The Amenity Value of Urban Trees and their Relationship to City Shape

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Abstract

I examine the extent to which the values created by urban amenities shape the city around them, and to what extent their values are a product of their context. In doing so, I argue that a functionalist narrative of amenity value is overly simplistic. Considering the interrelationships between form and function, I offer, is a more useful approach. To support this notion, I focus on Portland, Oregon, and on trees as an urban amenity. In this respect, I investigate the extent to which trees function as an amenity in providing value for the city around them, and conceptualize the urban forest as a system of trees providing value throughout the city.

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1 Introduction

Form follows function. Although the phrase is ascribed to modernist architect Louis Sullivan, it has been used since the beginning of the 20th century by practitioners ranging from artists to neuroscientists to cardiologists. The ubiquity of the adage may be ascribed to the wide relevance of its message—that to a certain extent, the shape of a given system is determined by the operational roles of its working parts.[1] Even as the motto has gained popularity, however, it has garnered criticism. Critics in areas such as economic development point out that form can create purpose, formality, independent value, and can even dictate function of its own accord.[2]

Sullivan used the phrase to describe office buildings, but the notion may well be applied to cities as a whole. In what aspects of cities does form follow function, and where might this maxim break down? For example, cities are frequently zoned, dividing their land area into residential, commercial, or industrial use, based on the needs of each area and the amenities that can be provided to it. Functionalism suggests that city shape should be a product of its useful components—its amenities. To examine the role of functionalism in shaping cities, we may examine the influence its amenities have on the form of the city around them.

To what extent, then, does the value created by urban amenities influence the shape of cities? Approaching this question requires reconciling narratives of the way cities work. To do so, we must take a broader view of *amenities* than might be initially apparent. Beyond schools for education, utilities for consumption, and parks for recreation, amenities may include less-defined and even less-tangible features of a city, such as sidewalks, daylight, and population density. In this way, we can begin by

[1] Sullivan 1896.
[2] Sewell 1966.

considering amenities by a definition close to that of the Oxford English Dictionary: "a desirable or useful feature of a building or place."

Considering the role of amenities in city development, however, requires examining amenities with a somewhat more in-depth perspective than the Oxford English Dictionary provides in a one-sentence definition. To begin with, consider the possible stance that amenities are only valuable so far as they are used. In *The Death and Life of Great American Cities*, Jane Jacobs criticizes modernist urban planners for espousing the virtues of certain amenities, while ignoring the context in which they appear. For example, grocery stores, though they may appear to have intrinsic value as a desirable and useful feature of a place, are only useful if consumers can access them by whatever methods of transportation are prevalent. Parks are only useful if their visitors have reason and opportunity to recreate in them. And bus lines are only useful if they run between places where residents live and where they want to go. Amenities, therefore, are not simply desirable in and of themselves; they rely on human use to have value.[3]

Furthermore, amenities may have different values in different contexts. Sidewalks, for example, can be seen as a tool for public safety, putting a barrier between automobile roadways and pedestrian walkways. Yet in a different light, sidewalks are a point of contact between members of a community and a catalyst for public life and social interaction. This type of interaction may run the gamut from passing exchanges to neighborhood block parties. But because they have different values activated by different contexts, sidewalks can be seen as a composite amenity, whose separate values are activated by the different contexts in which they are useful.

Even if form does follow function, therefore, neither exists in the singular. Amenities' multiple values are activated by the different contexts in which they appear.

[3]Jacobs 1961.

To be valuable and useful features of a place, it is not necessary that they have a constant function, or even a constant form. To illustrate, I turn to a particularly dynamic urban feature, which will be the focused topic of my analysis—trees.

Within the context of the city, it is certainly conceivable to consider trees as an amenity, and to thereby construct the notion of an urban forest—the system of trees providing differential value throughout a city. To begin with the Oxford English Dictionary's definition, trees can certainly be considered desirable or useful features of a place. It remains to us, however, to consider how the urban forest is used, and what contexts activate its values for distinct users. In this way, I consider to what extent the urban forest appropriately functions as an amenity, providing multiple values activated by different contexts. In contributing value, moreover, I consider the extent to which trees may influence the shape of the city around them.

My research centers on Portland, Oregon, which makes a dynamic case study regarding the role of the urban forest due to significant shifts in prevailing attitudes toward trees over the city's history. Portland has a long history of traditional, timber-producing forestry. Early merchants arriving in Portland began by clearing large swaths of forest along the Columbia and Willamette rivers to make room for industrial production and shipping trades, which remained the dominant local industries for many years.[4] However, Portland has experienced an industrial and cultural shift in the last few decades. Portland's economy, no longer based on industrial production and shipping, is now based largely in service industries, such as hospitality and business services. It also has significant real estate and construction markets, largely owing to population growth as a result of interstate immigration (notably, there is still a significant timber industry, supplying lumber to growing industries such as construction). A young city, Portland is frequently referred to as "green" and "en-

[4]Snyder 1970.

vironmentally friendly," cited among the top cities in the world in those categories.[5] Portland's shifting demographic has created a cultural attitude for its residents which emphasizes the value of trees in the abstract, if not for more specific purposes.

To approach the question of to what extent trees' values as amenities have influenced Portland's development, I begin with a discussion of city shape and a review of studies in the functional values of trees. I move from there to analysis of Portland's history through the narratives told by a milestone event and a landmark artifact. I use these narratives as context to examine the present-day distribution of Portland's urban forest through several spatial metrics.

2 Application of Concepts

2.1 The Study of the City

The scholarship surrounding urban morphology is characteristically interdisciplinary. Urban morphologists study the city beginning with its early formation through its ensuing transformations, breaking it down into geographic, linguistic, economic, and many other components. Morphologists also study varying levels of resolution, from individual lots to citywide systems.[6] The breadth of this study is enough that it is frequently necessary to classify it along more specific metrics.

Gauthier and Gilliand (2005) categorize approaches to urban morphology along two continua. Cognitive versus normative approaches attempt to differentiate, respectively, between attempts to explain urban phenomena with descriptive frameworks, and attempts to prescribe methods for future city planning. Internalist versus externalist approaches, on the other hand, attempt to differentiate between frameworks

[5]Business Insider 2013.
[6]Moudon 1997.

which consider urban form as an independently determined system, and those that view it largely as a product of external variables.[7]

Of these two continua, the second is more pertinent to this study. Consideration of the extent to which the functions of amenities influence the shape of the city around them bears directly on internalist versus externalist modalities of urban morphology. This study will be primarily cognitive, as I attempt to describe the relationship between the values produced by urban amenities and how that might bear on city shape. When describing city shape, I begin with matters of the city's layout—for example, the extent of sprawl, the areas of heavy development, and the location of residential versus commercial areas. I continue into less-literal measures of the city's characteristics—characteristics of residents, businesses, policies, and how they are distributed in the city.

To describe characteristics of a city's residents, I borrow the term **population dynamic** from the life sciences. There, it describes the distribution of age and size in an animal population.[8] In an urban context, I use it to describe the demographic makeup of the city, and how that makeup is distributed. For example, the population dynamic of some cities could indicate a growing population of college-educated 20–35 year olds, who are more likely to be located towards the city center, and who work for a proportionally large number of technology firms compared to other demographic categories. More specific measures of the population dynamic would describe where in the city the affluent neighborhoods are, or where immigrants tend to settle.

The population dynamic generalizes the distribution of amenity users in a city. As such, it is important to remember that it does not represent all individuals perfectly, but does describe the systems of how they interact. Just as I do not wish to consider

[7]Gauthier and Gilliand 2005.
[8]Levin 1976.

amenities in a vacuum, separated from the realities of human use, I do not wish to conceptualize the city separately from the context of the its citizens' lives and its business and political institutions' livelihoods. By constructing the city as a composite of these influences, I avoid casting it as a static or uni-dimensional entity, but rather one which operates along multiple aspects.

2.2 Review of Studies in Tree Value

Having established a framework on which to consider urban form, I wish to lay similar groundwork for discussing amenities' function—in particular, the contexts which activate the values of urban trees. Throughout the United States and elsewhere, scholars have undertaken studies in the value which trees create for their urban surroundings, city planners have proposed systems to make better use of their urban forest, and advocacy groups have cropped up to further the cause of using urban trees. Here, I review some instrumental studies in tree value which establish terms to view trees as a functional amenity.

2.2.1 The Property Value of Tree Canopy

Realtors, economists, and scholars of property value have long been interested in the value which trees contribute to private homes. One of the earliest endeavors in this matter was undertaken by Brian R. Payne, who in 1973 published a two-page write-up in *Natural History* entitiled "The Twenty-Nine Tree Home Improvement Plan." In it, he writes

> The amenities provided by trees in residential neighborhoods are sufficiently sought after to make nurserymen a major influence on the metropolitan landscape. Shade, wind reduction, screens for privacy, an environment for wildlife,

climbing areas for children, and natural beauty are the motivations behind the annual purchase of veritable forests by American homeowners.

Payne goes on to discuss an experiment in which a scale model house was appraised with varying quantities of trees "planted" on the model. As the title implies, he achieved the maximum addition of value with twenty-nine trees on a half acre lot, adding $4,300 to the property value. Subsequent experimenters have extended beyond his method, estimating values per tree, as well as spillover effects, whereby trees on one property create an external benefit for nearby properties.[9]

I myself have undertaken an economic and spatial study of the influence of tree canopy on house prices in Portland, Oregon, and found a both substantive and significant relationship between levels of surrounding canopy and property value. This is one of the most concrete and accessible means to assess the value created by trees and their resultant influence on the city around them, but it does miss estimating values which are not directly considered by individual homeowners in the private market. These values are more thoroughly observed in other studies of tree use.

2.2.2 Street Trees and Crime

One such passive value which private homeowners may not directly assess, though they benefit from it, is public safety. A 2001 study in Chicago suggested that areas with more mature trees had lower rates of crime. When areas had more mature trees, the author's argue, parents were more likely to expect their children to be playing outside. This increases residential "eyes on the street," leading to increased public safety and reduced crime rates.[10]

[9] Payne 1973.
[10] Kuo and Sullivan 2001.

A 2012 study in Portland elaborated on this notion, finding that while small, dense trees and other view-obstructing vegetation were positively correlated with crime rates, large trees were inversely correlated with crime. These authors add to the previous hypothesis, declaring that large trees may signal to criminals that an area is well cared-for, and therefore a risky target for illicit activity. It is notable, however, that low-lying vegetation able to produce a screen from view may serve as an aid to criminal activity, and thereby increase crime rates.[11]

This echoes Oscar Newman's sentiment of vegetation contributing to his concept of *defensible space*. Newman espouses the virtues of a feature he terms "Natural Surveillance," whereby the safety of an area is improved by increasing the visibility which residents have over it. The visibility of an area to surrounding residences not only increases residents' ability to surveil an area, it increases occupants' of the area's feeling that they are being surveilled. By attracting the attention of local residents, therefore, urban trees may contribute positively to the natural surveillance of an area.

2.2.3 Stormwater Management

Stormwater runoff can pose a significant cost to large cities, where the majority of surfaces are impermeable to water. Recently, cities have attempted to alleviate the problems of stormwater management with rain gardens: vegetated areas permeable to water. These areas allow stormwater to drain into the ground, while plant roots hold the soil together to prevent erosion. In addition to these benefits, tree canopy also intercepts rainfall over a larger area and channels it to permeable surfaces. Through bioturbation, trees increase the porosity of the soil and its resultant permeability to water. Tree canopy can therefore be seen as an even more efficient solution to

[11] Donovan and Prestemon 2012.

stormwater management than rain gardens, in that it decreases the cost of stormwater runoff.

In Boise, Idaho, the Department of Parks and Recreation has created a Silva Cell program, designed to increase the efficacy of trees in dispersing stormwater. Silva Cells are a steel reinforcement structure like those often used to support sidewalks, but filled with soil, rather than concrete or other substrate not easily penetrable by tree roots and permeable by water. By creating a permeable layer underneath sidewalks, Silva Cells allow tree roots to expand to cover a larger area. This both supports the tree more fully, allowing it to grow to a greater size and maturity, and increases the area in which it can channel stormwater. Boise only began experimenting with Silva Cells in 2015, but is so far enjoying success with their results.[12]

2.2.4 The Dubious Value of Parks

Trees are commonly associated with parks, preserves, playgrounds, and other places where children play and adults recreate. Jane Jacobs cautions, however, that activating this context requires that users have sufficient opportunity and incentive to make use of the urban forest for recreation. Philadelphia's Rittenhouse Square makes for a prominent example of this phenomenon. It is cited by Jacobs as Philadelphia's most successful and well-used park owing to its "diverse rim and diverse neighborhood hinterland." Rittenhouse square forms a mutualistic system with its nearby mixture of commercial, residential, recreational, liturgical, and other surroundings, activating each others' values as amenities.[13]

Jacobs rightly observes that consideration of the value of an amenity requires consideration of the users who are able to extract that value. Jacobs relates these users

[12]City of Boise 2015.
[13]Jacobs 1961.

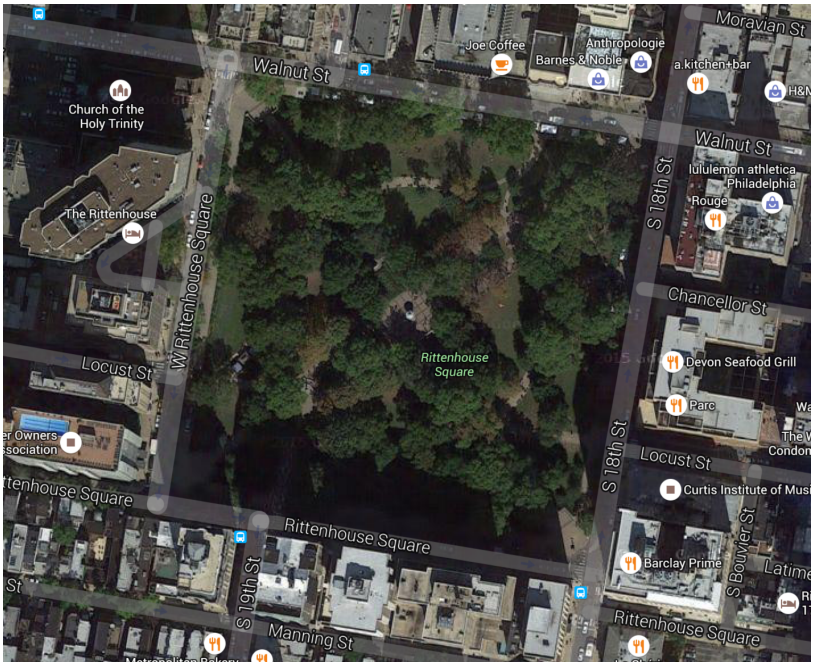

Figure 1: Rittenhouse Square is the lynchpin of a neighborhood system of mixed uses. Satellite imagery from Google.

to the surroundings of parks and what other amenities they interact with through proximity, but also to the local demographic makeup and how it is distributed. This raises a corollary to the functionalist maxim—the shape of the city around parks affects their use values. To an extent, this creates a situation where function follows form. In this view, the urban forest provides opportunities for recreational use based on the fabric of amenities surrounding it.

It is already apparent, then, that the landscape of value which trees create for cities is widely dependent on the context in which they are located and the users who are activating them. The relationship between form and function is clearly up for questioning, largely in terms of its directionality. As we magnify our focus on Portland, Oregon, it is therefore of paramount importance to consider the context of

amenities in which trees appear. The following section offers consideration of several historical narratives in Portland which inform the value of trees in the city.

3 Historical Narratives

The Portland we see today does not very closely resemble Portland in its early years. Today's coffee shops and technology firms are a far cry from the lumber yards and shipping ports that grew Portland into one of the early economic centers of the American West. Nevertheless, trends leading up to the present day emerge in considering Portland's transformation over time. The importance of trees to Portland as a city can be traced back to the founding of the northwest timber industry, but the values expressed toward trees have transformed since then. It becomes clear that trees may take on the values which residents of the city project onto them.

Portland's first amenities were its forests and its rivers. The Stumptown legend goes that early merchants, arriving in the Pacific Northwest, cleared vast areas of Douglas Fir, Western Red Cedar, Sitka Spruce, and Western Hemlock to make room for settlement and start the burgeoning northwest timber industry. They chose the confluence of the Willamette and Columbia rivers as a spot accessible to trade ships, settlers, and migrants traveling the rivers' paths. Equipped with valuable lumber and a port for trading, Portland quickly grew wealthy in these trades.[14]

There is absolutely a certain amount of truth to this tale—photographs and illustrations of early Portland make it obvious where Stumptown got its name. There certainly was a flourishing timber industry, and Portland's accessibility via two major rivers certainly did contribute to the affluence of the city's first major landowners. The whole truth, however, has additional subtlety that does not make it into the

[14]Snyder 1970.

Figure 2: An 1882 illustration from West Shore Magazine shows the young trees growing in the downtown Park Blocks a few years after their planting. Image courtesy of Portland Parks & Recreation.

legend. For example, accounts of the city's early establishment suggest that trees were an important aspect of Portland's development from the very beginning, with some of Portland's oldest trees today planted by wealthy families in the 1870s—about 20 years after Portland's incorporation. Early illustrations, such as the one shown in Figure 2, also indicate the establishment of park blocks, with young trees planted there as early as 1882.

This figure is particularly instructive in considering the values projected by residents onto their arboreal surroundings. In the foreground, we see newly planted trees growing on the park blocks, which were established by Daniel H. Lownsdale in 1848, soon after Portland's founding.[15] The park blocks form the edge of the downtown city at this time, and are faced by elegant and affluent residences. These same tree-facing residences, however, turn their back on the hillside behind them, nearly denuded

[15]Oliver 2002.

of trees. This photograph reflects the values placed by the affluent upon trees as an architectural element of planned space, separately from the seemingly untamed, limitless forests that surrounded it, and could be extracted as a resource.

3.1 The Centennial Exposition of 1905

The theme of Portland's civility and ascendancy from wilderness would once again emerge as it prepared to host its first World's Fair in 1905. At this time, Portland had become established as one of the wealthiest cities in the American West. However, Seattle was quickly approaching it in population, and the business elite of Portland sought a means to draw their city back into the spotlight. The Lewis and Clark Centennial Exposition would provide immense opportunities for local businesses, for tourism, and for city development.[16]

Portland's amenities, at this time, appear to have been a mixed bag. Ray Stannard Baker, an influential journalist, commented in 1903 that "Portland is noted for the solidity of its financial institutions, its fine clubs and hotels, its good schools and libraries." Only two years earlier, however, banker Abbot L. Mills observed in a public speech that Portland "was lagging behind [other cities] in public kindergartens and municipal libraries," that it "was ill-protected by a police force that was totally inadequate," and that it "needed much greater revenue for municipal services." He did also note that the city "was well-lighted" and "well-served by a water system that was one of the healthiest and purest in the nation." The discrepancy between their observations likely indicates the divide between the amenities available to Portland's elite and those available to its lower classes. Mills concluded this same speech observing that Portland's elite had been "riding first class on a steerage ticket"; that is,

[16]Rydell 1983.

Figure 3: The Forestry Building displayed Oregon's forest riches, largely through the manner of its construction. Image courtesy of the Oregon Historical Society.

they had enhanced the quality of their private experiences, while creating few services of public value.[17]

At this time, the City Beautiful movement was becoming increasingly influential in American city planning. The movement emphasized monumentalism and aesthetic grandeur in the hopes that beautiful surroundings would inspire civic virtue in city populaces. The movement was frequently steeped in notions of social class—in these cases, the notion of "civic virtue" roughly translated to "instilling the values of the urban elite in the lower classes." Nonetheless, the movement did make amenities increasingly available to the public. The movement remained popular throughout the beginning of the 20th century, and displayed its influence in the design of the Lewis and Clark Exposition.[18]

[17]MacColl 1976, 221–230.
[18]Bluestone 1988.

One of the Exposition's major attractions used the monumentalism of the City Beautiful movement to display a particular attitude toward trees—that of forestry. The Forestry Building displayed Oregon's wealth in the form of timber resources—the building itself was constructed from a million board feet of lumber, including 52 uncut six-foot-wide trunks, and displayed features of the northwest's sylvan landscape. This treatment of trees imbued them with value in contrast with the treatment of trees planted in the city.

These constrasting values placed on cultivated versus harvested trees displayed elsewhere in the Exposition as well. Figure 4 shows Centennial Park, an open space outside the Forestry Building set aside for fairgoers to lounge and recreate, featuring a number of cultivated trees. Figure 5 shows the same Centennial Park, but from a few hundred feet further back. In this image, we see that just behind the park is a hillside totally cleared of trees.

This treatment of trees displays another feature of the monumentalism of the City Beautiful movement. Parks and open space, such as Centennial Park, beautified the clean and orderly spaces they occupied. The external forests, by contrast, were an untamed and bountiful resource suitable for harvest. By turning these forests into parks, however, the city could symbolically bring them into the societal, tamed sphere, and, in practical terms, open them up to use by its residents. In this case, the relationship between form and function starts to become less dichotomous and more nuanced. It may be most appropriate, in this case, to say that the treatment of trees followed their location, where neither of these aspects are totally in the realm of form or the realm of function.

Figure 4: A photograph of Centennial Park, a recreational area of the Exposition adjacent to the Forestry Building. Image courtesy of the Oregon Historical Society.

Figure 5: Another image of Centennial Park, from further away, and showing the logged hillside adjacent to it.

3.2 The Olmsted Plan

When Dr. Thomas Lamb Eliot, a member of the City Parks Commission, hired the prestigious Olmsted Brothers as the designers of the fair, he brought one of the largest proponents of the City Beautiful movement into Portland. To the Olmsted Brothers, City Beautiful frequently manifested in the form of public open space. Dr. Eliot hoped their design would produce an Exposition fairgrounds which could be converted to a public park upon completion of the exhibition—indeed, their initial plan for the fairgrounds was designed as such. This would parallel the Chicago World Columbian Exposition of 1893, with which chief architect Daniel Burnham hoped to restore the shoreline of Lake Michigan to the people of the city, and was largely successful. Today, the site of the World Columbian Exposition has become Jackson Park, a well-frequented public space home to the Museum of Science and Industry. Extending along the shoreline from there are the Lakefront Trail, the Lake Shore Drive, and Lincoln Park, which features a zoo, a golf course, bird sanctuaries, and museums. In short, the Chicago Exposition paved the way for a host of new amenities available to the city residents, and residential development opportunities which still line the lakeshore. In 1905, less than 2% of Portland's area was covered by parks (compared to 15% in Hartford, Connecticut), and Eliot believed the city could benefit from their addition.[19]

In 1902, much to Dr. Eliot's chagrin, the city leased 406 acres of swampland from private landowners in the Guild's lake region of northwest Portland to serve as the fairgrounds. Leasing the property indicated the city's intention's to return the land to private use following the exposition, banishing Dr. Eliot's hope to give the fairgrounds over to public use after the completion of the exposition. The City Parks

[19]McCarthy 1970.

Commission then attempted to set aside some portion of the grounds for parkland following the exposition, or, failing that, to simultaneously develop parks elsewhere in the city. Preparations for the exposition had generated substantial citywide interest in development and in the City Beautiful movement, and Dr. Eliot hoped to capitalize on this to establish riverfront parks, preserves on the city's hills and crests, and the conversion to recreational use of Ross Island and Swan Island.[20]

Little of Dr. Eliot's vision, however, would immediately come to pass. Upon completion of the exposition, the majority of the attractions were dismantled. The one structure retained by the city was the Forestry Building. The structure continued to stand as a monument to the productivity of the Northwest timber industry, but after several close calls with fire, it burned to the ground in 1964. By this time, the Guild's lake area had already been converted into an industrial park, and is today protected as an "Industrial Sanctuary," zoned to be preserved for industrial purposes.[21]. The area houses mainly manufacturing and distribution firms.[22]

As for Eliot and Olmsted's ambitious plans for parks elsewhere in the city, very few were completed immediately. Ross and Swan Islands represented the largest failures, with Ross Island converted to a gravel mine, and Swan Island to an airport. Within 30 years, however, some developments had been made, including the city's acquisition of Council Crest, and its conversion into a well-used city park. Today, some of Portland's major open-space areas line up with the Olmsted Plan, including Sellwood Waterfront Park, Tryon Creek State Park, and Mt. Tabor Park. It would take years for many of these to be established. Their ultimate execution, however, which was set in motion by the infrastructural developments of the Centennial Exposition, does indicate a

[20]MacColl 1796.
[21]City of Portland 2001
[22]MacColl 1976.

growing relationship between the city's development, public infrastructure, and the use of the urban forest as an amenity.[23]

One of the most successful legacies of the Olmsted plan was what would go on to become Forest Park. Although the plan ambitiously set aside the area northwest of the Centennial fairgrounds to become one of the largest urban forest preserves in the United States, the city was only able to acquire the land in small parcels. The land had previously been divided into donation claims, with individual property owners intending to construct residences on them. Once tracts had been logged, however, the combination of rain and steep slopes made the area unsuitable for development. As a result, many of the tracts were abandoned or defaulted to the city. Others retained their land, however, and it took the city until 1948 to acquire what is now Forest Park.[24]

The tensions surrounding the development of permanent public infrastructure, which stemmed from the Centennial Exposition and continued throughout the 20th century, illustrate the differential values placed on public amenities throughout Portland's development. The disparity between cultivated trees and wild trees demonstrates this, with different values being projected onto the same trees before and after their adoption into a system of city parks. This placement of values would further be extended to individual trees as the city would go on to adopt a Heritage Tree Code.

3.3 The Burrell Elm and the Heritage Tree Code

My second example of Portland's historical relationship with its amenities centers on one tree. Although a single tree does not create enormous tangible value in and of itself, individuals may still ascribe value to a tree, and thus imbue it with additional

[23]ibid.
[24]Houck and Cody, 2000.

context for amenity value. In the case of the Burrell Elm, a tree which we might describe as "standing witness" to much of Portland's development, the tree is often constructed as a *charismatic individual*, and produces value through the historical content it conveys. In this case, it is appropriate to consider the value of an amenity through the stories we tell about it.

The Burrell Elm, as it is known today, was planted by Martin and Rosetta Burrell in approximately 1875. Martin Burrell was the wealthy owner of a company supplying goods first to farmers in the Willamette Valley, and later to farming and mining centers all throughout the northwest. A talented business manager, Martin Burrell soon expanded his business to include financial interests in farming, mining, and banking operations around the northwest. Their large estate sat prominently in what is now downtown Portland.[25]

Rosetta Burrell was a prominent force in shaping the early city, and was somewhat of an early social justice advocate. She fought for public schools throughout Portland and the Oregon Territory; she helped to found the Portland Women's Union, of which she was the first president; and she was an active member of the First Unitarian Church. In 1887, she partly funded and largely founded the Martha Washington Hotel for Self-Supporting Women, a boarding-house which provided educational and occupational training to single women.[26]

In this period, Portland was largely divided into tracts individually owned by private estates. Portlanders will likely recognize names such as John H. Couch, Benjamin Stark, and James Terwilliger—early Portland landowners whose names have been immortalized as prominent streets. As the city grew, however, the large landowners began to sell or rent lots to smaller parties. The growing resource production and

[25]Hedberg 2014.
[26]ibid.

shipping industries put pressure on the city for denser development, and Portland began to take on a recognizably modern form by the end of the nineteenth century. In 1891, the city merged with East Portland and the Town of Albina—present-day North Portland.[27]

When Martin Burrell died in 1885, the first wave of development had only just begun. His son, Walter, was given control of his estate, including his large business. At age 22, however, Walter Burrell lacked his father's talent for managing what had become a business empire, and the business slowly fell apart. The arrival of the Great Depression in the 1930s finished what Walter Burrell's business management skills had started, and he sold his property to move with his wife to Santa Barbara, California, where he lived the remainder of his days.[28]

Over the years, as Portland's population grew, the Burrell estate was slowly dismantled to give way for the dense development that characterized the city's pattern of growth. By 1973, no original structures from the Burrell estate were left. The Elm that Martin and Rosetta planted in the 1870's, however, remained standing. In 1975, the Oregon Historical Society and the Portland Historical Landmarks Commission designated the tree a historic landmark, a designation previously only applied to buildings and built structures.[29]

In 1993, Portland created its Heritage Tree Code, with the Burrell Elm first on the list of Heritage Trees. The Heritage Tree Code recognizes trees that are "of special importance" to the city. This can be for reasons of their age, size, type, or horticultural value, but frequently it is due to their historical significance. In designating this code, the City Council recognized the value of trees as individuals who have, so to speak, witnessed change in the city through their survival. In doing

[27]Scott 1890.
[28]Hedberg 2014.
[29]ibid.

so, we ascribe value to trees which we deem to have experienced stories that we have not experienced ourselves.

The Burrell Elm and the Heritage Tree Code illustrate how humans ascribe value to individual trees in order to commemorate broader processes of city history. The Burrell Estate is taken to represent many aspects of the city's history—the creation of large business interests, the prominence of socially-minded institutions, and the rise of dense city development, to name a few. The Heritage Tree Code personifies the trees which it treats as participants in this process of change. By virtue of its preservation through shifts in the values of city administration, policies now value these trees as witnesses and charismatic individuals.

4 Spatial Method

To what extent has Portland's urban forest played a role in the development of city shape?

Answering this question requires examination of the extent to which the urban forest functions as an amenity in shaping cities, and what contexts activate its value. One significant element of my method is a spatial approach. This relies upon measuring the distribution of Portland's urban canopy, and conjecturing to what extent it is correlated with elements of city shape. By joining these correlations with historical and comparative data, I hope to more fully illustrate the relationship between the distribution of the urban forest and the shape of the city.

To accomplish this, I construct a spatial model of Portland's urban forest using high-resolution lidar data. I then use several spatial analysis techniques to search for patterns in the distribution of the urban forest throughout the city, the object of which is to describe Portland's urban forest through multiple metrics. A discussion of each

of these metrics and its associated descriptive properties follows in the subsequent sections.

4.1 Construction of Data

Initial lidar data for the spatial analysis was acquired from the Oregon Department of Geologic and Mineral Industries (DOGAMI). Data was collected by Quantum Spatial Imaging (QSI) between July and September 2014, and released in 2015. As such, the data is relatively up-to-date at the time of writing, although it does not include the most recent events in the city.

Analysis began with two lidar rasters, which were used to construct an elevation model of the city. Lidar functions by firing a laser from an aerial sensor, and recording the surfaces it encounters as it progresses toward the ground. An individual lidar beam will return several times, as it comes into contact with surfaces which partially arrest the beam, but are also partially permeable. In this way, lidar detects an array of surfaces starting from the highest-elevation surface and progressing down to the first impermeable surface. This is typically the ground, or another impermeable object such as a building.

Constructing a useful terrain model of Portland involved using the first-hit and last-hit lidar returns to flatten the topography underlying the surface features. By subtracting the values of the last-hit raster from the highest-hit raster, I control for the topography of the city and effectively flatten it, yielding a model with values which only vary as a result of the differential height of surface objects. Figure 6 shows a sample of the resulting map.

I originally intended for this process to remove buildings from the elevation model, as they appear to be impermeable surfaces which would be subtracted with the last-

Figure 6: The raster image of Portland resulting from subtracting a terrain elevation lidar raster from a highest-hit lidar raster.

hit raster. Unfortunately, the last-hit raster which I employed did not include built structures, and I was forced to employ other means to distinguish trees from buildings in my analysis.

From this point, identifying the urban forest became a task which I would tackle with multiple approaches. The first, and most simple, was based on the height band in which mature trees were located. Throughout the majority of Portland, the band of objects 35 feet and higher in elevation consisted predominantly of trees. Heights lower than 35 feet were increasingly likely to include buildings, while heights above 35 feet were likely to omit mature trees. Constructing a raster of only objects with an elevation value above 35, therefore, was the first attempt at identifying the urban forest. Heavily developed areas were omitted from this raster, including downtown and several major industrial parks, because of the height of their buildings. The rest

of the raster, however, was largely true to form. The major limitation of this model was not that it accidentally included objects which were not trees, but that it missed less-mature and smaller trees under 35 feet in height.

To attempt a more nuanced model of the urban forest, I constructed an analysis based on tree peaks. Doing so used tools designed for watershed analysis, which test the points to which water would flow from nearby locations—local minima, in terms of elevation. On the base elevation raster of the Portland metropolitan area, tree peaks represented local maxima. Inverting the raster, therefore, produced a set of identifiable points at the low position of its surrounding "basin." By discarding the points along unforested low-elevation areas and re-inverting the raster, I was left with a set of points identifying local peak elevations in the city—largely tree peaks.

The limitation of this method is that it captures other peaked structures which are not trees—namely, certain styles of rooftops. In the absence of an elegant solution to this problem, this fact dramatically reduced the usefulness of this measurement of data. Although I attempted to apply the below tests to this method, all of the results were inconclusive due to interference caused by false tree peaks. The results of this method of investigation are therefore not included. The method of identifying trees is likely redeemable, however and it is for this reason that I include it here.

4.2 Measures of Urban Forest Distribution

4.2.1 Block-Group Analysis

A simple technique to describe the distribution of the urban forest is to divide it into discrete areas. One advantage of this technique is that it can easily be compared to data that are also collected over areas, rather than as points. In this case, I divide the land area of Portland into block groups defined by the American Community Survey

in their 2011 Assessment. The ACS is a division of the U.S. Census Bureau which administers a demographic assessment every five years, and by using their units of division for the city, I facilitate comparison of spatial data from each block group to demographic data collected by the ACS.

Block-group analysis is useful for viewing an area through a set of fixed areas. Because each point occupies only a single group, block-group areas are mutually exclusive and do not share data. Also because of this, however, each point can only be associated with one other set of points, and limits the possibilities for comparison. The wider range of comparisons is possible with Neighborhood Analysis.

4.2.2 Neighborhood Analysis

While dividing land area into discrete sections provides one perspective on distribution, considering a continuous gradient of neighborhoods provides another. Neighborhood analysis uses the ArcMap tool Focal Statistics to generate a "neighborhood" around each pixel in the the raster image of an area, and calculates a value for that pixel based on the mean value of its surrounding neighborhood. In this way, the area is not divided into mutually-exclusive areas, but rather overlapping ones. Doing so allows displaying information for every neighborhood of a given size throughout the city.

Neighborhood analysis helps to visualize trends, as each point is treated as a composite of its surroundings. After several tests, I determined a 10 foot radius around each pixel to be most representative of its surroundings. Figure 7 shows a sample area of Portland, with a color ramp applied to show neighborhoods of higher and lower mean object elevation (once again, terrain elevation is controlled for and not displayed). With the exception of a few tall buildings in the south waterfont area west of Ross Island (which are controlled for or omitted in later tests), all buildings in

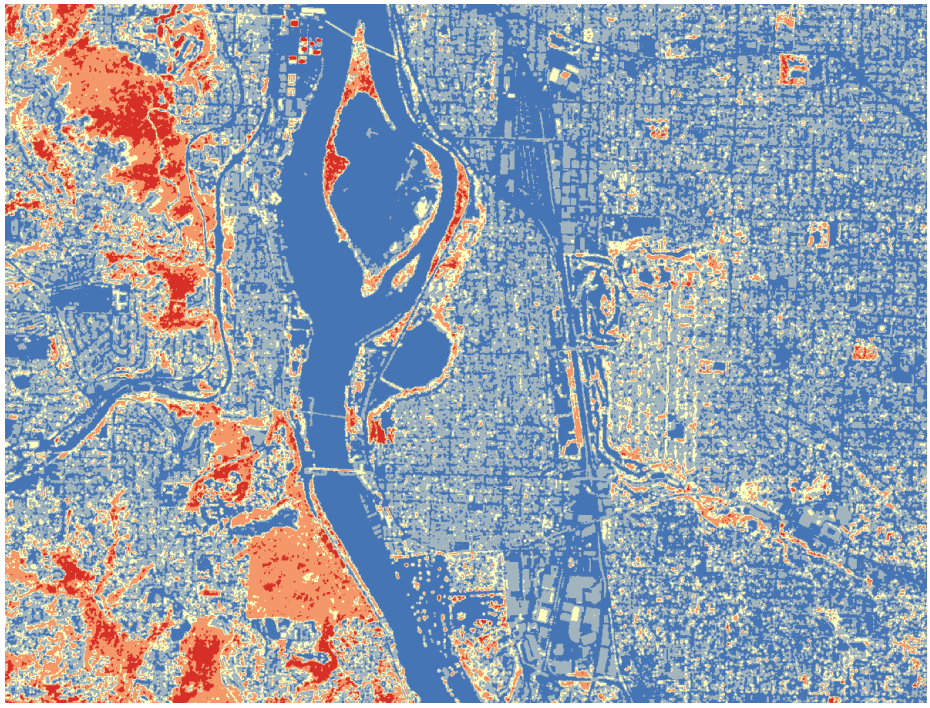

Figure 7: A sample area of Portland, showing trends in mean neighborhood height.

this visualization occupy the lowest nonzero bin of elevation, leaving the upper bins to display mature trees.

Neighborhood analysis is useful for generating as complete a set of comparisons as possible. Because every point is compared to those within a given radius of it, every possible "neighborhood" is considered. This method is limited, however, in that not all comparisons between two points are equally valuable. For example, two points on properties across a highway from one another may be less comparable than two points across a neighborhood street. While block-groups are drawn with consideration of which points make sense to group together, no such logic is applied to neighborhood analysis, which treats all points equally.

4.3 Correlation with Elements of City Shape

4.3.1 Canopy Proportion and Demographic Statistics

Within block groups, it is possible to compare the distribution of the land area of tree canopy to other measurements taken by the American Community Survey, including household income, level of education, race, and neighborhood age. This suggests elements of the relationship between the distribution of the urban forest and the population dynamic of the city. Summary statistics for the listed variables follow in Table 1. Tree Canopy Proportion is the percentage of each block group's land area registering over 35 feet in height. Bachelor's Degree and Proportion White are both the number of residents reporting that characteristic divided by the total residents in each block group, with Bachelor's degree only reporting for residents over 25 years old. Median House Age uses construction dates to estimate the age of the neighborhood overall.

Table 1: Descriptive Statistics for Block-Group Variables

Variable	Observations	Mean	Std. Dev	Min	Max
Tree Canopy Proportion	963	0.185	0.109	0.027	0.758
Median Household Income ($)	963	62,400	26,400	11,600	193,000
Bachelor's Degree	963	0.378	0.198	0.00	0.871
Proportion White	963	0.811	0.136	0.230	1.00
Median House Age	962	46.8	18.8	11	77

All data reported to three significant figures.

With these observations made, I construct a multiple linear regression to relate the latter four variables to the proportion of tree canopy in each block group. For this purpose, I compute the logarithm of Median Household Income, in order to describe the correlation of a percentage, rather than absolute, change of the variable with Tree Canopy Proportion. The results of the regression are shown in Table 2.

Table 2: Regression of Income, Education, and Race on Tree Canopy Proportion

Variable	β
ln(Median Household Income)	0.0477
	(0.0117)
Bachelor's Degree	0.153
	(0.0235)
Proportion White	0.147
	(0.0218)
Median House Age	-0.00129
	(0.000163)
Observations	963
F(3, 957)	76.6
$P > F$	0.00
R^2	0.271

All coefficients statistically significant at a greater than 0.01 confidence level.
All regressions constructed using heteroskedasticity-adjusted standard errors.

This regression shows a significant relationship between all four right-hand-side variables and the proportion of tree canopy in their respective block groups, with all coefficients over four standard errors from zero. The relationships are substantive—for example, a 1 percentage-point increase in the proportion of tree canopy is associated with a 0.107 percentage-point increase in the proportion of residents with a Bachelors' degree. This means that, on average, a block group with 60% of residents bearing a Bachelor's degree would have just over 1% more tree canopy than a block group with 50% of residents bearing the same.

The results for Median House Age are also remarkable. Although the coefficient is not substantively large, it is significantly negative, indicating an inverse relationship between house age and levels of tree canopy. I had expected to see older neighborhoods exhibit more and larger trees, on average, since the age of the trees would roughly correlate with the age of the properties.

This problem would perhaps best be addressed with an individual examination of neighborhoods involved in the study. For example, there may be significant out-

lying neighborhoods where particularly old trees were preserved as a feature of new development. In general, a more granular approach to studying the phenomena of individual neighborhoods would be the most appropriate jumping-off point for further study.

4.3.2 Relative Distribution of Point Data

The continuous data of neighborhood analysis, by contrast, lends itself well to comparison with the distribution of point data throughout the city. In this case, I use the distribution of businesses throughout the city, acquired from the City of Portland based on the address on their business license. The metric of interest is the general level of urban forest in their vicinity, or how proximate they tend to be towards areas of heavy forestation. A method of radius composition analysis is perhaps most appropriate to analyze the distribution of point data with respect to the urban forest.

This method considers the composition of the urban forest within a prospective radius from each point. This is constructed using a buffer of a given radius around each data point, followed by the calculation of zonal summary statistics for each radius. Having determined the levels of urban forest present within each radius, the distribution of points can then be compared to distribution of the urban forest within Portland overall. Comparing the distribution of the means of height composition within the radii to the mean height distribution over the area in which the points are located tests the relationship between the locations of businesses and the surrounding levels of tree canopy. A sample area is shown in Figure 8.

Table 3 summarizes the results of a t-test comparing the mean height distribution of the business radii to to mean height of the overall area in which the points are located. The point data cover only the city of Portland, excluding the larger metropolitan area. Once again, the downtown area of west Portland is omitted due

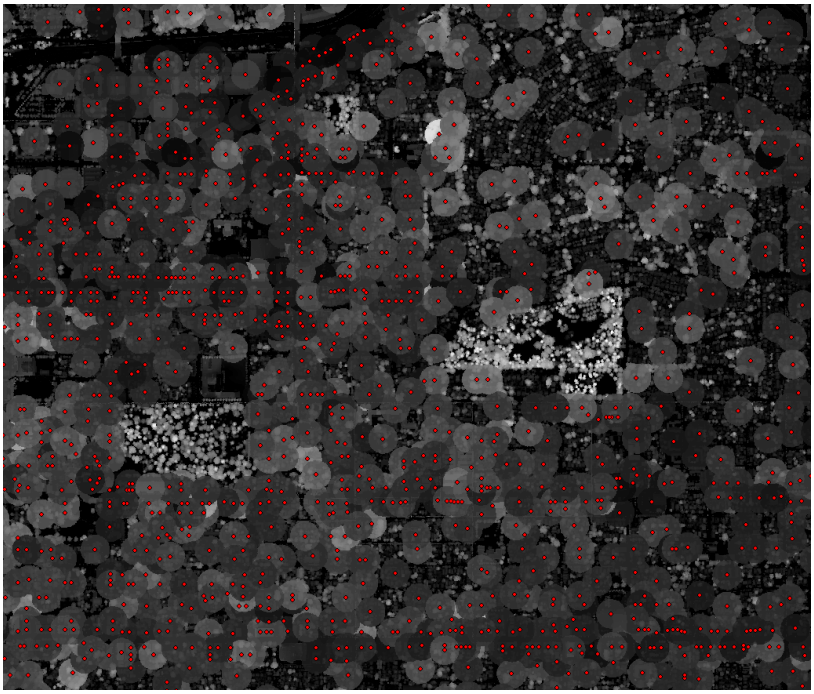

Figure 8: A sample of Portland, showing point data for businesses, the 50 meter buffers surrounding them, and the mean height profile for each.

Table 3: Comparison of Business Radius and Overall Composition

Area	Mean
Overall	25.8
	(35.1)
Radius	16.2
	(0.0809)
Degrees of Freedom	15,861
95% Confidence Interval	16.1
	16.4
P(T < t)	0.00

All data reported to three significant figures.

to concerns over outliers in building height. The test is conducted at a 95% confidence level.

The results are striking. The mean height profile surrounding businesses has a substantively small standard error, suggesting that businesses in the Portland area have similar amounts of tree cover around them. This small standard error also increases the significance of the difference between the business radius height profile and the overall height profile for the area, which is substantively higher. This suggests that there is more tree cover in the areas further from businesses.

There is a certain logic to this analysis—businesses take up space that could otherwise be used by trees. It is also possible, however, that large amounts of tree cover were simply located in areas outside the business radii, and this skewed the results. To test this, I constructed a second t-test for difference in means, this time omitting all of west Portland. This removed Forest Park, the largest area of tree cover likely to skew the results. The results are shown in table 4.

With Forest Park removed as an outlier, the results shift dramatically. Within east Portland, the areas surrounding businesses have significantly higher height profiles, not significantly lower. It is certainly possible that the height of the businesses themselves plays a role in this phenomenon. Anecdotally, however, the majority of

Table 4: Comparison of Business Radius and Overall Composition, Forest Park Omitted

Area	Mean
Overall	14.8
	(21.3)
Radius	16.2
	(0.0809)
Degrees of Freedom	15,861
95% Confidence Interval	16.1
	16.4
P(T < t)	1.00

All data reported to three significant figures.

the height variation in the business radii appears to come from trees. The data appear to suggest that businesses tend to have more tree cover surrounding them than the average of their area overall.

5 Discussion

5.1 Analysis

The history of some of Portland's significant developmental events suggests a multifaceted relationship between the development of forested areas and the shape of the city. This relationship is reflected in the multiple levels of correlation which the spatial data suggest between the distribution of urban forest and the city's shape. There is no single correlation coefficient, however, that concisely expresses the plurality of this set of relationships. To better interpret these plural results, I attempt to extrapolate trends from Portland's history into the results of the spatial analysis, and connect them through the metrics of city shape I set forth in the Application of Concepts section.

Through mechanisms such as the Heritage Tree Code, city authorities place value on individual trees. Doing so turns these trees into the lynchpins of their surroundings—for example, the Burrell Elm has literally affected the form of the buildings surrounding it. Due to its status as a Heritage Tree, the presence of the Burrell Elm has restricted the development of the YWCA building which sits next to it, creating a courtyard-esque space around the tree. An imposing figure of a tree, the Elm also affects the sight lines of surrounding buildings, such as the Portland art museum, and is likely to be an active consideration for any business or development in the local region of the park blocks.

The relationship between form and function which this suggests is twofold. The functional value which Heritage Trees have as individuals is ascribed to them based on their historical context, suggesting that their function is derived from the form surrounding them and the contexts in which they have appeared. However, their monumental status currently restricts and influences development around them, an instance of their functional values influencing the surrounding city's form. It appears, then, that in the case of Heritage Trees, the relationship between form and function goes both ways.

We see this same relationship again in the development of city infrastructure. This relationship has been historically tied up in the city's interaction with its forest, especially in the form of parks and open space. Although the Centennial Exposition failed to immediately achieve the Olmsted brothers' goal of creating public open space, it did spur investment in development, ultimately leading to the creation of public infrastructure, including substantial park development. Forestry constituted one of Portland's major industries at this time (indeed, forestry remains a major industry throughout Oregon), and the combined influence of this industry and the City Beautiful movement created a divide between cultivated trees which were appreciated

for the value they provided to the city, and wild trees, which were appreciated as a resource to be harvested. Here, the form of trees' context dictated the functional value they took on.

It is also telling, however, that some of the city's oldest and largest trees, as well as its largest forested area, lay directly adjacent to the fairgrounds of the Centennial Exposition. This area can still be seen in the neighborhood analysis as one of the major forested areas in Portland today. The Hoyt Arboretum was founded less than 20 years after the Exposition, reflecting a growing public interest in urban trees. Twenty-six years after that, Forest Park was founded in the area that had been adjacent to the fairgrounds. The growing interest in incorporating forest into the city, turning what was previously categorized as wild into parks, reflected a desire to create new recreational spaces where individuals could appreciate the beauty of their arboreal surroundings. In this case, the function which the space was to take on dictated its form.

We can observe similar relationships in the multiple regression of income, education, and race on tree canopy cover, which suggests a significant positive relationship between the proportion of land area of block groups which are covered by tree canopy and the median household income, the proportion of residents 25 and older with a bachelor's degree, and the proportion of residents who are white. This is a strong indicator of the population dynamic of Portland, and suggests that access to trees as an amenity is not independent of demographic characteristics.

These results line up with those found by Landry and Chakraborty in their 2009 study of equity in the distribution of street trees in Tampa, Florida. The authors discuss street trees as a publicly-funded resource, which should, in theory, be equitable in its distribution and in the services it provides. They find significantly less tree cover in areas with higher proportions of African Americans, low-income residents,

and renters. In addition to activating value for users, the distribution of the urban forest may act as an instrument for social bias in the layout of cities. Landry and Chakraborty suggest that, given trees' status as a public resource, this should be actively planned against.[30]

This discrepancy in access to resources also suggests a relationship between form and function. The increased access to trees as a valuable amenity by those with greater means echoes Abbot Mills' admonition in 1901 that Portland's elite were "riding first class on a steerage ticket." In 1901, Mills was referring to the increased quality of amenities such as financial and educational institutions which the wealthy had access to, while the lower classes did not. Today, a similar logic might be applied to trees. If the well-to-do are able to surround themselves with a greater quantity of a valuable amenity, then the function of that amenity is, to an extent, determining the form of its presence in the area.

5.2 Conclusions on City Shape

Considering the relationships which I have shown the urban forest to exhibit with respect to metrics of city shape, it should be clear that within the context of urban Portland, trees do function as an amenity in the manner in which they create value for the city around them. As a composite amenity, moreover, there are multiple distinct related ways in which trees produce value and relate to the form of the city. In some of these cases, the form of their surroundings appears to follow from the functional value of the urban forest. In other cases, trees derive their functional value from the form of their surroundings.

The distribution of trees with respect to demographic data suggests that trees correlate with affluence and societal standing, with trees covering a greater percentage

[30]Landry et. al. 2009.

of the land area in block groups with higher income, more bachelor's degrees, and a greater proportion of white residents. Photographs of Portland's early development and accounts of affluent families show that trees were planted to increase the aesthetic value of the most desirable parts of the city—a trend which has given rise to many of Portland's oldest trees today.

The composite nature of trees' amenity values allows us to discuss how the values of the urban forest are activated by different contexts. The separate settings in which varied stakeholders interact with the urban forest influence what value they extract from it. Trees are additionally unique, to a certain extent, in that their values are a product of the value which humans ascribe to them. Programs such as Portland's Heritage Tree Code exemplify this process, whereby trees are personified as individuals and made to carry the values of the city's heritage. Such charismatic individuals, such as the Burrell Elm, take on unique value in our descriptions of them as standing witness to events which we deem historically relevant. The values which the urban forest takes on are activated not only by their literal setting, but by the human narratives which surround them.

The results of my analysis neither support nor refute the notion that form follows function, but suggest that such a notion is overly simplistic. Neither form nor function exist in the singular, and the relationships between the forms and functions which trees take as an amenity span multiple interpretations of the directionality of the relationship between the two A city's form is not just one thing, and the operational roles of its working parts are not constant across space or across time. To appropriately consider the use of amenities, one must examine the multiple possible roles which amenities take in influencing manifold aspects of urban shape, and how those uses interact.

Within the city, therefore, I propose to augment the notion of functionalism with a more nuanced notion of reciprocity. Rather than attempting to consider, in all cases, whether form appropriately follows function or whether another tabulation of the relationship is more appropriate, I suggest a more liberal analysis of the relationship between form and function, and how they interact. Because form and function influence each other in so many cases, analysis of how they relate may be much more helpful than assuming a one-directional relationship.

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