Ordinances & Intersection Density*.
- The 2007-2008 financial crisis had a significant impact on residential development in Oregon, and may have influenced street connectivity indirectly. See *Effects of 2007-2008 Financial Crisis on Oregon Residential Development*.

CONNECTIVITY ORDINANCES & INTERSECTION DENSITY

After Bend adopted connectivity ordinances in 2006, intersection density levels in residential subdivisions increased 0.12 intersections per acre during the second 10-year period, going from 0.33 to 0.45. During that period, the other cities saw a decrease in intersections per acre, going from 0.34 to 0.30 in Beaverton and from 0.40 to 0.36 in

Hillsboro. This seems to suggest that Bend's ordinances were effective in raising connectivity, as the other two cities' connectivity ordinances remained the same during the study timeline and both of their connectivity levels decreased in the second period, while Bend made changes to their ordinances and their connectivity level increased. Table 4 presents the intersection density findings (see appendix A for intersection definitions).

Beaverton and Hillsboro's connectivity ordinances remained the same during the study periods and their intersection density decreased, while Bend adopted new connectivity ordinances and their intersection density increased.

Hillsboro's strict connectivity ordinances have not led to significantly higher levels of intersection density than the other cities, with Bend's somewhat more relaxed ordinances in place during the second 10-year period producing a higher level of intersection density. See figure 2 for maps showing all intersections included in the study.

Beaverton's ordinance that encourages mid-block accessways may have a significant impact: creating areas with high levels of internal street and path connectivity but low levels of external street connectivity. Song and Knaap (2004) found that overall density had increased in Washington County, home to Beaverton and Hillsboro, since the 1960s. Their research also suggests that while internal street connectivity improved from the 1990s to the time of their study, external street connectivity decreased during that time. This could be a product of the path system throughout Beaverton, which winds through the residential portions of the city but does not have very many connections to commercial areas (see appendix D).

Table 4 | Summary of Residential Subdivisions & Intersections

	Beaverton	**Bend**	**Hillsboro**
Total Residential Subdivisions			
1997-2006	75	403	204
2007-2016	19	114	62
Percent Change	-74.7%	-71.7%	-69.6%

Residential Subdivision Area (Acres)			
1997-2006	416.34	5560.05	1192.72
2007-2016	96.93	1067.31	294.68
Average Residential Subdivision Area (Acres)			
1997-2006	5.55	13.80	5.85
2007-2016	5.10	9.36	4.75
Intersections			
Street-Street Intersections			
1997-2006	121	1817	418
2007-2016	27	476	93
Street-Street & Street-Path Intersections			
1997-2006	142	1853	482
2007-2016	29	480	106
Street-Street, Street-Path, & Path-Path Intersections			
1997-2006	172	1871	562
2007-2016	39	481	113
Intersections Per Acre			
Street-Street Intersections Per Acre			
1997-2006	0.29	0.33	0.35
2007-2016	0.28	0.45	0.32
Street-Street & Street-Path Intersections Per Acre			
1997-2006	0.34	0.33	0.40
2007-2016	0.30	0.45	0.36
Street-Street, Street-Path, and Path-Path Intersections Per Acre			

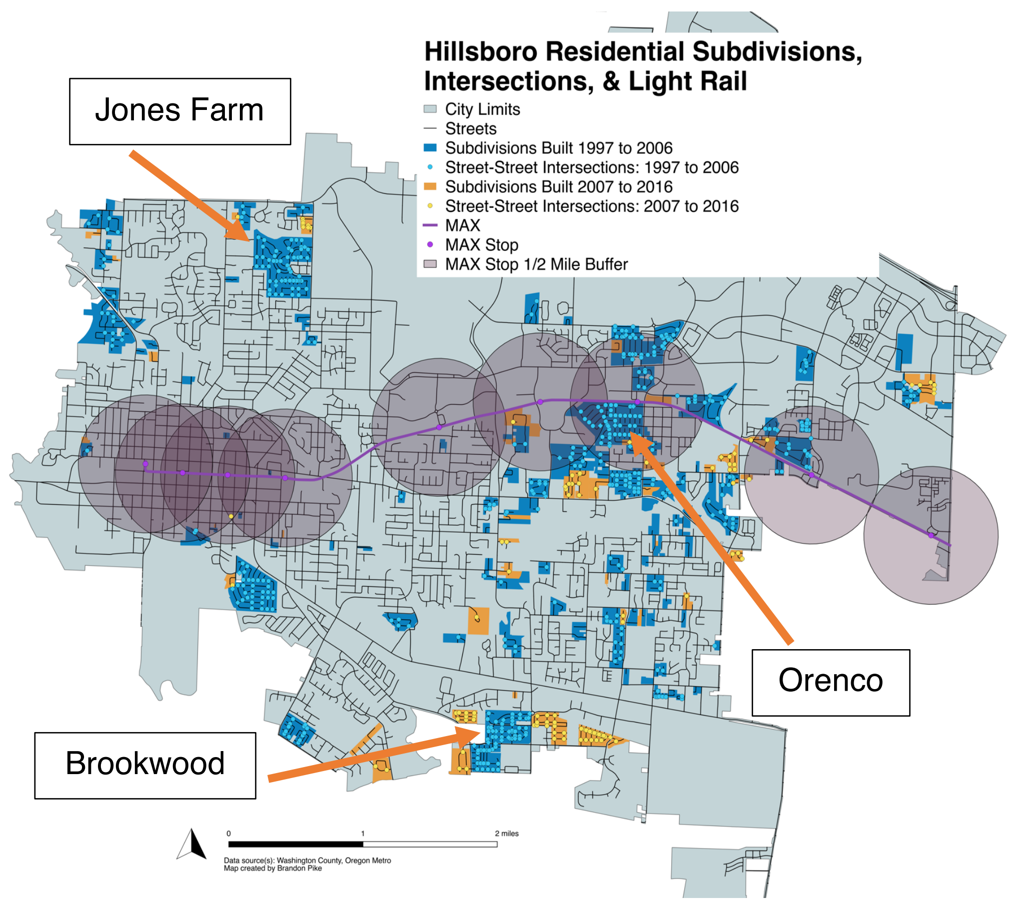
1997-2006	0.41	0.34	0.47
2007-2016	0.40	0.45	0.38

STREET CONNECTIVITY & TRANSIT

Of the three study cities, Hillsboro is the only one that has connectivity ordinances that change as subdivisions get closer to transit stops. The regional light rail system, MAX, passes through the city, bisecting Hillsboro from east to west almost perfectly in half. Hillsboro requires subdivisions that occur within ½ mile of MAX stops to adhere to slightly stricter development practices than in some other parts of the city. Within those transit stop buffer zones, residential block perimeter sizes drop 35 percent, from 2750 to 1800 feet, and block lengths drop from 600 to 530 feet. Figure 2 shows subdivisions and intersections alongside the MAX system, with half-mile buffers from the MAX stops shown in purple.

Many of the stops adjoin areas that were already heavily developed before this study's timeframe, such as downtown Hillsboro. The Orenco neighborhood was developed at a later date—after Hillsboro's transit-specific connectivity ordinances were established. Orenco lies along the MAX line and includes the New Urbanist transit-oriented development (TOD) Orenco Station, and has an understandably high intersection density of

Figure 1 | Hillsboro Light Rail



0.54 intersections per acre (see figure 1). What is somewhat surprising, however, is that other developments (namely those to the northwest and south of Orenco) that are nowhere near the MAX stop buffer zones and, therefore, have less strict connectivity ordinances in place have levels of intersection density that are as high or even higher than Orenco. The Jones Farm neighborhood in northwest Hillsboro, for example, has 0.56 intersections per acre—slightly higher than the Orenco neighborhood even though Jones Farm is well outside the MAX buffer. Likewise, the Arbor Roses development in southwest Hillsboro has 0.54 intersections per acre. Sixteen of the Brookwood development's 46 intersections are street-path intersections, as the developer chose to include a number of pathways through the neighborhood. This led to a very high relative density of 0.92 intersections per acre inside Brookwood. Even without including street-path intersections, Brookwood has an intersection density of 0.60 intersections per acre. Table 5 summarizes these neighborhoods/developments.

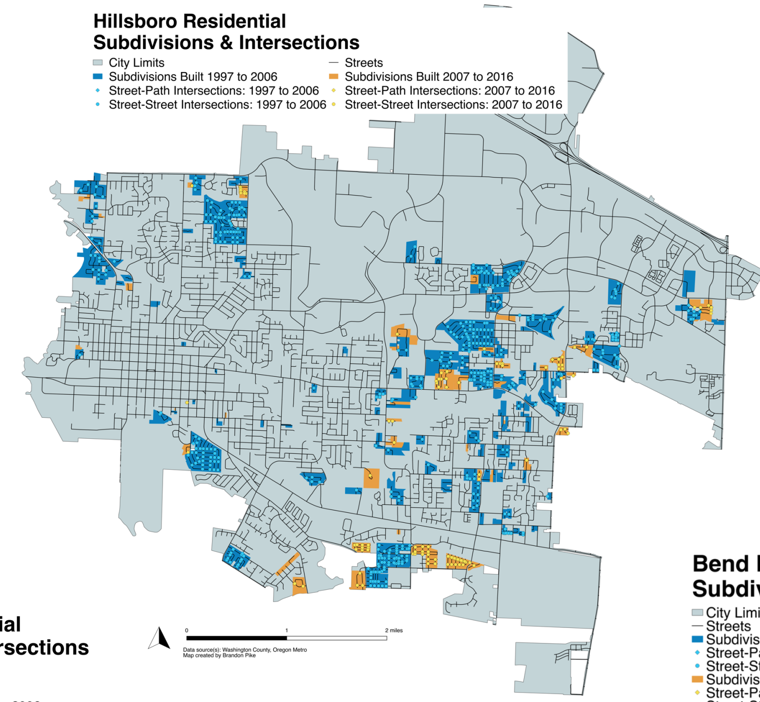
Table 5 | Intersection Density of Neighborhood Examples in Hillsboro

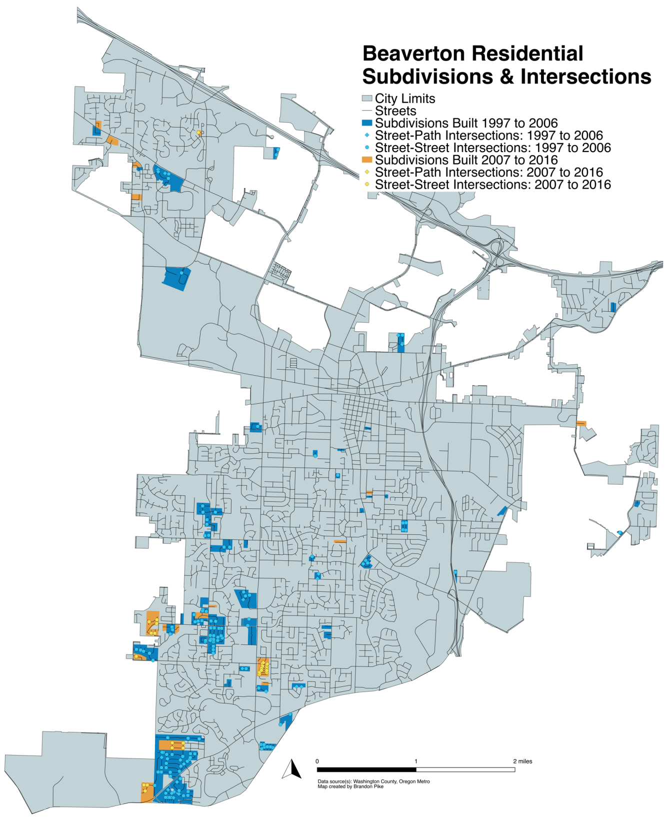
	Orenco*	**Jones Farm**	**Arbor Roses**	**Brookwood**
Intersections	99	55	34	46
Acres	181.7	98.8	62.8	49.9
Street-Street & Street-Path Intersections Per Acre	0.54	0.56	0.54	0.92

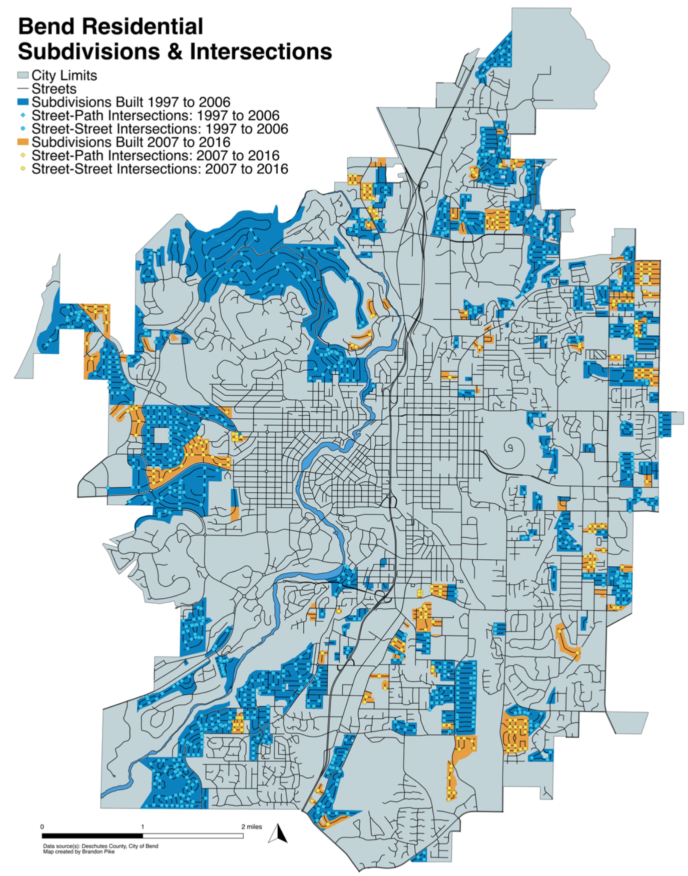
*Includes Orenco Station, Orenco Gardens, and Orenco Meadows

INTERSECTIONS

Figure 2 | Residential Subdivisions & Intersections



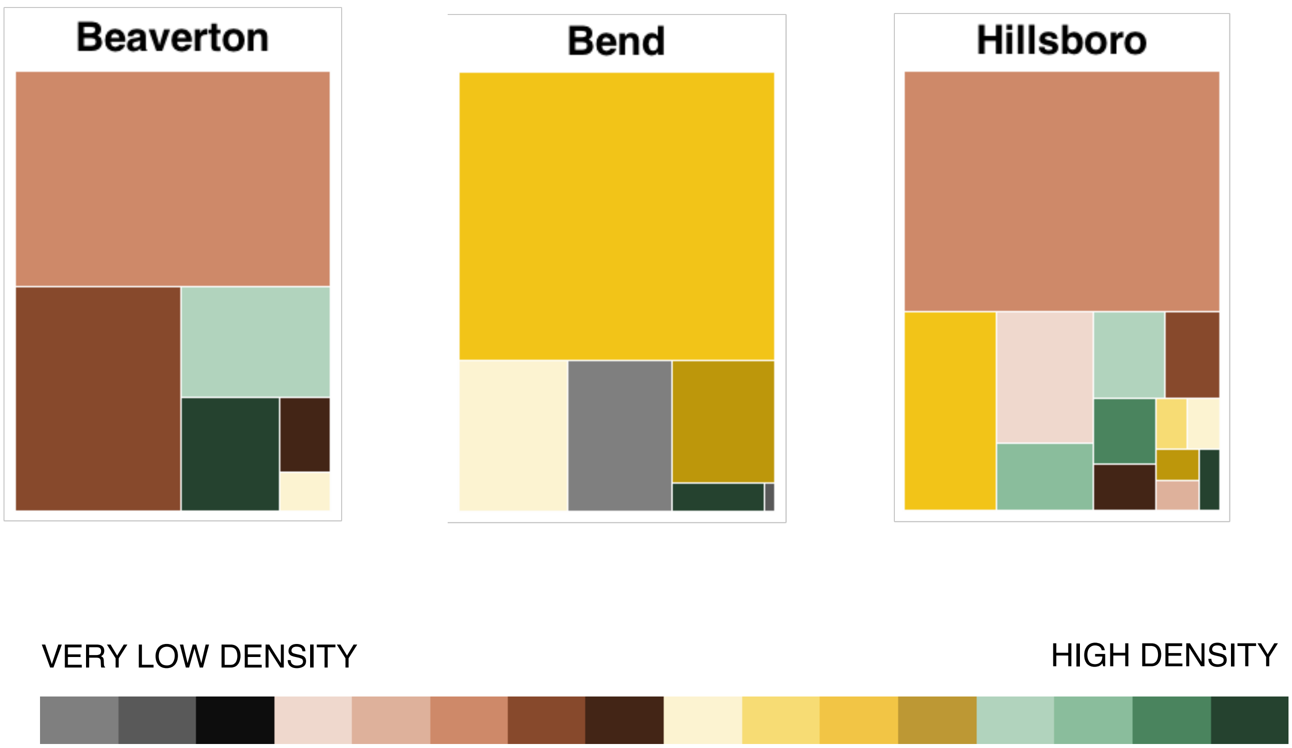




LAND USE ZONING & STREET CONNECTIVITY

It is worth briefly examining the zoning strategies employed by each city, since development type is largely influenced by the zoning in place. Figure 3 shows the amount of land in each residential zone by city. Gray colors represent very low density zones, red colors represent low density, yellow colors represent medium density, and green colors represent high density zones. The darker the shade, the higher the density within its color category.

Figure 3 | Area of Residential Zones

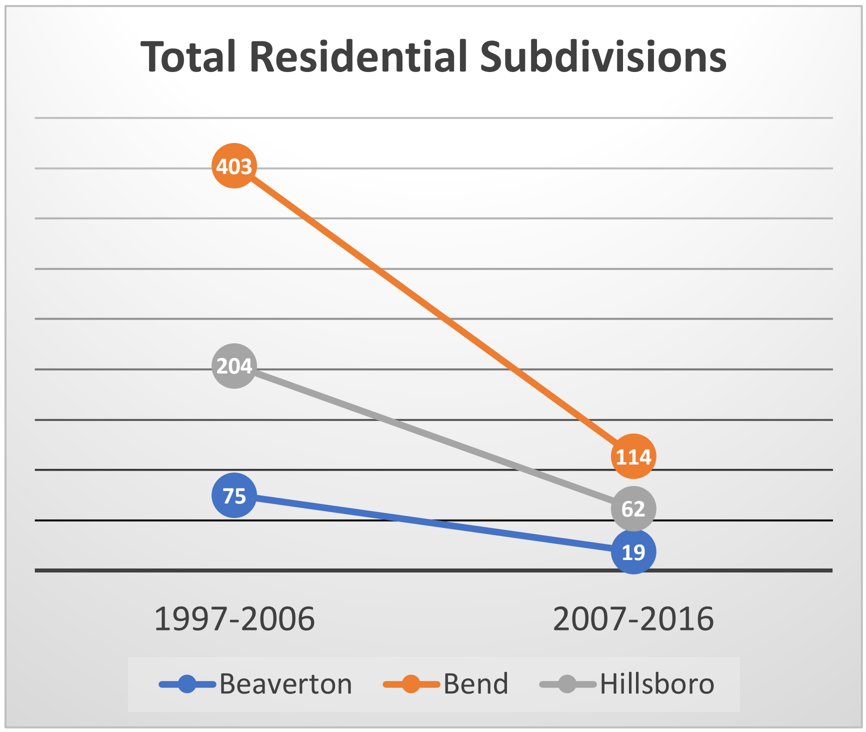


Bend has a very small amount of its residential land zoned as high density residential (1.8 percent), with most of its land zoned as either medium or very low density. Beaverton and Hillsboro, on the other hand, have more of their residential land zoned for high density (20 and 13 percent, respectively), with the remainder of their residential land zoned predominantly low or medium density. Neither Beaverton nor Hillsboro have any land zoned below 3.5 units per acre, while Bend has 11.5 percent of their residential land zoned as what's categorized as very low density for the purposes of this study: between 1 unit per 2.5 to 10 acres. See Appendix E for a detailed summary of the study cities' residential zones.

While Beaverton and Hillsboro both zone for higher population density, Bend achieved higher levels of intersection density in the second 10-year period than the other two cities while maintaining predominantly very low- to medium-density zones.

EFFECTS OF 2007-2008 FINANCIAL CRISIS ON OREGON RESIDENTIAL DEVELOPMENT

Figure 4 | Residential Subdivisions Platted Over the Study Periods



The impact of the 2007-2008 financial crisis greatly affected Oregon development, as evidenced through declining development activity that occurred immediately afterward. Figure 4 shows the reduction in development in the study cities when comparing the first 10-year period with the second. All three cities saw a reduction of between 70 and 75 percent in the total number of residential subdivisions during the second 10-year period. As previously mentioned in the literature review, subdivision size can affect street layout. Since the number of subdivisions platted as well as their average size decreased during the 2007-2016 period, it is likely that this is due to the 2007-2008 financial crisis. Further research would need to be conducted to confirm this (see *Future Research*).

CHAPTER 4: CONCLUSIONS & RECOMMENDATIONS

CONCLUSION SUMMARY

This chapter first summarizes the conclusions that can be made about each of the three cities' connectivity ordinances based on this study's data analysis. The chapter then presents policy recommendations for future development, and ideas for future related research.

1. Connectivity ordinances can lead to an increase in street connectivity
2. Population density does not equate to intersection density, and vice versa.
3. Connectivity ordinances that become more strict based on proximity to transit can lead to high levels of connectivity. However, some neighborhoods outside the transit buffer zones perform even higher in terms of intersection density, suggesting there is more to consider than just proximity to transit.
4. High density zoning does not appear to lead to high levels of street connectivity by itself

CONNECTIVITY ORDINANCES OF THE THREE STUDY CITIES

It appears that Bend's connectivity ordinances increased intersection density in residential subdivisions after being adopted in 2006. Based on this analysis, the residential subdivisions built between 2007 and 2016 had 0.12 more intersections per acre than the subdivisions built between 1997 and 2006. This change is unlikely the result of mere market forces, since Hillsboro and Beaverton's ordinances remained the same during the study's timeframe, and both of their intersection density levels decreased in the second 10-year period. This finding suggests that Bend's implementation of connectivity ordinances worked to increase street connectivity in residential development.

Hillsboro's strict connectivity ordinances, along with their required connectivity analysis, may have led to slightly higher levels of intersection density in residential subdivisions than Beaverton, who takes a more relaxed approach to connectivity ordinances. In two measures Beaverton achieved slightly higher levels of intersection density than Hillsboro: when street-path intersections were included in the first 10-year period, and path-path intersections were included in the second period. This suggests that

Beaverton's flexible ordinances that encourage accessway paths can produce relatively high levels of connectivity when including street-path and path-path intersections, yet the low street-street intersection density levels from both periods in Beaverton (lower than the other cities saw in either period) may indicate that their ordinances are too lax to produce high levels of street-street intersection density. While path intersections can lead to walkability, vehicular and road-based transit do not benefit from areas with high levels of path-path intersection density in the same way they benefit from areas with high street-street intersection density.

ZONING, POPULATION DENSITY, & INTERSECTION DENSITY

While Beaverton and Hillsboro's developments in the twenty years of the study were significantly more dense in terms of population, the second 10-year period saw Bend's developments achieve a higher level of intersection density while maintaining a much lower population density—Bend has approximately 2,322 people per square mile, Beaverton has 4,795, and Hillsboro has 3,833 (see appendix H). This leads to an important recognition for planners: population and/or housing density does not equate to street connectivity, and more broadly, walkability and transit viability/access. In the same way, high levels of street connectivity do not necessarily equate to population density. Instead, the two can complement each other, with high street connectivity in places of high density working together to benefit the area's economy, transportation network, and so on. Likewise, a densely-populated area without an accompanying connected street network is unlikely to lend itself to multimodal transportation options.

A noteworthy conclusion: Population density does not equal street connectivity, and vice versa.

FUTURE RESEARCH

This study has far-reaching connections between the built environment and the policies that affect it. Accordingly, there are a number of research questions that were prompted by the research in this report. Table 6 summaries the potential opportunities for continued study.

Table 6 | Opportunities for Future Research

Research Question	Potential Method(s)	Potential Data Source(s)
Why did Bend's moderately-strict ordinances work better than Hillsboro's strict ordinances to promote street connectivity?	Interview planners, developers, and various stakeholders from Beaverton, Bend, and Hillsboro to explore why this was the case	This study's dataset; people involved with planning and development in the study cities
How does the presence of urban growth boundaries influence street connectivity?	Using cities from different states with different UGB policies, compare cities with both similar and contrasting street connectivity policies. This could control for both state/regional policy and street connectivity policies themselves.	State, regional, county, and local planning agencies
How did the 2007-2008 financial crisis impact street connectivity in Oregon cities?	In addition to conducting a similar connectivity analysis, researchers could compare economic factors both leading up to and immediately after the financial crisis. These factors could include building applications and sizes and types of developments.	Municipalities' economic development departments; US Census Economic Data; councils of government (COGs)
How likely is it for street stubs to one day connect to the greater street network?	This could take an approach similar to this study; updated street and path data would need to be obtained at some point in the future and analyzed for a given location(s).	State, regional, county, and local planning agencies
What types of businesses exist in these cities? Do the industries present in a given city affect its street connectivity?	Conduct a land-use mix analysis of the cities, alongside a review of relevant literature	US Census Economic Data, COGs
How accurate is intersection density in predicting walkability and bike-ability in these cities?	Measure walkability and bike-ability in the same subdivisions used in this study, comparing those findings with the findings from the study.	This study's dataset; sidewalk and bicycle infrastructure data from city, regional, county, and state agencies

How much does zoning influence street connectivity?	Compare findings from this study against the specific zones—low, medium, and high density, for instance—that development took place.	This could be accomplished using the same dataset used in this study.
How does street connectivity in the cities used in this study compare to cities in other states and countries?	Conduct a similar analysis of cities in other states and/or countries, and compare with these results	Varied, depending on locations chosen, plus this study's dataset

RECOMMENDATIONS & EVALUATIONS

Based on the findings and conclusions presented within this paper, the following are two policy recommendations for cities interesting in adopting connectivity ordinances.

1. ***Cities with high rates of growth should adopt connectivity ordinances aimed at increasing street connectivity in new development.***
2. ***Cities should consider the strengths and weaknesses of adopting policies similar to Hillsboro's connectivity analysis, and should not assume those policies will be effective in all cases.***

These recommendations are based upon the following observations:

- Bend adapted to high levels of growth by adopting connectivity ordinances, and those ordinances seem to have worked to increase street connectivity in new development.
- Hillsboro has had moderate success with their more strict connectivity ordinances, but likely has had to devote more resources to achieve their street connectivity levels than Bend, who had even higher levels during the second 10-year period than Hillsboro.

While it is not possible to say with certainty that these findings can provide concrete ways to encourage higher intersection density in residential development, it is possible to offer a critique of the policies analyzed within this study. Finally, table 7 outlines the connectivity ordinances used by the three cities and their potential strengths, weaknesses, and impacts.

Table 7 | Evaluation of Connectivity Ordinances Analyzed in this Study

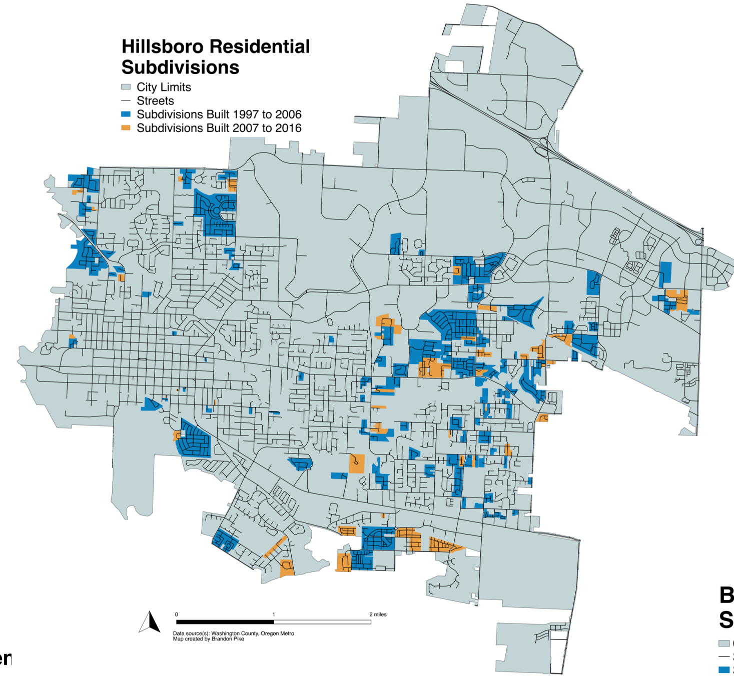
Regulatory Approaches	Strength(s)	Weakness(es)	Impacts
Block Perimeter, Block Length, and Cul-de-Sac Ordinances	Moderately effective with low operating costs for planning agencies; can be relatively flexibility for developers	Effectiveness likely depends on how strict the code is written	Can lead to an increase in street connectivity. See Bend as an example.
Mid-Block Accessways	Allows developers flexibility in design; creates more pedestrian and bicycle connections	Creates fewer roadway-based travel routes	May lead to areas with high internal street connectivity, but low external connections (Song and Knaap, 2004). See Beaverton as an example.
Connectivity Analysis	Comprehensive analysis and potential influence over subdivision connectivity on a case-by-case basis	Resource-intensive for both private and public sectors	Could lead to slight increase in connectivity, but may not be worth the resources required. See Hillsboro as an example.

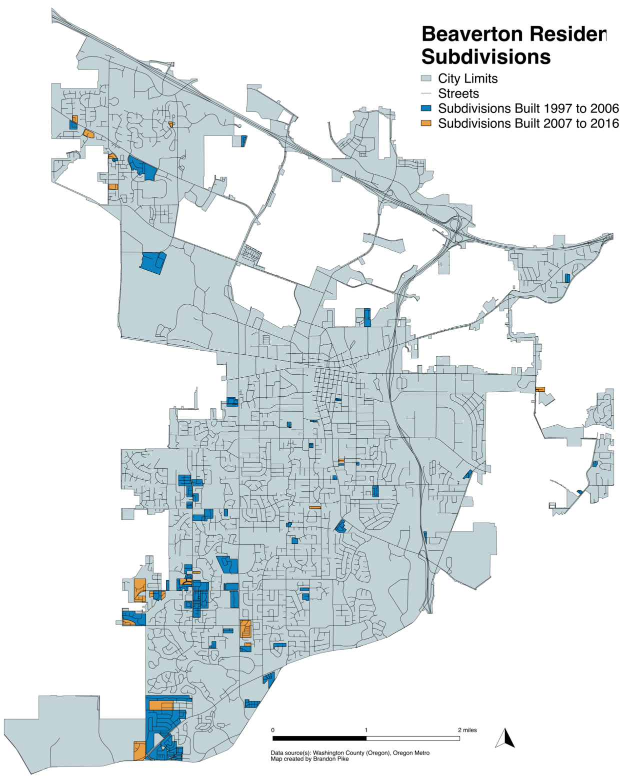
APPENDICES

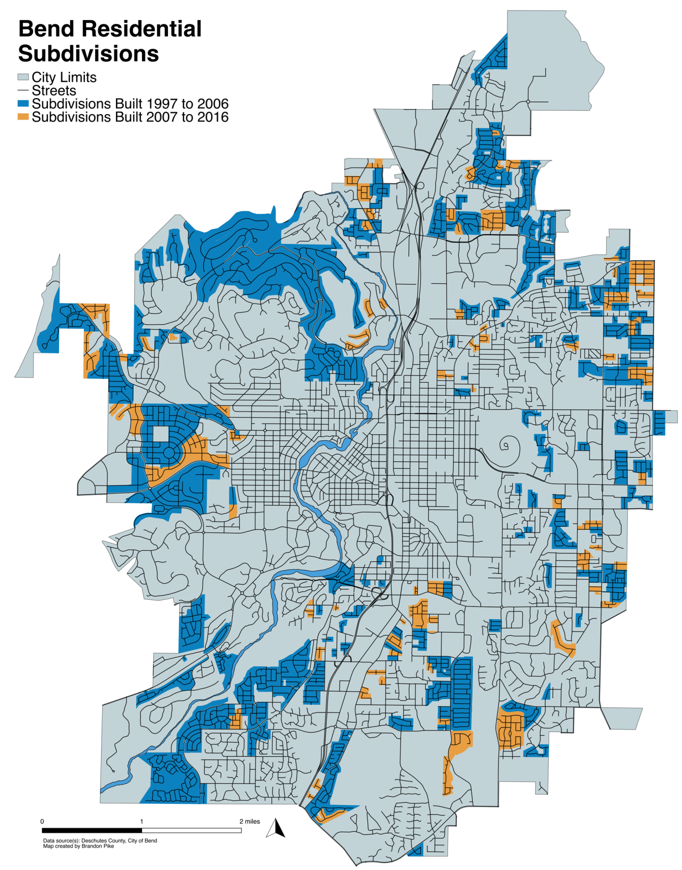
APPENDIX A: DEFINITIONS

- Block Length – “The distance along a street between the centerline of two intersecting through streets from lot line to lot line.” (Bend Development Code Chapter 10-10 1.2, 2006).
- Block Perimeter – “The distance to travel once completely around the block, ending at the starting point as measured from the centerline of the street.” (Bend Development Code Chapter 10-10 1.2, 2006).
- Cul-de-Sac – “[A] short street having one end open to traffic and terminated by a circular vehicle turnaround. Cul-de-sacs shall include partial cul-de-sac bulbs or "eyebrows" designed and developed according to City standards” (Bend Development Code Chapter 10-10 1.2, 2006).
- Circuit – “A finite, closed path starting and ending at a single node” (Tresidder, 2005).
- Dangle node – “The endpoint of a link that has no other connections. A dead-end or cul-de-sac” (Tresidder, 2005).
- Development Code – “Development codes are ordinances implementing a local government’s comprehensive plan. They include two components: a zoning ordinance and a subdivision ordinance, which may be adopted and published as separate documents under their own titles. In some cases the sections pertaining to subdivision of land may be included in the zoning ordinance” (University of Oregon Libraries).
- Link – “A roadway or pathway segment between two nodes. A street between two intersections or from a dead end to an intersection” (Tresidder, 2005).
- Node – “The endpoint of a link, either a real node or a dangle node” (Tresidder, 2005).
- Path-Path Intersection – An intersection between two paths and/or trails that are used by pedestrians and/or cyclist
- Real node – “The endpoint of a link that connects to other links. An intersection” (Tresidder, 2005).
- Street Intersection – Any junction of two streets or roadways, as defined by ORS 801.320 (Legislative Counsel Committee, 2017). Additionally, merging lanes of highways do not meet the definition for this study.
- Street-Path Intersection – An intersection between a street and a path or trail that is used by pedestrians and/or cyclists
- Street-Street Intersection – An intersection between two or more streets
- Street Stub – Usually temporary dead-end streets that do not abut existing development that would inhibit future transportation connections.

APPENDIX B: RESIDENTIAL SUBDIVISIONS







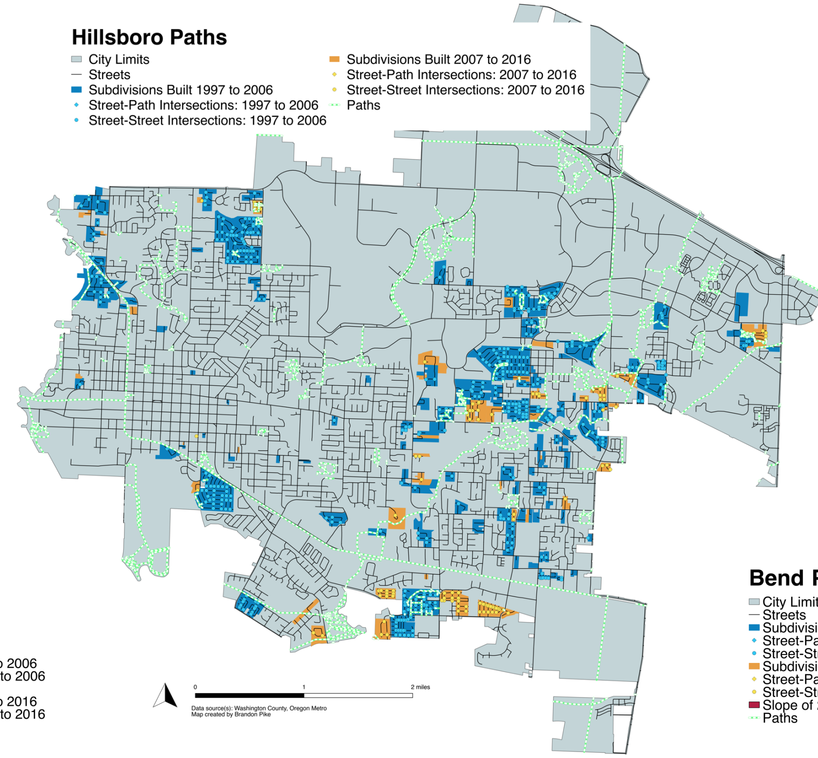
APPENDIX C: CONNECTIVITY ORDINANCE BY CITY

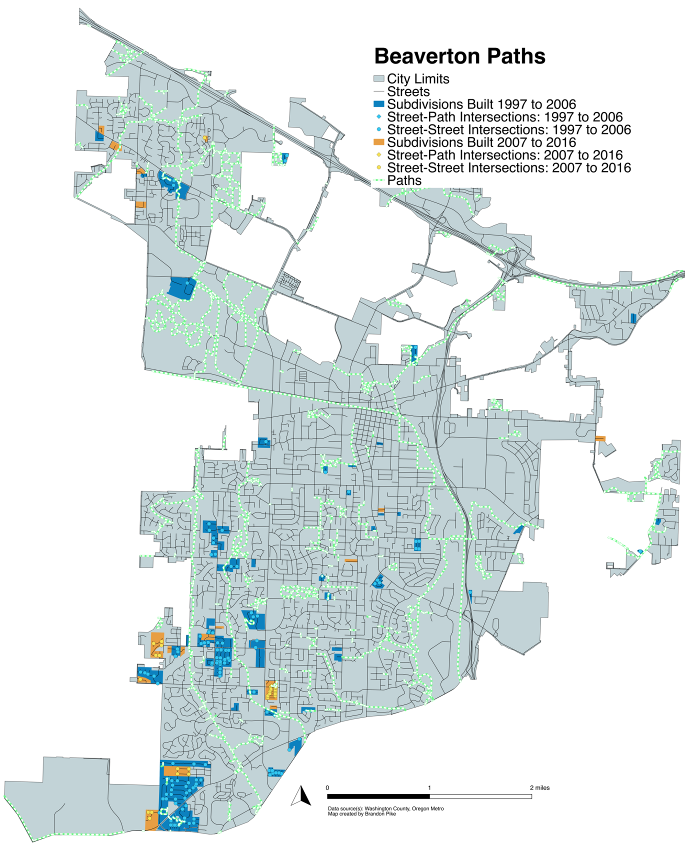
	Beaverton (Adopted Prior to 1997)	*Bend (Adopted 2006)*	*Hillsboro (Adopted Prior to 1997)*
Block Length: Ordinance	"In any block that is longer than 600 feet as measured from the near side right-of-way line of the subject street to the near side right-of-way line of the adjacent street, an accessway shall be required through and near the middle of the block." Beaverton Development Code 60.55.25	"The block lengths […] shall not exceed the following standards as measured from centerline to centerline of through intersecting streets. 660 feet block length […] in all Residential zones." Bend Development Code (2006) 3.1.200 B	"Unless exempted under paragraph 4 below, full street connections spaced not more than 530 feet apart shall be provided in all contiguous vacant and/or underdeveloped sites 5.0 gross acres or larger planned or zoned for residential or mixed-use development." "Within 1/2 mile of existing neighborhood activity centers or transit stops, maximum block lengths shall be 600 feet." Hillsboro Development Code (2007) 12.50.520
Block Length: Exception(s)	" 14. Street and Bicycle and Pedestrian Connection Hindrances. Street, bicycle, and/or pedestrian connections are not required where one or more of the following conditions exist: A. Physical or topographic conditions make a general street, bicycle, or pedestrian connection impracticable. Such conditions include but are not limited to the alignments of existing connecting streets, freeways, railroads, slopes in excess of City standards for maximum slopes, wetlands or other	"An exception may be granted to the maximum block length in conformance with the Class C Variance criteria in Chapter 5.1.400 for Transportation Improvement Requirements. The applicant must demonstrate that the block length cannot be satisfied due to topography, natural features, existing development or other barriers. When a variance is granted, the land division or site plan shall provide blocks divided by one or more walkways or access ways, in conformance with the provisions of Section 3.1.300; Pedestrian Access and Circulation, below. Walkways	"Full street connections are not required where barriers prevent their construction or require different street connection spacing. Such barriers include the following: a. Topography; b. Railroad right-of-way; c. Freeway right-of-way; d. Pre-existing development patterns;

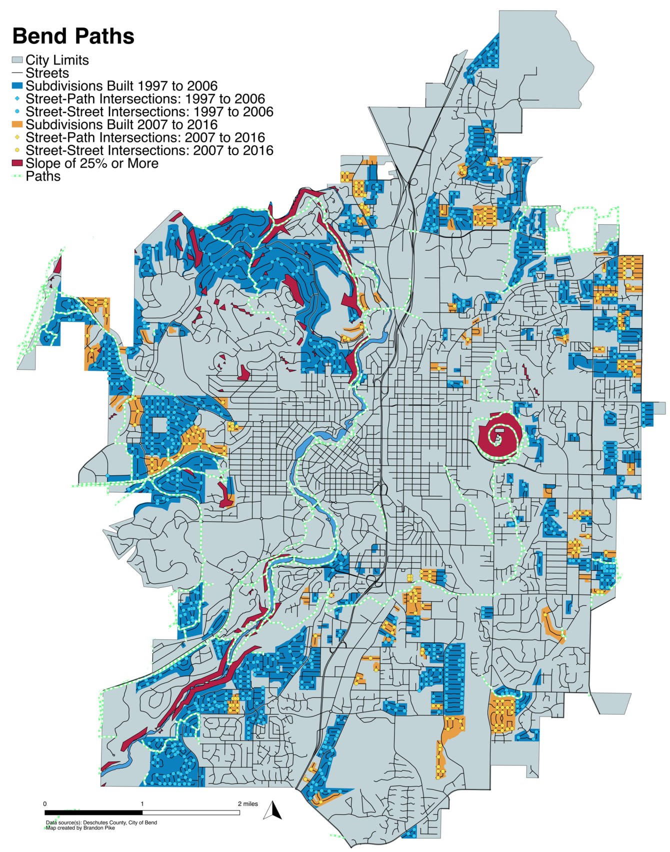
	bodies of water where a connection could not reasonably be provided; B. Existing buildings or other development on adjacent lands physically preclude a connection now and in the future, considering the potential for redevelopment; or, C. Where streets, bicycle, or pedestrian connections would violate provisions of leases, easements, covenants, or restrictions written and recorded as of May 1, 1995, which preclude a required street, bicycle, or pedestrian connection." Beaverton Development Code (2005) 60.55.25.14	shall be located to minimize out-of-direction travel by pedestrians and shall be universally designed to accommodate full access to bicyclists and pedestrians alike, regardless of disability." Bend Development Code (2006) 3.1.200 B	e. Streams, wetlands or waterways regulated under Metro UGM Functional Plan Title 3; and/or f. Significant Natural Resources regulated under Section 12.27.200." Hillsboro Development Code (2007) 12.50.520
Block Perimeter	–	"The block [...] perimeters shall not exceed the following standards as measured from centerline to centerline of through intersecting streets. [...] 2,000 feet block perimeter in all Residential zones." Bend Development Code (2006) 3.1.200 B	Standard Zones: "Except where precluded by the barriers listed in Subsection 4, above, maximum block lengths between local and Collector streets shall be 1000 feet, and the maximum perimeter of blocks formed by local and Collector streets shall be 2750 feet." Light Rail and Mixed-Use Zones: "Maximum block perimeter lengths created by the street and alley pattern shall be 1600 feet." (Ord. 6120 § 1, 2015)

Cul-de-Sacs	"The City may require an accessway to connect from one cul-de-sac to an adjacent cul-de-sac or street." Beaverton Development Code 60.55.25.9.A.	"A cul-de-sac street shall only be used when the applicant demonstrates that environmental or topographical constraints, existing development patterns, or compliance with other standards in this code preclude street extension and through circulation. " Bend Development Code (2006) 3.4.200 N	Only permitted when approved by Review Authority and City Engineer
Connectivity Analysis	–	–	"Connectivity Analysis Required. Land use applications on sites with proposed internal street systems shall include a connectivity analysis describing how the proposed internal street, pedestrian and bicycle network provides safe and convenient access to the following: a. Adjacent residential developments and transit stops; b. Adjacent undeveloped property likely to be developed in the future; and c. Neighborhood activity centers, major transit routes and other transit facilities within one-half mile of the site." Hillsboro Development Code 12.50.520

APPENDIX D: PATHS & TRAILS IN STUDY CITIES







APPENDIX E: RESIDENTIAL ZONES BY CITY, ARRANGED BY SIMILAR HOUSING DENSITY LEVELS

Beaverton		***Bend***		***Hillsboro***	
Zone	**Units /Acre**	**Zone**	**Units /Acre**	**Zone**	**Units /Acre**
—	—	Area Reserve District (UAR)	0.1	—	—
—	—	Suburban Low Density Residential (SR 2 1/2)	0.4	—	—
—	—	Low Density Residential (RL)	1.1 - 4.0	SFR-10 Single Family Residential	3.5 to 4.35
Urban Low Density Single Family (R10)	4.4	—	—	SFR-8.5 Single Family Residential	4.0 to 5.0
Urban Standard Density Single Family (R7)	6.2	Standard Density Residential (RS)	4.0 - 7.3	SFR-7 Single Family Residential	5.0 to 6.25
—	—	—	—	SFR-6 Single Family Residential	6.0 to 7.5
Urban Standard Density Single Family (R5)	8.7	—	—	SFR-4.5 Single Family Residential	8.0 to 10.0
Urban Medium Density Single Family (R4)	10.9	—	—	—	—
—	—	—	—	SCR-OTC Station Community Residential Orenco Townsite Conservation	6.0 to 12.0
—	—	—	—	SCR-LD Station Community Residential Low Density	9.0 to 14.0
—	—	Medium Density Residential (RM and RM-10)	6.0 - 21.7	MFR-1 Multi-Family Residential	11.0 to 16.0
—	—	—	—	SCR-DNC Station Community Residential Downtown Neighborhood Conservation	9.0 to 23.0*
Urban Medium Density Multi-Family (R2)	21.8	—	—	MFR-2 Multi-Family Residential	17.0 to 21.25
—	—	—	—	SCR-MD Station Community Residential – Medium Density	18.0 to 23.0

—	—	—	—	MFR-3 Multi-Family Residential	23.0 to 28.75
—	—	—	—	SCR-HD Station Community Residential – High Density	24 to 30
Urban High Density Multi-Family (R1)	43.6	High Density Residential (RH)	21.7 - 43	—	—

APPENDIX F: NOTES ON LAYOUT OF STUDY CITIES

Beaverton's city limits resemble a tapestry with a few large holes cut out of the upper portion. Neighborhoods and census designated places such as Cedar Hills, West Slope, and Marlene Village have maintained their position technically outside the boundary of the city of Beaverton, though Beaverton surrounds them in all directions (see appendix B). Most of Beaverton's residential development lies to the south of the central business district (CBD).

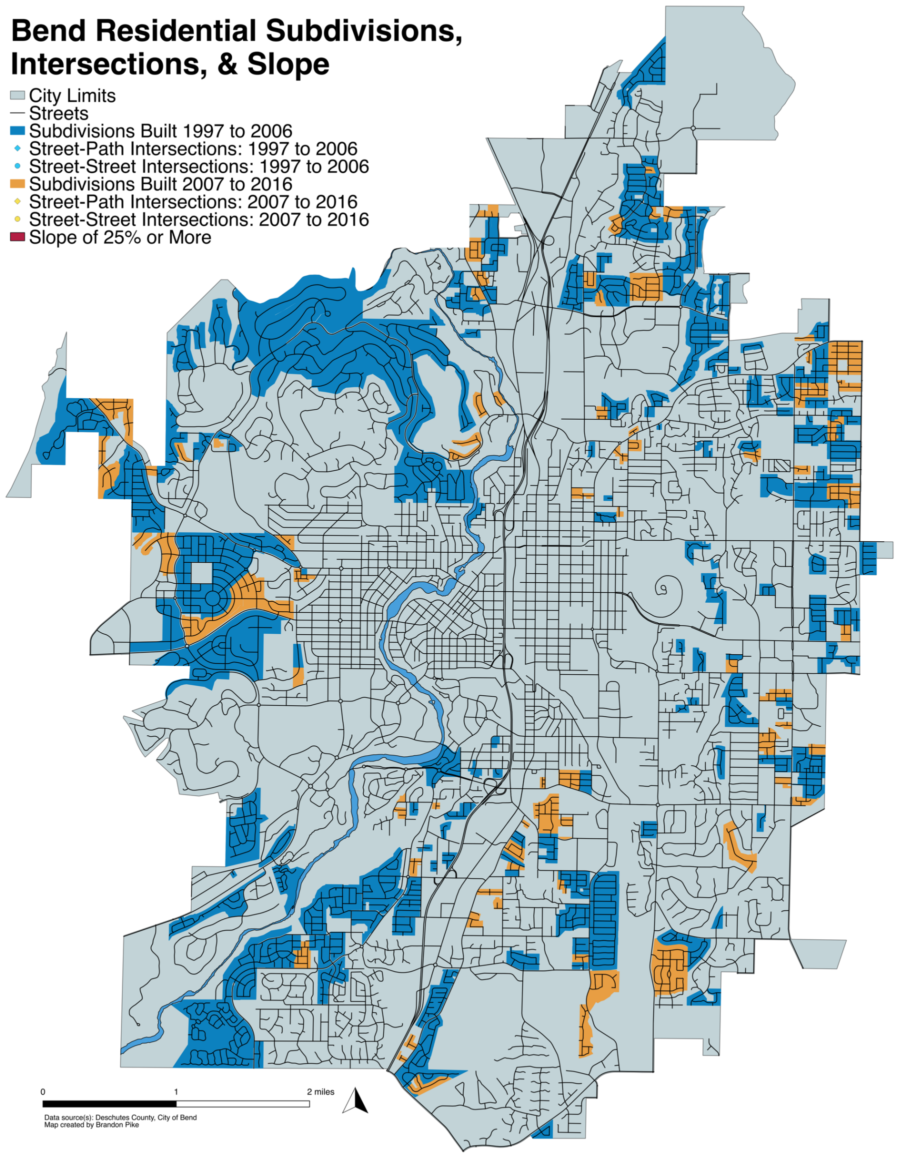
Conversely, Bend and Hillsboro have layouts and city limits that may be considered more traditional. Bend's CBD sits directly in the middle of the city, with the remaining development radiating out in an oval shape. Other than its CBD falling in the western portion of the city, Hillsboro has a layout more similar to Bend than to Beaverton.

These distinctions are worth noting when considering the effect city layout can have on development patterns, and, indirectly, street connectivity.

APPENDIX G: TOPOGRAPHY

Topography is often used as a reason to build winding streets with low connectivity, often with developers and cities citing environmental hazards or degradation as a reason to not build connected streets on hilly terrain. Perhaps a better question that municipalities should ask themselves when it comes to topography and street connectivity policy, is should they allow residential development on hilly terrain at all? If the answer is yes, why not encourage connected street networks? At what point do hills become so steep that they can no longer support connected streets, but can still somehow support suburban development with low street connectivity? To some of the most prominent examples of cities in the western United States with high street connectivity, the answer to that question is almost never. Cities like Seattle and San Francisco, both water-adjacent and built up into hillsides, offer examples of cities that adhered to a strict pattern when first developing. The time period that those cities' cores were developed were in times when active transportation modes such as walking and cable cars were the standard forms of urban transportation. It should be said that, no matter the slope development occurs upon, mitigation of environmental degradation should take place, and building into a hillside poses particular challenges when it comes to things like storm water runoff and maintaining the health of the watershed (Goldshleger, Karnibad, Shoshany, and Asaf, 2012). However, a trade-off can occur when the positive environmental effects of not building into a hillside are outweighed by the negative ones of building automobile-centric cities that consume large amounts of energy.

Bend, while surrounded by buttes and mountains, is actually relatively flat in terms of topography. This map shows all land within the city with a slope of 25 percent or greater. This amounts to just under 7 percent of Bend's total land area, and much of this land is undevelopable—namely in riparian zones and Pilot Butte Neighborhood Park. Beaverton and Hillsboro, similarly, are developed on land that is relatively flat based on examination of topographic data, though slope data was not readily available to conduct the same analysis in those cities.



APPENDIX H: CENSUS DATA FOR STUDY CITIES

	Oregon	Beaverton	Bend	Hillsboro
Land Area (Acres)				
2000	61,437,888.00	10444.79	20492.78	13804.79
2010	61,432,268.81	11987.19	21126.38	15295.99
Population				
2000	3,421,399	76,129	52029	70,186
2010	3,831,074	89,803	76639	91,611
2016 (Estimate)	3,982,267	94,865	84416	100,462
Housing				
Population Density (People/Square Mile)				
2000	35.6	4,664.5	1,624.8	3,253.80
2010	39.9	4,795.1	2,322.0	3,833.30
Housing Density (Units/Square Mile)				
2000	15.1	1,991.3	702.9	1,261.5
2010	17.5	2,109.1	1,094.0	1,484.9
Housing Units				
2000	1,452,709	32,500	22,507	27,211
2010	1,675,562	39,500	36,110	35,487
2016 (Estimate)	1,706,290	40,267	37,406	38,495
Percent Change	14.9%	19.3%	39.8%	29.3%
Vacancy				
2000	8.2%	5.2%	6.4%	7.8%
2010	9.3%	5.8%	12.0%	6.2%
2016 (Estimate)	9.4%	5.1%	8.9%	6.2%
Owner Occupied				
2000	64.30%	47.7%	62.9%	52.3%
2010	62.2%	49.7%	57.9%	54.5%
2016 (Estimate)	61.4%	47.6%	58.9%	55.6%
Renter Occupied				
2000	35.7%	52.3%	37.1%	47.7%
2010	37.8%	50.3%	42.1%	45.5%

2016 (Estimate)	38.6%	52.4%	41.1%	44.4%
Income				
Median Household Income				
2000	$40,916	$47,863	$40,857	$51,737
2010 (Estimate)	$49,260	$54,885	$53,006	$60,695
2016 (Estimate)	$53,270	$59,620	$55,625	$70,180
Percent Change	23.2%	19.7%	26.5%	26.3%
Population for Whom Poverty Status Is Determined				
2016 (Estimate)	15.7%	13.4%	12.4%	12.9%
Transportation				
Means of Transportation to Work (2016 Estimate)				
Drove alone	71.4%	68.3%	75.1%	73.2%
Carpooled	10.3%	11.2%	7.5%	11.3%
Public transportation (*excluding* taxicab)	4.4%	10.0%	0.6%	6.7%
Walked	3.9%	3.4%	3.3%	2.4%
Bicycle	2.4%	1.1%	3.1%	1.6%
Taxicab, motorcycle, or other means	1.1%	0.9%	1.0%	0.9%
Worked at home	6.4%	5.1%	9.4%	3.9%
Means of Transportation to Work (2010 Estimates)				
Drove alone	72.0%	71.3%	78.6%	73.2%
Carpooled	10.8%	9.2%	7.5%	11.1%
Public transportation (*excluding* taxicab)	4.2%	7.9%	0.6%	7.2%
Walked	3.9%	4.3%	2.9%	2.7%
Bicycle	2.1%	1.1%	2.2%	1.3%
Taxicab, motorcycle, or other means	1.0%	1.4%	0.7%	0.8%
Worked at home	6.1%	4.6%	7.5%	3.7%
Means of Transportation to Work (2000)				
Drove alone	73.2%	72.5%	74.6%	73.4%
Carpooled	12.2%	10.6%	12.7%	13.8%

Public transportation (*including* taxicab)	4.2%	8.3%	1.4%	6.5%
Walked	3.6%	3.1%	2.8%	2.2%
Other Means	1.9%	0.6%	2.8%	1.2%
Worked at home	5.0%	4.5%	5.7%	3.0%
Sources: 2012-2016 American Community Survey 5-Year Estimates, US Census 2010 Demographic Profile, US Census 2000 Demographic Profile; US Census 2000 Summary File 1; US Census 2010 Summary File 1; Census 2000 Summary File 3 (SF 3) - Sample Data				

APPENDIX I: POPULATION OF STUDY CITIES OVER TIME

Census	Beaverton	Bend	Hillsboro
1880	-	-	402
1890	-	-	1,246
1900	249	-	980
1910	386	536	2,016
1920	580	5,415	2,468
1930	1,138	8,848	3,039
1940	1,052	10,021	3,747
1950	2,512	11,409	5,142
1960	5,937	11,936	8,232
1970	18,577	13,710	15,365
1980	31,962	17,263	27,664
1990	53,310	20,469	37,598
2000	79,277	52,029	70,187
2010	89,803	76,639	91,611
2016 (Estimate)	97,590	91,122	105,164

APPENDIX J: REFERENCES

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