Carbon Culprits:

Identifying Urban Design Elements that Influence to Carbon Emissions

Introduction

This investigation serves to find a correlation between urban elements and carbon emissions in a major metropolitan area, using New York as an example. The United Nations (UN) estimates that urban areas account for 60 to 80% of global energy use and are the source of 70% of greenhouse gases. Today while roughly 54% of the world's population lives in cities, by 2050 the number is expected to increase to 80%. The UN predicts that there will be as many as 41 metropoles (cities with 10 million inhabitants or more). While urban centers emit large amounts of greenhouse gases, in terms of amounts emitted per capita the number is much lower than people who live in rural and suburban areas. For this investigation six parameters of the urban fabric will be analyzed: block area, block perimeter, distance to public transit, car ownership per capita, residential density, and floor area ratio (lot coverage).

Information was obtained from surveys conducted by the Center for Neighborhood Technology (CNT) on urban areas. The data was obtained at the level of census tracts in the New York metropolitan area. The US Census Bureau was the source the shapefiles of the 13 counties that compose the metropolitan area. The shapefiles were merged and clipped accordingly to construct a base map for the metropolitan area. The base map presented over 15,000 census tracts where data could be filled in.

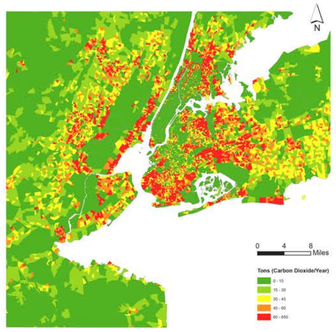

Figure 1. Average Carbon Dioxide Emissions per Census Tract

CNT provided different parameters which were overlaid on the base map. Since carbon emissions were the major point of comparison, the figures presented by the CNT were separated into their various components. Elements such as amount of carbon dioxide in terms of tonnage were mapped on the first base map (Figure 1.) This number was then divided on excel by the amount of people living in each tract to provide a figure for the second map showing carbon emissions per capita (Figure 2.).

Methodology

In terms of block size and block perimeter, the CNT database provided sufficient data from each of the census tracts. Two parameters of calculating block size were used, block perimeter and block area. These two parameter were mapped independently on the base map (Figure 3 and 4 respectively) to create an illustration of the locations of tight urban blocks. For transit, CNT provided figures on average car ownership, these were rounded and joined with the base map (Figure 5.). In terms of urban density, surveys on residential density and lot coverage were overlaid on Figures 7 and 8 respectively. The information in figures 3 – 8 were organized according to quantiles. Each data layer was also organized via symbology by color gradient. Afterwards, information was compiled from the Metropolitan Transportation Authority (MTA) and the New Jersey Transit (NJT) lines. Line shape files were overlaid on a base map. Using the buffer tool, analysis was provided to show transit accessibility in terms of walking time.

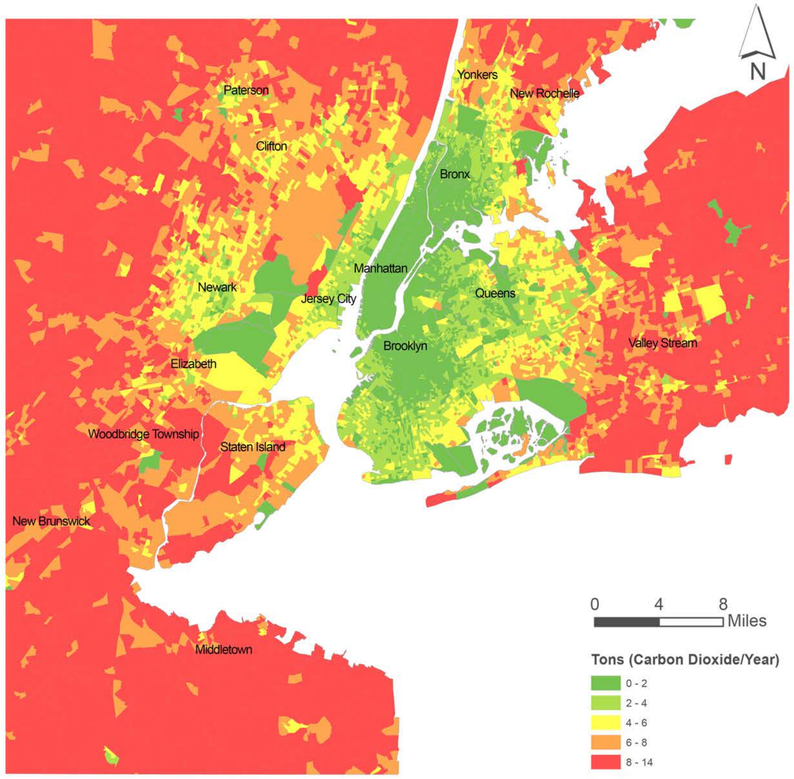

Figure 2. Average Carbon Dioxide Emissions per Capita n the New York Metropolitan Area

CNT provided different parameters which were overlaid on the base map. Since carbon emissions were the major point of comparison, the figures presented by the CNT were separated into their various components. Elements such as amount of carbon dioxide in terms of tonnage were mapped on the first base map (Figure 1.) This number was then divided on excel by the amount of people living in each tract to provide a figure for the second map showing carbon emissions per capita (Figure 2.).

Results and Limitations

The New York metro area is part of a larger network of development along the northeastern section of the United States the (Bos-Wash Corridor), however, for purposes of highlighting differences between the practices of block size in urban and suburban developments only the New York-Newark area was used. Further analysis in the analyzed correlations are open for continuation with cities that connect to the area studied: Philadelphia, New Haven, Trenton etc.

This investigation used data from 2010, however since then several developments have occurred in the metro area. In Manhattan for instance, parts of Broadway were closed purely for pedestrian traffic. As a result the term street no longer applied for these parts, increasing block sizes along the thoroughfare. Additionally new developments in Midtown have added thoroughfares. For this survey, the term block was defined as an area surrounded by car traffic, however based on the investigations of walkability, these terms are open for revision, with block sizes recalculated to incorporate the presence of changed thoroughfares that still exhibit the characteristics of other streets. Furthermore, walkways and other pedestrian bypasses should be included in the definitions of blocks. Further analysis is open in these areas as well.

The investigation also showed limitations in the analysis of the public transportation systems, with transit lines selected only from the MTA and the NJT. Additional service such as Amtrak trains and community bus lines were not explored and are open for additional analysis on the map. The investigation also used distance from the transit lines, however some stops along these routes may be distant, and thus a more appropriate analysis would involve immediate distance to transit stops only.

Sources:

Census Tracts: Tiger Line Shapefiles for New York, New Jersey and Connecticut (accessed on census.gov)
MTA Transit Lines: Subway and Bus Data (accessed on gc.cuny.edu)
NJT Transit Lines: New Jersey Geographic Information Network Vector Data (accessed on njgin.state.nj.us)
Survey Data: Housing and Transit Affordability Index for New York-Newark-Jersey City, NY, NJ, PA (htaindex.cnt.org)
Bottom Image Credit: Matt Flaschen

References:

1. Information: United Nations. "World's population increasingly urban with more than half living in urban areas." http://www.un.org/. Last modified July 10, 2014. Accessed June 28, 2016. http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html.
2. Jones, Christopher and Kammen M., Daniel. "Spatial Distribution of U.S. Household Carbon Footprints Reveals Suburbanization Undermines Greenhouse Gas Benefits of Urban Population Density."Environmental Science and Technology, 2013, 1-12. https://rael.berkeley.edu/wp-content/uploads/2015/04/Jones-Kammen-EST_proof-NationalCarbonMap.pdf
3. Chen, Siqing, and Robert H. Crawford. "Modeling the carbon footprint of urban development: a case study in Melbourne." Living and Learning: Research for a Better Built Environment: 49th International Conference of the Architectural Science Association 267, no. 277 (2015).

Cartographer: Sebastian Torrente
Developed for: CEE187A Tufts Engineering
Date produced: July 30, 2016
Projection: NAD1983

Tufts UNIVERSITY

Urban Design Elements

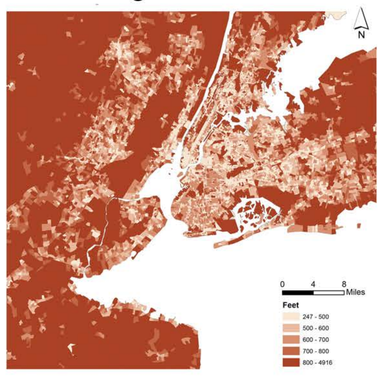

Figure 3. Average Block Perimeter per Census Tract

Compared with the two carbon emission maps Figure 3 shows the correlation with block perimeter is observed in the historic urban areas of Lower Manhattan and Downtown Brooklyn. Unlike the block area map, the measured block perimeter tends to be more present in the Newark and Paterson areas. This may be due to differences in the changes of blocks as much of the New Jersey area is laid out irregularly. Overall the correlation between small blocks and low carbon emissions provide design guidelines for architects and urban planners for lower emissions.

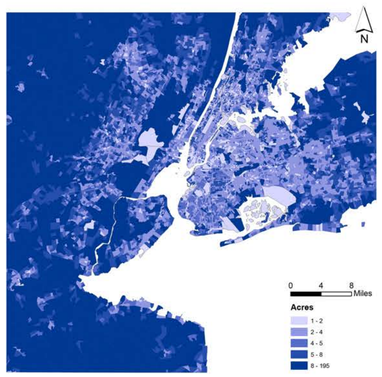

Figure 4. Average Block Area per Census Tract

Compared to the carbon maps, Figure 4. shows a correlation with both carbon emissions maps, as the smaller block areas concentrated in Manhattan and Brooklyn tend to be the sites where the least emissions are present. Correlating with the second carbon map, as block sizes increase in rural areas, more carbon is emitted per capita. Exceptions to this correlation include parts of Queens and Newark where relatively high amounts of carbon are emitted. Carbon emitted in these areas may be subject to other parameters.

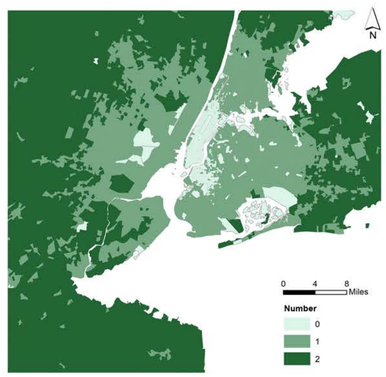

Figure 5. Average Cars per Capita per Census Tract

Comparing Figure 5. with the data on carbon emissions reveals a strong correlation in both. In the amount of carbon emitted levels are at their highest in the immediate surrounding suburbs with an average of 1 car. Carbon emissions decrease farther out even though the average number of cars per household becomes 2. While this may appear illogical, the carbon emissions per capita completes the story. Carbon dioxide emissions per person increase with the same amount gradient as the number of cars owned.

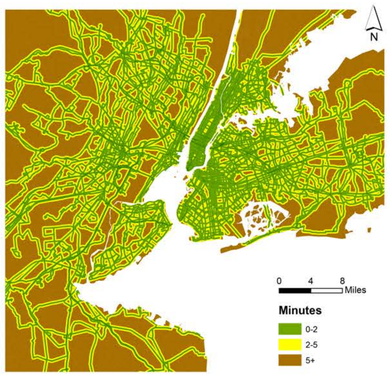

Figure 6. Average Distance to Public Transit Lines

Comparing Figure 6 to the carbon emissions map reveals that areas with complete access to public transit (2 minutes or less) again correlate more strongly with the least amount of total carbon emitted and carbon per capita. These areas include Manhattan, Downtown Brooklyn, Downtown Newark and sections along the Grand Concourse in the South Bronx. As more yellow opens up there appears to be more tendency to for car ownership, as identified in the previous map. Similar to cars per capita, the trends appear to correlate with more yellow opening up in the suburbs leading to no public transit access at all. Both figures reveal that immediate access to public transit is an important factor in determining car ownership and the higher its quantity the lower emissions are.

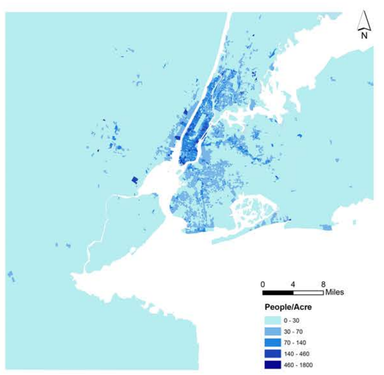

Figure 7. Average Residential Densities per Census Tract

Comparing the results with the carbon per capita Figure 7. shows there is a strong correlation in the more urban areas of New York City, Manhattan and Downtown Brooklyn. Other areas stand out in terms of residential density, include parts along Queens Boulevard. From the previous analysis of public transit lines it is shown that residential densities are at their highest in locales that have immediate access to public transportation. Thus these areas correlate with the carbon emissions map showing that areas with the highest residential densities have lower emissions.

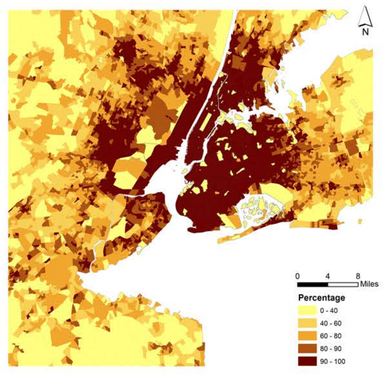

Figure 8. Average Floor Area Ratios per Census Tract

Figure 8 reveals a correlation with carbon emissions per capita. The extent of the yellow areas in the carbon emissions data appears to be very similar with the extent of the burgundy in the floor area ratio analysis. Areas that don't agree are again green spaces. The outline of the areas with yellow or little to no lot coverage agree with the red in the carbon dioxide per capita analysis. The overall study of density analysis reveals that lower emissions are present where residents closely share space and resources. It also serves as a guideline for urban designers when planning cities, by incorporating developments with complete lot coverage and consistent densities similar to those present on the map (over 70 people per acre).