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Change in Urban Fabric Through Space and Time at Differing Levels of Automobility

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Change in Urban Fabric Through Space and Time at Differing Levels of Automobility

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ABSTRACT

For thousands of years cities have been centers for commerce, creativity, and livelihood, consisting of relatively unchanged characteristics such as walkable streets, diverse land-uses, and human-scaled buildings and streets. With the introduction of the automobile, this past century the desire for free-flowing traffic and convenient parking has drastically transformed the fabric of many cities. Transforming cities into places that accommodate automobiles has transformed downtowns into office parks rather than vibrant mixed-use environments and destroyed communities.

Investigation into reducing automobiles in cities has increasingly piqued the interest of stakeholders in the environmental, safety and economic development communities. This body of research first quantifies the differences between cities that have and have not accommodated the automobile. The second component consists of an in-depth examination of how one city, Bridgeport in Connecticut, has changed since the advent of the automobile.

The first component builds upon prior studies that have investigated parking supply, parking policies, and the taxation of parking in selected New England cities. Our major finding is that regardless of the level of automobile accommodation, city streets in our four case studies account for between 21% and 24% of the area of downtown. The amount of land devoted to parking in our two accommodative cities (Bridgeport and Lowell) was 20% and 23% respectively. This was five-fold the amount found in Cambridge and Somerville—4% and 9% respectively. While the parking figures reveal stark differences, our most dramatic finding was that Bridgeport, CT, devotes 21% of its downtown land to freeways. As a result, Bridgeport has almost two-thirds (62%) of its downtown land oriented towards automobiles.

The second study takes a closer look into the characteristics of Bridgeport, CT, prior to the widespread use of the automobile. The most startling result is the change in density and

diversity of land uses. From the passenger train station in downtown, a pedestrian can reach only 28% of the number of establishments that a 1913 pedestrian could in a 5 minute walk. If examined by land use only a startling 6% of the number of residential properties can be accessed today, greatly diminishing the walkable nature of the city. Analysis of this type helps to further inform the general debate about the place of automobiles in cities and may help city planners and developers understand the extent of the challenges they are facing in becoming more walkable, livable, competitive and fiscally solvent.

INTRODUCTION

Cities have been centers for commerce, creativity and livelihood for thousands of years, consisting of relatively unchanging characteristics such as walkable streets, diverse land-uses, and human scaled buildings and streets. In the last one-hundred years the invention of the automobile has radically altered human settlement patterns. Many cities such as Lowell, Massachusetts, and Bridgeport, Connecticut, have changed from being oriented towards humans to places that prioritize personal vehicles. The resultant changes represent a drastic departure from the way that cities were designed for thousands of years. The changes were so monumental that it may be difficult for society to imagine a city without the automobile playing a significant role in the form and function.

The influential urban activist, Jane Jacobs, spoke of "mass amnesia" in her 2004 novel, *Dark Age Ahead*. She wrote, "People living in vigorous cultures typically treasure their cultures and resist any threat to them. How and why can a people so totally discard a formally vital culture that it becomes vitally lost?"*(42)* Jacobs questioned how society had forgotten the treasure of a complex urban environment and its many advantages. The question of how and to what extent to accommodate automobiles is a major challenge that needs to be addressed in any attempt to revive walkable and livable cities. This thesis aims to characterize and quantify the differences between cities who have accommodated automobiles to different extents in an attempt to better help cities understand the extent of the challenges they are facing in becoming more walkable, livable, competitive and fiscally solvent.

This thesis is laid out in two parts. The first is "An Assessment of How Land is Used in Cities at Different Levels of Automobility". Four cities were chosen—two with a high proportion of motor vehicle drivers and two with a low proportion of motor vehicle drivers. Lowell, Massachusetts, and Bridgeport, Connecticut, were chosen as high automobility case studies

having 80% or more commuters using a personal vehicle to drive to work, while Cambridge and Somerville in Massachusetts with 50% or less of the population driving to work, were chosen as the low automobility case studies. This component of the research sought to quantify the differences among the city's downtowns in terms of area devoted to off-street parking, streets, and freeways, as well as the total area of the land that is not able to be taxed.

The second part, "Urban Fabric Through Time", takes a closer look into how Bridgeport, Connecticut, a city with high levels of automobility, has changed since the advent of the automobile. In 1913, the city was a booming industrial center with dense and diverse streets. This study aims to quantify just how much the city has changed one-hundred years later in terms of walkability, density and diversity of land use, and consider how these outcomes may have affected livability.

AN ASSESSMENT OF HOW LAND IS USED IN CITIES AT DIFFERENT LEVELS OF AUTOMOBILITY

INTRODUCTION

The compatibility of cities and automobiles has come under increasing scrutiny in the past two decades. Inquiry into this issue has been far-reaching and motivated by a wide range of factors. Stakeholders focusing on global climate change have suggested that public transit use in cities would provide better environmental outcomes than private automobile use *(1, 2)*. Public transit may also help to reduce the often high levels of traffic congestion associated with private automobile use that exacerbates air pollution and increases travel times *(3)*. Researchers focusing on transportation safety have noted the risks faced by vulnerable users such as pedestrians and bicyclists who use city streets that have been designed to maximize automobile speed *(4, 5, 6, 7)*. Concerns about the role of automobiles in cities have also come from those focusing on economic development. The concepts of walkability, livability, and sense of community have become increasingly recognized as important elements that together shape sense of place *(8, 9, 10, 11, 12)*. Creating places that are more livable, walkable, and environmentally-friendly has become especially important in an era where cities compete with one another for capital and people *(13, 14)*. Place-making considerations along with lack of funding to replace crumbling highway infrastructure have come together in support of freeways being removed from cities entirely *(15,16,17)*.

Greater consideration of the role of automobiles in cities stands in sharp contrast to the attitudes that prevailed in the decades following World War II. Many city officials—especially those in the United States—embraced the automobile to such an extent that cities were completely reconfigured. Freeways replaced and/or bisected neighborhoods *(18)*. Urban renewal programs displaced even more neighborhoods, replacing them with modernist automobile-oriented structures reminiscent of Le Corbusier's "Towers in the Park" (Citation). Many cities also widened or reoriented roads that were not part of the freeway system to further accommodate the free flow of automobiles *(19)*. Reconfiguring roadways resulted in a complete reworking of the urban fabric which, prior to the automobile, tended to comprise of more intricate

networks *(20)*. The Complete Streets movement has been especially vocal in highlighting the need for streets to accommodate a wider range of users, not just those driving automobiles *(21, 22)*. Tactical Urbanists have illustrated that strategies as simple as painting part of the roadway can be effective in reclaiming space for people *(23, 24)*.

This component of the study also involves examining parking, an accommodation for automobiles that is receiving growing attention. Donald Shoup's ground-breaking work "The High Cost of Free Parking" clearly articulated the many explicit and sometimes hidden burdens placed on cities by having to provide free or subsidized parking to automobile users *(25)*. This research has inspired a small but influential body of literature directed towards uncovering insights as to how parking affects cities *(25)*. What is particularly noteworthy about this work is that it has begun to influence the crafting of parking policies in some cities *(26,27, 28, 29, 30)*. That said, more research is needed to understand precisely how accommodating the automobile has affected specific cities and how they compare to places that were less welcoming of automobiles.

In this paper we present data in the form of maps and accompanying tables that show how land is used in four cities in New England. The goal is to understand in particular how much land is devoted to automobile use. Automobile-oriented land use is divided into the three distinct categories of freeways, streets, and parking. The four cities (Bridgeport, Connecticut, and Lowell, Cambridge, and Somerville in Massachusetts) were deliberately chosen to represent a wide range of automobile accommodation. With automobile commute shares of 80% and 88% respectively, Bridgeport, Connecticut and Lowell, Massachusetts, represent automobile-dependent cities. In contrast, Cambridge and Somerville's commute shares of 34% and 50% respectively provide examples of cities that are less automobile-oriented *(32)*.

LITERATURE REVIEW

In Donald Shoup's "The High Cost of Free Parking", he argues that "parking lots are asphalt holes in the urban fabric. They make driving easier, but walking more difficult and less rewarding" *(25)*. He further cemented his statement by estimating the parking coverage of 44 cities worldwide including New York City, Tokyo, Melbourne, Detroit, and Montreal using Kenworthy and Laube's parking space counts *(32)*. He derived the parking area using the total amount of parking spaces assuming each hectare of land accommodates 325 parked vehicles. It is important to note that structured parking is accounted for as if every floor is on the ground level. Obviously, this is not the case in most of the cities he studied. He determined that parking would cover between 2% - 81% of the CBD in cities around the world. The U.S. cities on the list ranged from New York City at the low end at 18% to Los Angeles at the high end at 81%.

Environmental researchers have also been interested in types of land cover to determine how the built environment impacts storm runoff, fresh water pollution, and other aspects of the environment. A study by Davis, Pijanowski, Robinson, and Engel did the reverse type of calculation as Shoup *(33)*. The researchers studied Tippecanoe County, Indiana, and developed a linear regression model to determine the number of parking spaces from the total parking lot size. They estimated that 0.44 percent of the entire county was made up of parking. However, when the researchers further separated the urban areas in the county they found that 6.6 percent of the urban land is devoted to parking. In 2003, Akbari, Rose and Taha used high-resolution orthophotos to determine the amount of paved surfaces, vegetation cover and roof cover in Sacramento, California *(34)*. They characterized five different land areas within Sacramento, one of which was the downtown or city center. The researchers found that 41% of the downtown was either roads, sidewalks, or parking. However, due to the vegetation cover this number is drastically underestimated. They concluded that 50-70% of non-residential areas are covered by paved surfaces, after accounting for the paved surfaces under vegetation cover.

Much of the research in this field is motivated by environmental concerns that aim to raise awareness about the impacts of high levels of impermeable surface coverage.

Very few studies have been conducted addressing the land area devoted to streets. In 1966, Wilbur Smith & Associates conducted a study of twelve CBDs *(35)*. They found that in large cities like Los Angeles, Minneapolis, and Sacramento between 22 and 40 percent of the land area was devoted to streets.

Researchers at the University of Connecticut have looked into parking supply from the policy view point. McCahill and Garrick studied the impacts of different parking policies on two cities over a fifty year span *(26)*. Hartford, Connecticut, was chosen as a city with an increase in automobile use and Cambridge, Massachusetts, as a city with a decrease. Hartford supported urban renewal projects and justified parking by pointing "to free parking in suburban shopping plazas" *(26, p.125)* as an argument for increasing parking in the downtown. Unlike Hartford, Cambridge fought against freeways and revolutionized parking policy by enstating a parking maximum in their 1981 zoning code. The researchers found that Hartford increased parking area by 171% and Cambridge increased 106% over the 50 year study period. They pointed out that even though they both increased significantly, the location of the added parking was different. Hartford added much of the parking to the urban core, while Cambridge's additions were to the outskirts of the city. This study was the first in a strand of research focused on understanding how policy, the built environment, and travel behavior interrelate

Haerter followed the findings in the previous study by focusing on the built environment of the CBDs of six American cities *(27)*. She found that cities who chose a demand-oriented approach to parking policy saw higher land areas devoted to parking and an increase in automobile mode share. Cities with a supply-oriented approach to parking policy "significantly increase(d) the amount of land dedicated to activities…include(ing) population and employment growth, an indicator of urban vitality" *(27, p.43)*. McCahill, et al. argued that fulfilling minimum parking requirements would drastically change how our cities are built and function *(28)*. They

show that even partially providing the minimum parking requirement will continue to drive up parking supply, furthering the unsustainable automobile cycle. Blanc et al. built off this work by comparing the tax revenues of lands devoted to parking and all other land-uses *(29)*. They found that in all six cities he studied, parking lots generated significantly lower taxes than the built environment. Using a combination of previous work at the University of Connecticut, McCahill, Garrick, Atkinson-Palombo, and Polinski set out to examine potential causality between parking and induced driving *(30)*. They used the Branford Hill criteria from the field of epidemiology to suggest causation using data from nine American cities. Some of the criteria included strength of association, consistency, and specificity. Using the data available they were able to satisfy most of the criteria for the data on parking provision. From this study, they were able to "infer that parking provision in cities is a likely cause of increased driving" *(30, p.12)* by both commuters and employees.

Many of the studies focus on the effects and causation that parking provision has on our cities. However few studies have investigated how automobility has affected the urban fabric as a whole. This study aims to build off of these parking studies and fill the gap by determining the total amount of land-use devoted to automobility, how that changed over time, and its effect on the amount of tax producing land.

EMPIRICAL STUDY

Case Studies

The four cities in our study are Bridgeport, Connecticut; and Lowell, Cambridge, and Somerville in Massachusetts. All four New England cities were founded well before the advent of streetcars, let alone automobiles. Cambridge was founded the earliest, in 1630, followed by Bridgeport in 1800, then Lowell (1836), then Somerville (1842). The cities were chosen based on how they transitioned from walking cities to places that accommodate the automobile to

varying degrees. In addition to the historical similarities, the availability of data was another major factor in choosing these four specific cities. Massachusetts has an easy to use geographical and tax assessment database that includes all Massachusetts cities and towns, with the exemption of Boston. Connecticut does not have a centralized repository for tax assessor data, but Bridgeport's geographical information department did have the pertinent data for the study.

Our proxy for automobile-orientation is the percentage of commuting undertaken by automobile for the city as a whole as of 2012 *(31)*. According to these data, Cambridge and Somerville are less automobile-oriented with 34% and 50% of their population commuting via automobiles. In contrast, Bridgeport and Lowell are more automobile-oriented with 80% and 88% of the population commuting via automobiles. Each city lies within commuting distance to one of two major U.S. cities, Boston and New York City. Cambridge and Somerville each house a subway stop providing access to Boston in addition to extensive local public transit networks. Bridgeport sits in the middle of one of the busiest commuter lines in the country that leads to New York City. Lowell is at the end of a less prominent commuter rail line into Boston. The cities are fairly comparable in terms of population. Bridgeport is the largest of the four with almost 150,000 people and Somerville is the smallest with under 80,000 people. Our analysis focused only on the downtowns of each city using prior research and government documents to determine the extent of the downtown *(27, 29).*

Data

Our analysis used parcel-level data in a GIS format for each of the four cities. Data for the three cities in Massachusetts came from the Massachusetts Office of Geographic Information (MASSGIS) *(36)*, while data for Bridgeport came from the city's Office of Planning and Economic Development. The most current data available for each city, which ranged from 2012 for Bridgeport and Somerville to 2015 for Lowell, were used for the study. This slight mismatch

in the years is not thought to present a problem because land use typically changes very little over such a short timeframe. The key attributes focused on in the analysis were land use and gross assessed value for each land parcel. The land use code was used to determine not only what the land was being used for but also whether or not it was exempt from property taxes.

METHODOLOGY

Tax Assessor's Parcel Data

The first stage of the analysis consisted of determining the central business district (CBD) for each downtown. For Cambridge and Lowell, I used the boundaries determined in previous studies that were determined by selecting the most densely built-up areas based on aerial photographs from the 1950s. The boundaries chosen coincided with census blocks to facilitate the use of Census Data. Bridgeport and Somerville were defined in a similar fashion. First by referring to aerials from the 1930s *(37)*. Second by checking with other sources for a downtown border. Bridgeport defines the downtown neighborhood as the ""teardrop" shaped area bounded by the elevated rail tracts to the south, Route 8 to the northwest, and Pequonnock River to the northeast". The Somerville downtown was confirmed with city officials.

With the downtowns defined, the next step was to create a GIS layer for parking. I did this by selecting all parcels coded as parking in the property use codes then adding in parking lots, parking structures and residential parking lots that housed more than four vehicles. Much of the parking is not explicitly coded because they are combined with other uses such as an apartment complex with residential parking or commercial buildings with parking surrounding it. These locations were selected based on identifying definitive parking on a current aerial base map. The parcels that contained parking were then cut to the approximate size of the parking on the parcel. The new area was then populated and used to calculate the proportion of the parcel that was devoted to parking.

The streets are characterized as the space between the parcels, or in other words the land the tax assessor does not assess directly. MASSGIS created a streets and other government property layer but the streets file needed to be created for Bridgeport. This was done by clipping the downtown parcels from the downtown census blocks. The street includes the vehicular right of way as well as sidewalks and medians, mainly to simplify the process.

Downtown Bridgeport lies at the intersection of two major highways, Interstate 95 and Route 8. Therefore for Bridgeport a highway level was created from the streets layer using a current aerial image. The MetroNorth commuter rail stops in the downtown of Bridgeport for commuters going towards New Haven, Connecticut and also south towards/to New York City. Approximately 10% of the Bridgeport population uses public transportation to get to work. It is safe to assume a large portion of those workers use MetroNorth. To account for this separate transportation mode, a rail level was also created to differentiate the land devoted to automobiles from land devoted to rail.

Individual parcels were categorized as property tax exempt or not exempt. This was done by selecting all property use codes classified as exempt in the metadata. A new exempt layer was then created by exporting the selected parcels. Parcels can have many tax assessments associated with them especially for developments such as condos or apartments that are individually/owner owned. Even though this is a rare case, if any of the assessments on a parcel were coded as exempt, I showed the entire parcel as exempt in our maps. This was mainly done to simplify the process.

Mode Share

Travel behavior was gathered to give insight towards how reliant each city is on automobiles. The American Community Survey (ACS) from 2012 categorizes the means residents travel to work into private or carpool vehicles, public transportation, bicycle, walk, etc. which was then used to calculate the proportion of the population using vehicles, private or carpool, to travel to

work *(31)*. These data were used both to help select cities and to understand the relationship between space devoted to automobiles quantified during this research and how it relates to mode share. Table 1 shows the mode share splits for each city.

TABLE 1 Means of Transportation to Work in 2012

Mode Share	Bridgeport, CT	Cambridge, MA	Lowell, MA.	Somerville, MA
Motor Vehicle (%)	80	34	88	50
Public Transportation (%)	10	24	4	30
Walking (%)	6	25	4	12
Other (%)	4	17	4	8

RESULTS

Downtown Land Composition

The key components of downtown land area include parking, streets, freeways, rail, and non-parking parcels. The four downtowns in the study have parking that varies from 4% to 23% of the total land composition. Cambridge and Somerville devote under 10% of the total downtown land to parking, at 4% and 9%, respectively. In contrast, Bridgeport and Lowell devote over 20% of their land to parking, at 20% and 23%, respectively. However the land devoted to parking is not the only land use that accommodates automobiles impinging upon downtowns.

Streets are a necessity in any environment, however over the past century streets have been widened in many American cities to better accommodate the automobile. All four cities in the study devote 21% of their land area to streets, with the exception of Somerville at 24%. While it is recognized that the street also caters to pedestrians and cyclists, a great majority of the street is solely devoted to the driving and parking of automobiles.

Only one city in the study, Bridgeport, has not only one but two freeways that carve up the downtown urban fabric unlike any of the other cities. The freeway covers just over one-fifth

(21%) of the total downtown land area. Bridgeport is also the only city with a rail line directly in the downtown. Compared to the freeway it takes up a negligible amount of space, 6% of the downtown. Table 2 below gives a more detailed explanation of how the land is allocated. Land devoted to automobiles in urban downtowns vary drastically from 25% to 62% of the total land area. Figures 1 to 4 show the land consumption of automobiles in all four of the cities. Cambridge and Somerville are at the low end at 25% and 33% respectively. Lowell is in the middle at 44%. Bridgeport is at the extreme of 62% of the entire downtown is used to support the use of automobiles. However Bridgeport is not alone. Many U.S. cities have fallen victim to excessive parking and freeways through their downtown *(26)*.

TABLE 2 Land Area Allocation in Urban Downtowns

Measure	**Bridgeport, CT**	**Cambridge, MA**	**Lowell, MA.**	**Somerville, MA**
Total Land Area (Acres)	294.81	655.70	244.87	90.84
Total Parking Area (Acres)	59.35	26.63	56.00	7.97
Total Street Area (Acres)	61.30	136.78	51.10	22.43
Total Highway Area (Acres)	61.18	0	0	0
Total Rail Area (Acres)	19.07	0	0	0
Land Devoted to Automobiles (Acres)	**181.83**	**163.41**	**107.10**	**30.40**
Parking Land Coverage (%)	20	4	23	9
Street Land Coverage (%)	21	21	21	25
Highway Land Coverage (%)	21	0	0	0
Rail Land Coverage (%)	6	0	0	0
Auto Land Coverage (%)	**62**	**25**	**44**	**33**
Vehicle Mode Share (%)	**80**	**34**	**88**	**50**

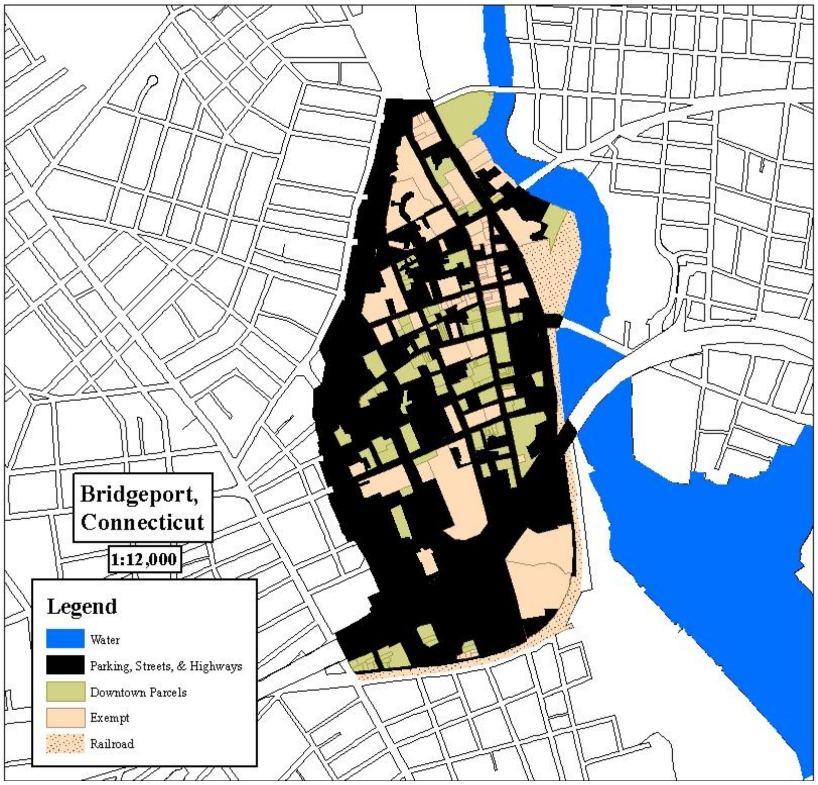

FIGURE 1: Bridgeport, Connecticut Land Composition

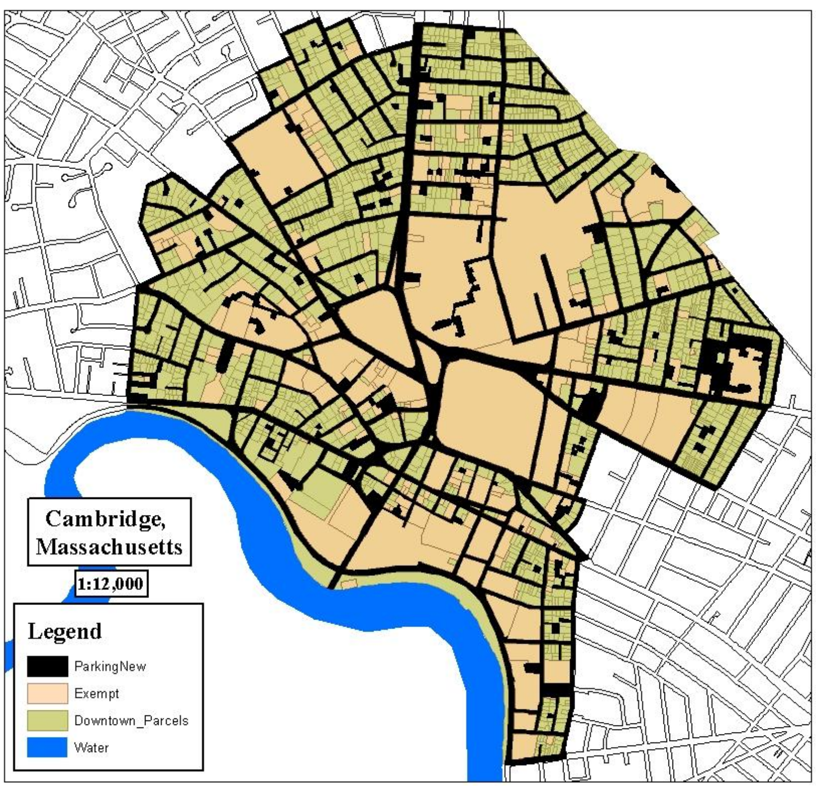

FIGURE 2: Cambridge, Massachusetts Land Composition

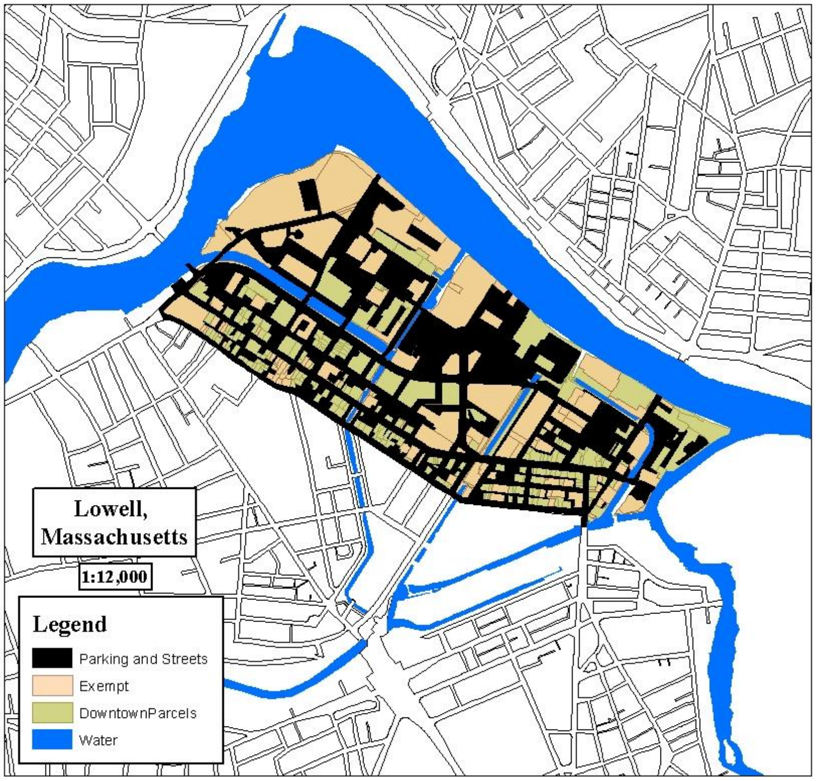

FIGURE 3: Lowell, Massachusetts Land Composition

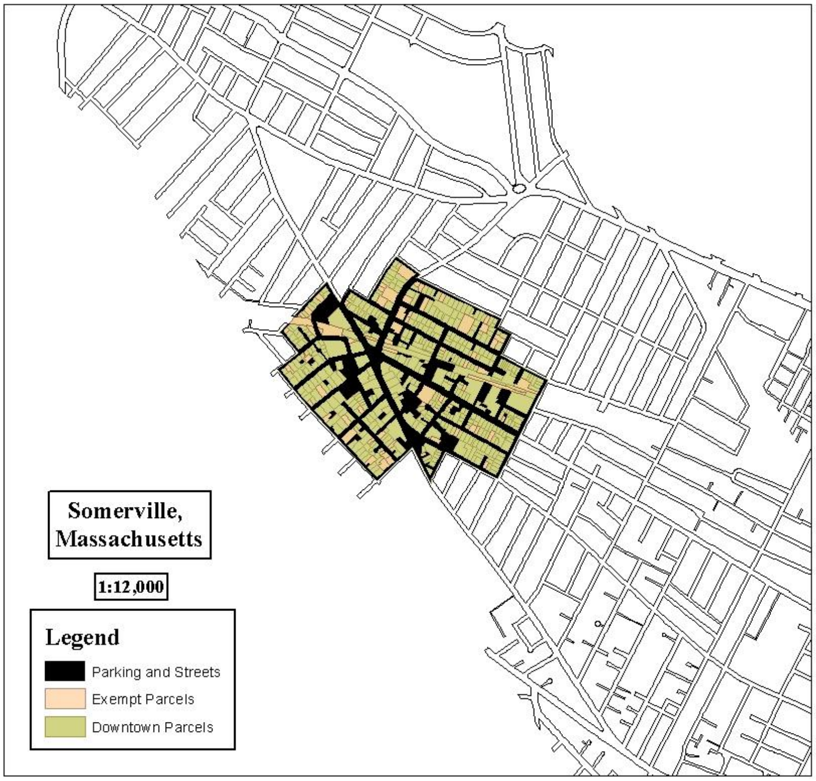

FIGURE 4: Somerville, Massachusetts Land Composition

Land Available for Taxable Uses

Every city has necessary property tax exemptions such as municipal government buildings, schools and universities, and green space. The cities in the study have differing amounts of exempt land, for example Cambridge hosts Harvard University which makes up the majority of their 250 plus acres of exempt parcels. Lowell also has an enormous amount of exempt properties due to the University of Massachusetts in the downtown. Much of the time when looking into property tax exemptions people fail to realize that streets, highways and rail are also exempt. If a city devotes a large amount of land to transportation, they forgo the taxes on the land that could have been built upon. After taking into account these other exempt land-uses Bridgeport has only 22 percent of the land left over for taxable buildings. Lowell has 36 percent left for taxable buildings, Cambridge 40 percent, and Somerville 61 percent. Table 3 summarizes the exemptions in each city.

TABLE 3: Downtown Land Exemptions

Measure	Bridgeport, CT	Cambridge, MA	Lowell, MA.	Somerville, MA
Total Land Area (Acres)	294.81	655.7	244.87	90.84
Exempt Parcels Land Area (Acres)	88.71	256.64	105.81	13.44
Other Exempt (Streets, Highway, Rail) (Acres)	141.55	136.78	51.1	22.43
Land Available for Taxable Properties (Acres)	64.55	262.28	87.96	54.96
Land Available for Taxable Buildings (%)	**22**	**40**	**36**	**61**

DISCUSSION AND CONCLUSIONS

Each city in the study devoted a fairly consistent amount of their land area to streets, generally $1/5$ to $1/4$ of the downtown land even though the configuration of the street network is different from city to city. The 12 cities investigated in the 1966 Wilbur Smith & Associates case study were found to have street area anywhere between 22 to 40 percent of total CBD area *(35)*. The disparity between the two studies could be explained by the locations of the cities. The majority of the cities in the Wilbur Smith study are in the Midwest and West of the United States which were developed much later than the cities in the Northeast. It is also unclear if the Wilbur Smith researchers included freeways into their calculations.

It is interesting to compare the street networks in this study against one another considering they have the same area devoted to streets but have very different urban fabrics. The street network in Bridgeport gets lost in the parking and freeway, note that in Figure 1 the streets are hardly recognizable because they blend in with the black of the freeway and parking. This is similar to how a pedestrian feels in an environment consumed by the automobile. When there is a loss in urban fabric the city becomes less livable. It is uncomfortable and unengaging for pedestrians to walk across expanse blank spaces. A similar effect happens in Lowell (Figure 3) but not to the exaggerated extent of Bridgeport.

Many cities around the world built freeways directly through their downtown with the promise of increased economic activity and improved mobility. The highways take up the same land area of the conventional streets, together they consume 42 percent of the entire downtown. Not only does this leave only half the downtown area for economic activity, but it also deters pedestrians from easily accessing the area from other neighborhoods.

Cambridge has a large proportion of exempt parcels, nearly 1.3 times the amount of Bridgeport, yet it still has the second largest amount of land available for taxable buildings. They are able to have nearly twice as much taxable land as Bridgeport by having conservative amounts of parking and no freeway. Lowell has only 36 percent of the CBD land available for

taxable buildings, this is due to a large quantity of land classified as exempt. Exempt parcels in downtown Lowell also have large quantities of parking, suggesting that parking should be regulated more strictly for all land in Lowell.

Cities that have considerable amounts of non-tax productive land face uncertain futures. A lower tax base makes cities rely on significantly less businesses and corporations to stay afloat. If a business fails or leaves town for a more favorable tax rate, the city feels this loss much more than a city with many businesses. By converting some of the non-tax productive land into businesses and residencies, cities will gain back the diversity in the land-uses of their downtowns. A diversity in land-uses create a more livable environment to attract both workers and residents. Adding more tax productive land spreads the tax burden over more residents and businesses, allowing for lower tax rates and a more stable municipal government.

URBAN FABRIC THROUGH TIME

INTRODUCTION

Nearly one century ago the first affordable automobile, Ford's Model T, was invented. Widespread automobile use expanded in the following decades as the middle class was able to own personal vehicles. Over the next century as more vehicles crowded roadways, cities faced a dilemma with how to best deal with congestion. Many cities turned to disproportionally allocating streets to the automobile, building limited access freeways, and creating vast amounts of vehicle storage facilities. The previous chapter of this thesis showed that cities that accommodated the automobile devoted nearly one-quarter of the land area to off-street parking whereas cities that did not accommodate the automobile devoted only five to ten percent of their land area to off-street parking. The argument for better access to downtowns resulted in limited access freeways that bisected neighborhoods. The automobile allowed for different types of travel patterns mostly where people can reside further from their employment and entertainment activities. The effects of urban sprawl have left cities with communities that are less walkable not only based on increasing trip distances but the lower density and diversity of land-uses. However, in the past two decades a new movement has begun to unfold where transportation efforts do not solely focus on vehicle free flow but on creating a vibrant, livable, and walkable city for all users.

This study aims to quantify the characteristics of cities prior to the changes made for the automobile. Solutions to auto dependency can lie in the urban fabric of a time where walking and streetcars were the main transportation modes. People had to live close to their jobs and extracurricular activities to be able to efficiently use their time.

This study is largely built off of the findings and methodology of Adam Polinski's research on "The Virtual Reconstruction of Transportation and Land Use in Transit Era Hartford, Connecticut" *(20)*. He characterized the urban fabric of three residential Hartford neighborhoods by average building height, average building footprint, and off-street parking areas in 1922 and 2014. Surprisingly, there were no changes in average building height,

however the building footprint increased by 26 percent and off-street parking increased by 1020 percent. However, the study did not look at the changes in downtown urban fabric where many of the urban renewal projects tend to be located. This study aims to fill this gap.

CASE STUDY: BRIDGEPORT, CONNECTICUT

This study explores how a typical American city has changed since the widespread use of the automobile. Bridgeport, Connecticut was first settled in the mid 17th century and officially established as the city of Bridgeport in 1836. Four years later the railroad was opened and in conjunction with the port, ensured the city's place as an industrial center. Industrialization increased the population from just over 3,000 residents in 1840 to 115,289 residents in 1914. The rate of population growth has declined significantly with a population standing currently at 147,216 residents. Even after this decreased rate of growth Bridgeport is still the most populous city in Connecticut.

It is located in the southwest region of Connecticut in Fairfield County (Figure 1). Fairfield County is known for being the wealthiest region of the United States, however in recent years Bridgeport has faced economic turmoil with low-income levels of $21,002 per capita, 23% of the population living in poverty and high crime rates *(43)*.

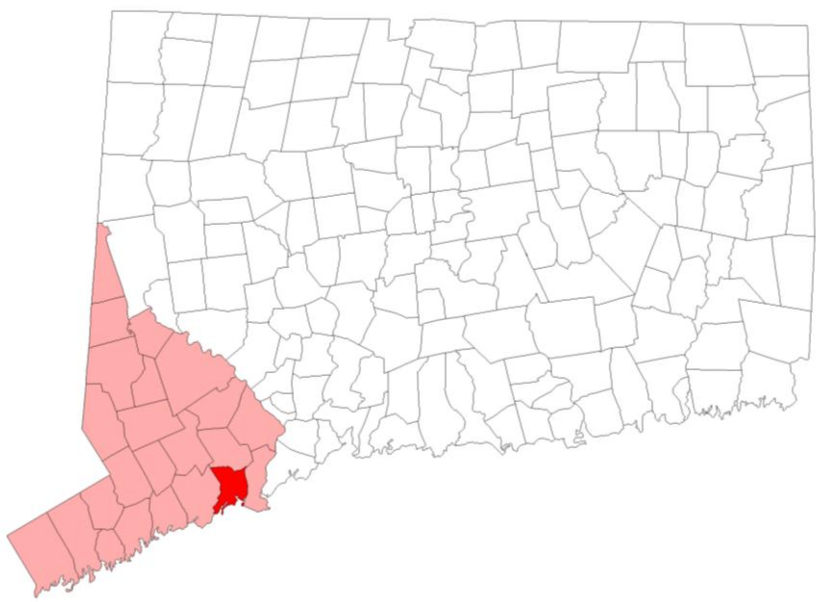

FIGURE 1: Bridgeport's location within Fairfield County

Bridgeport started to slowly accommodate the automobile in the beginning of the 20th century by increasing parking. However the most drastic change in the city started in the late 1950's, after President Eisenhower signed the Federal-Aid Highway Act of 1956. By January 1958, Interstate 95 was completed in most of Connecticut. It was built through much of the existing downtown. Figure 2 shows an aerial photograph of Bridgeport in 1965. The aerial shows how much of the downtown was carved out in order to build the freeway. By 1972, the Route 8/25 segment between Interstate 95 and Trumbull, Connecticut were completed. At this time Bridgeport starts to resemble the present day conditions of the city. Figure 3 is an aerial prior to the opening of Route 8/25 in February 1970. It is also interesting to take note of how the razed land cover in 1965 was replaced by 1970 with large-scale box stores, surrounded by parking.

FIGURE 2: Aerial Photograph of Bridgeport 1965

FIGURE 3: Aerial Photograph of Bridgeport 1970

METHODOLOGY

A database was created that depicted the land cover and land use for both 1913 and 2013 downtown Bridgeport. The 2013 database was created using the 2013 parcel shapefile and a 2016 aerial image. The earliest aerial image available for much of Connecticut was produced in 1934, this was used to georeference Sanborn Fire Insurance maps from 1913. These maps were chosen based on the online availability and high resolution from the University of Connecticut's Map and Geographic Information Center (MAGIC) and Yale University Library's Digital Collections, respectively.

Georeferencing

Over the century of this study, much of the built environment has changed; only twenty percent of the remaining land cover dates back prior to 1913. Due to this limitation an intermediate year was used to georeference the Sanborn maps. The current world imagery basemap in the ArcGIS software was used to georeference the 1934 aerial, as there are more buildings in

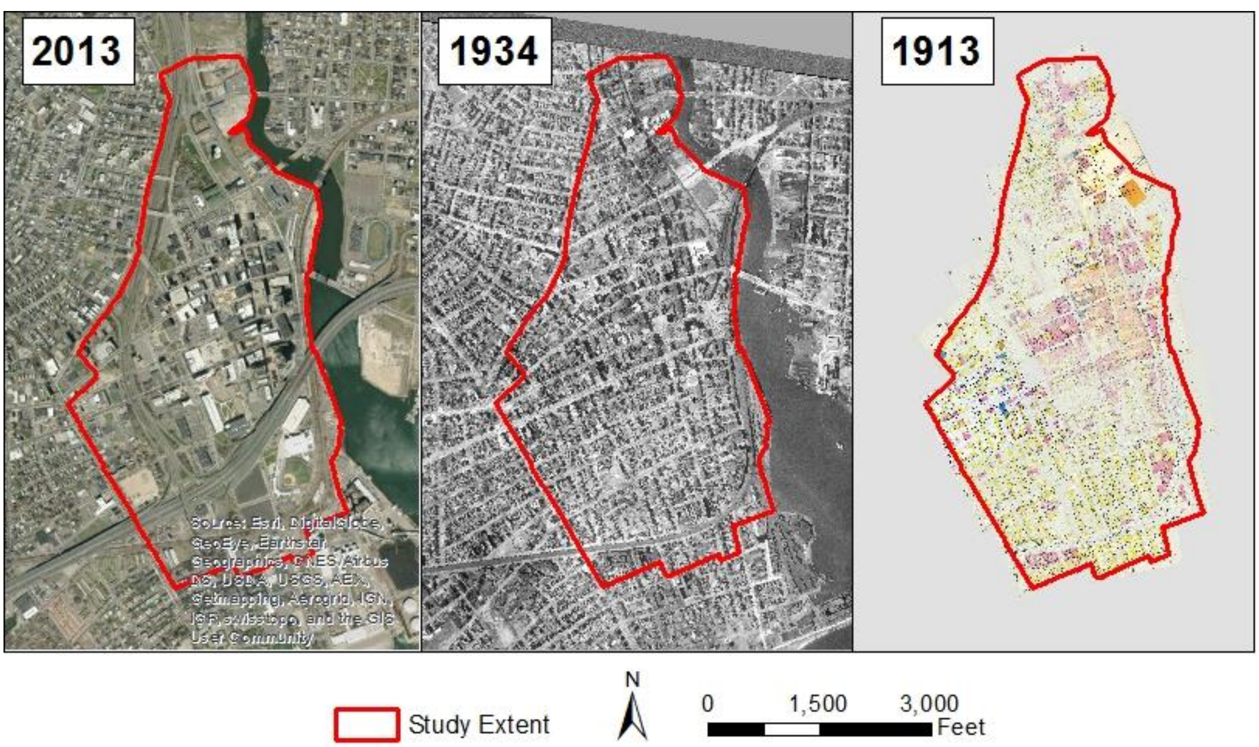

FIGURE 4: Georeferencing progression

common than in the 1913 maps. By picking a point on each map in common the map could be shifted to the correct location. To distribute and orient the map a second point was detected. A third point was used to fine tune, as well as ensure the spatial distribution of the 1934 aerial. In order to georeference the twenty-two maps from 1913 a similar approach was used however the 1934 aerial was used as the point of georeference. Figure 4 shows the study extent of each georeferenced map to scale back to 1913.

Digitizing

1913

After each Sanborn map was georeferenced, every building was digitized by outlining the Sanborn map. Buildings directly adjacent to each other with the same land use and height were combined for simplification purposes. Each sketch includes the land use type as a multitude of categories. Flats, Apartments, and Dwellings were coded as residential properties; Stores, hotels, offices, bakeries, etcetera were coded as commercial properties; Manufacturing facilities were coded as Industrial; Theaters, social clubs, bowling alleys were coded as Entertainment; Churches, Schools, Police Stations, and other Municipal or Exempt type land uses were coded as Municipal/Exempt; Stables, carriage houses, rail, streetcar and automobile structures were coded as Transportation with associated subcategories of automobile, stable, and rail.

A separate attribute was created for the number of stories of the building. Buildings with varying heights were averaged based on proportional area if the differing area was substantial. For example, small porches that were only one story while the entire building was three stories were said to have a height of three stories.

The area of the building footprint was calculated using the “Calculate Geometry” application in ArcMap. Total floor area is generalized by multiplying the building footprint by the number of floors.

2013

A layer of buildings from 2013 was created using the parcel shapefile with associated attributes. Each parcel was edited to the shape of the building footprint using the topographic map baselayer. Parcels without buildings were deleted, however the information associated with them were maintained in a separate parcel file. Attributes of interest, including buildings value, land value, and land-use were checked for accuracy on the tax assessor's online database. This was also done to add the number of stories of each building to the attribute table, as they were not included at the parcel layer.

3-Dimensional Model

ArcScene was used to create a view of the city that represents how a human would see it, unlike aerial maps. To create a 3-D model, the building layer as well as streets and interstate layers were added in ArcScene. The height was used as the extrusion value for each building. The height was determined by multiplying the number of stories by fifteen feet.

RESULTS

Pedestrian Street Network

The pedestrian street network comprises of all streets legally accessible to pedestrians; freeway segments being removed. Figure 5 shows the pedestrian network for both 1913 and 2013.

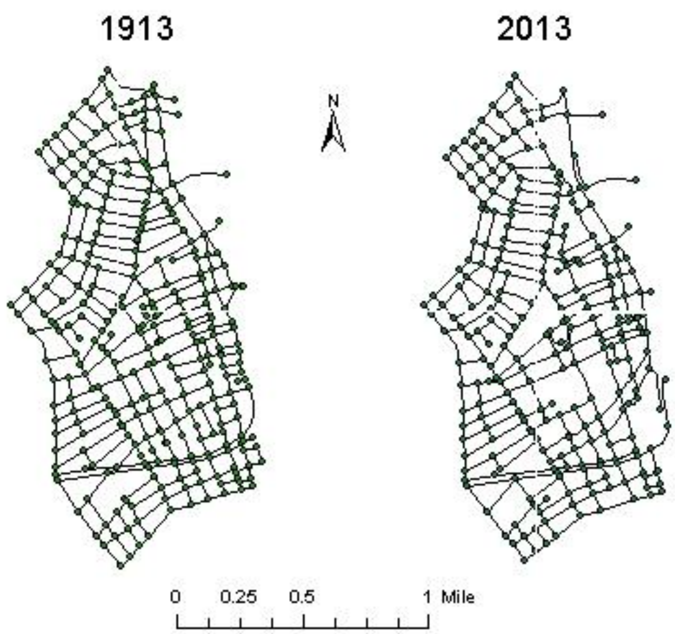

FIGURE 5: Pedestrian Street Network

In the core of the downtown there are visible changes to the street network including the loss of connectivity where the two freeways interchange. Connectivity can be measured in many ways, one of which is intersection density. The downtown intersection density changed from 314 intersections in 1913 to 281 in 2013. In other terms there was a reduction from 258 intersections/mi^2 to 231 intersections/mi^2.

Pedestrian access maps in increments of 5, 10, and 15 minutes are shown in Figure 6. Three locations were picked based on examples of 2013 origins, one in a residential

neighborhood, the second is the Housatonic Community College, and the last is the passenger train station.

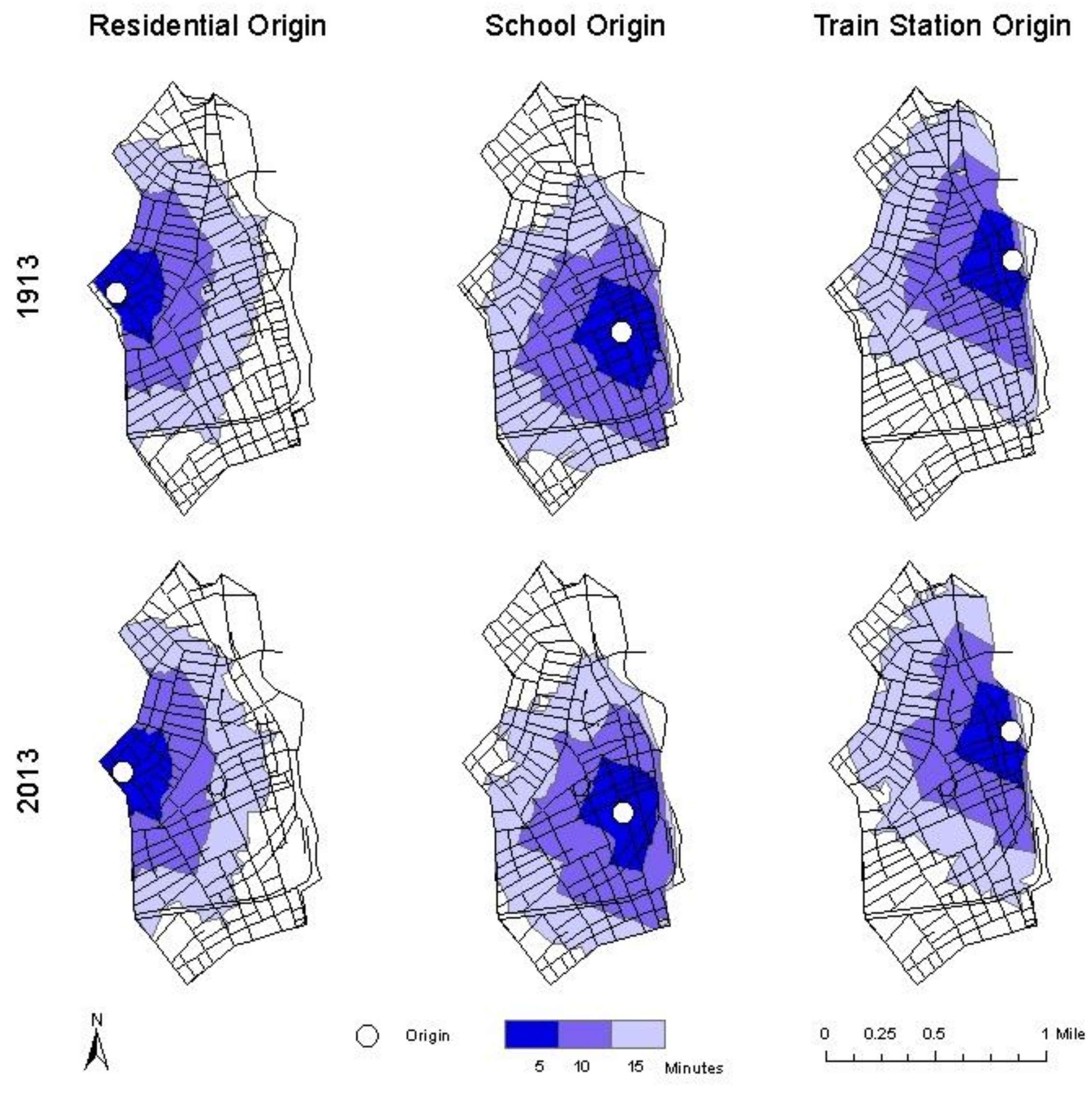

FIGURE 6: 5, 10, and 15 Minute Pedestrian Access Maps

The change in area access changed minimally with a .5% to 11% decrease in service area between the two time periods. However further investigation reveals that even though the access area has decreased minimally the amount and diversity of establishments have been diminished significantly, telling a more compelling story of the walkable nature of the city in 1913

compared to today. Using the 5 minute pedestrian accessibility maps for the train station and school origins, all buildings within the capture area were selected. The residential origin was omitted from this study as it was not contained within the building layer only the street network. Table 1 shows how many buildings with their coordinating land uses that are accessible for each year and origin. From the train station a pedestrian could reach 276 establishments in a 5 minute walk in 1913; today a pedestrian can reach only 28% of what was attainable in 1913. Commercial establishments were reduced to only 22% of what is accessible in 1913 and only 6% of the residences in 1913 are walkable in 2013. The pedestrian access to the school has also significantly changed between 1913 and 2013. One residential building is accessible today while in 1913, 287 residences were within a 5-minute walk of the school. The total buildings accessible in 2013 are only 10% that of 1913 from the school origin.

TABLE 1: Accessible in 5 minute walk

Origin\Land Use Type	Commercial	Industrial	Municipal/Exempt	Residential	Total
1913 Train station	199	33	8	36	276
2013 Train Station	43	3	28	2	76
% of 1913 accessible	22%	9%	350%	6%	28%
1913 School	189	27	18	287	521
2013 School	44	1	8	1	54
% of 1913 accessible	23%	4%	44%	0%	10%

Land Coverage

Investigation into the fine-grained urban fabric shows on first observation of Figure 7, the differences between the two time-periods can be characterized in terms of scale; both building footprint and land use diversity, as well as the drastically different street networks. In 1913, thirty percent of the downtown land was occupied by a building. Over the next hundred years

downtown Bridgeport lost eleven percent of that land cover making only nineteen percent of the land area covered by a building.

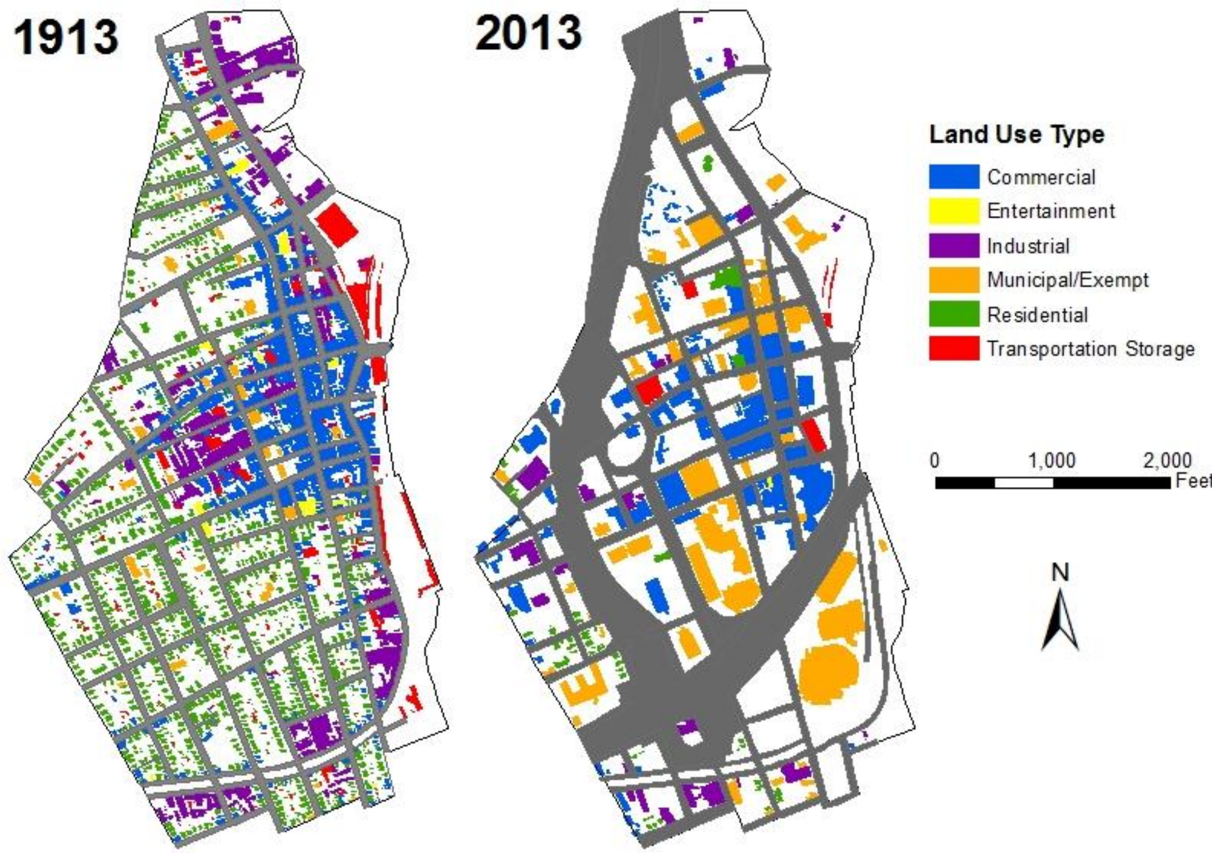

FIGURE 7: Land Coverage by Land Use and Year

Figure 7 shows how the land was covered in 1913 and 2013. In 1913 there is a clear central business district (CBD) where the majority of the commercial buildings are located. However, there are also smaller commercial establishments sprinkled along main corridors of residential neighborhoods. Industrial establishments are also distinctly defined along the railroad tracks, for uninhibited movement of goods. The residential neighborhoods surround the CBD making up 32% of the cover. Commercial covering 32%, Industrial 21% and Municipal/Exempt establishments only covering 4%.

The land coverage in 2013 differs drastically from the composition of the city in 1913. Commercial land, including stores but mainly office buildings makes up just over 1/3 of the land coverage. Municipal and other exempt properties make up nearly 45% of the land coverage today, consisting of multiple courthouses, community college, stadiums as well as others types of properties. Table 2 compares land coverage by land-use type for 1913 and 2013.

TABLE 2: Total Land Area

Land Use Type\ Year	1913	1913 as % of Total	2013	2013 as % of Total
Municipal/Exempt	214,757	4%	1,429,261	45%
Commercial	1,611,273	32%	1,181,716	37%
Residential	1,612,446	32%	161,244	5%
Industrial	1,052,391	21%	309,834	10%
Built Transportation Storage	518,087	10%	109,477	3%
Total	5,008,955		3,191,532	
Total Study Area	16,471,794		16,471,794	
% Land Cover	30%		19%	

Building Footprint

Over the past century the scale of the building footprint has grown up to 4.7 times larger. Table 3 shows the average building footprint for the four generalized land-uses for the two time periods.

TABLE 3: Average Building Footprint Size

Land Use Type\Year	1913 (ft^2)	2013 (ft^2)	Change
Commercial	2,891	10,704	370%
Industrial	6,417	14,083	219%
Municipal/Exempt	4,994	23,431	469%
Residential	1,477	3,583	243%

Figure 8 is a visualization of the change in footprint size over the past century. Overall the building footprint was much smaller in 1913, the largest buildings were industrial land-uses and the smallest were residential buildings. In 2013, municipal/exempt buildings grew two-thirds larger than industrial buildings, with the average municipal/exempt building footprint expanding over 23,431 ft^2.

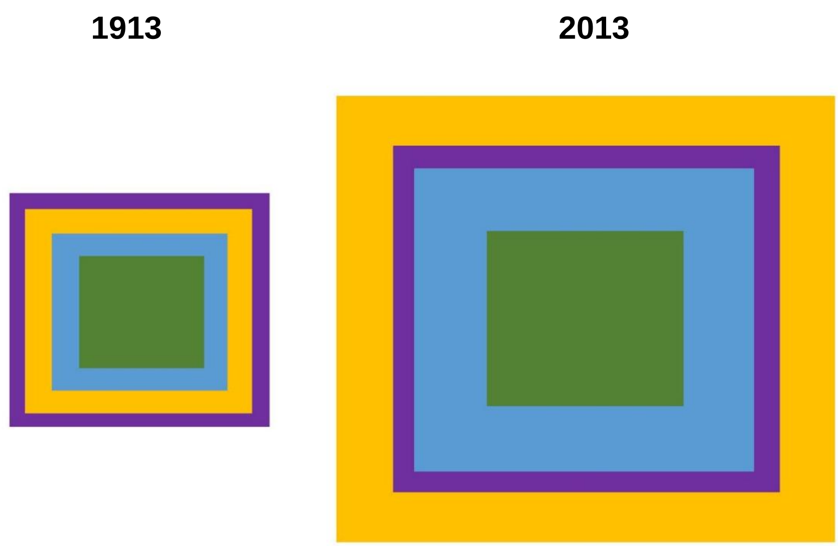

FIGURE 8: Visualization of Average Building Footprints

Figures 9 and 10 are histograms showing the distribution of the areas of building footprints.

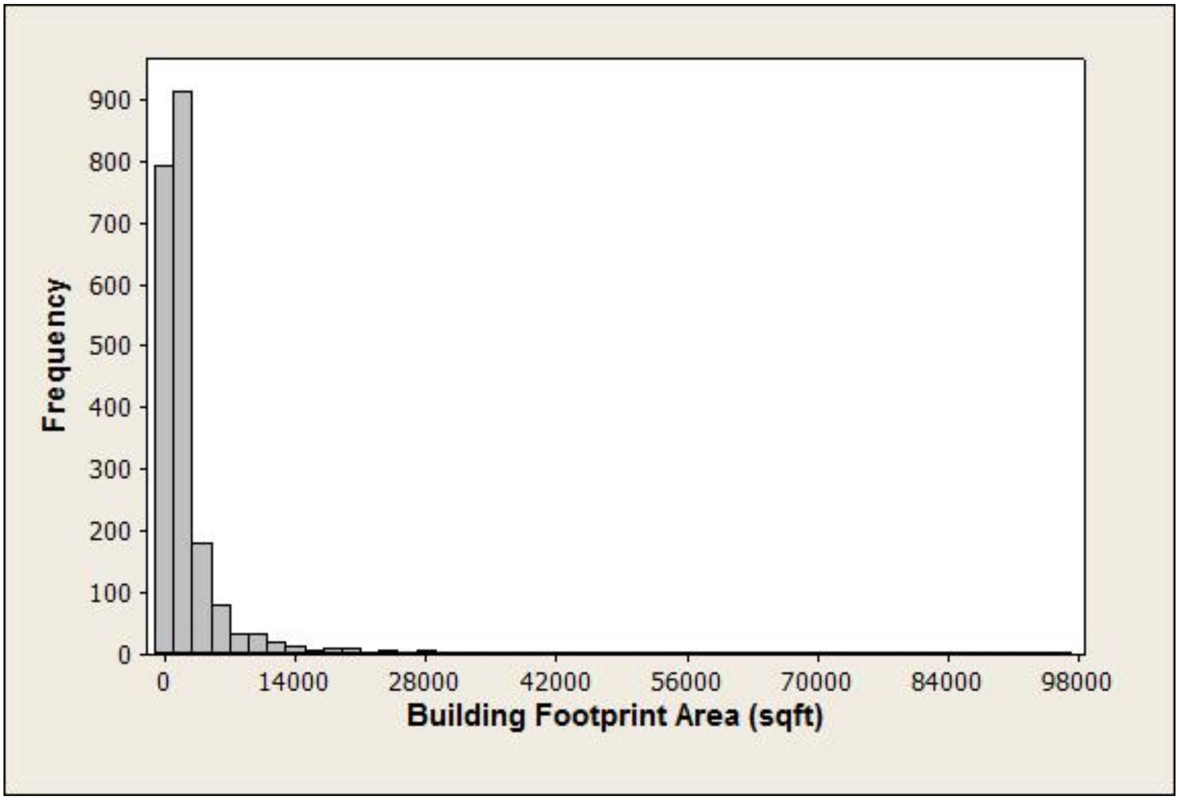

FIGURE 9: Building Footprint Distribution in 1913

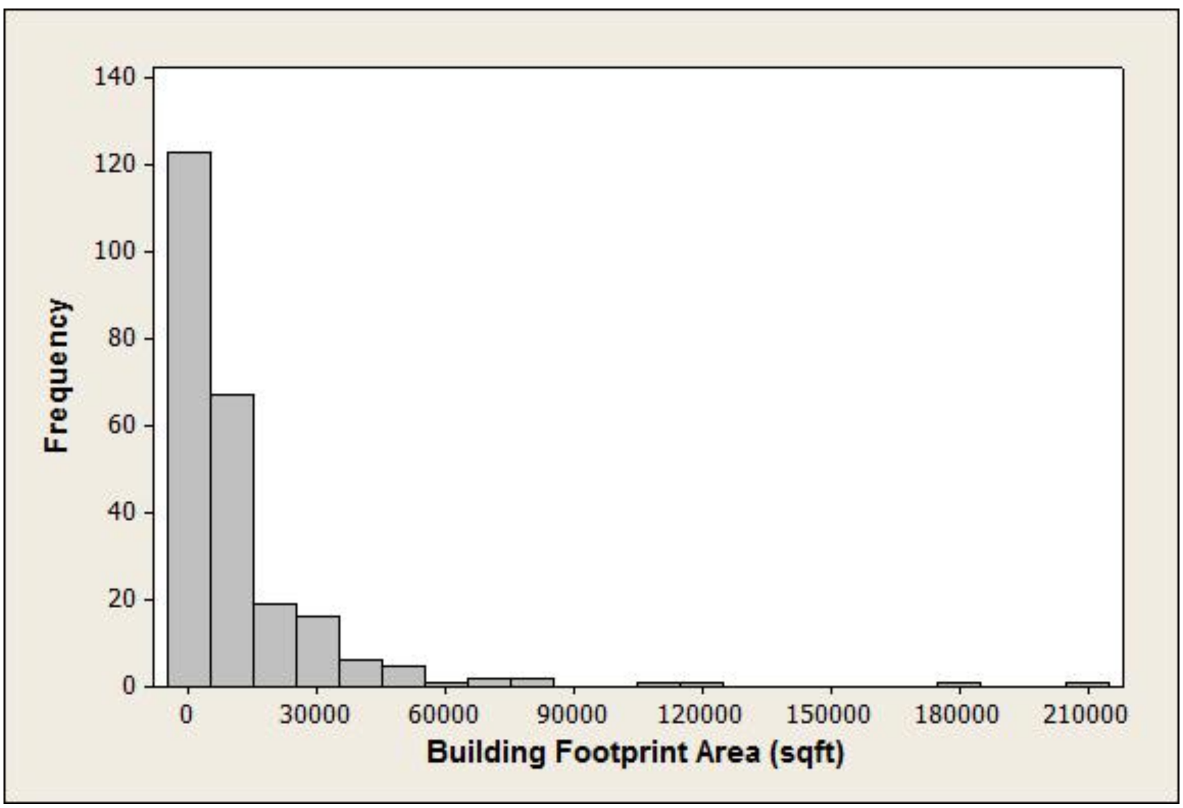

FIGURE 10: Building Footprint Distribution in 2013

Building Heights

Not only was there a drastic shift to larger building footprints, but the heights of buildings increased as well. Table 4 shows the change in building height per land use for both time periods. The most significant change was in residential buildings, rising up 41% higher today than they were in 1913. Commercial buildings also grew 38% taller than commercial buildings in 1913. Overall buildings are 41% on average taller than the buildings in 1913. Figure 11 visualizes the change in building heights.

TABLE 4: Average Building Heights

Land Use Type\Year	1913	2013	Change
Commercial	2.34	3.23	138%
Industrial	1.97	2.23	113%
Municipal/Exempt	2.12	2.61	123%
Residential	2.07	2.91	141%
Overall Building Change	2.08	2.93	141%

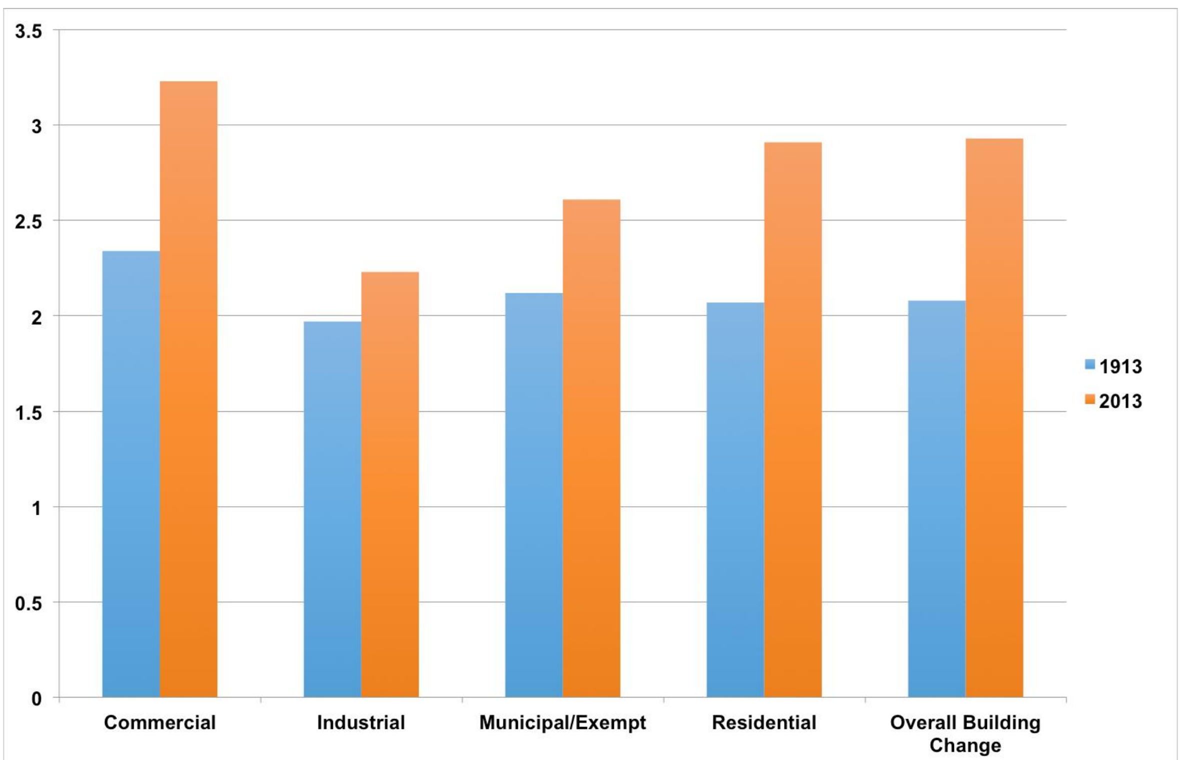

FIGURE 11: Average Building Height by Land Use and Year

Gross Floor Area

The gross floor area for each building was estimated using the building footprint areas and the number of stories. By calculating the gross floor area, a more realistic land-use allocation could be compared. In Figure 12, the proportions of total floor area are shown. There was a drastic change in residential floor area housed in the downtown over the past century. It reduced from 34% to 6% of the total gross floor area, a shift to the balance of work and residential land uses. Municipal and exempt buildings increased from 4% of the total gross floor area to just over a third of the floor area.

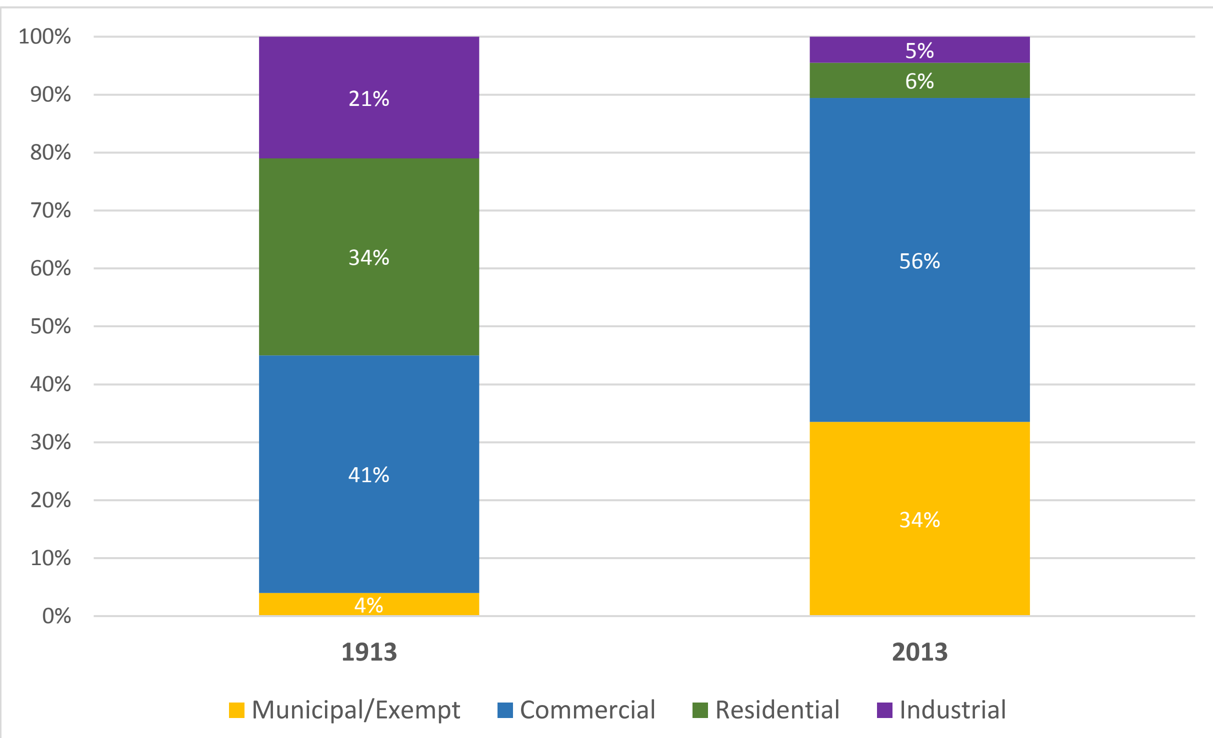

FIGURE 12: Gross Floor Area Proportions

Another benefit to creating databases that include both number of stories and spatial characteristics of each building is the capability in making three-dimensional models of the city, a useful comparison visual. Figure 13 is a three-dimensional representation of how the city looked in 1913 and Figure 14 of 2013. Both are approximately the same view looking north.

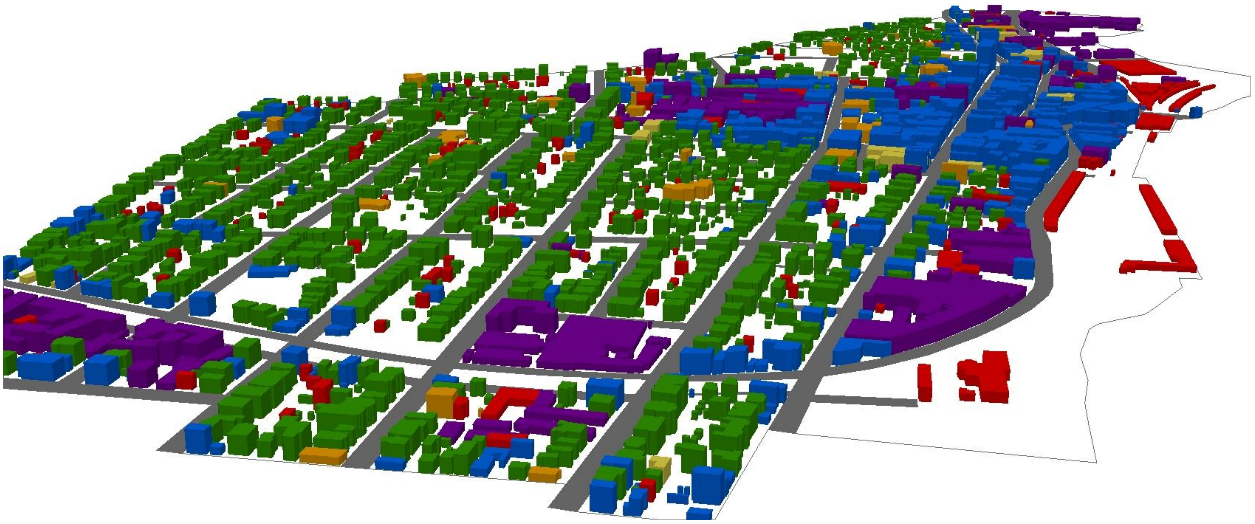

FIGURE 13: Three-Dimensional Model of 1913 Downtown Bridgeport

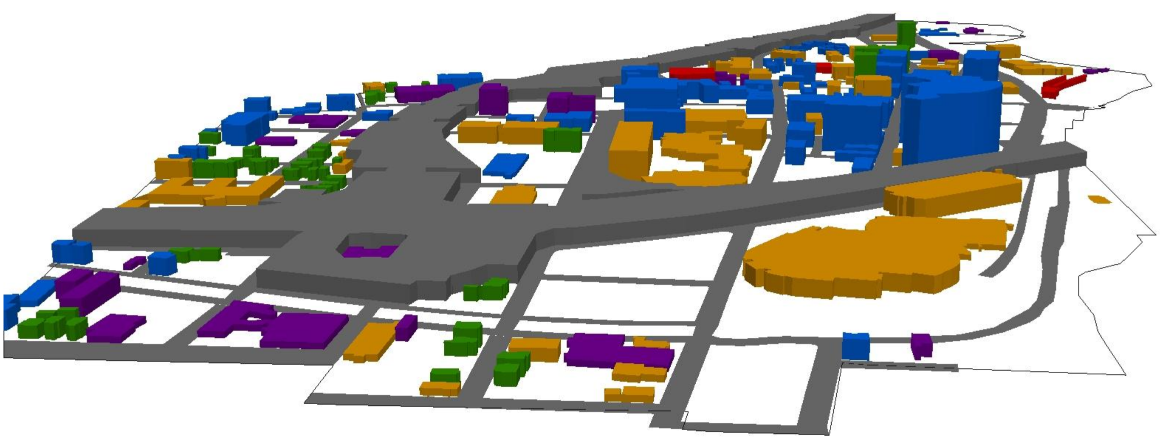

FIGURE 14: Three-Dimensional Model of 2013 Downtown Bridgeport

DISCUSSION

In the century since the advent of the affordable automobile, many cities have been reconfigured in a multitude of ways. Not only has there been an increase in parking and roadways but the urban fabric has been completely altered. Downtown Bridgeport, Connecticut has seen the footprint of buildings increase by a factor of 4.7 and heights increase by 41% over a 100 year time period. The overall scale of the buildings has rapidly increased in the comparatively short existence of the automobile to the human. Buildings are no longer at a human scale.

The underlying street network has not changed enough to significantly affect the accessible walking area, however the density and diversity of this walkable area has significantly changed. A pedestrian leaving Housatonic Community College today can reach a mere 10% of establishments that a 1913 pedestrian could reach in 5 minutes. This complete loss of density has greatly disrupted the walkable nature of the downtown.

The passenger train station has remained in the same location over the last century however the accessible businesses have not. A pedestrian arriving at the train station in 1913 can have 199 commercial, 33 industrial, 8 municipal, and 36 residential establishments at their fingertips in under a 5-minute walk. Today, pedestrians can only access 43 commercial, 3 industrial, 28 municipal and 2 residential establishments in the same amount of time. By reducing the density and diversity of the urban fabric the city is reducing the likelihood of a person exploring their city using a train or other vehicle less mode. Density and diversity of land uses create a city people want to live, work and play without having to own an automobile.

CONCLUSION

The urban activist Jane Jacobs wrote:

> *"Borders can thus tend to form vacuums of use adjoining them. Or to put it another way, by over simplifying the use of the city at one place, on a large scale, they tend to simplify the use which people give to the adjoining territory too, and this simplification of use—meaning fewer users, with fewer different purposes and destinations at hand—feeds upon itself. The more infertile the simplified territory becomes for economic enterprises, the still fewer the users, and the still more infertile the territory. A kind of unbuilding, or running-down process is set in motion (41, p.259)."*

Jacobs saw how the single use of the automobile would continue to wreak havoc in her 1961 novel, *The Death and Life of Great American Cities*. Borders by all definitions and types perpetuate cities into noncomplex, infertile economical disasters. The obvious solution for cities to revive themselves is by removing borders that weaken their ability to create a vibrant and livable environment.

The research set forth in this thesis identifies and quantifies the borders cities have created in terms of transportation and land use. A significant barrier in many cities are limited access freeways, the freeways in Bridgeport, Connecticut make up more than 1/5 of the downtown land area, land that could be used towards tax producing uses. Off-street parking creates barriers of single-use storage that makes pedestrians feel uncomfortable *(41)*. Off-street parking makes up 20 to 23% of land cover in auto-friendly cities while walkable, vibrant cities only allocate 4 to 9%.

Further investigation into changes Bridgeport has made since the advent of the automobile reveals a startling difference in diversity and density of land-uses. Prior to the widespread use of the automobile there were equal proportions of land devoted to commercial and residential uses. In contrast, today there are very few residential properties in the downtown and municipal and exempt buildings out number residential properties nine to one.

Successful cities have been defined by low poverty levels, high percentage of citizens with higher educations, high-income levels, good environmental health as well as many other metrics. Cambridge, Massachusetts boasts many of these characteristics and is commonly said

to be a very successful city. Cambridge has minimal parking provisions, no limited access freeways, and a dense, diverse urban fabric; characteristics they also have in common with the 1913 City of Bridgeport. These characteristics have proved to increase the walkable and livable nature of a city. Much of what those studying cities can learn about being successful starts with looking into the past and avoiding barriers that suppress the exchange of ideas.

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