A brief look at urban transportation

S. Sabina Wolfson, Intro to GIS Final

Introduction

In this paper we will consider transportation choices in New York City (NYC), the District of Columbia (DC), Chicago, and Boston. These cities were chosen since they have the largest subway/elevated systems (by ridership) in the US. After considering how these transit systems relate to transportation choices, we will briefly consider – at a gross level – transportation trends over time in the US and transit usage throughout the world.

Three of these systems (NYC, Boston, and Chicago) are very old, primarily constructed in the *pre-car-era* while the fourth system (DC) was constructed in the *car-dominated-era*[1,2]. Thus, we can consider how transportation choices relate to the generation in which mass transit is built. The general idea is as follows. Since the introduction of automobiles, the number of automobiles owned and the miles traveled in those automobiles has been steadily increasing while mass transit ridership has been decreasing.[3] This trend has implications for density since successful mass transit requires high-density development[4], whereas automobiles inherently require a great deal of space (parking at a residence, parking at a destination, and while driven on the street or highway) and thus enforce low-density development.[5] We will return to this discussion later (in the *Transit usage over time in the US* section).

The subway/elevated systems we are going to consider – the NYC subway, the DC metro, the Chicago "L", and the Boston subway – are shown in Figure 1 (four inset panels). All systems are shown at the same scale. The location of each system is shown on the map of the US in the upper-right corner of the figure. The older systems (Chicago, Boston, and NYC) are bigger than the newer system (DC), but clearly the NYC system dominates all the others in terms of tracks. Before proceeding with the analysis, let us establish some history and facts regarding each of the systems.

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[1] By *pre-car-era* I mean before the automobile became a significant mode of transportation (roughly 1940s). The time after this I refer to as the *car-dominated-era*.

[2] The San Francisco rapid transit system, BART (Bay Area Rapid Transit), is another system constructed in the car-dominated-era. San Francisco has some interesting qualities that will be discussed later. I would like to have included BART in all the analyses, but could not find all of the necessary data.

[3] This trend of increasing car use and decreasing transit use is not limited to the US, but is exemplified by the trend in the US. For example, while about 2% of urban trips are made in the US via public transit, over 20% of urban trips in Italy are made via public transit (Institute of Transportation Engineers, 1999, Table 13-1.). Transit throughout the world will be briefly discussed later in the *Transit usage throughout the world* section.

[4] This is particularly true for rail transit given the inherently fixed nature of the tracks. Bus rapid transit (BRT) does not have this problem to the extent that rail transit does, but BRT has had limited success. BRT often has relative low ridership, is not very rapid, and is not cheap to implement or maintain when done well. However, a few BRT systems – such as that in Curitiba, Brazil (see Cervero, 1998, Chapter 10, for details) – are very successful.

[5] For details of this argument with a pro-car slant see Dunn (1998). For details of this argument with a pro-transit slant see Vuchic (1999).

NYC Subway[6] (Metropolitan Transportation Authority)

The majority of the NYC subway was built by the 1940s. The first NYC subway line was opened in 1904 by the IRT (Interborough Rapid Transit Company). During the next 20 years the subway expanded under the IRT and BMT (Brooklyn-Manhattan Transit Corporation, formerly Brooklyn Rapid Transit Company). Both the IRT and BMT were private companies. The city entered the subway-building business in the 1920s as the IND (Independent Subway System). In the 1940s the city took over the bankrupt IRT and BMT lines, resulting in a slow unification of the subway system (and the closing of the remaining old elevated lines in Manhattan). Some subway construction continues to the present day, but the construction has not created connections into significant new areas. (Source for above paragraph: Hood, 1993.)

DC Metro (Washington Metropolitan Area Transit Authority)

The DC metro began operating in 1976 with continued major construction in the 1980s and 1990s. Like other new systems, most notably BART, the degree of automation is higher than in older systems. In addition, "suburban" type features, such as park-and-ride lots play a larger role. (Sources for above paragraph: Gray & Hoel, 1992, and www.wmata.com.)

Chicago "L" (Chicago Transit Authority)

The Chicago "L" is, as the name implies, an elevated system. The first "L" opened in 1892, and the majority of the system was built by the 1920s. Many cities, such as NYC, built elevated systems in the late 1800s but Chicago is the only city in North America that still has elevated service into the downtown business district. Interestingly, the "L" was built through alleys rather than over city streets due to an unusual Illinois statute. (Source for above paragraph: Cudahy, 1995.)

Boston Subway (Massachusetts Bay Transportation Authority)

Boston's first subway line opened in 1897, making it the first subway line in North America. It was also the first mass transit system to use a great deal of public money. (This was unusual since transit was considered to be a private, for-profit enterprise.) A significant portion of the subway system was built by 1930. (Source for above paragraph: Cudahy, 1995.)

[6] While the Staten Island Railroad is included on the MTA's official NYC subway map, we will not consider it further here since it is not contiguous with the rest of the subway. The transportation mode that dominates Staten Island is the automobile.

Journey-to-work by mode

The transportation data we will consider is from the US Census Bureau's Summary File 3 (2000) *Means of transportation to work for workers 16 years and over* category[7]. Since trips to work are the majority of the trips made in transit systems, these values are a reasonable estimate of relative usage. Figure 2 shows the census tracts around each of the four subway/elevated systems. This is the smallest geographical unit for which the data is provided in Summary File 3. This scale should be kept in mind when considering the following maps.

Journey-to-work data for each of the subway/elevated systems is shown in Figure 3. As would be expected, usage is generally higher near the subway/elevated lines. However, this trend is slightly less clear around the DC metro than around the other systems. Given that the DC metro was built during the car-dominated-era, it is reasonable that it would not have had as significant an impact in shaping the environment. However, in terms of overall usage, it is *not* the case that the newer system (DC) looks different than the older systems (Chicago, Boston, and NYC). In terms of overall usage, the NYC subway is clearly the oddball with massive usage in comparison to the other systems. Figure 4 shows the population density around these systems[8]. The oddball is, again, NYC, not DC. It appears that the correlation is less between age-of-system and usage than between population-density and usage.

We can be more general and consider journey-to-work data for all modes of public transportation (Figure 5). The usage is similar to that shown for the subway/elevated system (compare Figures 3 and 5, but note that the class ranges are not the same), but some of the space between the subway/elevated lines is now "filled in". Not surprisingly, much of this "filled in" space is due to bus ridership as shown in Figure 6.

To get a clearer picture, we can consider the various modes of public transportation in a select area (using the same class ranges across all modes). Figure 7 shows each mode for the Boston area (chosen for no particular reason). This figure shows that the bus usage and the subway usage complement one another – bus usage is generally high in areas not well serviced by the subway. It is also apparent that streetcar, ferry, and taxi usage play a minimal role. As one might expect, railroad appears to play a role in longer-distance transportation. This is confirmed by looking at railroad usage across all the systems as shown in Figure 8. Except in the case of DC, railroad use is clearly for transportation from more distant parts of the cities (presumably into the city centers).

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[7] Within this category (P30) are sub-categories (sub-sub-categories): Car/truck/van (Drove alone, Carpooled), Public transportation (Bus/trolley bus, Streetcar/trolley car, Subway/elevated, Railroad, Ferryboat, Taxicab), Motorcycle, Bicycle, Walked, Other means, and Worked at home. Data were obtained from the U.S. Census Bureau using DataFerrett. These data were joined to TIGER files for each county obtained from www.esri.com. Mapped data are normalized by the population in P30 – or sub-category or sub-sub-category – as appropriate.

[8] Population for each tract normalized by the tract's land area.

Before considering the automobile's role, we will consider "green" transportation. Figure 9 shows journey-to-work data via walking and bicycling. These modes are used a reasonable amount of the time in the city centers where journeys are most likely to be short. There are also isolated patches of high usage outside of the city centers. Are these patches special? Looking at NYC, the four dark patches in the Bronx (clockwise starting at the furthest north-west patch) are Fordham University, Jacobi Hospital and Bronx Municipal Hospital Center, Ferry Point Park, and the Hunts Point Market. The tracts with the university and hospitals have reasonably high populations (4011 and 3801, respectively) and it seems reasonable for many people to walk/bike to work – i.e., live very near work – in such places. The Hunts Point Market tracts are a bit surprising – why would market workers in particular live near their place of work? – but the population of both tracts combined is only 546 so this does not represent all that many people (though it is still intriguing). The tract around Ferry Point Park has a very low population (371). (Also, looking at the dark tract very far to the east in Queens, we again find a park, Cunningham Park, with a very low population of 56). From this small sample, it seems the obvious is true: many people walk/bike to work in dense uniform areas (universities, hospitals, etc). Other areas that appear to have a high proportion of people who walk/bike to work simply have very low population (such as tracts dominated by parks). Moving on from these green modes, we next consider the ubiquitous un-green mode: the automobile.

Automobile usage is massive. Figure 10 shows journey-to-work data via car/truck/van. Use of this mode clearly increases with distance from the city center (which is generally the same as saying it increases with distance from mass transit lines, or saying it increases as population density decreases). NYC has a significantly larger area of low automobile usage, but it also has a much larger subway system with higher usage (see Figure 3) and a much larger area of high population density (see Figure 4) than Chicago, Boston, or DC.

A brief digression. Consider NYC. Before NYC had a subway (or the old elevated lines) it was effectively impossible for someone to work in downtown Manhattan and live in, say, the Bronx – the travel time was too great. ("Before [the subway] routes opened, the Bronx was mostly fields and farms. By the 1920s, it was one of the fastest-growing counties in the United States."[9]) As mass transit lines were built, population spread out along the lines, establishing high-density land use. This should be the case for Chicago and Boston too, give that these systems were also built in the pre-car-era. On the other hand, the DC system was built in the car-dominated-era, so land use had already been established. So why do the Chicago and Boston data resemble the DC data more than NYC data? Or, to turn the question around, why does the DC data resemble the Chicago and Boston data? As stated before, the use of mass transit correlates with population density, but this does not establish a causal relationship. I do not propose to answer to these questions but will discuss them further below (in the *Transit usage over time in the US* section). Now we will return to considering the automobile and find another little puzzle.

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[9] Burns, Sanders, and Ades (1999), p307.

It is interesting to separate the journey-to-work data via car/truck/van (Figure 10) into two sets: journeys driving alone and journeys in a carpool. The driving alone data are shown in Figure 11 and this looks much like the overall data (compare Figures 10 and 11, but note that the class ranges are not the same). The carpool data are shown in Figure 12 and look very different. To try to understand this better, we can consider a single location and plot all the data with the same class ranges. The data for Chicago (chosen for no particular reason) are shown in Figure 13. While it is clear that most of the automobile journeys are *not* in carpools (or motorcycles), carpool usage is more intense towards the city center, the inverse of the drove-alone data. Why might this be? It could be that this just reflects population density (that is, population density decreases away from the city center, so there are fewer nearby persons to carpool with). It might also reflect the movement of jobs from the city center to the suburbs (that is, persons living away from the city center might *not* work in the city center but in other suburban areas). Neither of these explanations is particularly persuasive.

Next we will briefly look at journey lengths (in terms of time). Shown in Figure 14 is the average travel time to work for all modes[10]. There is some tendency for journey lengths to be greater the more distant they are from the city centers, but the trend is not very strong. This makes sense since (i) people will try to minimize journey time by changes in residence location or job location or mode of transportation and (ii) as more jobs appear in the suburbs journey times for people living and working in the suburbs can be shorter. (NYC again appears to be the oddball with the highest number of areas in the long travel time categories. Do these represent long subway journeys?)

We can also consider travel times by mode[11]. The data for DC (chosen for no particular reason) are shown in Figure 15. Clearly most journeys to work take less than 45 minutes and most journeys – particularly the very short ones – are *not* via public transportation. Given that taking public transportation can add significant time at both ends of the journey (getting to the transit stop, waiting for the transit vehicle, and getting from the transit stop to the destination), whereas private automobiles (often) only add significant time at the destination end of the journey (parking and getting from the parking to the destination), it should not be surprising that public transportation usage peaks in the 30-44 minute range whereas *not* via public transportation usage peaks in a shorter range (in the less than 30 minute range).

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[10] These values were calculated using the P31 variable (*Travel time to work for workers 16 years and over*) which is broken down into the following intervals: less than 5 min, 5-9 min, 10-14 min, … 40-44 min, 45-59 min, 60-89 min, 90 or more min. Ignoring the 90 or more min interval, the midpoint of each of the other intervals was used as an estimate of travel time, and these values – weight by the number of journeys in each interval – were summed and normalized by the population in P31.

[11] These values are from the P32 variable (*Travel time to work by means of transportation to work for workers 16 years and over who did not work at home*) which is broken down into the intervals shown on the map. Values are normalized by the population in P32.

Land value and subway stops

Does mass transit affect land value? Manhattan is a particularly poor place to analyze land value by subway stop location since the subway stops are so numerous and so close together. But this is the only data we have, so we shall proceed, but not make too much of the results. The data are shown in Figure 16. At upper-left is land value (total assessed, normalized by land area) within census block groups. At upper-right is the same data compiled within a 3-minute walking distance buffer[12] around each subway stop (note that only subway stops on the island of Manhattan are used). Considering the data in this way is no more insightful than considering it by block groups. If we look at the amount of commercial and residential area (normalized by land area) within each block group we see that, for the most part, high land value is simply a function of high commercial or residential area. Thus, built-up areas have high land value. This is not surprising or insightful.

Transit usage over time in the US

As stated in the Introduction, since the wide-spread introduction of the automobile, car usage has been increasing and transit usage has been decreasing. This is shown in Figure 17 which plots *means of transportation to work by mode* census data over time. Transit usage is shown in red (solid line all public transportation, dotted line bus, dashed line subway/elevated). Car/truck/van usage is shown in black. For reference, population is shown in blue. The figure shows that (i) total population is increasing over time, (ii) automobile usage is increasing at least as fast as population is increasing, (iii) transit usage has been decreasing though it may have leveled off (but note that this means, in terms of percentages, that the transit share is continuing to decline). The figure also shows data for walking to work in green. The number of people walking to work has been decreasing even faster than transit.

To consider these relationships extending further back in time, we have to use variables that are not as neatly comparable. Figure 18 plots time on the x-axis and various measures of automobile/transit usage on the y-axis. Population is again shown in blue, automobile variables are again shown in black (solid line is urban automobile passenger miles and dashed line is privately owned autos), and transit variables are again shown in red (solid line is urban transit passenger miles, dashed line is transit trips per capita, and dotted line is rapid transit ridership in NYC). We see that population has been steadily increasing over the whole length of time. Since the introduction of the automobile, automobile usage has been increasing rapidly and, since the automobile became well established, transit usage has been (generally) decreasing.

Let us consider transit usage and population over time for select cities that (in some sense) represent pre-car-era cities and car-dominated-era cities. Figure 19 (left panel) shows the

[12] The buffer is 0.2 miles which is a 3 minute walk assuming that a pedestrian walking briskly can travel 2 miles in 30 minutes (Grava, 2003, p 29).

population of 9 cities over time (the population for each city is normalized by the population of that city in 1990). The cities shown in black are our car-dominated-era cities. As can be seen, these cities continue to increase in population but the population density is relatively low (middle panel). Correlating with the low population density is low transit usage (right panel). The cities shown in red are our pre-car-era cities. The population in these cities has generally declined since around 1950. In contrast to the car-dominated-era cities, the pre-car-era cities have relatively high population density and transit usage. Two of the cities are particularly interesting:

San Francisco. It is not quite clear which category San Francisco should be in, so it is shown in dark-red. Based on population density and transit usage, it is clear that San Francisco belongs in the pre-car-era category, but in terms of population over time, San Francisco has continued to increase (a bit) over time. Perhaps there is hope for high-density cities?

DC. From the data in Figure 19, DC (shown in gray) should clearly be in the pre-car-era category: population has been declining, relatively high population density, and high transit usage. However, throughout this paper, we have been considering DC in light of the fact the DC metro was built during the car-dominated-era. Maybe this data is a clue as to why all the DC maps have looked relatively similar to the Boston and Chicago maps: DC's population trends are like those of Boston and Chicago. But this would only replace one question with another: Why and how did DC grow in this way while other cities did not? Clearly it cannot simply be a function of having a pre-car-era subway/elevated system since DC did not[13]. Is it simply that DC attained a great deal of its present-day population before 1950? (But, note, this is not an explanation per se since it just flips the data around and uses it to explain itself.)

Figure 19 also shows, as noted earlier, that NYC transit usage looks different (much more intense) than the usage in other cities. This is shown dramatically in the upper plot of Figure 20. In terms of ridership, NYC is greater than the sum of the rest. If we consider the modal split for each of these cities (middle plot), NYC again looks distinctly different with its high subway usage and relatively low car usage. Finally, returning to the age-of-system and usage theme, is there a correlation between the year in which a subway/elevated system is built and ridership? As shown in the lower plot, the answer is "not really" – except for NYC the data is quite flat. (Again NYC is the oddball – the y-axis is on a log scale so that the other systems can be on the same plot as NYC.)

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[13] It would be interesting (and possibly enlightening) to map journey-to-work data for DC over time. As shown in Figure 17, the US Census Bureau has been asking journey-to-work questions since (at least) 1960 though the questions have changed somewhat over time. Since the DC metro was built starting in the 1970s, this historical data would allow us to see how the metro changed travel behavior. However, while I could find other census data (in electronic format) going back to 1960, I could find no source for the journey-to-work data by tract (or other small geographical unit) over time. This data could be recovered from *paper* sources, but it is not clear to me that it would be so informative as to warrant the time this would take.

Transit usage throughout the world

Let us briefly consider transit throughout the world. We have noted that NYC has a massive subway system with very high ridership, but it is actually only fifth in the world in terms of ridership (Figure 21, top plot). The ridership in Moscow, Tokyo, and Seoul is quite impressive – ridership on the Moscow subway is over twice that of the NYC subway. We can also consider the "intensity" of transit usage by location. There are many ways to measure this, one of which is passenger-miles per line-mile as shown in the middle plot. The intensity of usage in North America and Europe is quite low in comparison to the other locations. (Note that the data is rather old, but it is difficult to find good comparison data across so many areas.) Finally, we again consider the year in which a subway is built and ridership. As shown in the lower plot, there is no positive correlation – there is even a weak negative correlation – indicating that new systems can have high usage.

Conclusions / Musings

The trends I found in the data fit some of my preconceptions, but not others. In particular, I am still intrigued by how similar the maps of DC are to those of Boston and Chicago. I truly expected that Boston, Chicago, and NYC would look very similar and that DC would look very different. However, it is clear that, of these four areas, NYC is the oddball (see Figures 3 and 10). This appears to mimic population density (see Figure 4).

Also of particular interest to me are the following:

(i) Cities with high populations before automobile usage was widespread have been losing population, have high population densities, and high transit usage (see Figure 19). San Francisco presents a hopeful anomaly since the population has continued to increase slightly.

(ii) In the US, new subway systems – DC, San Francisco, Atlanta – can be used as much as old subway systems – Chicago, Boston, etc. – though nothing like the usage seen in NYC (see Figure 20, top and bottom panels). This may be a function of already-existing relatively high population density (see Figure 19 middle panel, though note that Atlanta, not shown in the figure, has a population density about that of Houston which is quite low). It will be interesting to see if Los Angeles changes over time with its newly built subway.

(iii) Outside the US, new subway systems can achieve massive levels of usage (see Figure 21, top and bottom panels). Maybe we can learn something from these achievements, though the US is so different (in terms of economics, politics, culture, etc.) that it is unclear how applicable any lessons learned would be.

References

Books/articles

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Subway/elevated system geography

Boston Subway

(lines and stations from 2004)

www.mass.gov/mgis/mbta.htm

DC Metro

(lines and stations from 2002)

dcgis.dc.gov, click "Dataset Search", search for "metro"

Chicago "*L*"

(stations from 2004, lines unknown but likely from 2004)

egov.cityofchicago.org, search for "shapefile"

NYC Subway

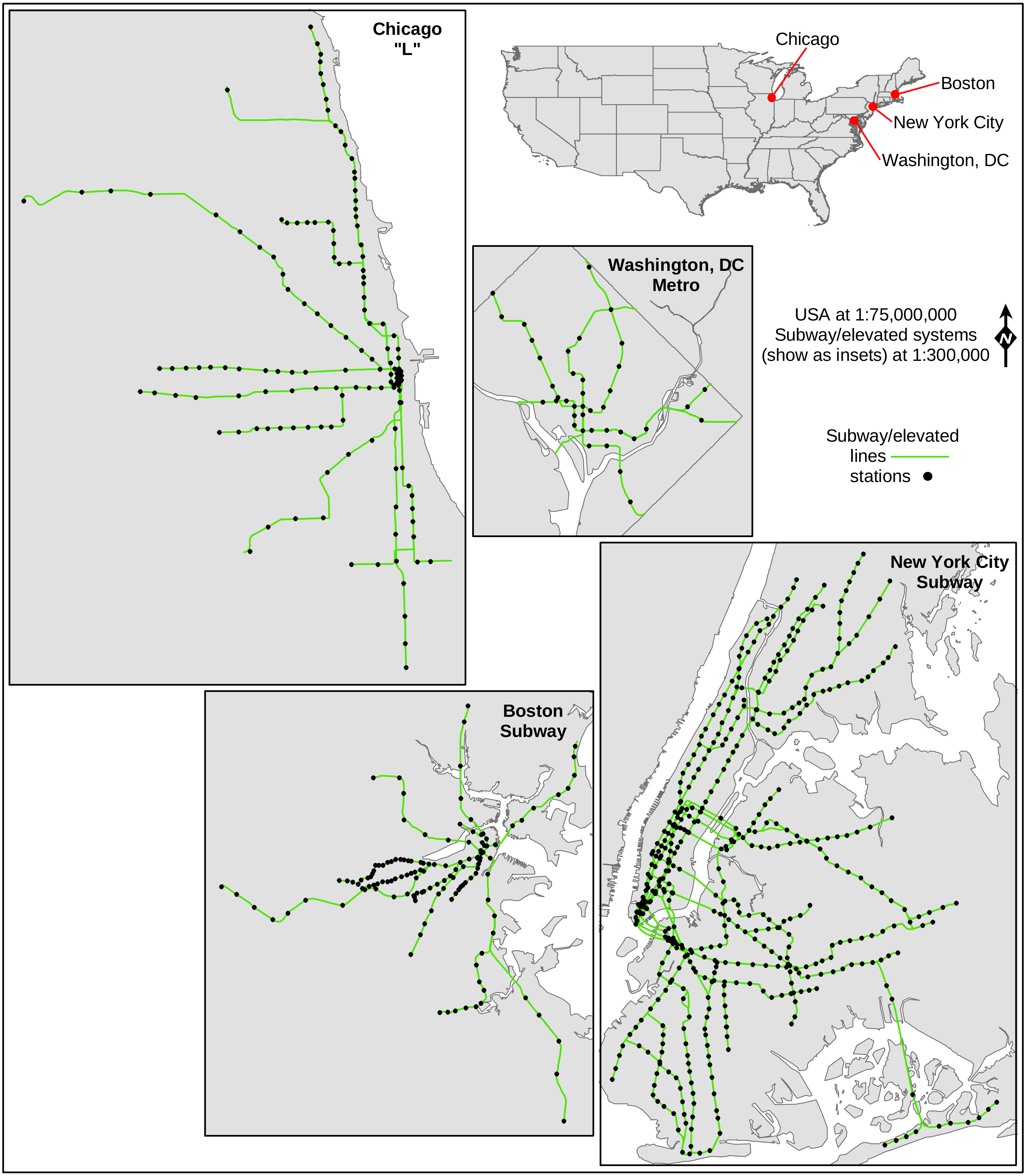
(lines and stations unknown but likely from 2003)

Community Cartography www.comcarto.com/trans.html, who got the data from NYCTA.

Other data and geography

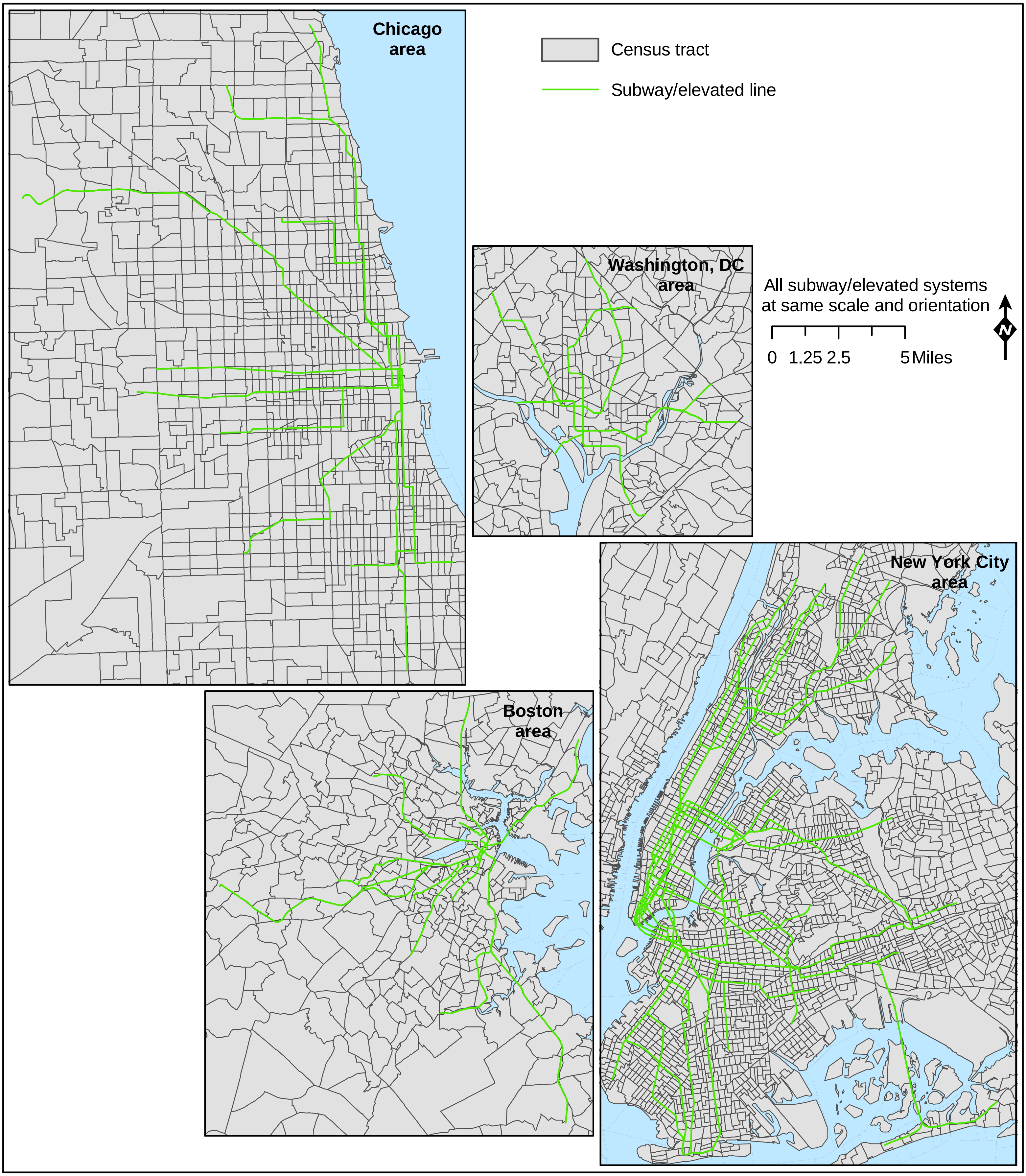
Listed on the figures, in the main text, and in footnotes.

Figure 1. Largest subway/elevated systems in the USA



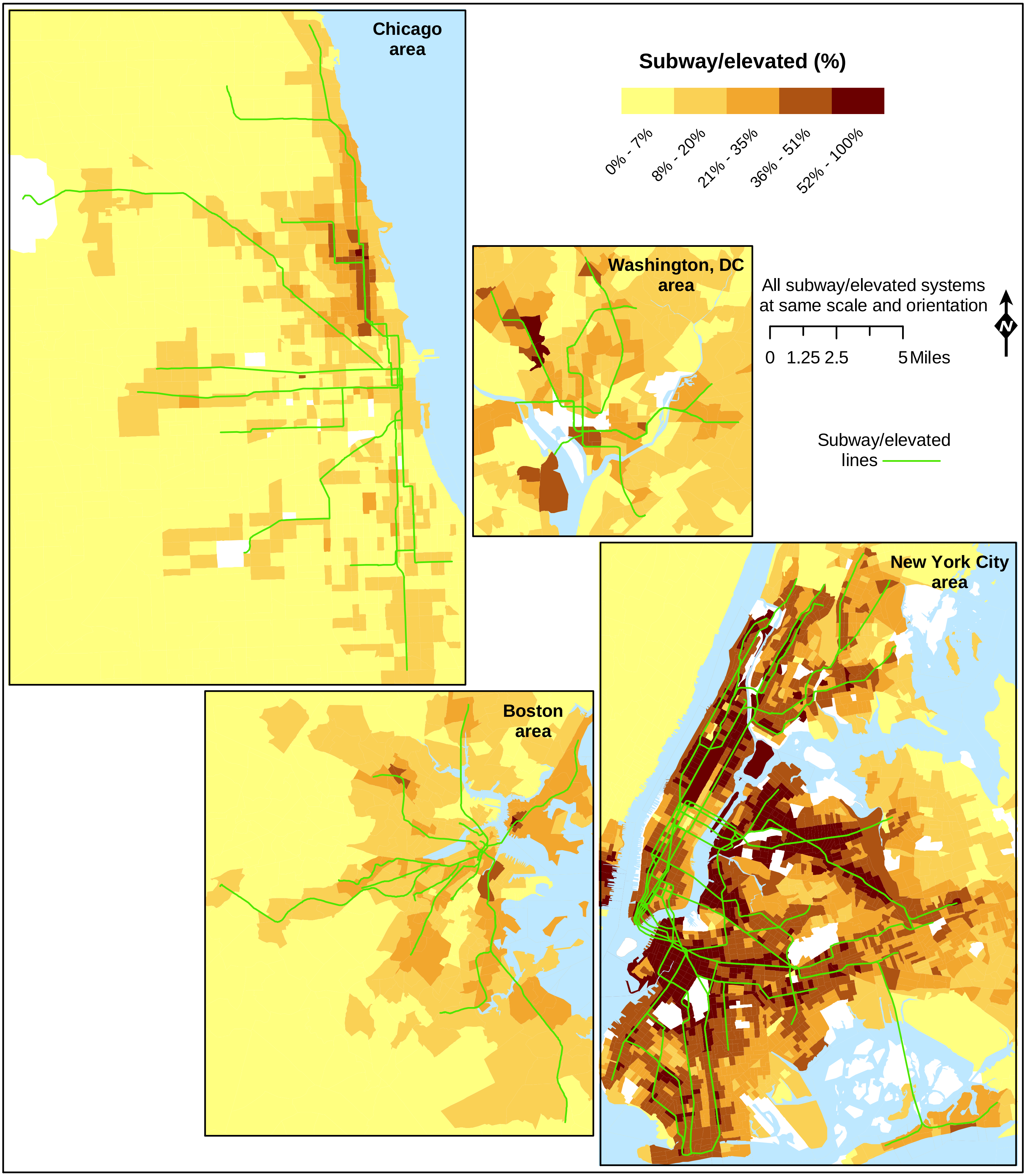
Produced by S. Sabina Wolfson, December 2004. State boundaries from from the U. S. Geological Survey.
Boston Subway lines from the Massachusetts Bay Transportation Authority (www.mass.gov/mgis/mbata.htm).
Washington DC Metro lines from the Government of the District of Columbia (dcgis.dc.gov).
Chicago "L" lines from the City of Chicago (egov.cityofchicago.org).
New York Subway lines from the New York City Transit Authority compiled by Community Cartography (www.comcarto.com/trans.html).

Figure 2. Census tracts around the subway/elevated systems



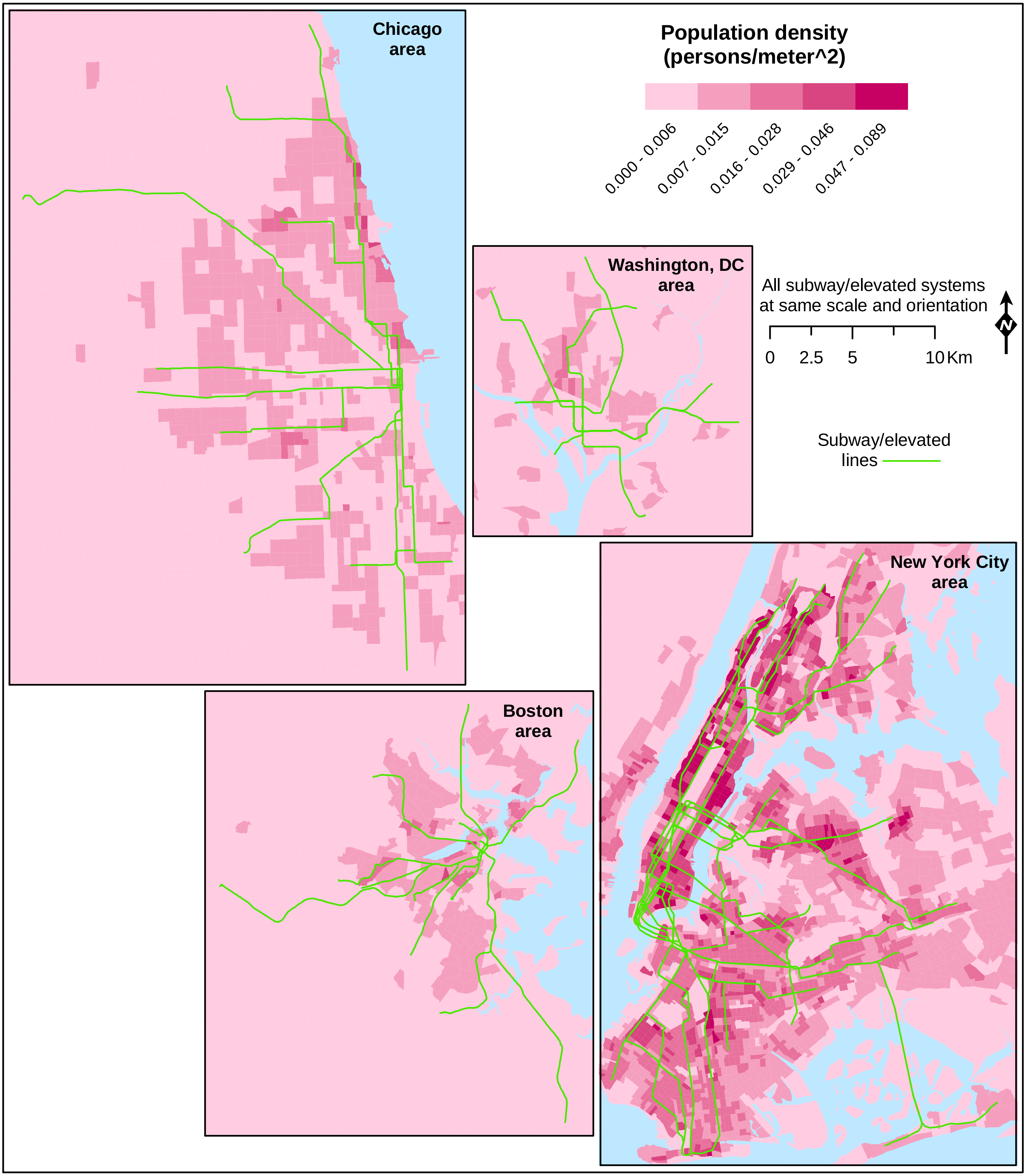
Produced by S. Sabina Wolfson, December 2004. Census tract boundaries from US Census Bureau (year 2000).
Chicago "L" lines from the City of Chicago. Washington DC Metro lines from the Government of the District of Columbia.
Boston Subway lines from the Massachusetts Bay Transportation Authority. New York Subway lines from the New York City Transit Authority.

Figure 3. Journey to work via subway/elevated



Produced by S. Sabina Wolfson, December 2004. Data at the census tract level -- boundaries and values from US Census Bureau (year 2000).
Chicago "L" lines from the City of Chicago. Washington DC Metro lines from the Government of the District of Columbia.
Boston Subway lines from the Massachusetts Bay Transportation Authority. New York Subway lines from the New York City Transit Authority.
White areas have no data and should not be taken to imply a low (or high) value.

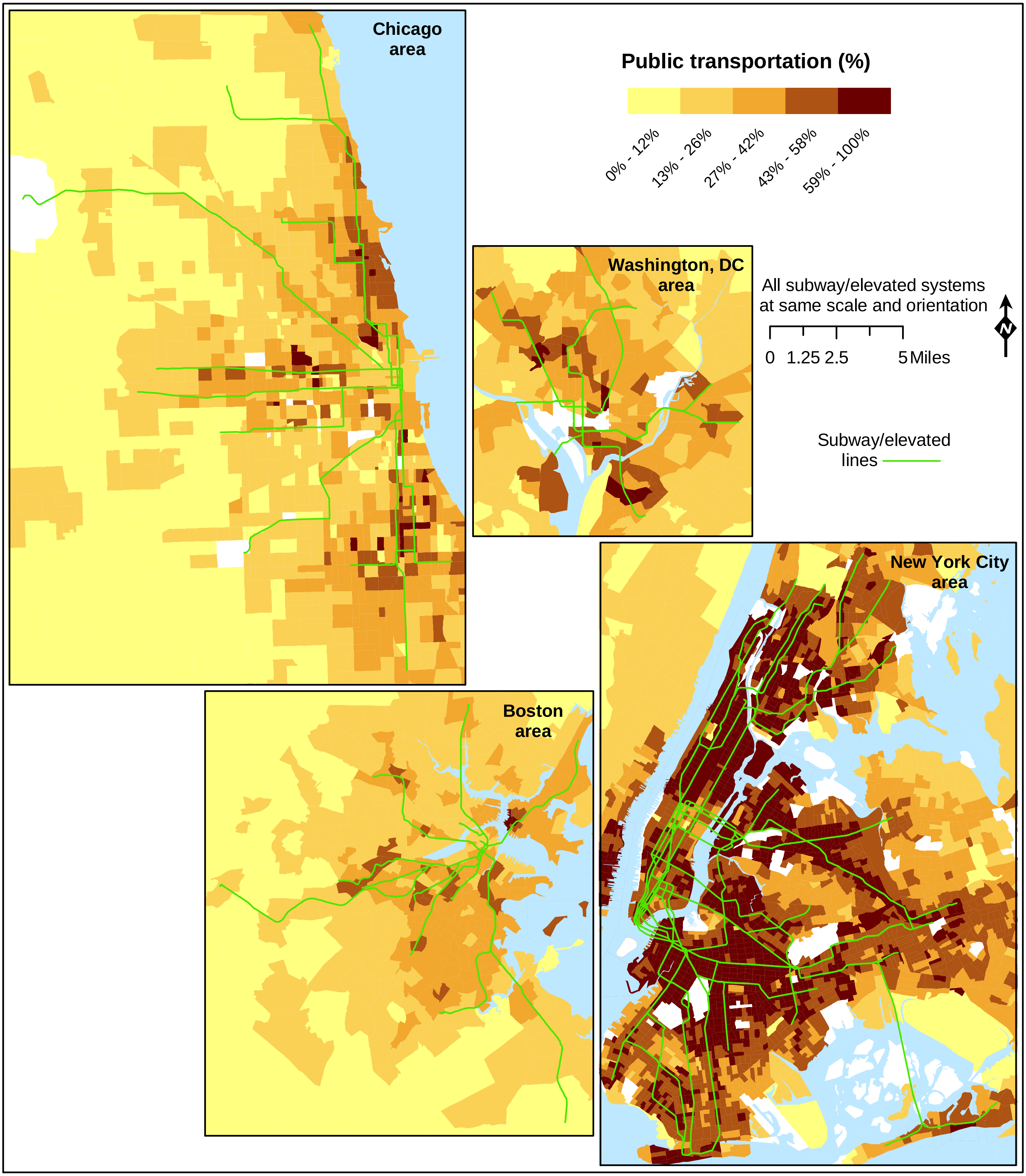
Figure 4. Population density around the subway/elevated systems



Produced by S. Sabina Wolfson, December 2004. Data at the census tract level -- boundaries and values from US Census Bureau (year 2000).
Chicago "L" lines from the City of Chicago. Washington DC Metro lines from the Government of the District of Columbia.
Boston Subway lines from the Massachusetts Bay Transportation Authority. New York Subway lines from the New York City Transit Authority.

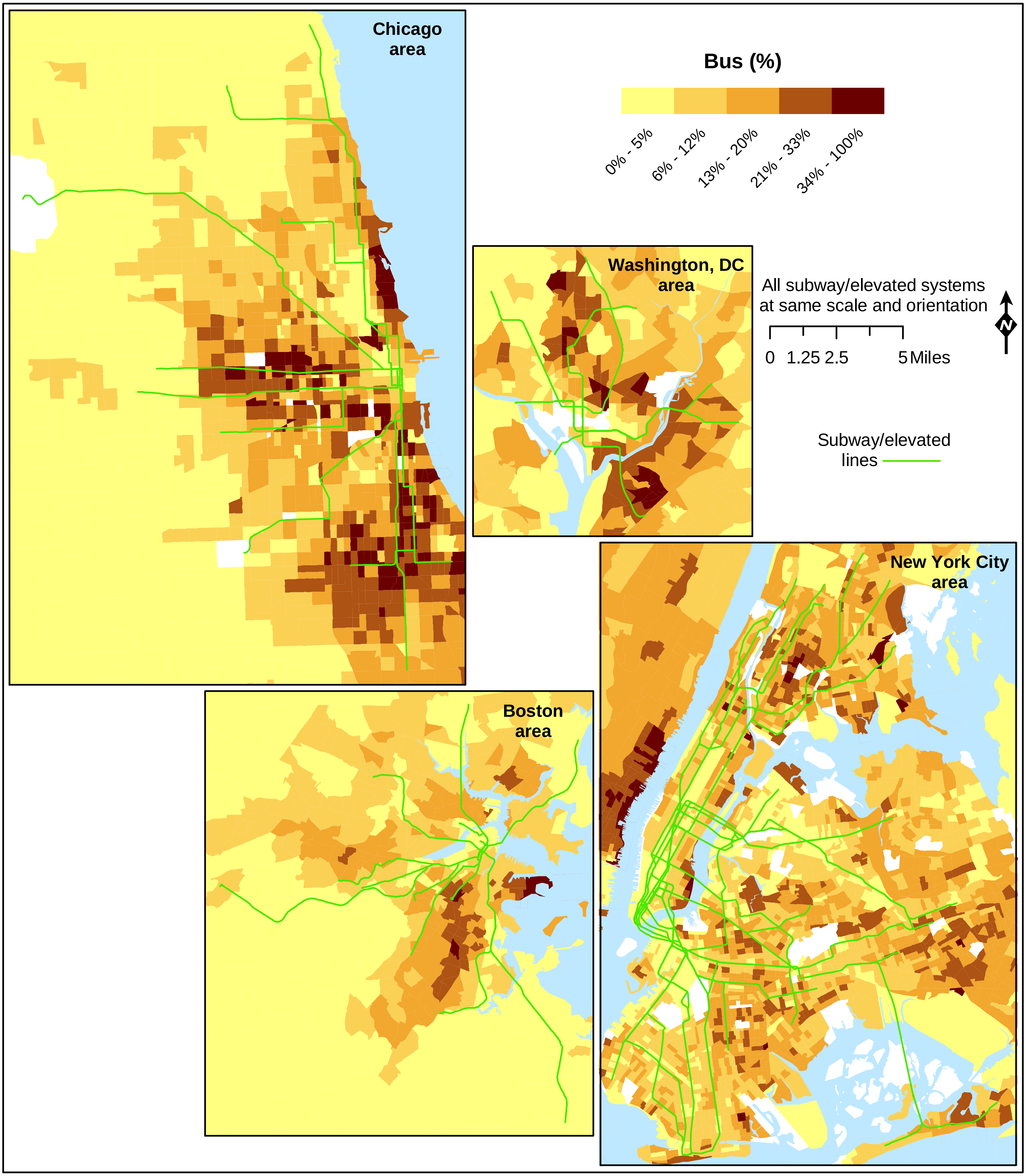
Figure 5. Journey to work via public transportation

(public transportation is bus, streetcar, subway/elevated, railroad, ferry, or taxi)



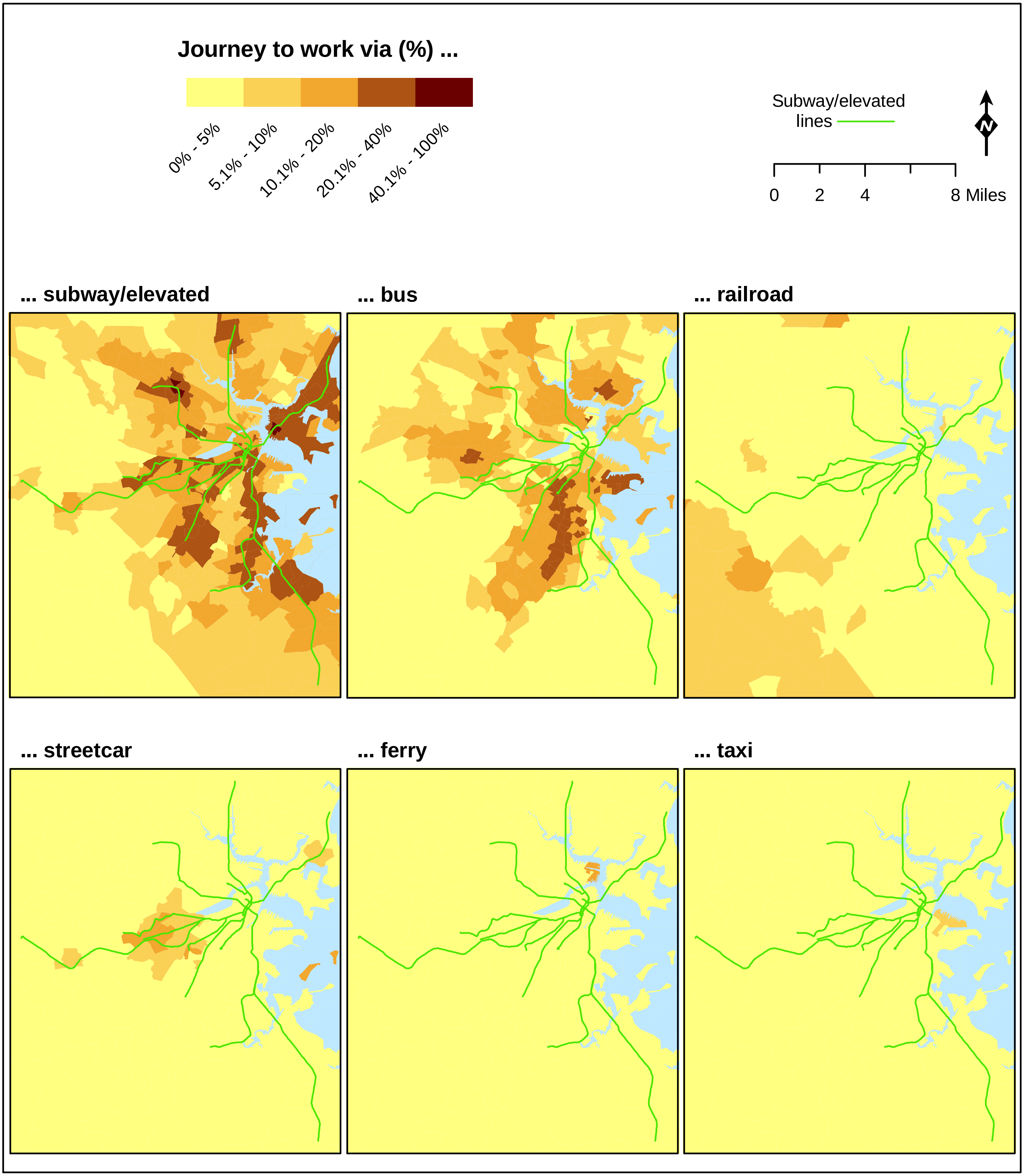
Produced by S. Sabina Wolfson, December 2004. Data at the census tract level -- boundaries and values from US Census Bureau (year 2000).
Chicago "L" lines from the City of Chicago. Washington DC Metro lines from the Government of the District of Columbia.
Boston Subway lines from the Massachusetts Bay Transportation Authority. New York Subway lines from the New York City Transit Authority.
White areas have no data and should not be taken to imply a low (or high) value.

Figure 6. Journey to work via bus



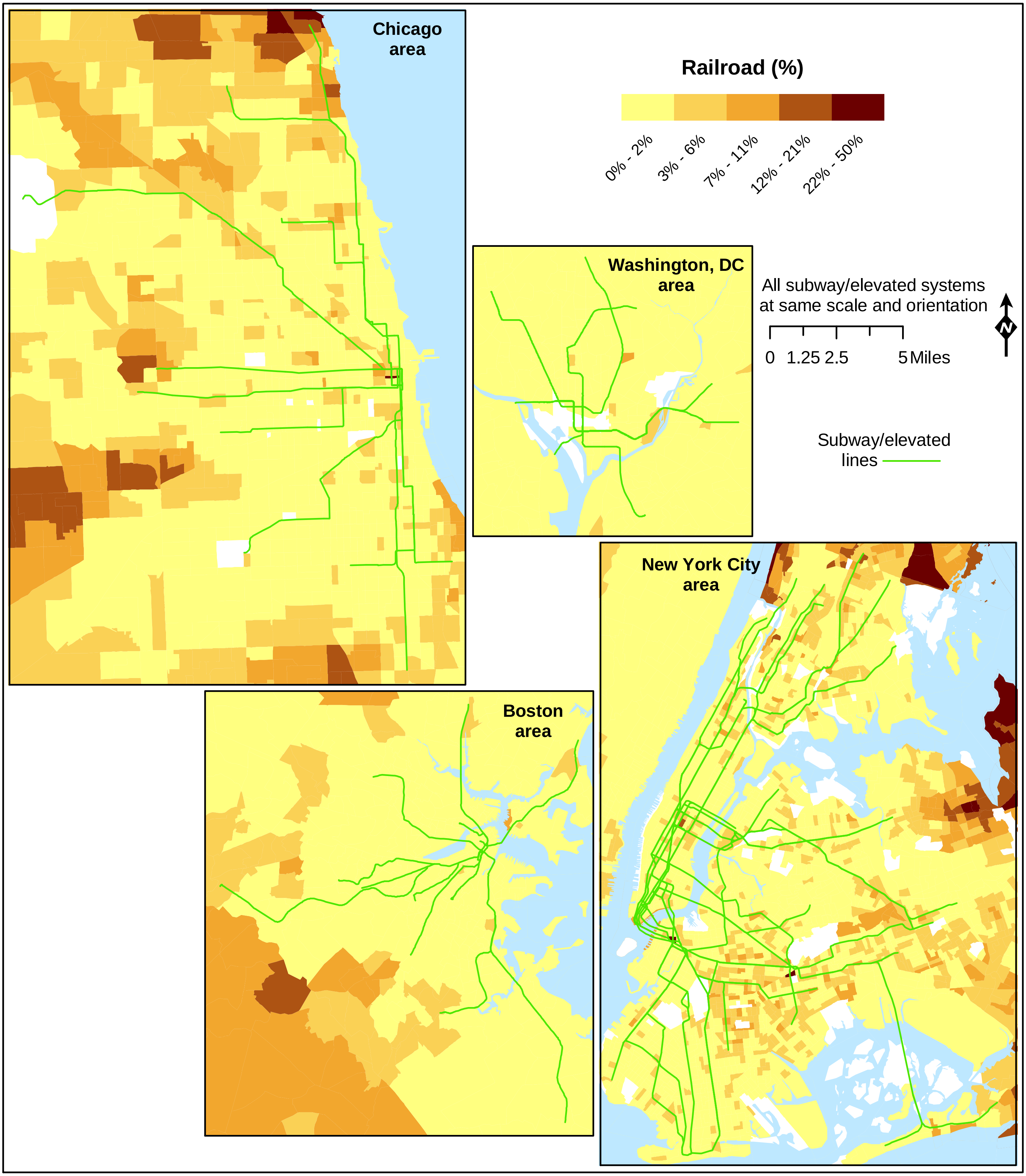
Produced by S. Sabina Wolfson, December 2004. Data at the census tract level -- boundaries and values from US Census Bureau (year 2000).
Chicago "L" lines from the City of Chicago. Washington DC Metro lines from the Government of the District of Columbia.
Boston Subway lines from the Massachusetts Bay Transportation Authority. New York Subway lines from the New York City Transit Authority.
White areas have no data and should not be taken to imply a low (or high) value.

Figure 7. Journey to work via public transportation in the Boston area



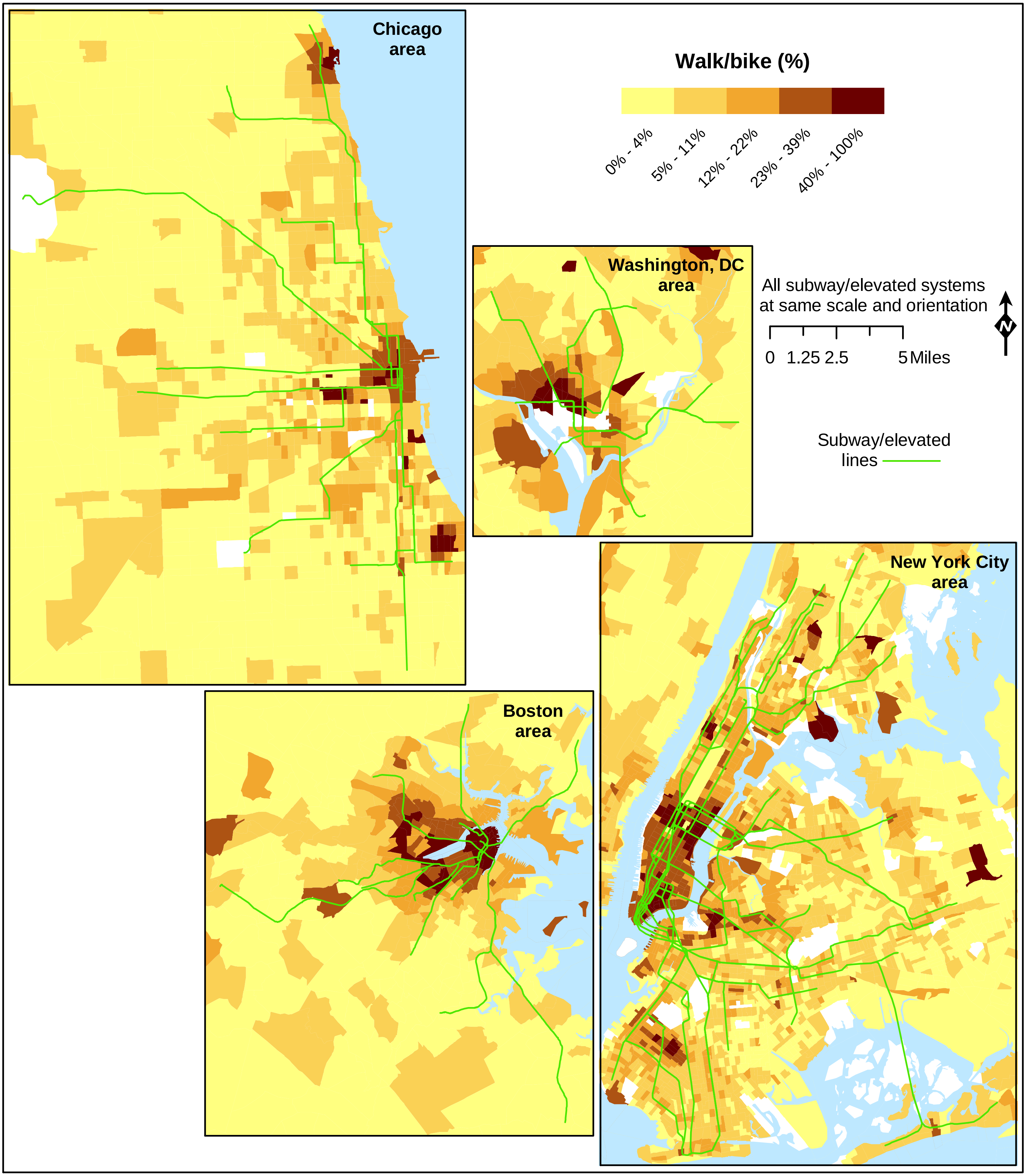
Produced by S. Sabina Wolfson, December 2004.
Data at the census tract level -- boundaries and values from US Census Bureau (year 2000).
Boston Subway lines from the Massachusetts Bay Transportation Authority.

Figure 8. Journey to work via railroad



Produced by S. Sabina Wolfson, December 2004. Data at the census tract level -- boundaries and values from US Census Bureau (year 2000).
Chicago "L" lines from the City of Chicago. Washington DC Metro lines from the Government of the District of Columbia.
Boston Subway lines from the Massachusetts Bay Transportation Authority. New York Subway lines from the New York City Transit Authority.
White areas have no data and should not be taken to imply a low (or high) value.

Figure 9. Journey to work via walk/bike



Produced by S. Sabina Wolfson, December 2004. Data at the census tract level -- boundaries and values from US Census Bureau (year 2000).
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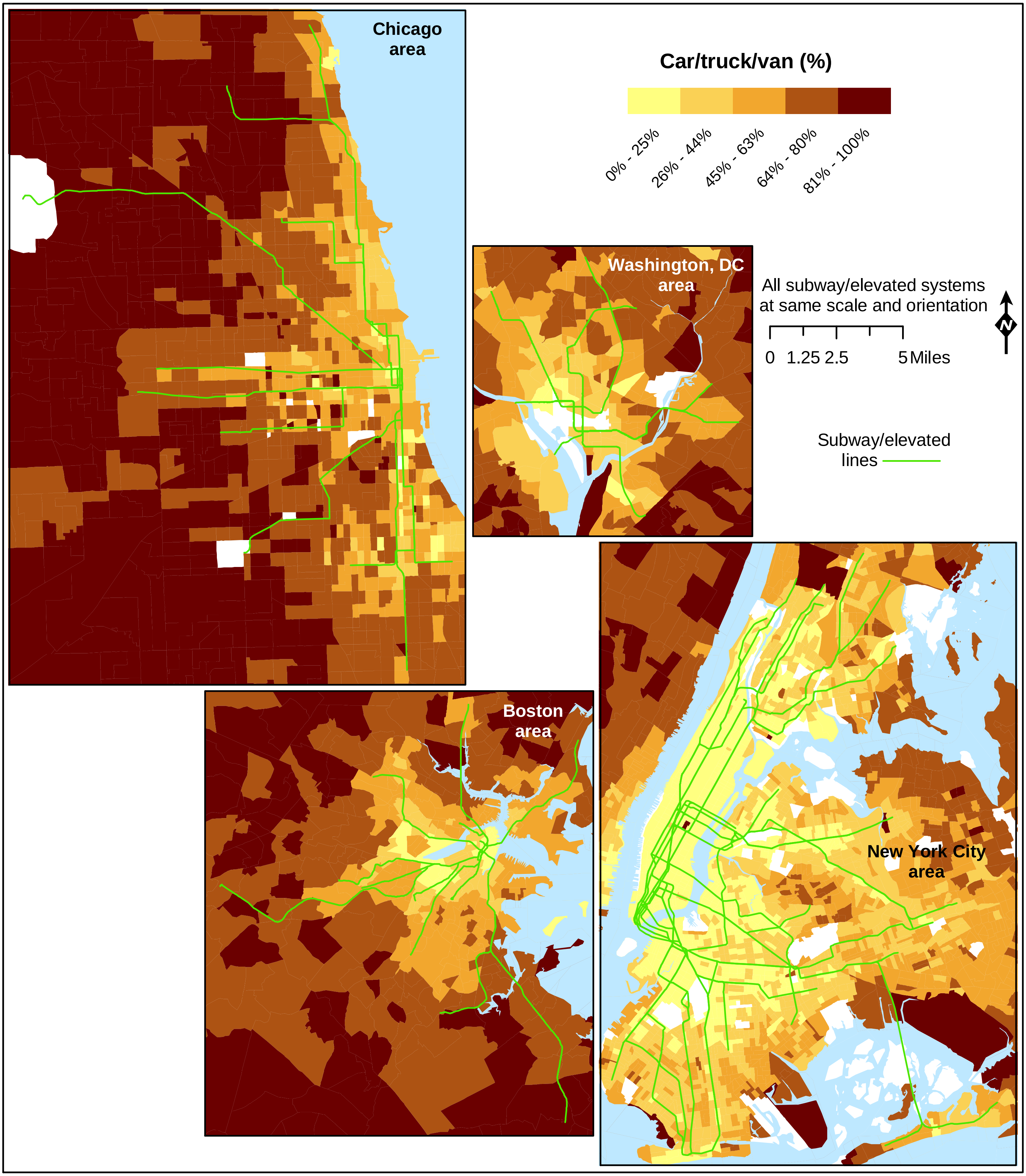
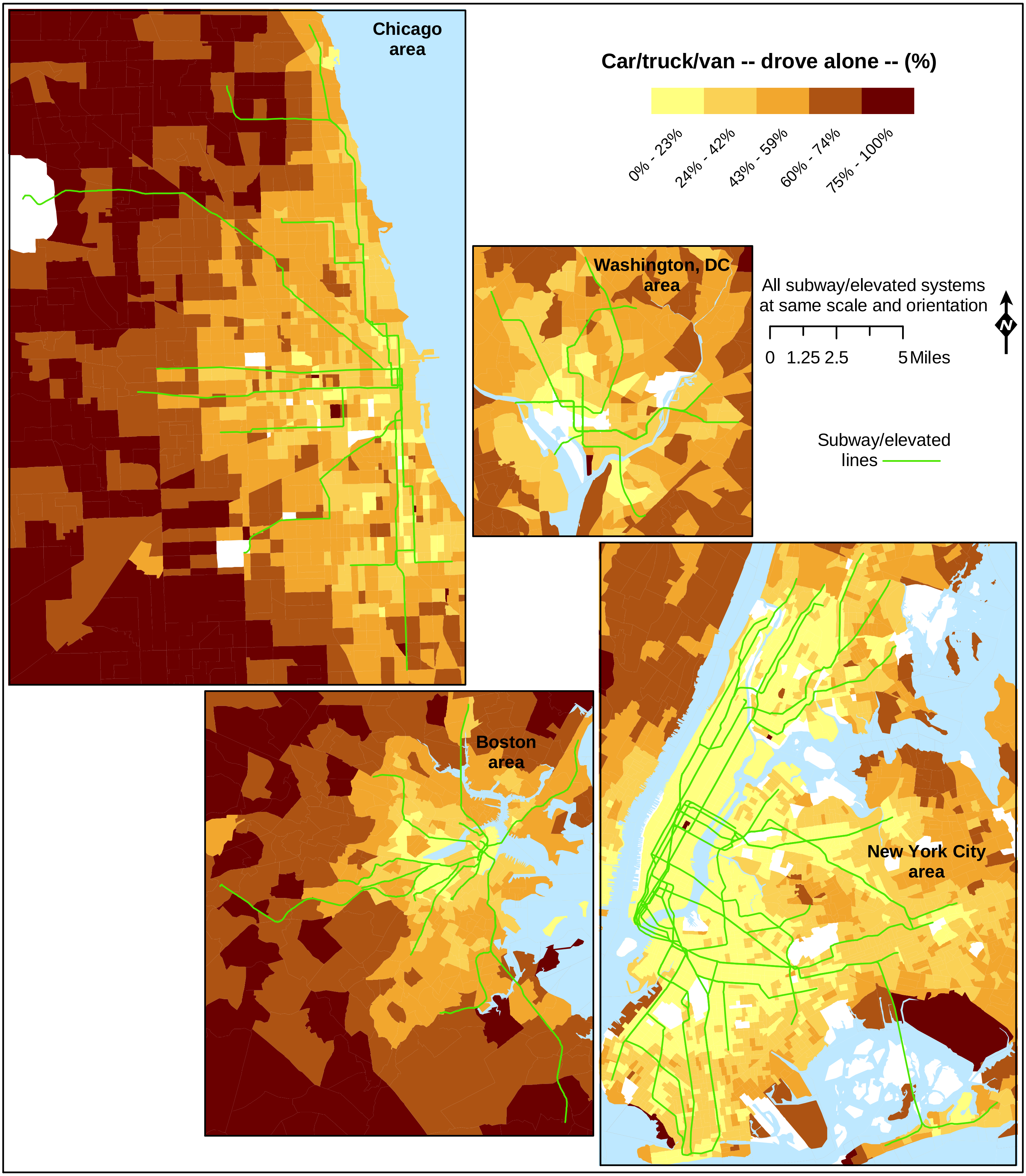
Boston Subway lines from the Massachusetts Bay Transportation Authority. New York Subway lines from the New York City Transit Authority.
White areas have no data and should not be taken to imply a low (or high) value.

Figure 10. Journey to work via car/truck/van



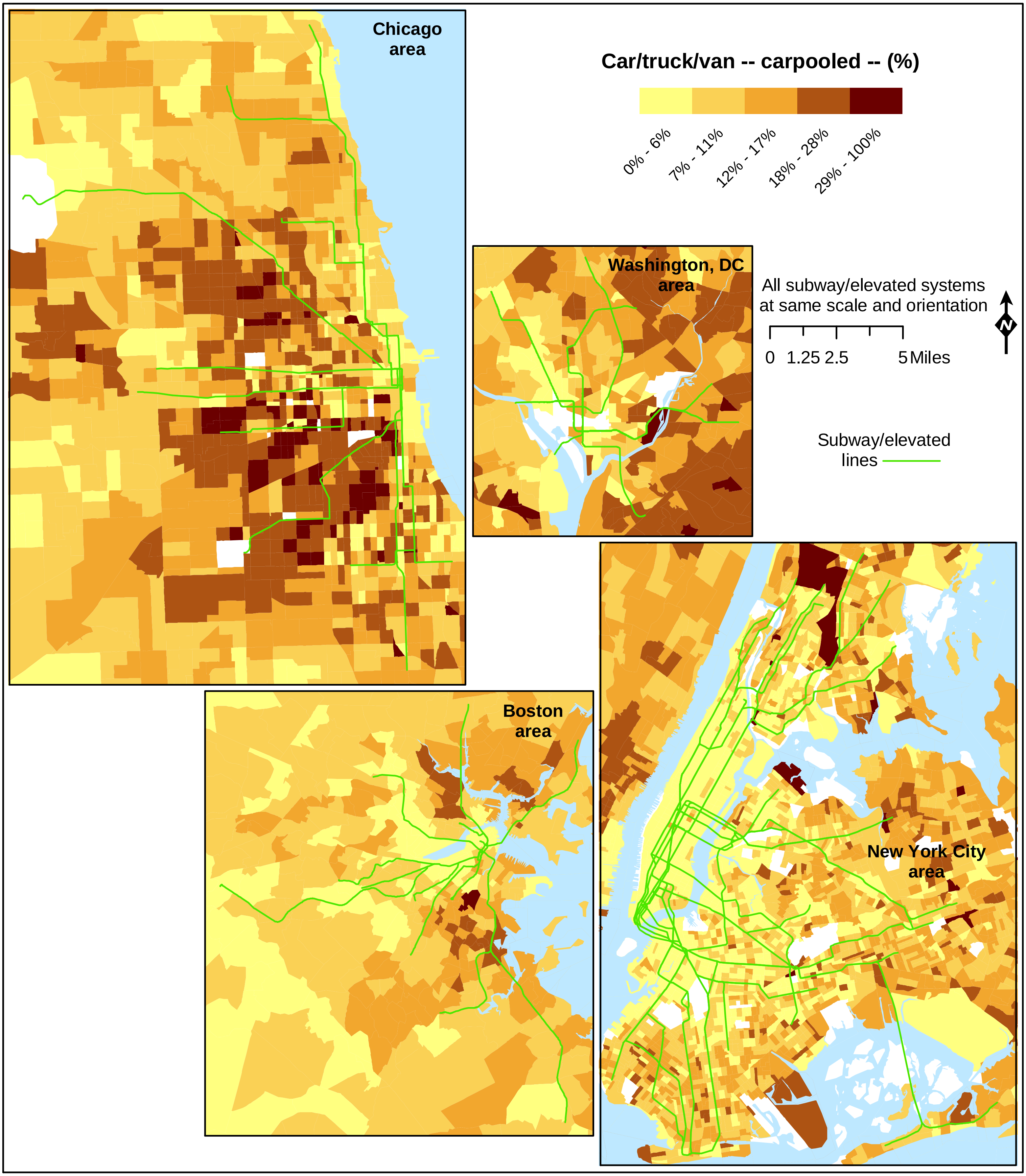
Produced by S. Sabina Wolfson, December 2004. Data at the census tract level -- boundaries and values from US Census Bureau (year 2000).
Chicago "L" lines from the City of Chicago. Washington DC Metro lines from the Government of the District of Columbia.
Boston Subway lines from the Massachusetts Bay Transportation Authority. New York Subway lines from the New York City Transit Authority.
White areas have no data and should not be taken to imply a low (or high) value.

Figure 11. Journey to work via car/truck/van -- drove alone



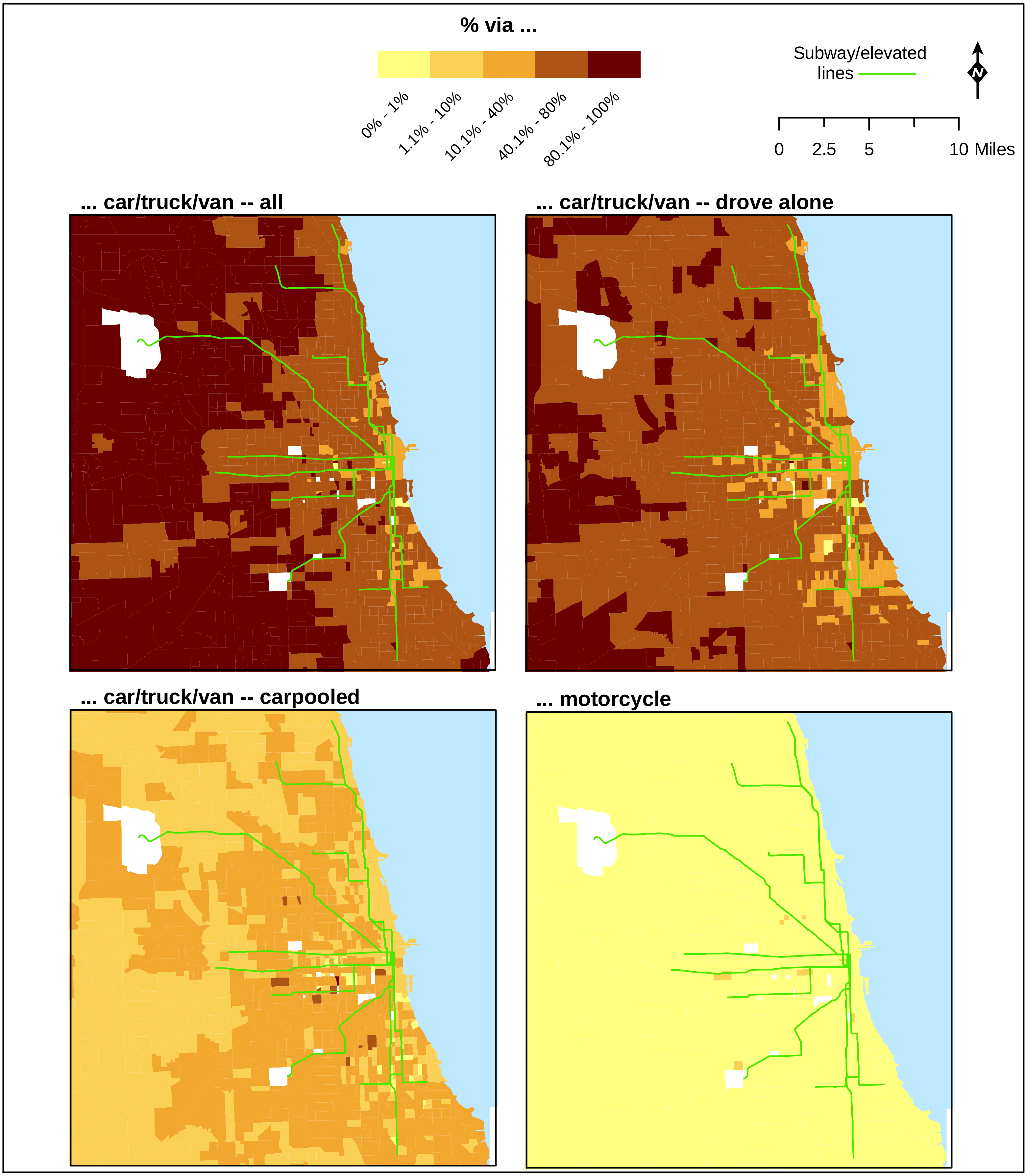
Produced by S. Sabina Wolfson, December 2004. Data at the census tract level -- boundaries and values from US Census Bureau (year 2000).
Chicago "L" lines from the City of Chicago. Washington DC Metro lines from the Government of the District of Columbia.
Boston Subway lines from the Massachusetts Bay Transportation Authority. New York Subway lines from the New York City Transit Authority.
White areas have no data and should not be taken to imply a low (or high) value.

Figure 12. Journey to work via car/truck/van -- carpooled



Produced by S. Sabina Wolfson, December 2004. Data at the census tract level -- boundaries and values from US Census Bureau (year 2000).
Chicago "L" lines from the City of Chicago. Washington DC Metro lines from the Government of the District of Columbia.
Boston Subway lines from the Massachusetts Bay Transportation Authority. New York Subway lines from the New York City Transit Authority.
White areas have no data and should not be taken to imply a low (or high) value.

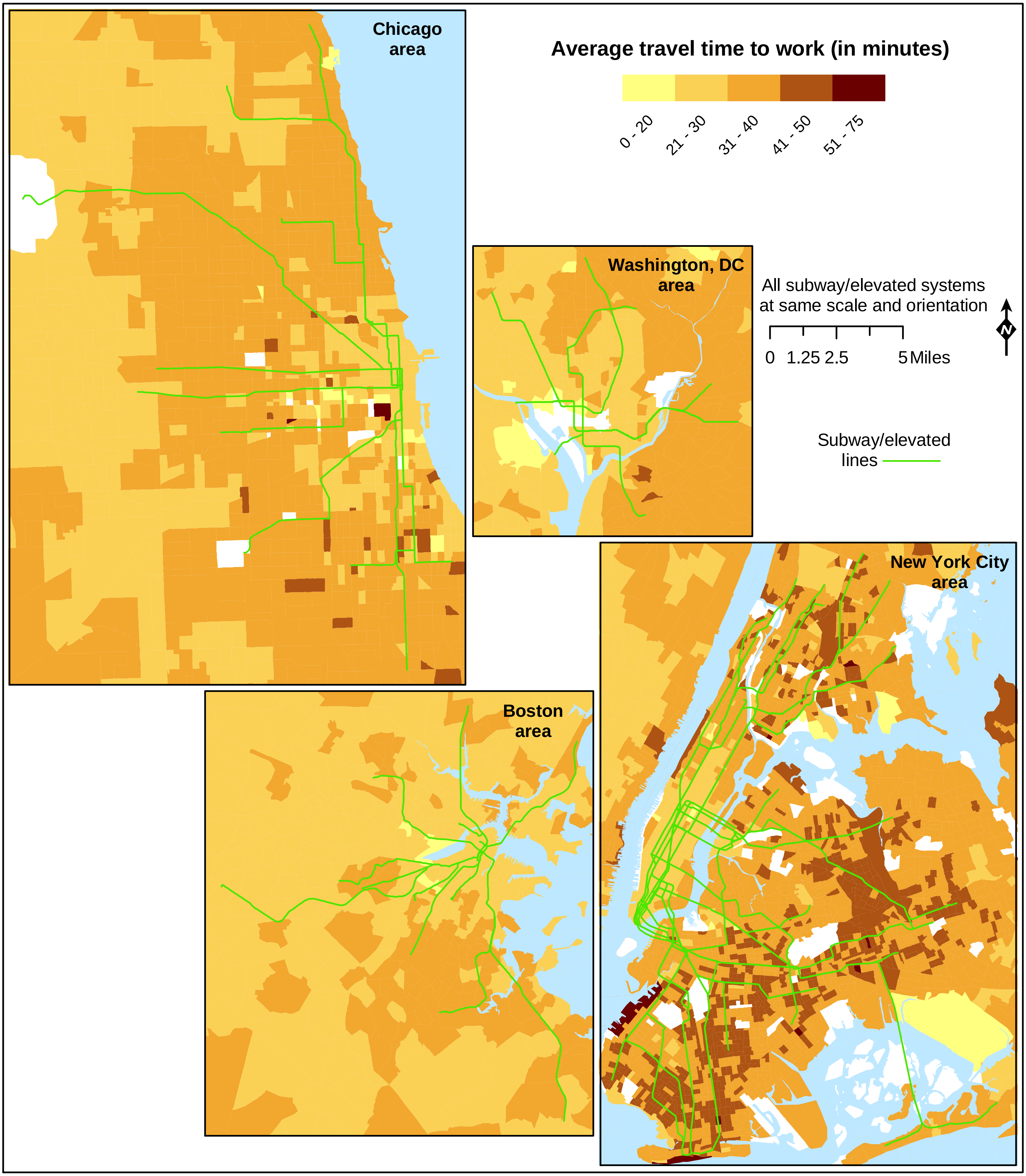
Figure 13. Journey to work via car/truck/van/motorcycle in the Chicago area



Produced by S. Sabina Wolfson, December 2004.
Data at the census tract level -- boundaries and values from US Census Bureau (year 2000).
Chicago "L" lines from the City of Chicago.
White areas have no data and should not be taken to imply a low (or high) value.

Figure 14. Average travel time to work (all modes)

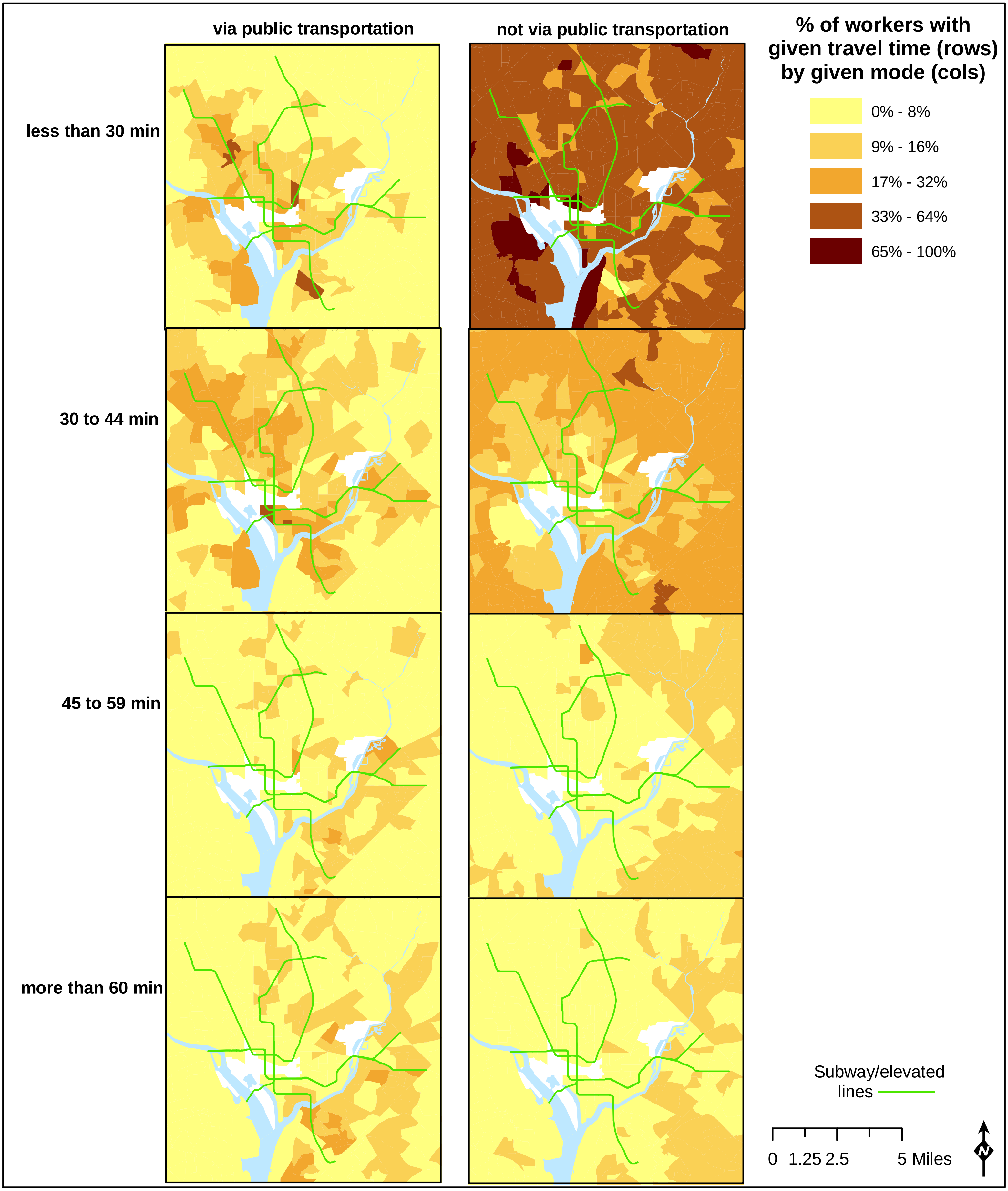
(for travel times less than 90 minutes for workers 16 years and over that did not work at home)



Produced by S. Sabina Wolfson, December 2004. Data at the census tract level -- boundaries and values from US Census Bureau (year 2000).
Chicago "L" lines from the City of Chicago. Washington DC Metro lines from the Government of the District of Columbia.
Boston Subway lines from the Massachusetts Bay Transportation Authority. New York Subway lines from the New York City Transit Authority.
White areas have no data and should not be taken to imply a low (or high) value.

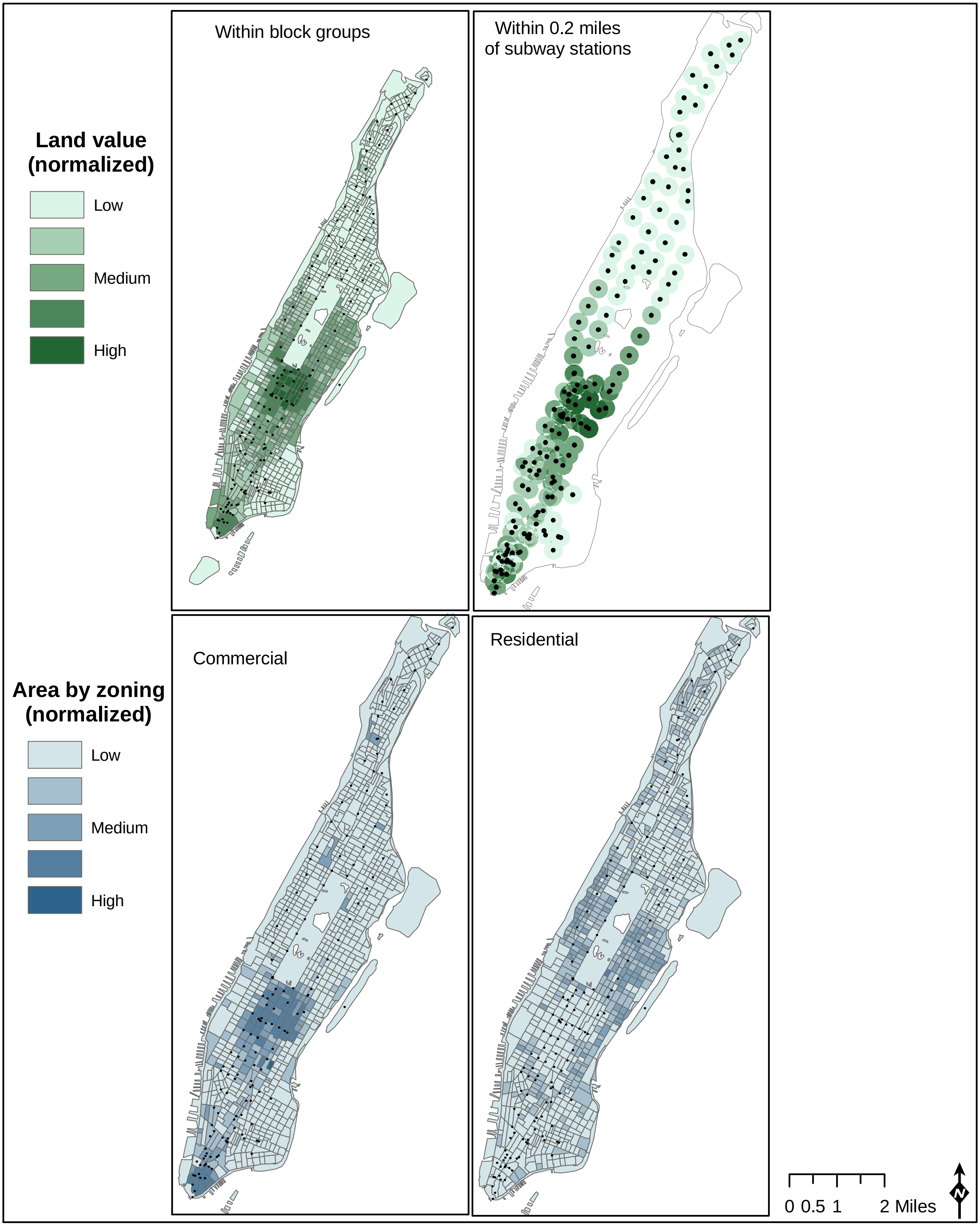
Figure 15. Travel time to work by mode in Washington DC area

(for workers 16 years and over that did not work at home)



Produced by S. Sabina Wolfson, December 2004.
Data at the census tract level -- boundaries and values from US Census Bureau (year 2000).
Washington DC Metro lines from the Government of the District of Columbia.
White areas have no data and should not be taken to imply a low (or high) value.

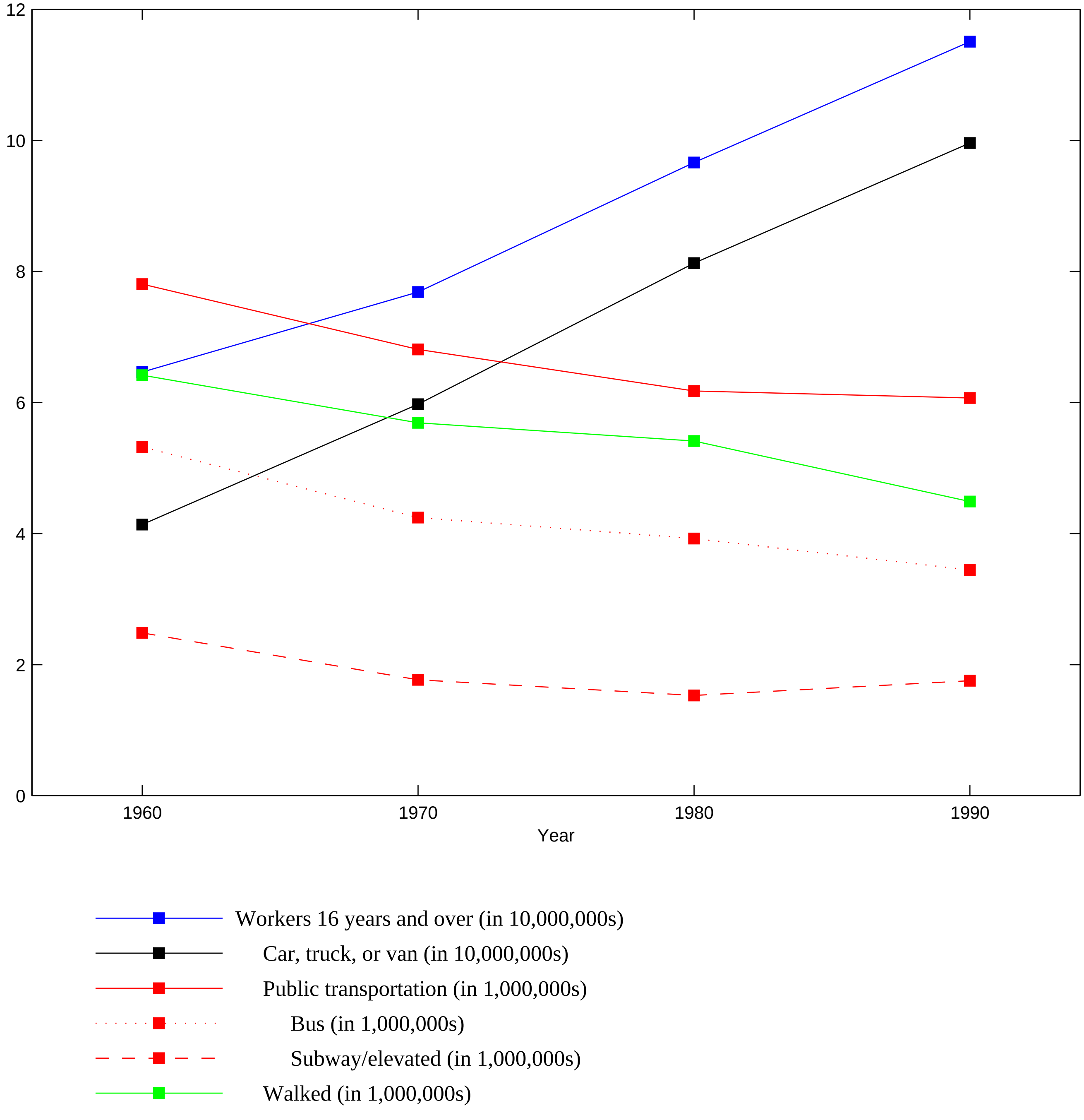
Figure 16. Select land attributes in Manhattan



Produced by S. Sabina Wolfson, December 2004.
New York Subway station locations from the New York Transit Authority.
Land value and commercial/residential area (2003) from NYC Department of City Planning.
Block group boundaries from US Census Bureau (year 2000).

Figure 17. Modal split in the US, 1960-1990

(Means of transportation to work data)



Source: US Census Bureau, www.census.gov/population/socdemo/journey/mode6790.txt

Figure 18. Transit vs auto in the US over time

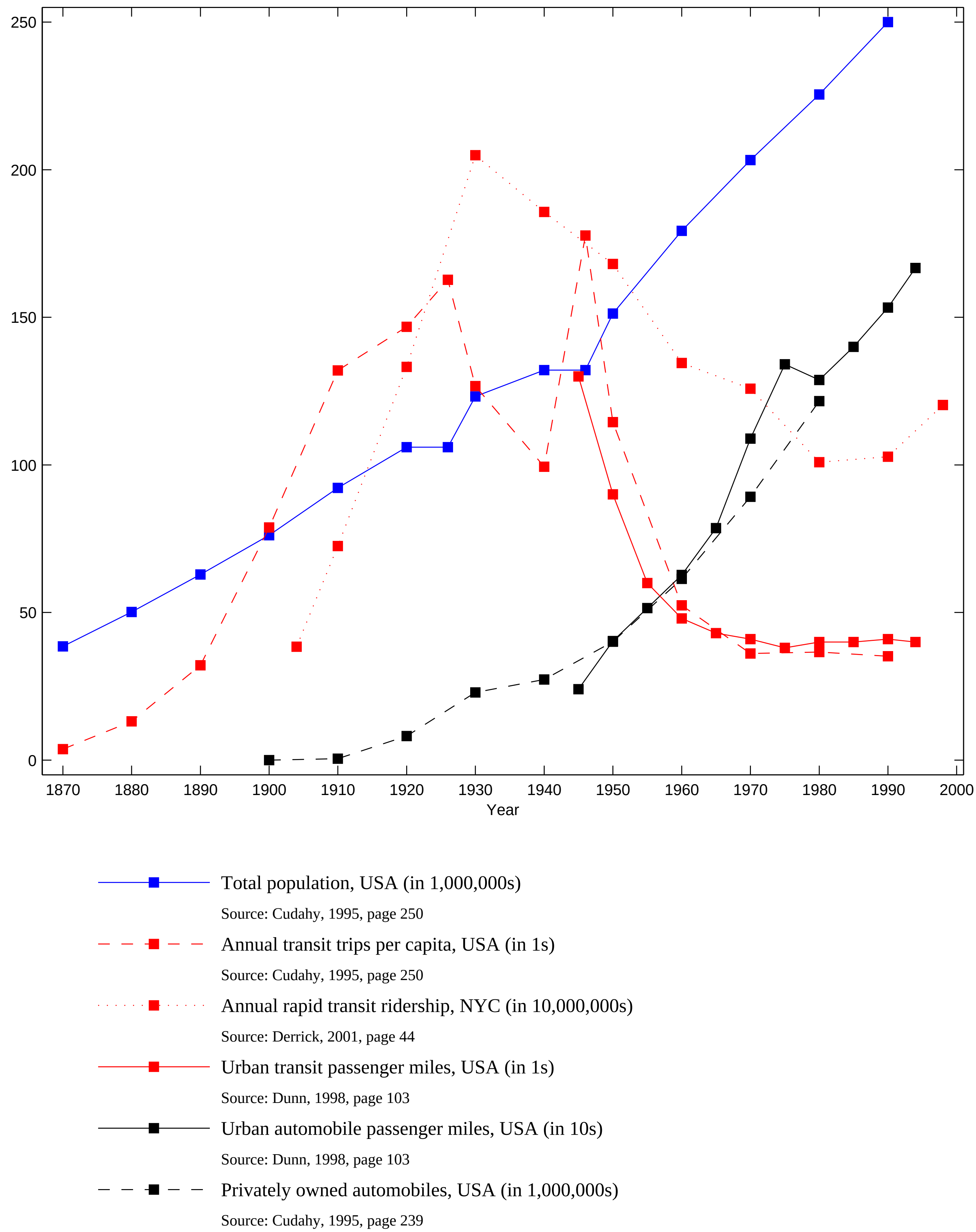
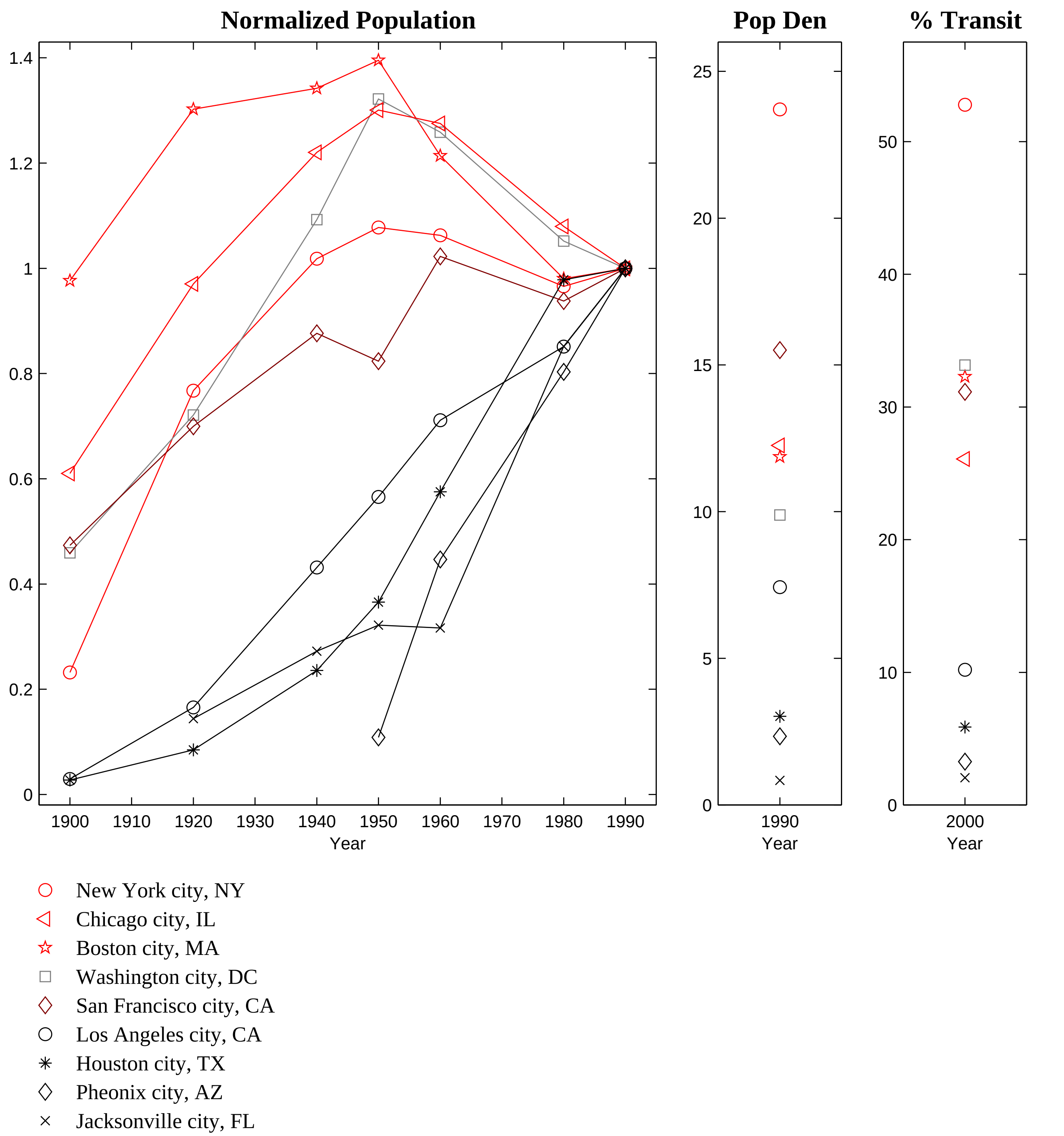


Figure 19. Population and transit in the US over time



Normalized Population values are normalized by year 1990 populations

Source: Gibson (1998) Tables 13, 15, 17, 18, 19, 21, and 22

Pop Den are population density values (average population, in 1000s, per square mile)

Source: Gibson (1998) Table 22

% Transit values are for travel to work via *Public transportation* (workers 16 years and over)

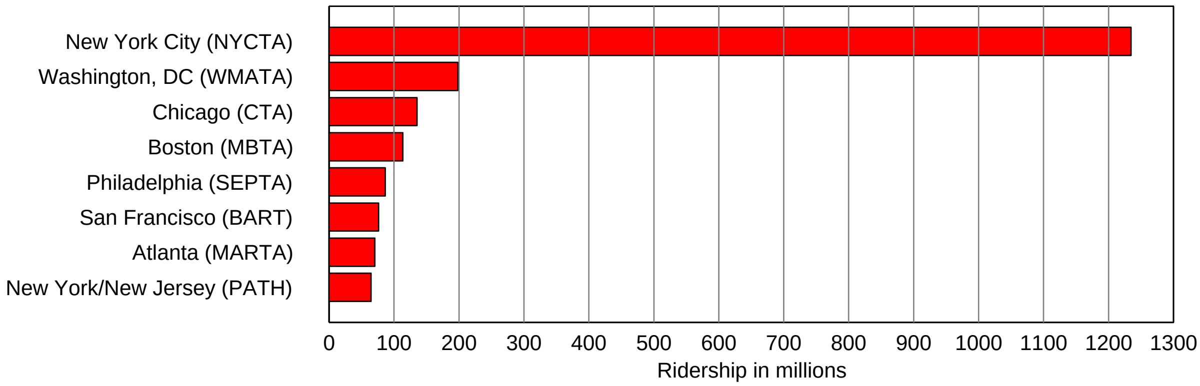
Source: US Census Bureau's American FactFinder, Census 2000, Summary File 3, *Means of transportation to work for workers 16 years and over*

Public transportation is via bus, trolley bus, streetcar, trolley car, subway, elevated, railroad, ferryboat, or taxi

Figure 20. Transportation statistics in select US cities

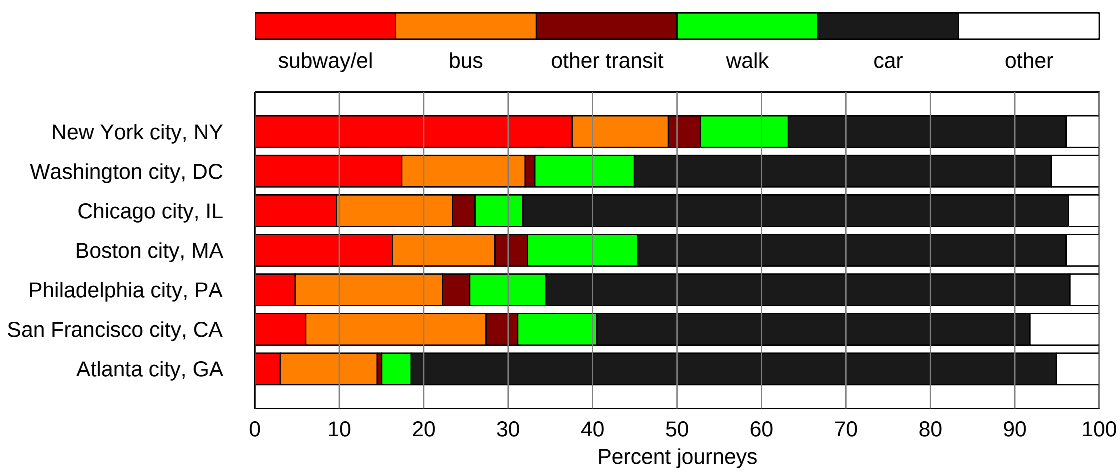
Subway/elevated systems in USA with highest annual ridership, 1995

Source: Institute of Transportation Engineers (1999) Table 13-8 (annual unlinked rides)



Journey to work by mode (for above cities), 2000

Source: US Census Bureau's American FactFinder, Census 2000, Summary File 3, *Means of transportation to work for workers 16 years and over*



Ridership (in 1999) by year opened

Source: Grava (2003), p 550

A	Atlanta
B	Boston
C	Chicago
H	Philadelphia (SEPTA)
I	Philadelphia (PATCO)
J	NY-NJ (PATH)
L	Los Angeles
M	Miami
N	New York City
S	San Francisco
T	Baltimore
V	Cleveland
W	Washington DC

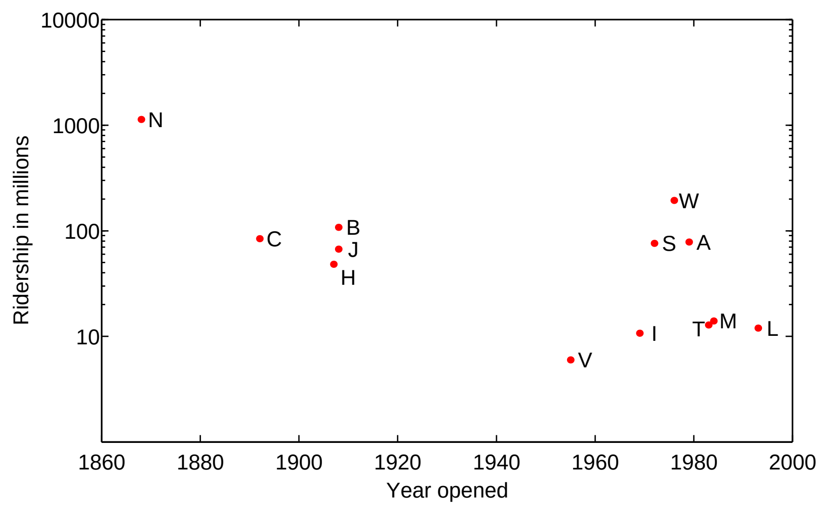
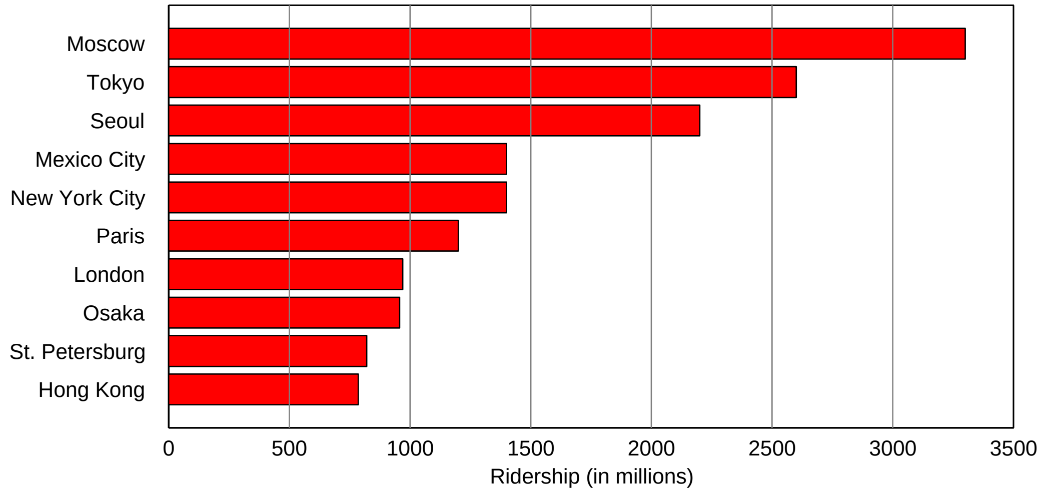


Figure 21. World transit systems

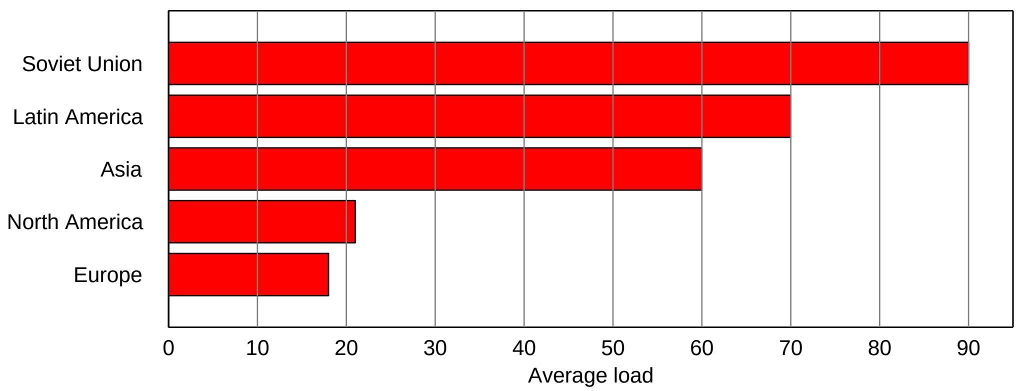
Annual subway ridership, 2002

Source: www.mta.info/nyct/facts/ffsubway.htm



Average rapid transit load (million passenger-miles per line mile), 1975

Source: Institute of Transportation Engineers (1999) Table 13-3



Ridership (circa 1995) by year opened

Source: www.infoplease.com/ipa/A0762446.html

Source: www.mta.info/nyct/facts/ffsubway.htm

G	St. Petersburg
H	Hong Kong
L	London
M	Moscow
M	Mexico City
N	New York City
O	Osaka
P	Paris
S	Seoul
T	Tokyo