THE EVOLVING METROPOLIS AFTER THREE DECADES:

A Study of Community, Neighborhood, and Street Form at the Urban Edge

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ABSTRACT

In a highly cited paper, Southworth and Owens (1993) studied eight suburban areas in the San Francisco Bay area at the scales of community, neighborhood, and of street and house lot, and observed their changing morphological characters over time. Using USGS and Google Earth data and census data, a more robust analysis of the same areas was performed to identify changes during the last three decades and to re-test the validity of the authors' original findings.

Findings support and amplify previously observed morphological characters. Taken together, they reveal only minor changes to the overall pre-existing morphological patterns. Community street and land use patterns show minor changes but reveal additional complexity. Community urban patterns show densification through small-scale developments. Neighborhood street patterns reveal previously unidentified differences between and within study areas. New residential developments also reveal previously unidentified types.

Despite only minor morphological changes, significant socio-economic changes are observed in the study areas showing improvements in living standards during the study period. These changes are characterized by an increase in per capita income, density and diversity. Therefore, it is concluded that positive socio-economic changes can occur in suburban areas at city edges, even when these areas resist any significant physical changes.

Keywords: Suburban Morphology; Morphological Change; Street Patterns; Land Use Patterns; Residential Development Types

INTRODUCTION

In a 1993 paper titled "The Evolving Metropolis: Studies of Community, Neighborhood, and Street Form at the Urban Edge" published in the *APA Journa*l, Michael Southworth and Peter Owens (1993) [henceforth, S&O] studied the morphology of eight suburban areas from the counties of Alameda and Contra Costa in the San Francisco Bay area (**Figure 1**). They studied these areas at three different scales - community, neighborhood, and street and house lot - using USGS and US Army topographic surveys from approximately 1895, 1915, 1940, 1960 and 1980, and windshield surveys. The purpose of their study was to identify the organizing principles and spatial typologies, and to observe the changing character, convenience and adaptability of these areas at the evolving metropolitan fringe.

Since its publication in 1993, the impact of S&O on the literature related to suburban developments has been considerable. According to Google Scholar, the study was cited more than 250 times between 1993 and 2017 in scholarly publications, which include books, journals, conference proceedings, and dissertations. A majority of these publications reports studies conducted in the USA, but studies from several other countries in different continents also cite this paper. These countries include, among others, Australia, Canada, China, Ireland, Iran, Iraq, Israel, Korea, and New Zealand. At least 10 publications in the *Journal of Urban Design* cite this study (Ameli, Hamidi, Garfinkel-Castro, & Ewing, 2015; Evans-Cowley, 2008; Hess, 2009; Lee & Stabin-Nesmith, 2001; Rifaat, Tay, & de Barros, 2012; Song & Knaap, 2007; Southworth, 2005; Southworth & Parthasarathy, 1996; Wheeler & Beebe, 2011; Xu, 2017). Another 8 publications in the *Journal of the American Planning Association* (*JAPA*) cite it (Crane, 1996; Forsyth, 2002; Garde, 2008; Krizek, 2003; Southworth, 1997; Weitz & Moore, 1998; Wheeler, 2002, 2015). The other publications citing it are frequently found in *Environment and Behavior*, *Environment and Planning B*, *Health and Place*, *Journal of Environmental psychology*, *Journal of Urbanism*, *Landscape and Urban Planning*, and *Urban Design International*.

The literature, in general, has remained productive on many issues that S&O have found lacking. Examples of these issues include the growth and evolution of various morphological elements and their relationships, and the factors shaping these relationships in areas at the urban edge (Pierre Filion, 2012; Pierre Filion & Hammond, 2003; Scheer, 2001; Southworth & Ben-Joseph, 1997); the similarities and differences between contemporary post-industrial suburbs and their industrial antecedents, and the usefulness and relevance of morphological methods to describe and understand the formal characteristics of suburban environments (Cortes, 2006; Moudon, 1998); the evolution of the form of large suburban commercial centers, examining how such forms compare with traditional development and with each other in terms of street plan morphogenesis, current land subdivisions, and building footprints (Scheer & Petkov, 1998); the changing nature of the public realm and how physical planning can contribute to restoring a more vibrant public realm in the evolving edge of the American metropolis (Southworth & Parthasarathy, 1996); the evaluation of "neotraditional" communities and suburban mixed-use centers in terms of patterns of built form, land use, public open space, street design and circulation, and pedestrian access (Southworth, 1997, 2003), in terms of the frameworks put forth by Kevin Lynch in his books on urban design and city form (Dagenhart, 2008; Ford, 1999; Garde, 2008), and in terms of the level of development, modal split, land-use pattern, inner synergy, and inner movements (Pierre Filion, 2001); and the role of retrofitting existing suburbs to deliver more sustainable environments and lifestyles (Dunham-Jones & Williamson, 2011; Erdely, 2011; P Filion, 2013; Rice, 2010; Vall-Casas, Koschinsky, & Mendoza, 2011).

None of the above publications however presents a comparative morphological study describing, assessing, and/or evaluating changes in the same or similar suburban developments several years after an initial study. This is important because changes in urban morphology are not always continuous. Like most complex systems, it is not always possible to predict how urban morphology would change in future based on what had occurred in the past. Urban morphology is complex not only because it has numerous layers representing a hierarchy of spatial-temporal processes, but it is also influenced by several local-global, internal-external, and dominant-dormant factors. In the absence of a theory that considers the complex interactions of all the variables of morphological change for explanatory and predictive purposes, a follow-up study of a previous study may give us the opportunity to learn if any previous morphological assessments and evaluations of a suburban development still hold true, or if the development has become significantly different from what had been observed previously. A follow-up study may also give us the opportunity to re-describe and re-analyze the morphology of a development revealing previously undisclosed morphological features.

Therefore, the primary purpose of this study is to re-describe and re-analyze the morphology of the same eight suburban areas used by S&O in their study using the most recent land use maps, GIS data, and satellite images of these areas. Based on the reanalysis at the three scales of the previous study, this study hopes to identify and characterize the morphological changes of these areas over the past three to four decades in terms of (1) organizing principles and spatial typologies as defined by street networks, and the land use patterns of these areas at the community scale; (2) the patterns of densification of streets and land use at the community scale; (3) the patterns of streets at the neighborhood scale; (4) the character of individual streets, lots, and buildings; and (5) the quantity of different morphological elements in the study areas.

It is however worth noting here that morphological changes provide only a partial picture of how cities evolve over time. If history is any indication, then one might suggest that urban morphology has always remained somewhat resistant to change even in many extreme cases where cities and/or parts of cities were destroyed by natural and manmade disasters. In these cases, cities were often rebuilt following earlier street and land use patterns. Therefore, urban morphology may be a poor indicator of changes communities may observe. Over time, communities may change considerably in cities that may show little or no noticeable morphological change. Therefore, the secondary purpose of this study is to investigate if communities in the areas studied by S&O have changed during the last thirty to forty years, and if these changes were related to the morphological changes of these areas.

METHODOLOGY

STUDY AREAS AND COMMUNITIES

The eight 3 miles x 3 miles areas selected for this study are the same ones that S&O studied. They are Castro Valley, Concord, Fremont, Dublin, Moraga, San Leandro (or, San Lorenzo), San Ramon, and Richmond from the Alameda and Contra Costa counties (**Figure 1**). S&O selected these areas because they represented different morphological patterns and growth processes of developments at city edges. Richmond grew in the early 20th century; Castro Valley and San Leandro in the mid-20th century; Dublin, Fremont, Moraga, and San Ramon after 1960; and Concord started in the 1890s and grew throughout the 20th century.

Following S&O, different morphological changes in the study areas over the last thirty to forty years are described in the next few sections of the paper. To help explain these morphological changes, first, changes in the communities of these study areas during this period are described using population density per square mile, housing units per square mile, persons per housing unit, the percentage of white population, and estimated per capita income of the cities represented by these areas. The sources for these city data include US Census Bureau, DATAUSA (https://datausa.io/about/) and Bay Area Census (http://www.bayareacensus.ca.gov/cities/).

Note however that the 3 miles x 3 miles study areas of S&O are suitable for comparative morphological studies, but they are not suitable for comparative social studies. That is because these study areas do not overlap with blocks, census tracts, zip codes, cities, or counties that are often used as units of analysis in social studies. While city data may not be exactly describe the communities in the 3 miles x 3 miles study areas, they should be sufficient to give us a sense of the changes these communities might have experienced during the last thirty to forty years.

After adjusting for inflation, per capita income shows a noticeable increase from 1990 to 2015 in Castro Valley, Dublin, and Richmond. In the other five study areas – Concord, Fremont, Moraga, San Leandro and San Ramon – per capita income shows a modest increase (**Figure 2.1**). More specifically, Moraga shows the highest per capita income in 1990 and 2015, as well as almost no change in per capita income during this period. Richmond shows the largest increase from 1990 to 2015. This city had the lowest per capita income in 1990, but now it has the second highest per capita income remaining only behind Moraga. The only city that shows a slight decrease in per capita income is San Leandro. It dropped from $33,565 in 1990 to $30,971 in 2015.

Population density shows an increase from 1990 to 2015 in all the cities (**Figure 2.2**). Dublin, San Leandro and San Ramon show the most noticeable increase, followed by Castro Valley, Concord, Fremont, and Richmond. Moraga shows the least increase in population density from 1696 per square mile in 1990 to 1863 per square mile in 2015. In addition to an increase in population density, all the study areas also show an increase in the number of persons per housing unit (**Figure 2.3**) and the number of housing units per square mile (**Figure 2.4**). Since all the study areas but San Leandro showed an increase in per capita income from 1990 to 2015 (**Figure 2.1**), it may be concluded that an increase in population density did not harm living standards in these areas except San Leandro.

The percentage of white population shows a remarkable drop from 1990 to 2015 in Castro Valley, Concord, Dublin, Fremont, San Leandro and San Ramon (**Figure 2.5**). In Moraga and Richmond, it also dropped quite a bit but not as much as it did in the other areas. In Moraga, the percentage dropped from 89.8% in 1990 to 78.3% in 2015; and, in Richmond, it dropped from 36.2% in 1990 to 16.5% in 2015. It must be noted here that while all the study areas but Richmond had a white majority population in 1990, now in 2015 only Moraga has a white majority population. This remarkable shift may indicate that these areas may be more diverse in 2015 than they were in 1990. It must also be noted that in Richmond even though the percentage of white dropped by more than a half (from 36.2% to 16.5%), income actually rose dramatically – doubling between 1990 and 2015. This suggests that in some suburban communities, the increasing diversity may correspond to greater wealth. This runs counter to prevailing assumptions that diversity usually correlate with economically disadvantaged communities.

In summary, data show significant changes in the communities of the cities representing the study areas. In general, these cities are more dense and diverse in 2015 than they were in 1990. Such an increase in density and diversity might not have affected living standards negatively, because all the study areas but San Leandro also saw an increase in per capita income. The purpose of this study, as described before, is not only to see how the morphology of these areas might have changed over the last thirty to forty years but also to see how the socio-economic changes just described here might have been related to the morphological changes.

SCALES OF MORPHOLOGICAL ANALYSIS

Like the previous study by S&O , this study analyses the eight study areas at the *community*, *neighborhood* and *building and plot* scales, because the problems of design and development at the urban edge exist at all three scales. At the *community* scale, following S&O, this study examines the patterns of streets, land use and densification in areas measuring six thousand acres (3 miles x 3 miles, or 4.83 km x 4.83 km). At the *neighborhood* scale, this study examines the patterns of streets in residential areas measuring approximately two hundred fifty acres (3280 ft. x 3280 ft., or 1 km x 1 km), instead of one hundred acres (2000 ft. x 2000 ft.) of the previous study, selected from the larger 3 miles x 3 miles study areas. S&O selected a residential unit of one hundred acres, because it would take less than ten minutes to walk across 2000 ft. However, this size is often too small for many residential developments at the edge where driving is more common than walking. Therefore, increasing the size of the neighborhood would take into account the fact that a 30-minute walk may be a more reasonable distance to cover than a 10-minute walk in today's suburban neighborhoods, and that street patterns of the residential neighborhoods at urban edges can be more fully described using two hundred fifty acres units instead of one hundred acres units. At the *building and plot* scale, like S&O, this study examines street characters, lot configurations, and building types.

In their study, S&O used hand-drawn maps and sketches to describe the morphological patterns and growth processes of the study areas. This was necessary because the historic US Geological Survey (USGS) maps they had used probably were not available in digital format at the time of their study. In contrast, this study uses the digital drawings created based on the maps produced by the USGS following the National Geospatial Program US Topo Product Standard of 2011 and Google Earth satellite images. Concerning this, it should be noted that the 1980 and 1990 maps used by S&O are represented most accurately by the 1993 Google Earth satellite images for all the study areas. Therefore, the comparative studies presented here are primarily based on the 1993 and 2015 maps and Google Earth satellite images of the study areas.

FINDINGS

A NUMERIC DESCRIPTION OF STUDY AREAS AT COMMUNITY SCALE

To understand how the study areas are different from each other at the community scale, first, they are described using some of the morphological descriptors used by S&O. These descriptors include the total street length, and the total number of street intersections, dead ends, urban blocks, and of access points within the study areas. In their description, S&O used 100-acre neighborhood units. They arbitrarily selected these units from the 3 miles x 3 miles (approx. 6000 acres) study areas and from other nearby urban areas. Since neither the study areas nor the nearby urban areas are uniformly laid out, it can be safely assumed that their 100-acre units do not represent the morphology of these areas adequately. Therefore, instead of the 100-acre units, this study uses the 6000-acre study areas as units of morphological analysis.

While the definitions of street lengths, street intersections, and dead ends are somewhat self-explanatory, the definitions of urban blocks and access points are not. Therefore, in this study, an *urban block* is defined as an island of platted area composed of one or more lots, built or unbuilt, and completely separate from other adjacent areas by streets, open spaces, and/or any other form of natural or artificial edges. The number of *access points* is defined as the number of connections an urban block has with its surrounding streets. In downtown areas like Manhattan, NY, urban blocks would generally have as many access points as the number of surrounding streets plus any curb cuts for motor vehicles to enter a driveway or parking lot inside the block. However, this is rarely the case for residential subdivisions or superblocks in suburbs. In suburbs, a very large residential subdivision containing hundreds of residential units often have no more than one connection to its surrounding streets.

Street lengths, urban blocks, street intersections, access points and dead ends are important for several reasons (Rashid, 2016). ***Total street length*** describes the quantity of streets and, hence, the amount of coverage given by streets in a given area. ***Total number of intersections*** quantifies discontinuities with movement choices. ***Total number of dead ends*** quantifies discontinuities without movement choices. ***Total number of access points*** describes how many options people have to get onto collector streets from the points of trip origin. The parts or subareas of an area may remain isolated from each other if the area has few access points. ***Total number of urban blocks*** describes how any given area is partitioned by streets. As the block number decreases, the block size may increase making the interface between the interior and exterior of a block inefficient.

According to the numbers presented in **Table 1** and the charts presented in **Figure 3**, with the exception of the number of dead ends, the Richmond study area has the most and the Moraga study area has the least length of streets and the least number of urban blocks, intersections, and access points. Despite the fact that both these areas are located at urban edges, differences between these areas are remarkable. The street length of Richmond is almost 3 times the street length of Moraga. The number of urban blocks of Richmond is almost 18 times the number of urban blocks of Moraga. The number of street intersections of Richmond is more than 4 times the number of intersections of Moraga. The number of access points of Richmond is 17.5 times the number of access points of Moraga. Between these two extreme study areas – Richmond and Moraga, the other six study areas are ranked almost consistently, indicating that street lengths, urban blocks, street intersections, and access points may be associated with one another.

As shown in **Table 2**, the amounts of net changes in street length and in the numbers of different morphological elements in the study areas from 1990 to 2015 have been small. That is because almost all the streets were already in place by 1990 in most study areas. Though small in amounts, these morphological changes occurred in different ways in different study areas. For example, Dublin, San Ramon, and San Leandro changed the most in street length. San Leandro and San Ramon also changed the most in the numbers of urban blocks, street intersections, access points and dead ends. In contrast, Castro Valley and Moraga changed the least in street length and in the numbers of different morphological elements from 1990 to 2015.

Urban Design Implications: Urban designers should take note of the fact that different morphological features of streets can affect the usability, livability and sustainability of an urban area by affecting, among other things, street coverage, continuity and discontinuity in traffic flows, and urban block characteristics. In urban areas, these qualities are interdependent – changing any one may change another. Since they do not change easily after a certain stage, there is a need to study their relationships for evidence-based urban design and planning at urban edges.

STREET PATTERNS AT COMMUNITY SCALE

This study uses the typologies of street patterns identified by S&O to describe the study areas. These typologies include *speculative gridiron*, *interrupted parallels*, *incremental infill*, *loops and lollipops*, and some *hybrid* of these types (**Figure 4**). According to this study, the "incremental infill" street grid of Castro Valley (**Figures 5**) remains irregular but continuous at the global scale, and discontinuous with numerous loops and dead ends at the local scale. Only a few local changes in the street grid have occurred between 1990 (as represented by the 1993 Google Map) and 2015. The "hybrid" street grid of Concord

(**Figure 6**) also shows minor changes between 1990 and 2015 with inconsistent street patterns between the major streets – some regular continuous, some regular discontinuous, some irregular continuous, some irregular discontinuous, some defining large blocks, and some defining small blocks. The “loops and lollipops” street grid of Dublin (**Figure 7**), defined primarily by curvilinear streets, loops and dead ends, remains confined between parks and mountains on the east and west sides. Several small-scale changes in the street grid can be observed here, but these changes had very little impact on the old street grid of the study area. The “hybrid” street grid of Fremont (**Figure 8**) and the “loops and lollipops” street grid of Moraga (**Figure 9**) show some minor changes, each at one location only, between 1990 and 2015. With only minor changes at three locations, the “speculative gridiron” street grid of the Richmond area (**Figure 10**) has also remained unchanged between 1990 and 2015. Likewise, with only minor local changes on the periphery, the “interrupted parallels” street grid of San Leandro (**Figure 11**) has not changed noticeably between 1990 and 2015. Finally, the street grid of San Ramon (**Figure 12**) has grown quite a bit on the east of the study area and at two locations on the west of the area between 1990 and 2015, but the old street patterns in the other parts of the study area have remained unchanged.

Urban Design Implications: Based on the above observations, it can be suggested that the street patterns of the study areas had already gained stability by the 1980s. Since then, these patterns have shown no significant change, despite significant differences in topography and street patterns. All changes but one (San Ramon) were local and small in scale, and most often occurred at the periphery of the study areas. About 25 years after S&O, therefore, this study finds no reasons to contradict their suggestion that the street patterns of these developments were focused on self-contained subdivision planning and, as a result, severed connections between neighborhoods. No attempts have been made during this period to re-establish the severed connections between the neighborhoods. These findings have lessons for urban designers and planners. Once laid down, street patterns change very little, even when our technical ability to make landscape changes has grown exponentially. As S&O noted, “streets are more than utility corridors for motor vehicles, but rather are critical urban design elements that help shape the quality of a community’s environment” (Southworth & Owens, 1993, pp. 276-277).

PATTERNS OF DENSIFICATION AT COMMUNITY SCALE

S&O identified three distinct growth patterns at the urban fringe: concentric, instant, and scattered. In place of growth patterns, this study looks at the scales, patterns and types of densification. While urban growth refers to outward expansions of cities from their central urban areas to rural peripheral areas, densification refers to inward expansions that occur by adding new buildings within existing urban areas or by upward expansions that occur by adding more floors and/or space to existing buildings. As a result, densification increases square footage, population, economic activity, walkability and many other qualities supporting urban liveliness. At the same time, it consumes less resource and potentially allows preservation of open space in conjunction with smart growth.

Between 1990 and 2015, as have been noted earlier, changes in street grids were minimal (**Table 2**). In line with this, all densifications in the study areas were limited in scale (**Figures 5 – 12**). In many cases, densification occurred at many locations – Castro Valley, Concord, Dublin, Richmond, San Leandro, and San Ramon (**Figures 5 – 7, 10 – 12**). In the other cases, densification occurred at single locations only – Moraga and Fremont (**Figures 8, 9**). In Castro Valley (**Figure 5**), densification has occurred at four different locations by adding single-family residences (1), apartments and commercial enterprises (2 & 3), and apartments (4). Apartments and commercial enterprises were added near highways, whereas single-family residences were added near the periphery. In Concord (**Figure 6**), densification occurred at three different locations by adding apartments (1, 2, & 3). In Dublin (**Figure 7**), densification occurred at six different locations by adding single-family residences (1 & 3), apartment complexes (2, 4, & 6), and by adding apartment complexes and commercial enterprises (5). In Fremont (**Figure 8**), densification occurred at one location by adding apartment complexes (1). In Moraga (**Figure 9**), densification also occurred at one location by adding apartment complexes (1). In Richmond (**Figure 10**), densification has occurred at two locations by adding apartment complexes (1) and commercial enterprises (3). In this study area, some clearings have occurred at one location to make room for parking (2). In San Leandro (**Figure 11**), densification has occurred at two locations by adding apartment complexes (1 & 2). In San Ramon (**Figure 12**), densification has occurred by adding residential developments on individual lots at two locations (1 & 2) and by adding apartment complexes at one location (3).

Most densifications in the study areas, therefore, have occurred by adding apartment complexes. In a few cases, commercial enterprises and single-family residential developments have occurred as well. These densifications by adding housing units are in line with the fact that the population density and the number of persons per housing unit of all the study areas have increased as well (**Figure 2**). At least two of the study areas now have more than 6000 people per square mile and another three have more than 4,000 people per square mile. To put things in perspective, it should be noted here that Berkeley, San Francisco has 10,752 people per square mile, and Santa Monica, LA has 10,179 people per square mile. Alongside residential units, new commercial enterprises have also been added to these areas. Mostly built as big boxes and strip malls, these commercial enterprises might have contributed less to the street life of these areas. Nevertheless, they have contributed to the density and diversity of functions in some of these areas. This topic is studied more carefully in the "land use patterns at community scale" section below.

Urban Design Implications: According to this study, only some physical densification has occurred in the study areas, even though these areas are not always densely built. This may point to the fact that the morphology of these areas might not have been conducive to physical densification. In most cases, these areas were defined by a loosely laid-out street network serving mostly residential lots that could not be changed easily due to individual land ownership patterns and restrictive zoning regulations. In most cases, necessary public infrastructures and institutions also could not be developed due to morphological limitations to support physical densification. In several cases including Castro Valley, Dublin, Moraga, and San Ramon, growth and densification were also thwarted by hilly, difficult-to-build outlying areas pointing to the fact that not enough thought was given to future growth and changing community needs when these areas were put to use. Despite a lack of physical densification, however, through socio-economic changes reported earlier in the paper, these suburban areas might be inching toward an urban life better than that S&O had found thirty to forty years back.

LAND USE PATTERNS AT COMMUNITY SCALE

The land use patterns of the study areas are described using the same land use categories used by S&O. These categories include residential, commercial (retail and offices), industrial, institutional, and parks and open spaces. S&O identify two types of land use patterns – strip commercial with continuous residential and contained commercial with fragmented residential (**Figure 13**). In general, the land use study in S&O is sketchy, and is only indicative of the actual land use patterns of the study areas. Therefore, this present study enhances the previous land use study using more accurate land use maps (**Figure 14**). These maps were prepared based on the maps collected from individual cities and/or counties within which the study areas are located.

According to the present land use maps, the total area with residential, commercial, industrial, and institutional uses vary between 46% and 93% of the 9 square mile (3 miles x 3 miles) study areas (**Figure 15.1**). Since these study areas have shown morphological stability with no significant developments over the last thirty to forty years, it is clear that stability in developments at city edges was not associated with land use.

Morphological stability was not associated with time either, since land uses did not depend on when these areas started to see suburban developments. For example, Dublin, Fremont, Moraga, and San Ramon – all started to see suburban developments after 1960. Yet, the total percentages of land with different uses are different in these study areas: 79% in Dublin; 93% in Fremont; 46% in Moraga; and 58% in San Ramon (**Figure 15.1**).

At a more granular level, the percentage of land with residential, commercial, industrial, and institutional uses vary significantly in the study areas, indicating that the mixture of land uses may be better in some areas than the other areas (**Figure 15.2**). For example, Moraga has 40% residential use, 2% commercial use and 4% institutional use, indicating that it has become a bedroom community during the last 60 years. A similar, but less prominent, phenomenon can be observed in Castro Valley as well. Yet, Moraga and Castro Valley has very different street patterns.

In contrast, Dublin, which started to see suburban developments around the same time as Moraga, has 40% residential use, 18% commercial use, 3% industrial use, and 18% institutional use. Such a mixture of land uses in Dublin may indicate that this area might have achieved a better balance between work and residential areas during the last 60 years. A similar balance can be observed in Concord, Fremont, Richmond, and San Leandro. Note however that a better balance between work and residential areas do not always ensure adequate public amenities in these areas. In Fremont and Richmond, for example, parks and open spaces use only 7% of the total study area.

According to S&O, Moraga and San Ramon showed a land use pattern composed of contained commercial areas with fragmented residential areas. In contrast, Richmond and San Leandro showed a land use pattern composed of commercial strips with continuous residential areas (**Figure 13**). However, a closer look at the land use patterns of these study areas reveals other significant differences. For example, in Moraga the contained commercial areas cover only 2% of the total area with no significant morphological presence, whereas in San Ramon they cover 18% of the total area with significant morphological presence in the study area (**Figure 14**). Likewise, the commercial strips of Richmond and San Leandro are not similar. In Richmond, these strips take 15% of the total area. They break the surrounding residential areas into several parts, and yet remain easily accessible from these discontinuous parts. In contrast, in San Leandro they take only 9 % of the area. As a result, they leave most of the surrounding residential areas contiguous, but they also remain distant from many parts of the residential areas. **Table 3** includes a description of these and other differences in the land use patterns of the study areas.

Urban Design Implications: Developments at urban edges show different land use patterns. Unlike street patterns that show clear differences between older and newer developments (compare Richmond with Moraga), land use patterns do not show such clear differences. Even though strip vs. contained commercial areas and continuous vs. fragmented residential areas are useful ways to describe the land use patterns in these developments, they do not always reveal the complexity of these patterns. Yet, it should be noted that different land use patterns may affect people's life and the environment differently. For example, a community without commercial, institutional and/or industrial functions may turn into a bedroom community forcing people to drive more for everyday shopping, work, and other services. Fewer and larger retail and institutional functions may not contribute to diversity and liveliness at the neighborhood level. Retail functions when concentrated and self-contained at one location may contribute less to the surrounding areas than those that spread out as strips throughout the community.

RESIDENTIAL STREET PATTERNS AT NEIGHBORHOOD SCALE

S&O identified five different types of street patterns in residential neighborhoods – *gridiron*; *fragmented parallels*; *warped parallels*; *loops and lollipops*; and *lollipops on sticks* – based on their study of residential unit, each measuring 100 acres. Since these units are often too small for today's subdivisions, this study of residential street patterns considers larger residential units, each measuring approximately 250 acres (≈ 0.4 square-miles or 1 square-kilometer), selected from the 6000-acre (≈ 9 square-miles or 25 square-kilometers) study areas. These 250-acre units are categorized into *low-density*, *medium-density*, and *high-density* units, determined visually based on the distribution of streets (**Figures 14-16**). Then, they are described based on whether they have or do not have a mesh formed by streets. These street meshes are described as continuous, broken, or split. The street patterns are further described based on the geometry of streets - straight, warped or both.

Low-density street patterns: Castro Valley, Concord, Dublin, Moraga, and San Ramon have units with low-density residential street patterns, some of which are shown in **Figure 16.** Most of them have streets in the shape of warped lines occasionally forming small to large irregular cells with or without sticks. In one case, the pattern has only warped lines and sticks without cells. None of these units has a street mesh. They are generally found on difficult sites at the periphery of the study areas.

Medium-density street patterns: Castro Valley, Concord, Dublin, Fremont, Moraga, Richmond, and San Ramon have medium-density residential units, some of which are shown in **Figure 17**. Several of these units have a broken irregular mesh of straight and/or warped lines containing irregular cells with or without sticks. At least one unit in the Fremont study area has warped lines with sticks but no mesh.

High-density street patterns: Castro Valley, Concord, Dublin, Fremont, Richmond, San Leandro, and San Ramon have high-density units. Some of these units are shown in **Figure 18**. There are several variations of these street patterns. Some have a high-density regular or irregular mesh of straight and warped lines containing cells with and without sticks. Some have a split regular or irregular mesh of warped and/or straight lines with disjoint parts containing cells with and without sticks in different patterns. Some have a split regular or irregular mesh of warped and/or straight lines containing cells with and without sticks in different patterns.

Urban Design Implications: According to this study, street patterns are significantly different in the residential units of the study areas. Not only are these units different from one study area to another, they are also different within the same study area. The fact that there are low-, medium-, and high-density street patterns in residential units in the study areas should not imply that overtime low-density had become medium-density and medium-density had become high-density neighborhoods by adding new roads and/or residential units. Based on our earlier findings on densification, such transformations did not occur in these areas between 1990 and 2015. Here, it should be noted that high-density street patterns increase infrastructure costs, but they also create high-density neighborhoods. Street patterns with continuous mesh provide more route choices and increase movement. In contrast, street patterns with no mesh or discontinuous mesh provide less route choices and decrease movement. Understanding the potential social effects of street pattern therefore may be important for creating safe and lively neighborhoods.

INDIVIDUAL STREETS, LOTS, AND BUILDINGS

S&O discussed the evolution of individual streets, lots, and buildings from the pre-World War II era to the 1980s. Their discussion was generic, and did not involve the streets, lots, and buildings of the study areas. In contrast, this study looks at the new residential developments in the study areas during the last three decades. These developments are classified using different residential types – single-family residences, residential condominiums built as detached condominiums or as apartment complexes, mobile homes, and mixed-residential developments (**Figures 17-19**). The description of these new developments encompasses (1) the relationships between streets and buildings; (2) provisions for pedestrians; (3) plots size and shape; and (4) the relationships between buildings and their sites.

Single-family residential developments: Several of the new developments in Castro Valley (1), Dublin (1 & 2), Fremont (1), Moraga (1), Richmond (1), and San Ramon (1) contain detached single-family residences (**Figure 19)**. Some show similar plot sizes, while other show dissimilar plot sizes. Some contain small plots, while other contain very big plots, as illustrated by the fact that the range of the number of houses within the same area varies from as few as 9 houses in Moraga (1) to as many as 70 in Richmond (1). Within any one area, the houses tend to have similar shapes. Except Dublin (1) where garages are built separately from houses and are accessed from back streets, most areas with detached single-family residences have garages built with houses.

All single-family houses in each of these developments have front yards. Separating streets from houses, these front yards erode a sense of continuity, community and togetherness along streets. These houses also have backyards, indicating a strong desire for a private outdoor space among homeowners. The backyards along with the footprints of buildings vary from one development to another, often indicating the wealth of the owners of these residences.

Streets in these new developments have sidewalks and trees. However, in some cases loosely laid-out buildings fail to provide a strong sense of street enclosure. In some other cases, the uniformity of building size, shape, and materials has weakened spatial variety and visual interests that pedestrians may find appealing. The fact that every detached residence still are built with a two or three car garage facing the street is probably the most persistent negative feature from the pedestrian viewpoint in these developments.

Detached condominiums and apartment buildings: Two of the new developments in Castro Valley (1) and Concord (1) contain detached condominiums only (**Figure 20**). Though detached condominiums may look exactly like single-family homes, the yards, building exteriors, and streets of the condominiums are jointly owned and jointly maintained by a community association. Lacking property boundaries, these detached condominiums float freely in open spaces and offer no strong street frontage.

Also shown in **Figure 20**, three of the new developments in Dublin (1, 2, & 3) contain apartment buildings only. In one of these new developments, Dublin (1), the apartment complexes have a strong presence on the streets, and include provisions for pedestrians. In another case, Dublin (2), streets and apartment buildings are separated from one another by car shades. In the third case, Dublin (3), the apartment buildings, set in open space, floats freely around a private driveway. These buildings have no association with the surrounding streets.

Mixed residential developments: As shown in **Figure 21**, at least two new developments in Concord (1) and San Leandro (1) contain some combination of single-family houses, detached condominiums, apartment buildings and/or mobile houses. These newly developed areas show stark contrasts among different residential types in terms of building footprints and interfaces between street and buildings.

Urban Design Implications: While it remains self-evident that urban designers should take a stronger role in defining residential areas for a better sense of community and identity (Southworth & Owens, 1993), it is not clear what this role must exactly be. Due to significant socio-technical innovations, residential living is no more defined by one type or another, like the way it used to be in many places in the past. Also due to vast differences in individual wealth, individual needs and demands are vastly different as well. It should be noted here that, despite the observed variations of residential developments in the study areas, closely spaced buildings, sidewalks and trees are found in many cases with detached single-family residences. Yet, a traditional sense of community is not to be found. Maybe, one should not compare these neighborhoods with an image of the past. Instead, one should try to accommodate individual needs in ways that make good social, economic and environmental sense for communities at city edge.

MORPHOLOGICAL CHANGES IN RELATION TO CHANGES IN COMMUNITIES

In an effort to find out how all the morphological changes described in several previous sections might have been related to socio-economic conditions of the study areas, some *exploratory* statistical analyses were conducted using the data that were used for the charts and tables presented earlier in this paper. The term *exploratory* is emphasized here because it is not possible to draw any definite statistical conclusions using the aggregate data of a sample of eight study areas. Yet, one could use such statistical analyses to identify important trends that would require more attention in future.

In 1990, per capita income had very strong positive correlation with white population ($r = .833$; $p = .05$), indicating that at that time increase in white population was associated with increase in per capita income in the study areas. However, no such correlation existed in the study sample in 2015, indicating that by this time population has become diverse enough to eliminate any effects of race on per capita income.

In 1990, population density had very strong negative correlation with persons per housing unit ($r = -.857$; $p = .05$). In contrast, no such correlation was found in 2015. Housing supply and demand, population growth and the cyclical turnover of households may help explain these changes in correlations from 1990 to 2015. In 1990, housing supply might have been more than housing demand. That is because, as was noted by S&O, these areas had seen significant residential developments during the 1970s and 1980s. Given an abundant supply of housing units, it is quite possible that new residents had moved into new housing units keeping the number of persons per unit low with growing population. In contrast, in 2015 housing supply is less than housing demand, because new housing units cannot be added to these areas at a previous rate. Now, with population growth, new residents move into existing housing units increasing the number of persons per housing units. In addition, the cyclical turnover of households may also be used for explaining the observed changes in the correlations between population density and persons per households from 1990 to 2015, because household size may change at different stages of life as young families grow bigger, raise children, and then become empty nesters.

In both 1990 and 2015, population appears to be a good indicator for many urban morphological features related to streets. According to the findings, increase in population shows strong associations with increase in street length ($r = .857$; $p = .01$ in both 1990 and 2015), urban blocks ($r = .810$; $p = .05$ in 1990 and $r = .738$; $p = .05$ in 2015), street intersections ($r = .786$; $p = .05$ in 1990 and $r = .810$; $p = .05$ in 2015); and access points ($r = .857$; $p = .01$ in 1990 and $r = .838$; $p = .01$ in 2015).

The 1990 median house values for the study areas were not available, but they were available for 2015. According to the findings of statistical analyses, an increase in median house values is related to a decrease in street length ($r = -.762$; $p = .05$), urban blocks ($r = -.810$; $p = .05$), and access points ($r = -.755$; $p = .05$), indicating that more expensive houses are probably built in areas with fewer streets, urban blocks, and access points for privacy and separation.

Urban Design Implications: Though exploratory in nature, the findings reported in this section give us some clues regarding the underlying social dynamics shaping morphology at city edges. For the areas studied here, increase in wealth might have been related to increase in white population until 1990. Today, this is no more the case. Since 1990, wealth in these areas has increased despite decreasing white population. In other words, according to this study, despite morphological inertia wealth and diversity have changed significantly in the resident communities of the study areas at city edges.

Along with wealth and diversity, the correlations between population density and persons per housing unit have also changed in the study areas between 1990 and 2015. These changes in correlations might have been due to changes in the relationships between the supply and demand of housing in the study areas. However, the changes in correlations might have also been due to the cyclical turnover of households. Future studies should focus on finding an appropriate explanation for changes in correlations between population density and persons per housing unit, because while changes in housing supply vis-à-vis demand assume morphological changes, changes in the cyclical turnover of households assumes no such changes.

Most importantly, this study finds that population size may be important for the morphology of these areas – as population size increases the quantity of many morphological features also increases; and that privacy and separation through morphology may be important for the relatively expensive houses of these areas.

For urban designers and planners, these findings presented in this section indicate that the design and planning of urban areas at the edge are not created by market forces only. Instead, these areas change slowly as a function of changing social dynamics within a rather static regulatory context and physical patterns.

DISCUSSION AND CONCLUSIONS

This study was undertaken to see if some of the negative trends that S&O had observed regarding developments at urban edges had diminished over time due to human ingenuity and adaptability. Since no significant morphological changes have occurred during the last three decades in the developments at urban edges that S&O studied, one imagines that the negative morphological trends they observed regarding these developments remain as true now as they were thirty or forty years back. The persistence of these trends reaffirms their concerns: “Retrofitting will not be easy, because most suburban developments are inflexible in their design” (Southworth & Owens, 1993, p. 284). Yet, they had hoped that “[changes] in energy supply, air and water quality, regional economies, and family structure and other social dynamics could exert enormous pressure for the physical reshaping of suburbia in the decades ahead” (Southworth & Owens, 1993, p. 284).

There is no doubt that all the changes in energy supply, climate, society, and economy continue to exert enormous pressure on urban and suburban developments. However, they did not have much positive morphological impact on the developments that were studied here. Aided by our lack of imagination and professional inabilities, these developments at urban edges remain somewhat static and unresponsive. Communities, neighborhoods, and individuals remain separated. Disconnected cul-de-sacs and looped and warped streets continue to reinforce the separation. A visible public spatial framework remains absent. The unique qualities of the place continue to be ignored. No substantive public policy framework has yet been developed to ameliorate the conditions at urban edges.

This study and many studies before this one have made it abundantly clear that, once put in place the physical reality of the city is difficult to change even when they do not produce the right results. Architects, urban designers, urban planners, and real estate developers usually get more freedom at urban edges than what they usually get in city centers and in transitional areas between city centers and edges in planning for communities and neighborhoods. That is because the preexisting physical, social and mental realities of city centers and transitional areas between city centers and edges offer enormous resistance to change. So far, they have not used the freedom offered by the absence of resistance at the edge for creating any social good using urban form and structure.

However, it is not fair to fault architects, urban designers, urban planners, real estate developers, and other professionals involved in city design and planning for all the failures at city edges. It is well known that Americans generally love living in suburbs, in private away from downtown hubbubs. As one of the reviewers of this paper correctly pointed out, people might discuss and dream about walkable or sustainable cities, but this does not mean that they will foster the emergence of such spaces in their own immediate environment. If individuals do wish to live, for example in a more urban/dense environment, they would be better advised to move to the city (if they can afford that), than to seek to bring such changes to their existing town/suburban landscape where their neighbors might have no interest in their lifestyle changes.

While individuals may be willing to maintain status quo, it is a fact that, due to radical changes in digital technology, transportation systems and global economy, individual wealth and life styles have changed significantly during the last thirty to forty years. As individuals, we could do very little to resist these changes. If that were so, why did not the suburban landscape at the urban edge change during the last thirty to forty years? An answer to the question cannot be found in urban morphology alone. "[A] urban morphological analysis is not sufficient to explain why certain forms developed or spread during a given period," as Scheer and Petkov (1998, p. 298) have aptly noted.

Concerning the above, it is interesting to note is that, despite a rather static urban morphology of the study areas, communities in these study areas were not static during the last thirty to forty years. Behind a relatively fixed scene of street and land use patterns of these areas, the racial composition and the wealth of the population had changed rather significantly; and so did population density, housing density, and persons per housing unit. These are related factors, as this study showed. As late as 1990, white people dominated these areas by size and wealth, and housing supply exceeded housing demand. In 2015, communities are racially diverse, and white people are the minority population in all but one area. Despite this significant shift in race, per capita income has increased in all but one area suggesting a promising fact that a redistribution of wealth has occurred. Along with this, population density, housing density and persons per house have also increased from 1990 to 2015 suggesting yet another promising fact that these areas are becoming not only diverse but also dense.

Despite inflexibility, therefore, this study provides some evidence for the fact that the morphology at city edges may not be totally disconnected from its communities. Here, both population and median house values seem to have strong associations with morphological features, but in different ways. As the population of these areas has increased, the quantity of many morphological features has increased as well to accommodate diversity and density. In contrast, as the median house value of these areas has increased, the quantity of many morphological features has decreased to accommodate an increased demand for privacy and separation. Through such complex trade-offs, many short-lived spatial practices of communities have found unique ways to accommodate themselves within the long-lived morphological and institutional frameworks of these suburban areas at city edges during the last thirty to forty years. To put simply, in spite of the concerns raised by S&O regarding the inflexible morphology of suburban developments at city edges, socio-economic changes can help improve urban environments at city edges.

In conclusion, two significant limitations of the study presented here must be identified. Again, these limitations were identified by a reviewer of the paper. While these are important limitations, it is difficult to overcome these limitations given the morphological focus and scope of the paper. The first limitation is related to the fact that the racial and ethnic data used in this study only trace changes in white population in the study areas. While other ethnic/racial groups are as important, it was not possible to use granular racial and ethnic data for a morphological study like this one, where the purpose was to identify a general social trend only. To make a proper use of granular racial and ethnic data in a morphological study, it is necessary to identify the spatial distribution of the data. This would have been a herculean task to accomplish in a study of eight communities, each measuring nine square miles. Yet, it must be acknowledged that the intersection of class and race/ethnicity is of fundamental importance for urban form and structure. While census or other data can never capture the full complexity of a diverse population, it is paramount, especially in a diverse state like California, to look at such demographics in more depth and detail. Looking at some of the general tendencies, it comes as no surprise that Richmond with over a third African Americans has the lowest housing prices, the highest density, and the most apartment complexes added. In a society that is rigidly divided by lines of class and race/ethnicity and where residential areas are marked by these lines, future studies on urban/neighborhood changes must take these lines into account.

The second limitation is related to the fact that the study did not cover larger political, economic, social, and geographic (locational) forces that often play a decisive role in shaping real estate dynamics in suburban areas at city edges. To paraphrase the reviewer, in any real estate developments developers want to make money, politicians want to maintain their electoral control, and wealthy residents want poor people away and out of their neighborhoods. These are powerful forces, and they often make and remake (or prevent the remaking of) existing residential areas. Therefore, it should come as no surprise that the wealthy residents of Moraga would want their neighborhood to remain exclusive and disconnected. They would not want commercial areas or anything that causes density, or would even bring outsiders to the community. (Just consider the outcry that often happens when a bus line should go through a quarter that might bring poorer people there, or the almost stereotypical outcry when an ALDI supermarket is announced anywhere other than in a low-income quarter). Wealthy people (like those in Moraga) do not want apartment complexes nearby as it brings another class of people, and they have the means and power to keep their neighborhood exclusive. One wonders, then, if and to what extent the forces of selfish class privilege that keep neighborhoods the same and largely closed to outsiders can thwart and/or influence what planners or scholars would like to do for creating good and sustainable urban form and structure in suburban areas at city edges. One also wonders if and to what extent a great geographical distance from city centers exacerbates such selfish forces in suburban areas at city edges. Future studies on the morphological characters of suburban areas at city edges would do well to recognize the importance of any such larger political, economic, social, and geographic forces in shaping urban characters.

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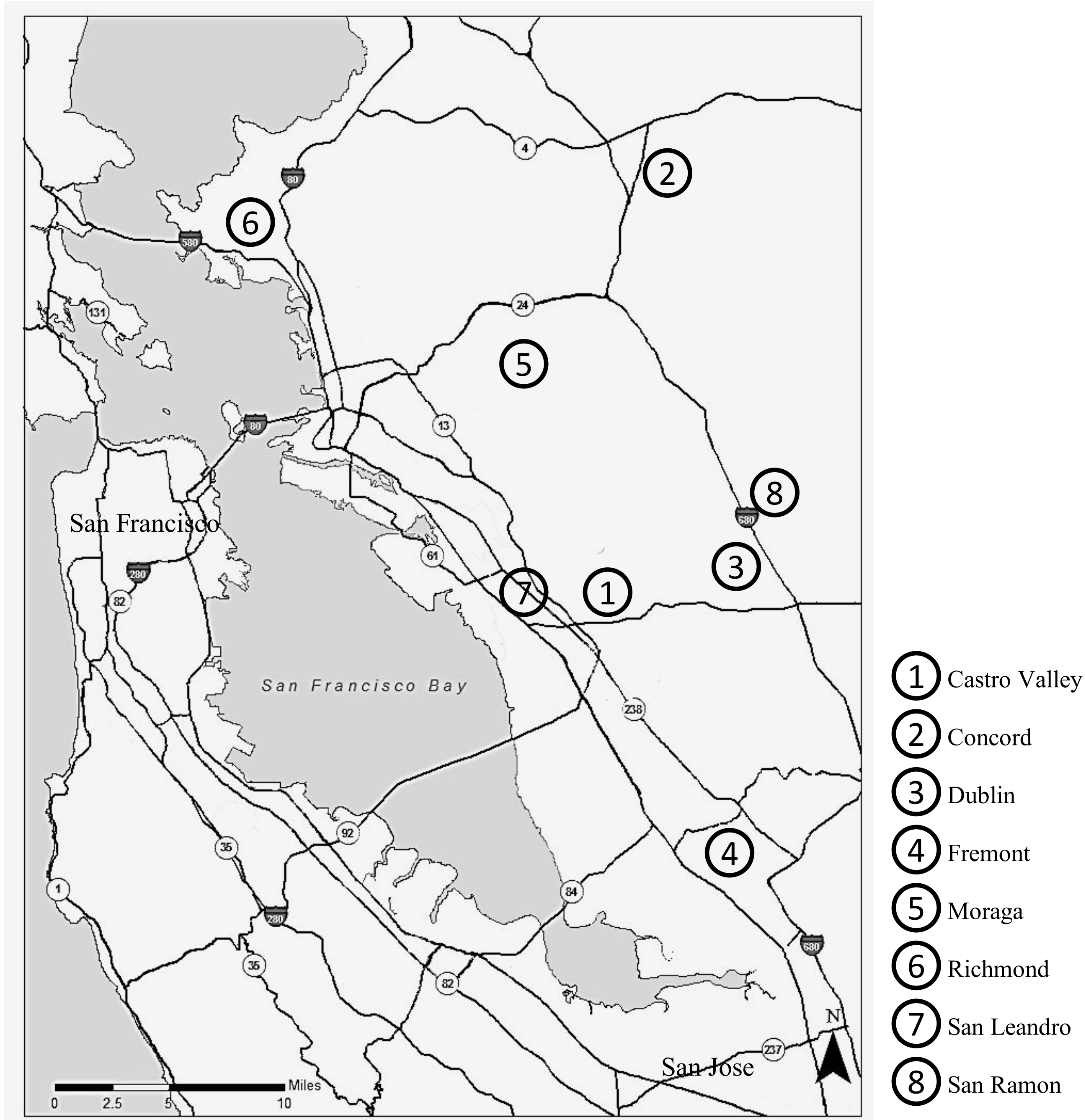
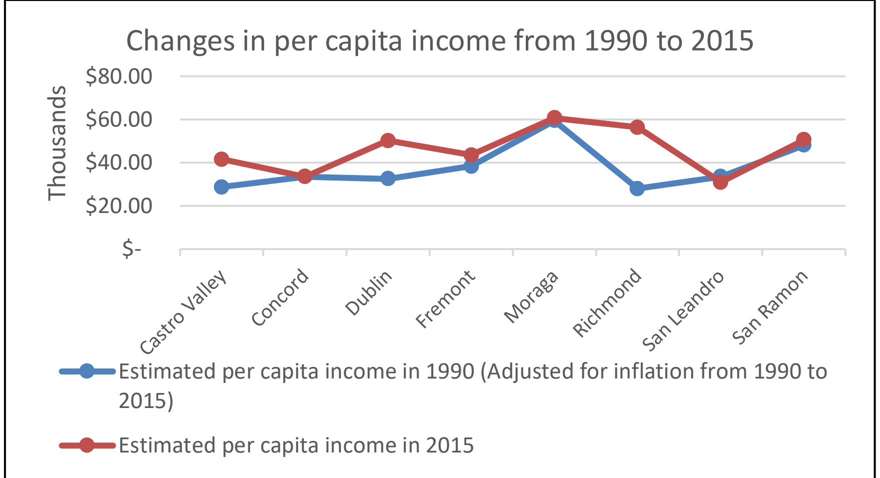


Figure 1: The eight study areas, San Francisco Bay Area. Source: Author



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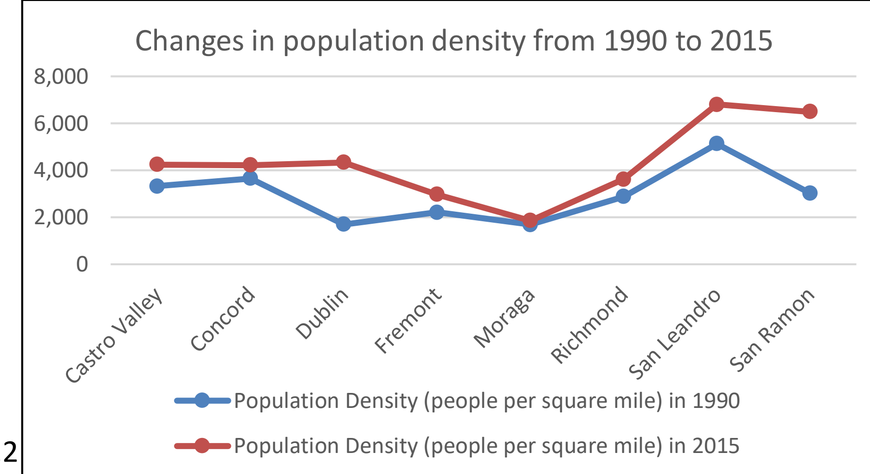

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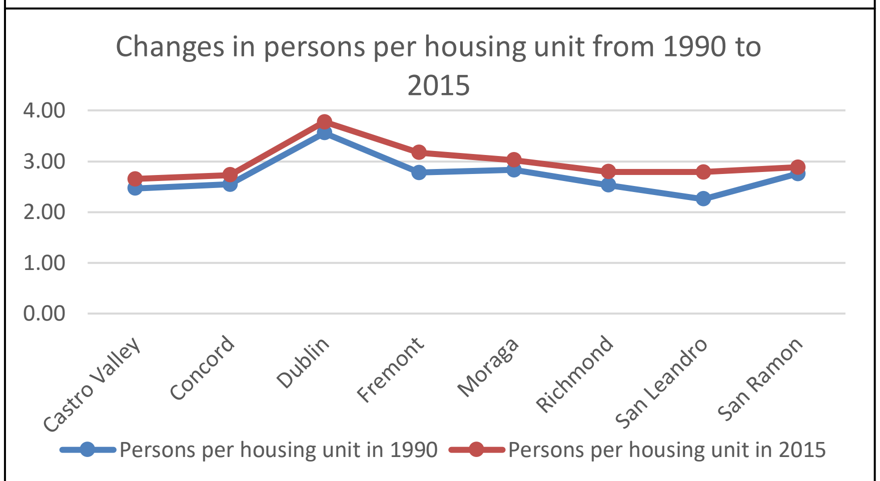

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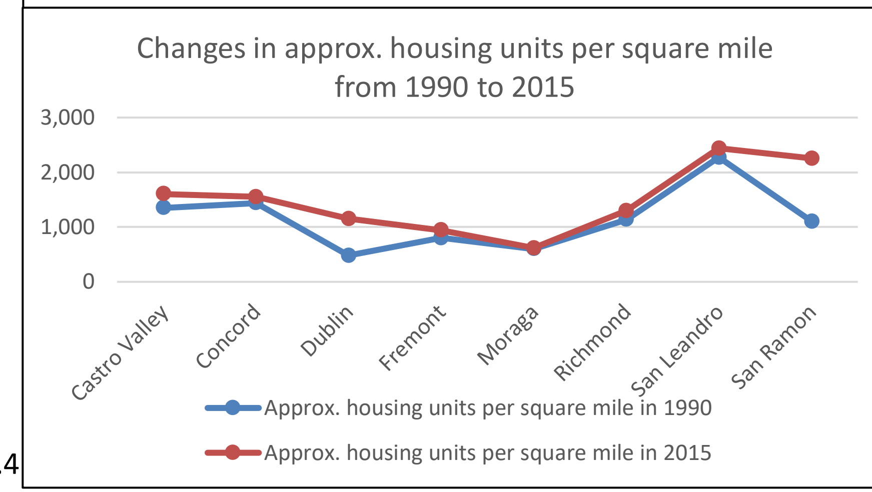

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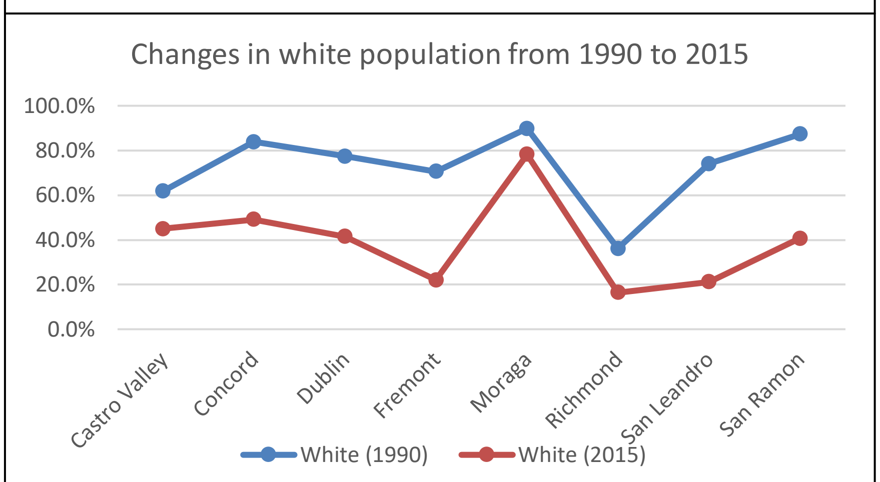

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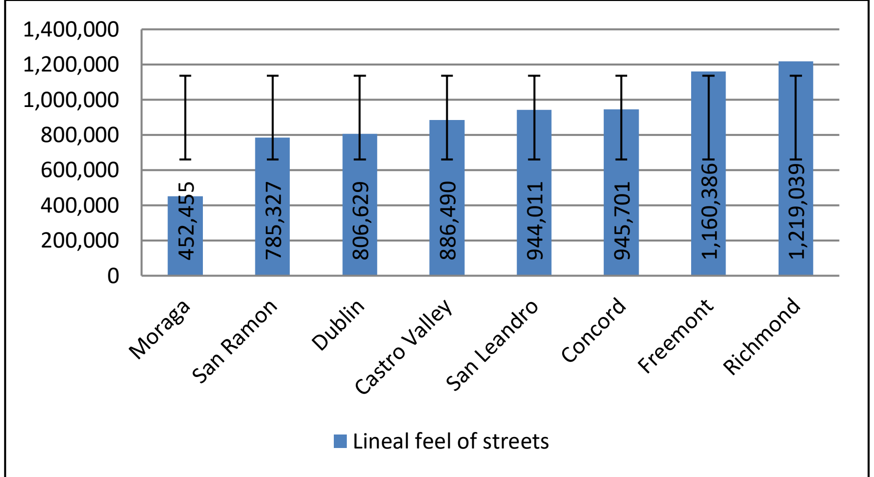
Figure 2: Charts showing changes in different socio-economic indicators of the study areas from 1990 to 2015.

4.1



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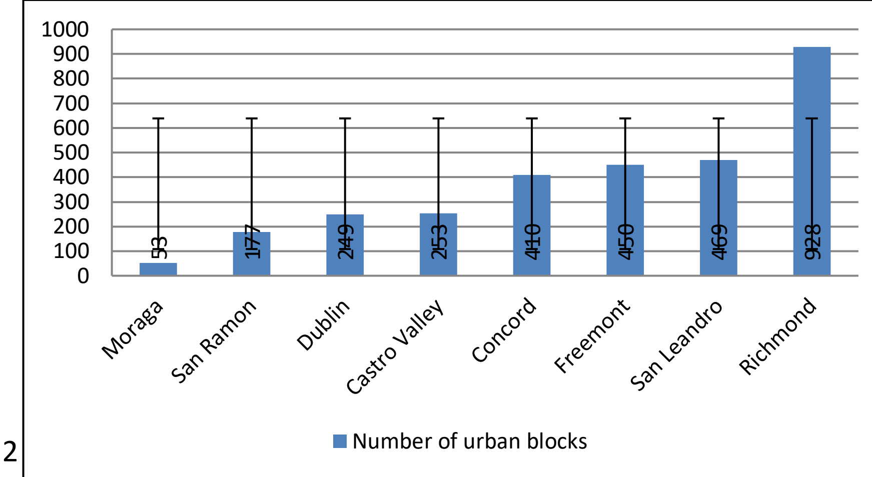

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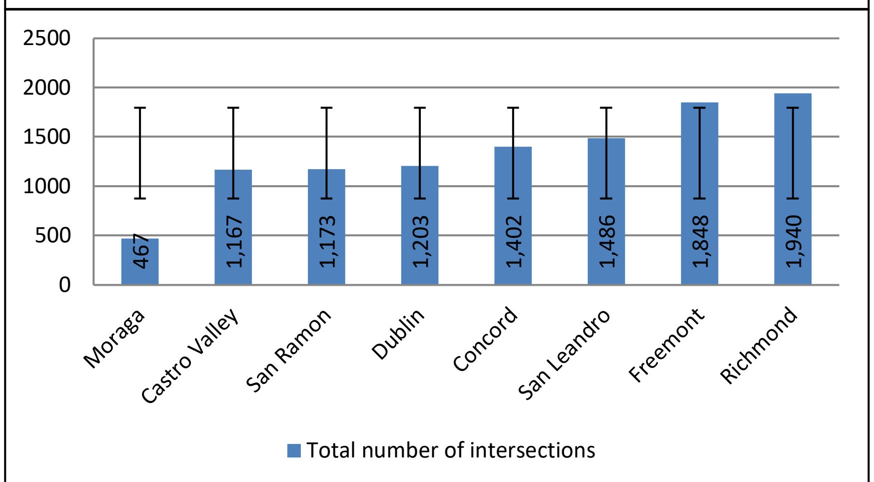

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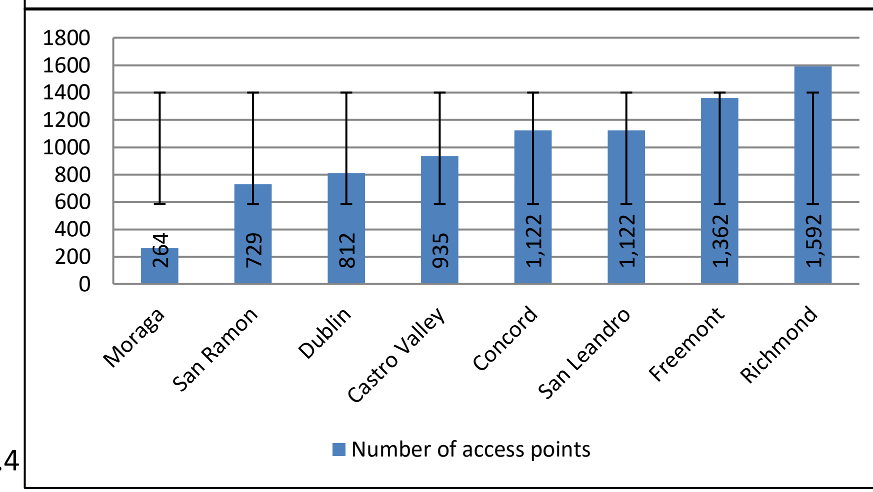

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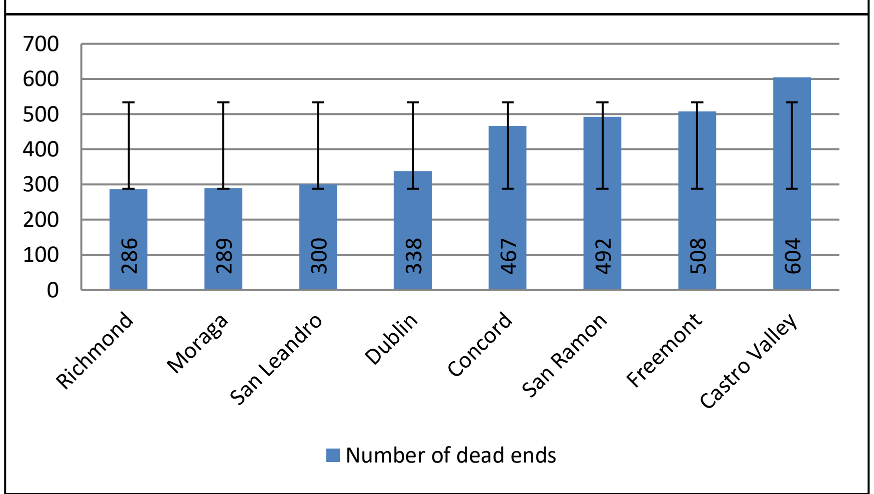


Figure 3: Charts showing a comparative analysis of the study areas in 2015 by different morphological elements.

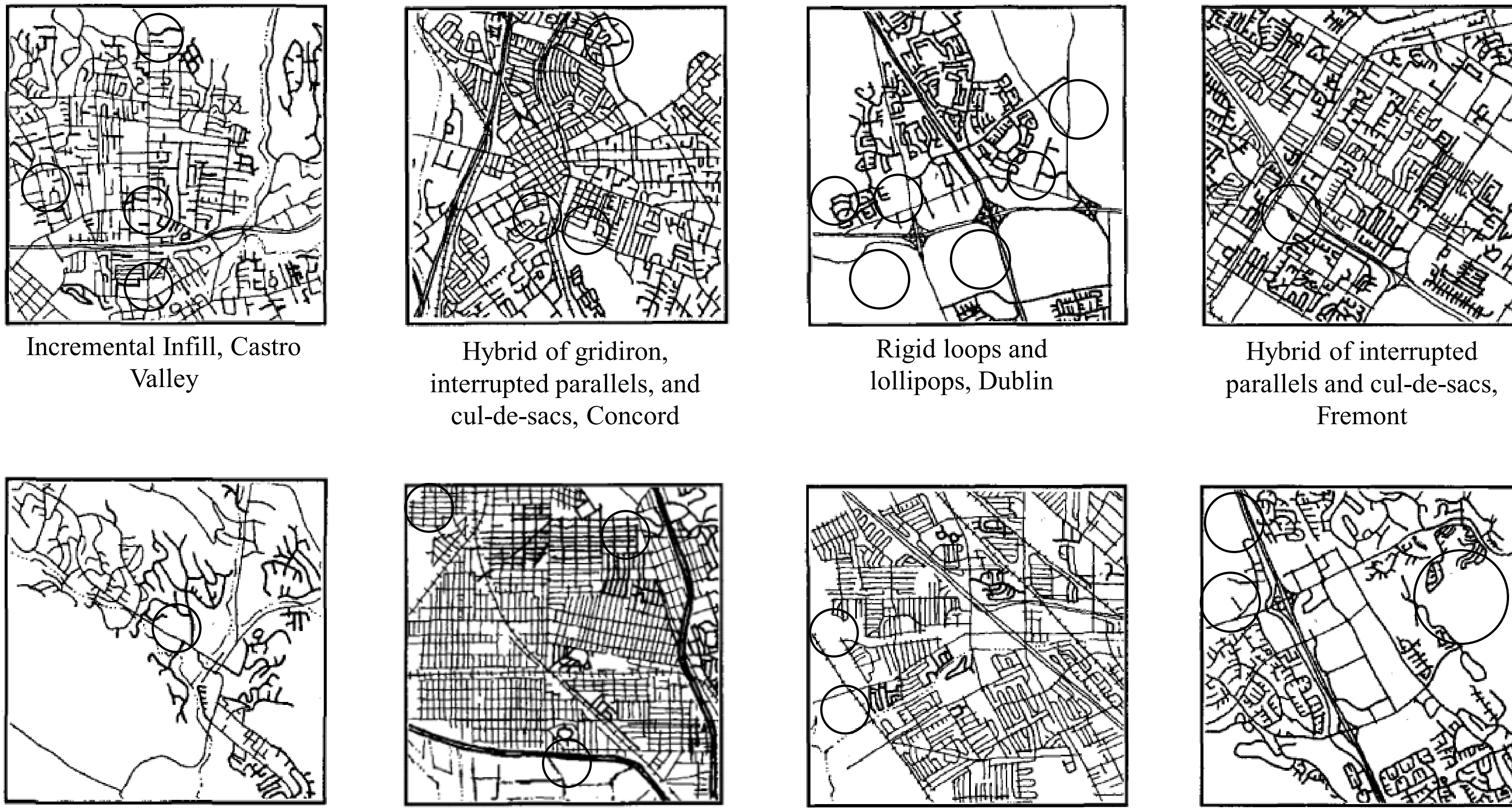


Figure 4: Street patterns in study areas in 1980s and 1990s. The locations of new developments are indicated by circles. [Source: Southworth and Owens (1993); reprinted by permission of the publisher (Taylor & Francis Ltd, http://www.tandfonline.com)]

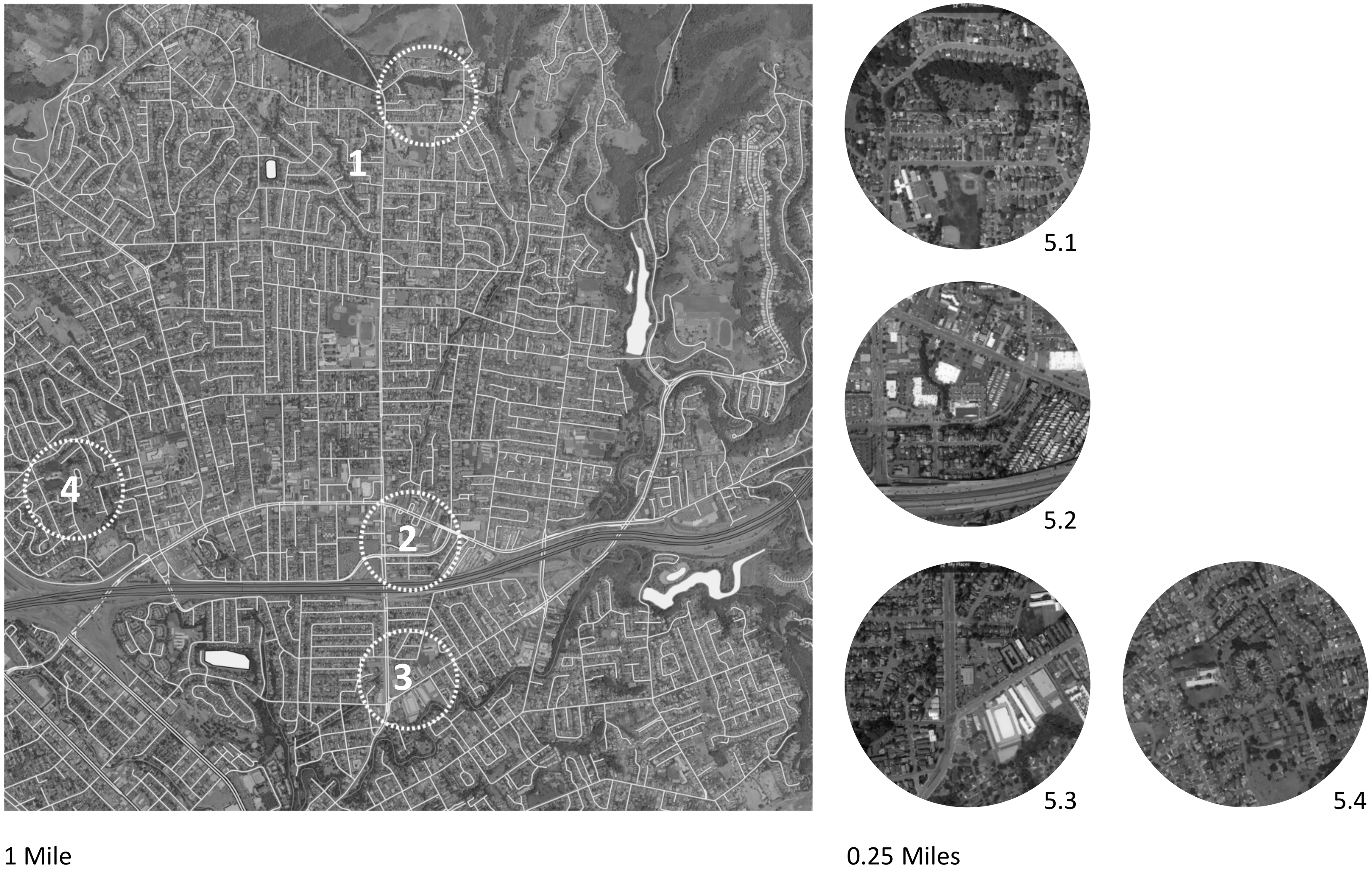


Figure 5: Castro Valley, 2015. Developments between 1990 and 2015 are shown in circles. Source: Author. Drawn based on Google Maps

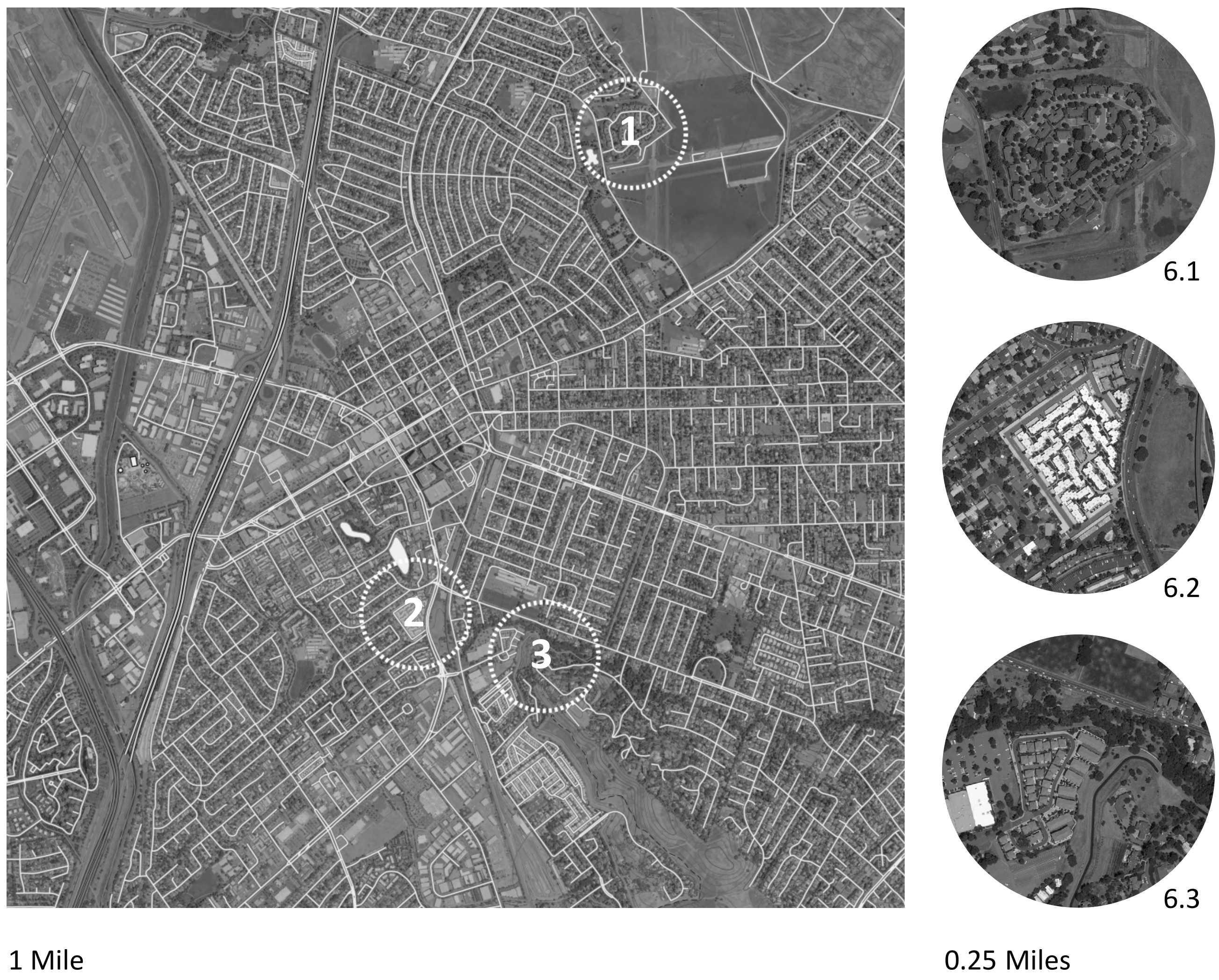


Figure 6: Concord, 2015. Developments between 1990 and 2015 are shown in circles. Source: Author. Drawn based on Google Maps

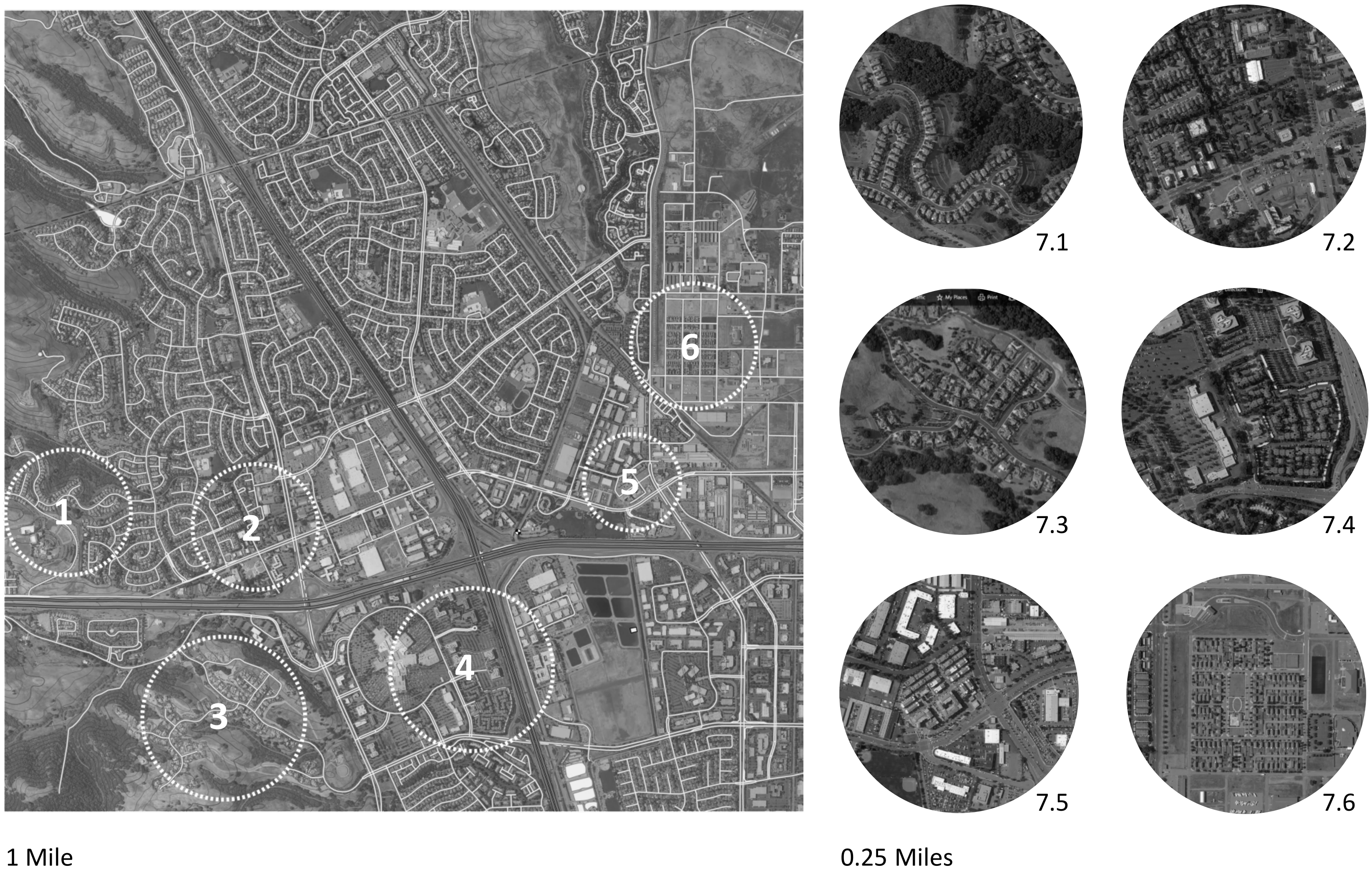


Figure 7: Dublin, 2015. Developments between 1990 and 2015 are shown in circles. Source: Author. Drawn based on Google Maps

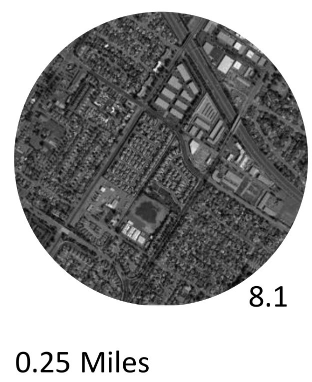
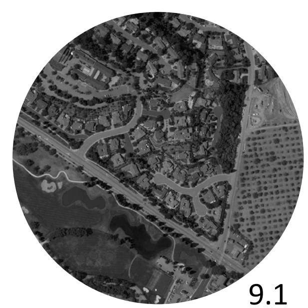


Figure 8: Fremont, 2015. Developments between 1990 and 2015 are shown in circles. Source: Author. Drawn based on Google Maps



1 Mile

0.25 Miles

Figure 9: Moraga, 2015. Developments between 1990 and 2015 are shown in circles. Source: Author. Drawn based on Google Maps

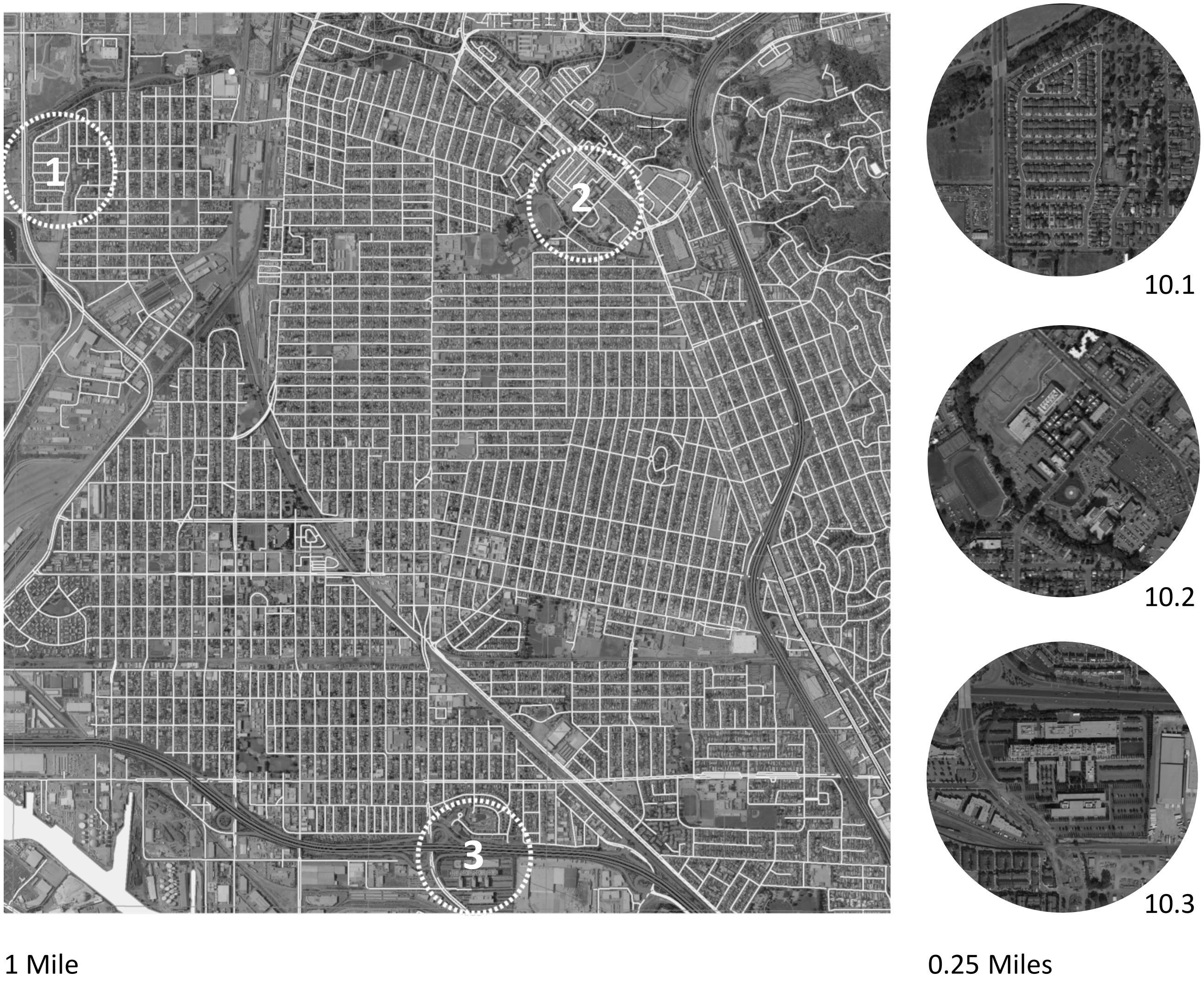


Figure 10: Richmond, 2015. Developments between 1990 and 2015 are shown in circles. Source: Author. Drawn based on Google Maps

Figure 11: San Leandro, 2015. Developments between 1990 and 2015 are shown in circles. Source: Author. Drawn based on Google Maps

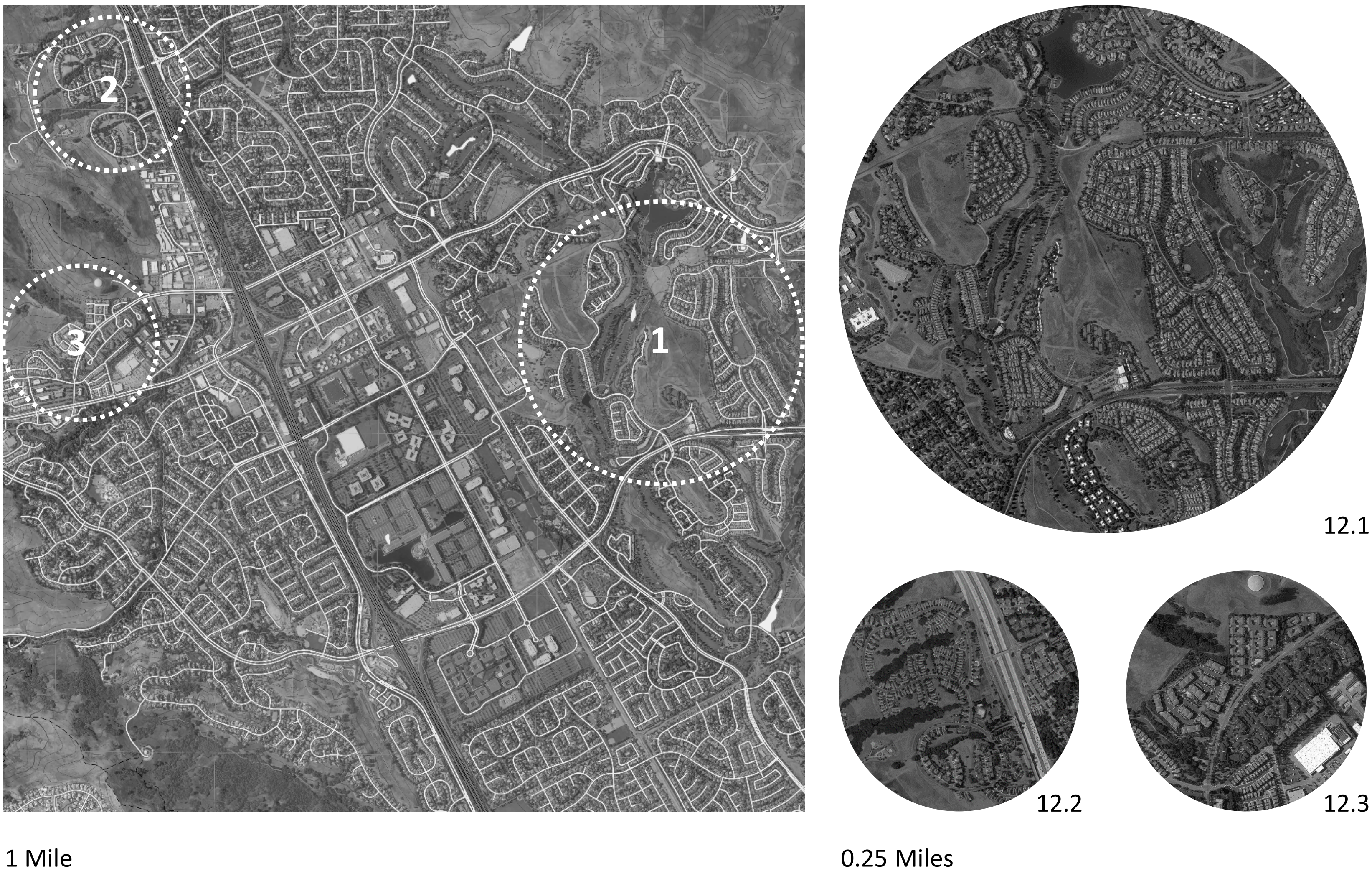


Figure 12: San Ramon, 2015. Developments between 1990 and 2015 are shown in circles. Source: Author. Drawn based on Google Maps

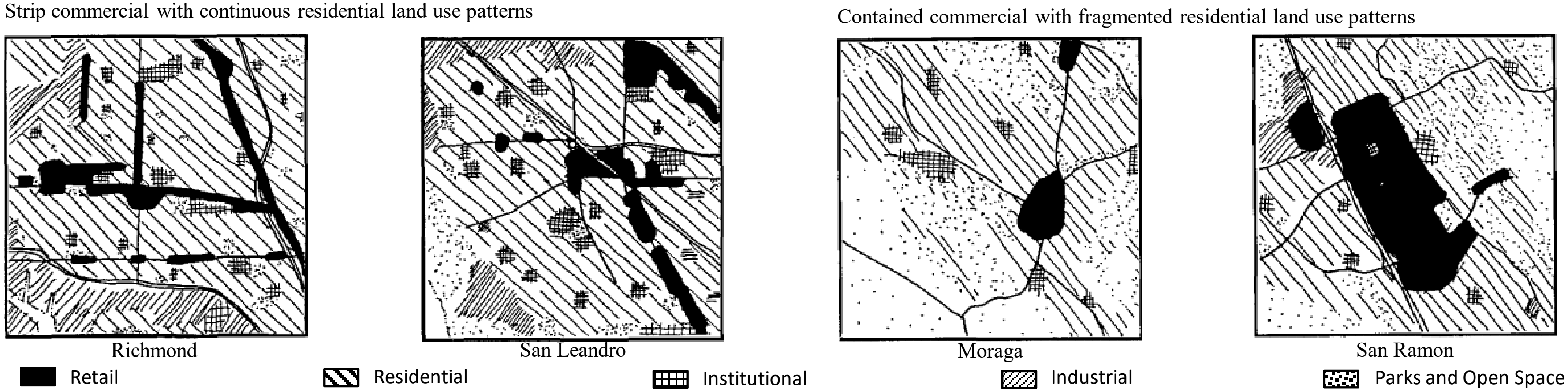


Figure 13: Land use patterns in study areas,1980s and 1990s. Source: Southworth and Owens (1993); [Source: Southworth and Owens (1993); reprinted by permission of the publisher (Taylor & Francis Ltd, http://www.tandfonline.com)]

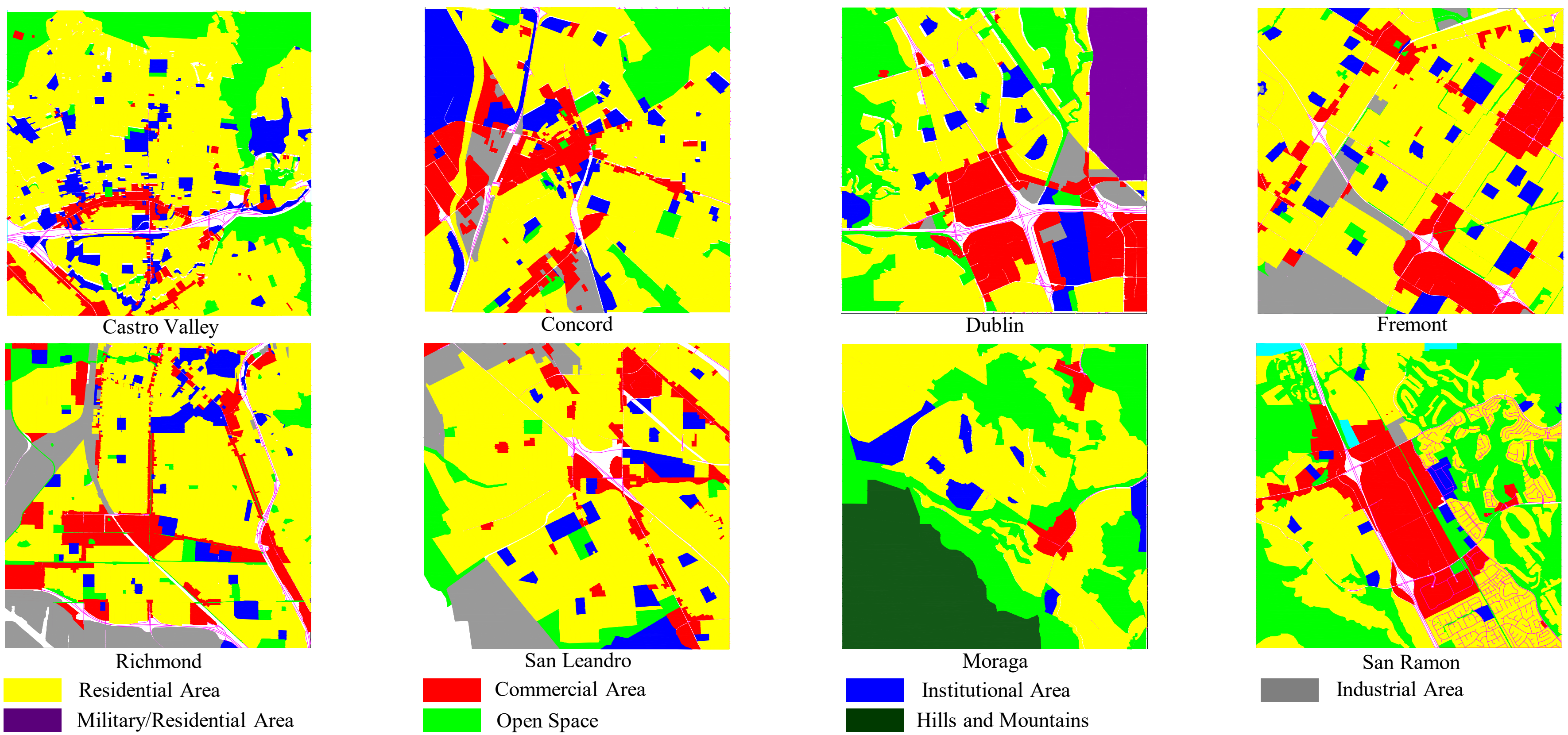
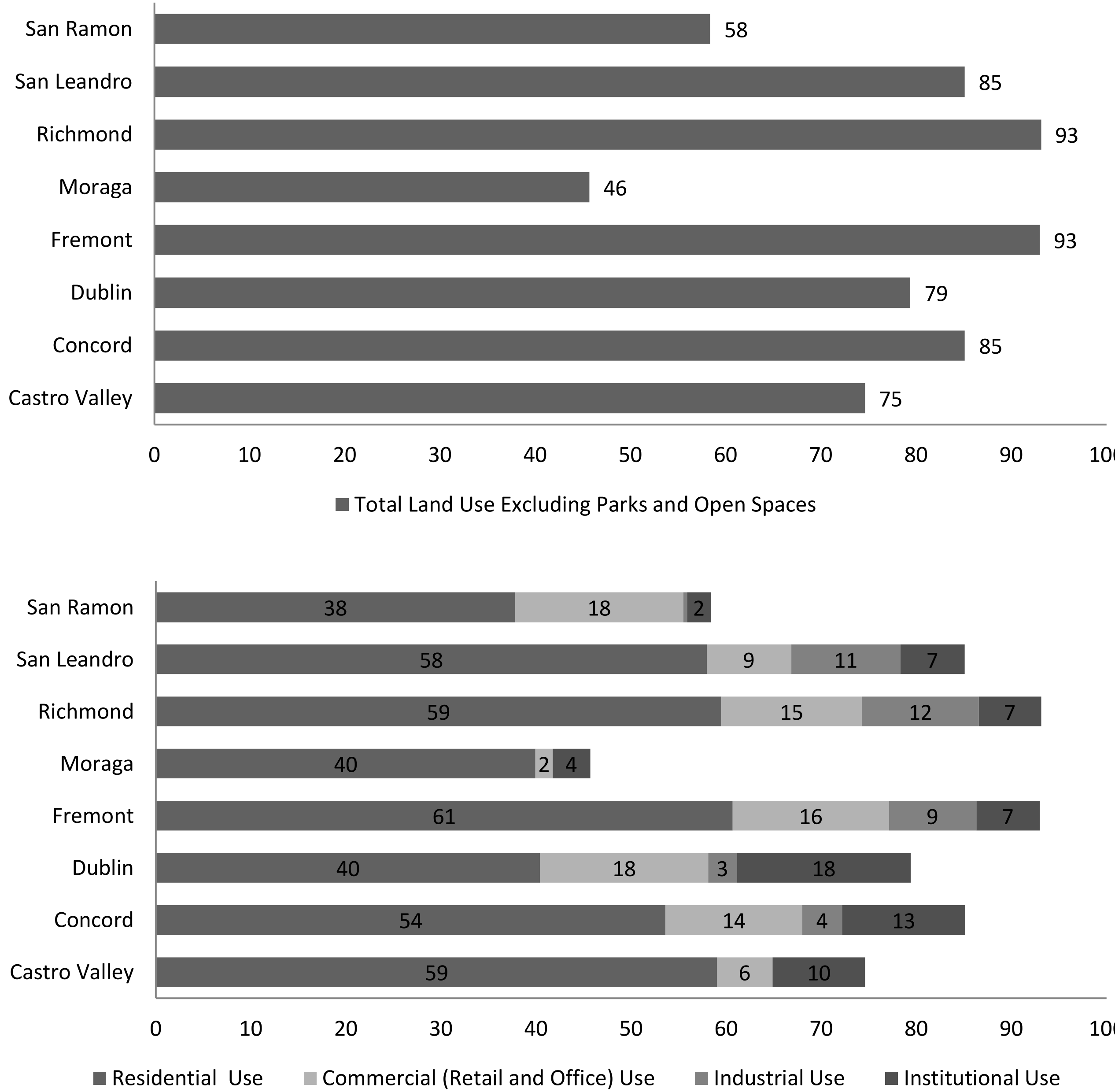


Figure 14: Land use patterns in study areas, 2015. Source: Author



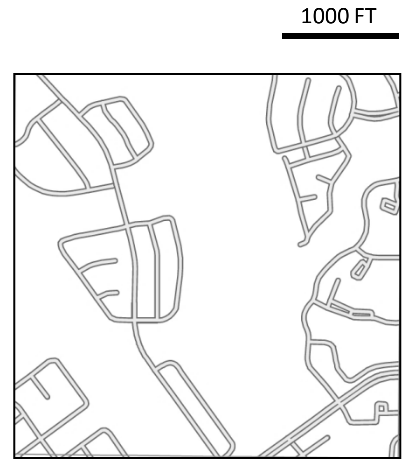
15.1

15.2

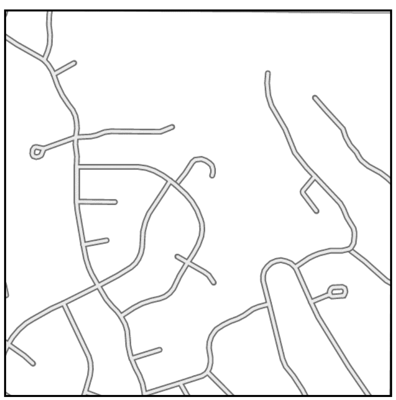
Figure 15: Different land uses as percentage of the total study area, 2015. Source: Author

Castro Valley. Warped lines and irregular cell/s with sticks

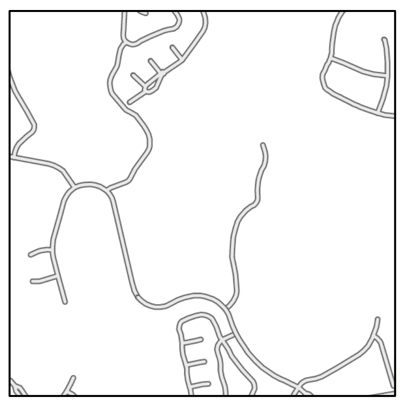
Concord. Warped lines with sticks



Dublin. Warped lines forming small irregular cells with sticks



Moraga. Warped lines forming large cells with sticks



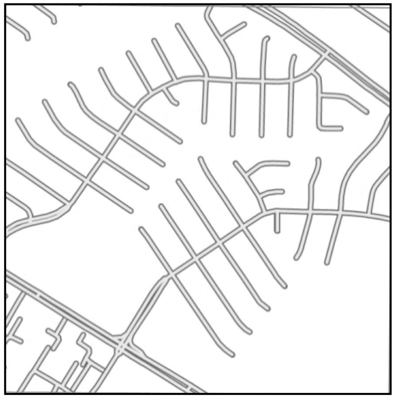
San Ramon. Warped lines forming small irregular cells with sticks

Figure 16: Low density neighborhood street patterns, 2015.

1000 FT

Castro Valley. Mesh of warped lines containing irregular cells with or without sticks

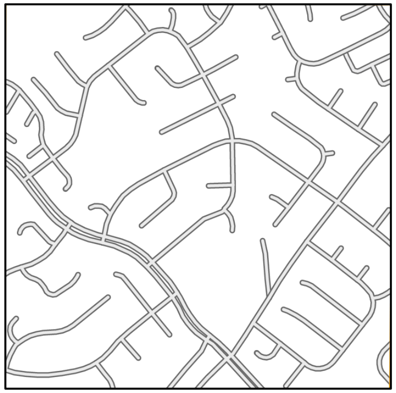
Concord. Irregular mesh of straight and warp lines containing large cells with sticks



Fremont. Warped lines with sticks

Moraga. Broken irregular mesh of warped lines containing irregular cells with or without sticks

San Ramon. Warped lines forming large irregular cells with sticks



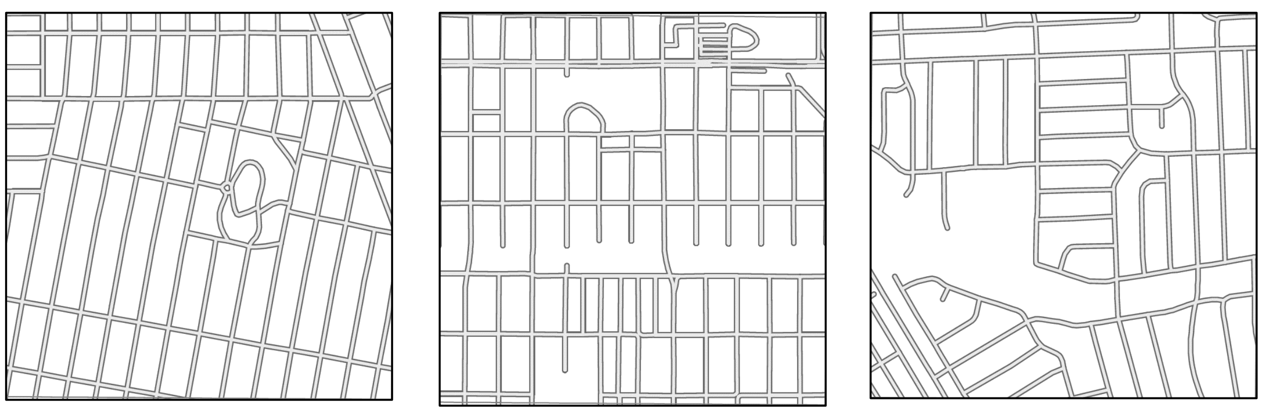
San Ramon. Mesh of warped lines containing irregular cells with or without sticks

Figure 17: Medium density neighborhood street patterns, 2015.

Concord. Irregular mesh of straight and warped parallels containing cells with and without sticks

Dublin. Split irregular mesh of warped line with disjoint parts containing cells with and without sticks in different patterns

Fremont. Split mesh of warped and straight lines containing cells with and without sticks in different patterns



Richmond. Continuous regular mesh of straight lines containing cells without sticks

Richmond. Split regular mesh of straight lines containing cells without sticks

San Leandro. Split irregular mesh of warped and straight lines containing cells without sticks in different patterns

Figure 18: High density neighborhood street patterns, 2015.

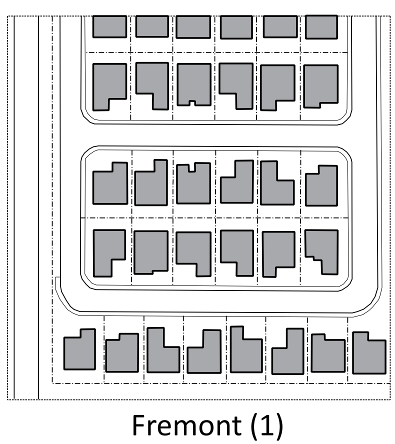
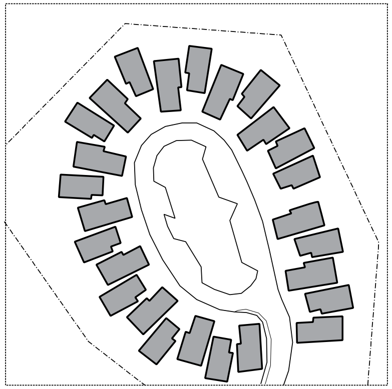
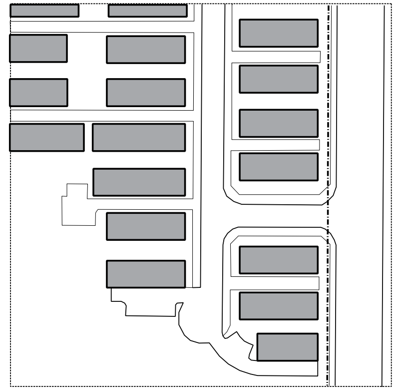


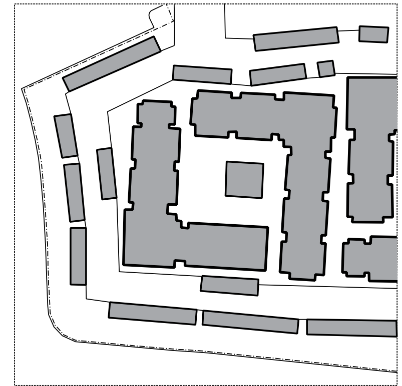
Figure 19: Detached single-family residential developments in the study areas between 1990 and 2015.



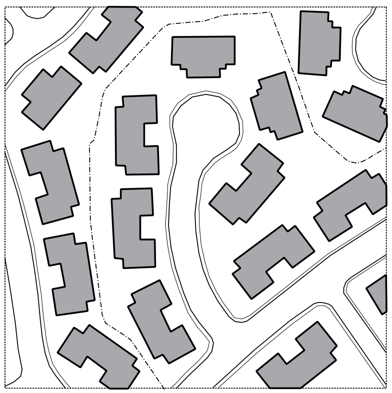
Castro Valley (1)



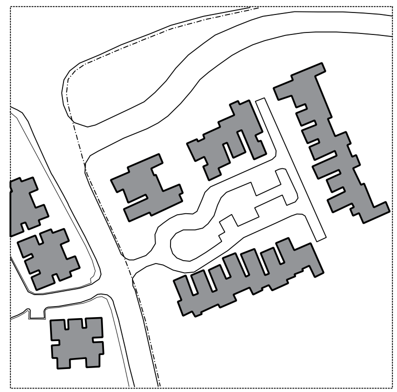
Dublin (1)



Dublin (2)



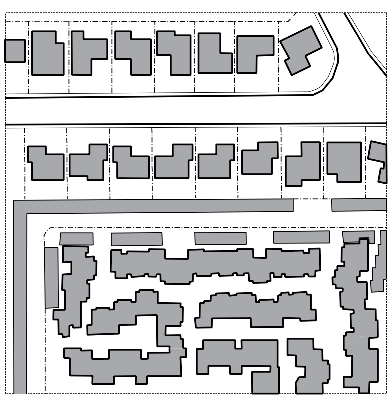
Concord (1)



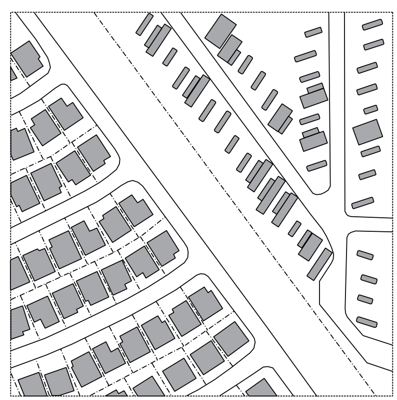
Dublin (3)

200’

Figure 20: Multi-family residential developments (condominiums and apartments) in the study areas between 1990 and 2015.



Concord (1)



San Leandro (1)

200’

Figure 21: Mixed residential developments (detached houses, condominiums, apartments, and mobile houses) in the study areas between 1990 and 2015.

	Approx. street length in miles	Number of urban blocks	Total number of intersections	Number of access points	Number of dead ends
Castro Valley	167.89	253	1,167	935	604
Concord	179.11	410	1,402	1,122	467
Dublin	152.77	249	1,203	812	338
Fremont	219.77	450	1,848	1,362	508
Moraga	85.69	53	467	264	289
Richmond	230.88	928	1,940	1,592	286
San Leandro	178.80	469	1,486	1,122	300
San Ramon	148.73	177	1,173	729	492

Table 1: A description of different morphological elements of the study areas in 2015.

	Number of locations with new developments	Approx. change in street length in miles from 1990 to 2015	Net change in the number of urban blocks from 1990 to 2015	Net change in the total number of intersections from 1990 to 2015	Net change in the number of access points from 1990 to 2015	Net change in the number of dead ends from 1990 to 2015
Castro Valley	4	0.37	4	3	2	3
Concord	3	1.49	4	18	10	10
Dublin	6	6.28	5	14	4	9
Fremont	1	1.11	6	17	17	1
Moraga	1	0.46	0	7	2	6
Richmond	3	2.20	6	11	12	2
San Leandro	2	4.46	26	88	76	48
San Ramon	3	5.43	36	84	68	38

Table 2: A description of the net changes in different morphological elements of the study areas from 1990 to 2015.

	Residential Areas	Commercial Areas	Institutional Areas	Industrial Areas	Parks	Boundary
Castro Valley	Continuous residential areas	Several commercial strips	Several dispersed small to large institutional areas	None	Very few parks	Boundary irregularly shaped by natural landscape
Concord	Residential areas broken into large segments	One large concentrated commercial area and two commercial strips	Several dispersed small to large institutional areas	Concentrated industrial areas	Very few parks	No natural limits
Dublin	Residential areas broken into large segments	One large concentrated commercial area	Few dispersed large institutional areas	Concentrated industrial areas	Very few parks	Boundary irregularly shaped by natural landscape
Fremont	Continuous residential areas	Two large concentrated commercial areas and one commercial strip	Several dispersed small to large institutional areas	Concentrated industrial areas	Very few parks	No natural limits
Moraga	Residential areas broken into large segments	Two small concentrated commercial areas	Few dispersed large institutional areas	None	None	Boundary irregularly shaped by natural landscape
Richmond	Residential areas broken into large segments	Several concentrated commercial areas and commercial strips	Several dispersed small to large institutional areas	Concentrated industrial areas	Very few parks	No natural limits
San Leandro	Partly continuous and partly fragmented residential areas	Several concentrated commercial areas and commercial strips	Several dispersed small to large institutional areas	Concentrated industrial areas	Very few parks	No natural limits
San Ramon	Fragmented residential areas	One large concentrated commercial area	Few dispersed institutional areas	One small industrial area	None	Boundary irregularly shaped by natural landscape

Table 3: A description of land use patterns as observed in 2015 in the land use maps of the study areas.