A Spatial Analysis of Job Openings and Access in a U.S. Metropolitan Area

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This article presents a study of spatial distribution of job openings and spatial variation in job accessibility in the Boston Metropolitan Area. The most striking finding is that despite decades of employment decentralization, job openings suitable for less-educated job seekers are still relatively concentrated in the central city. This is due to the fact that the great majority of job openings are vacancies resulting from turnover, the spatial concentration of which reflects the spatial concentration of current employment. A related finding is that for a given transportation mode, less-educated job seekers who reside in the central city still have, on average, somewhat better access to job openings than those who reside at the periphery of the metropolitan area. However, accessibility differentials among locations are small as compared to accessibility differentials between transportation modes. For job seekers who can travel by car, the majority of residential locations will allow them to have an access level higher than the average. For job seekers who depend on public transit, on the other hand, very few residential locations will allow them to have an above-average access level. These findings have important policy implications.

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An important objective of antipoverty policy in the United States is to reduce spatial separation between economic opportunities and low-income people who seek these opportunities. Hughes (1995) identifies three basic strategies for helping low-income people to overcome spatial obstacles. One strategy is to enable them to relocate their residence in or near job-rich communities. This strategy is often equated with housing dispersal because its proponents tend to believe that the suburbs have more jobs suitable for less-educated workers. A second strategy is to create employment opportunities in low-income communities. A third strategy is to improve transportation between residential locations and potential job locations. Noticeable efforts to implement these strategies are, respectively: housing projects and vouchers for low-income households, community economic development programs such as enterprise zones, and vanpool and transit services linking the central city to suburban employment centers.

To assist policymakers in evaluating and improving these strategies, urban researchers must gain a deeper understanding of the economic geography of U.S. metropolitan areas. We need to examine more closely factors such as the spatial distribution of economic opportunities that do not require a high level of educational attainment, the spatial distribution of less-educated workers who seek such opportunities, and the spatial variation of accessibility of such opportunities. We need more fine-grained descriptions and analyses of the existing conditions (Jencks & Mayer, 1990).

Current welfare reform has added urgency to the task. The Personal Responsibility and Work Opportunity Reconciliation Act of 1996 has terminated the federal government's open-ended welfare support to needy families. The new legislation requires work participation of all adult welfare recipients after they receive cash assistance for 2 years. Undoubtedly, welfare reform is faced with major barriers, which include spatial barriers. A high percentage of adult welfare recipients are single females with depen-

dent children but without a car. It is difficulty for them to find jobs that do not require an intolerable amount of travel time or cost. Strategies for increasing welfare recipients' access to job opportunities, therefore, should be considered an important component of all urban policies aimed at facilitating the welfare-to-work transition (Blumenberg & Ong, 1998; Lacombe, 1997; Laube et al., 1997; Rich & Coughlin, 1998; Wachs & Taylor, 1998). A good understanding of the economic geography of metropolitan areas is a prerequisite for designing effective strategies.

For job seekers, including welfare recipients, the relevant economic opportunities are job openings—positions that are currently available. Therefore, it is essential for urban researchers to ask the following questions:

1. How are job openings, especially those that are suitable for less-educated workers, spatially distributed in the metropolitan area?
2. What are the distinctive patterns of variations in access to these job openings?

This research is an effort to answer these questions, which seem simple but are in fact challenging because there are no systematically collected data on intrametropolitan distribution of job openings. The article reviews current literature, describes the research methodology, and reports the findings. Although the analysis is based on the case of the Boston Metropolitan Area, the findings shed new light on the search for approaches to enhancing less-educated workers' access to opportunities. In particular, they suggest that residential dispersal is unlikely to be effective as a strategy for lifting spatial barriers in the dispersing metropolitan economy. On the other hand, they indicate the growing importance of transportation mobility strategy for overcoming spatial separation between economic opportunities and the economically disadvantaged population.

Importance of Examining Job Openings

A large volume of research on spatial patterns of residence, employment, and commuting in U.S. metropolitan areas has been completed over the past three and a half decades. Researchers have drawn different, and in many cases conflicting, conclusions on the spatial distribution of job opportunities for less-educated workers and how to improve access to these opportunities. Instead of attempting a comprehensive review of the literature, the discussion here is focused on several recent studies that clearly illustrate the disagreement.

Kasarda (1995) shows that while a high percentage of less-educated workers still live in low-income neighborhoods in the central city, jobs suitable for them are increasingly decentralized. Furthermore, he indicates that U.S. metropolitan areas are undergoing a fundamental industrial transition and, as a result of that process, the central-city economy is becoming more and more information intensive. He argues that these two general trends have caused both spatial mismatch and skill mismatch, which together have put less-educated workers who reside in the central city at a disadvantage with respect to job access. This view is widely shared among urban researchers (Holzer, 1996; Hughes, 1995; Kain, 1992; Rosenbaum, 1995; Wilson, 1996). Many of these researchers argue that public policy should be aimed at offering low-income households the opportunity to relocate from the central city to the suburbs through promoting affordable suburban housing.

Other researchers, however, indicate that less-educated workers living in the central city have no disadvantage in job access when compared with otherwise comparable workers living in suburbs. Taylor and Ong (1995) show that existing disparities in access among workers are largely caused by their use of different transportation modes. Shen (1998) finds that, in the case of the Boston Metropolitan Area, living in the central city actually still gives low-income workers some advantage in job access. But this location advantage, according to his empirical measurement, is relatively modest and is more than offset by the low level of automobile ownership among low-income households located in the central city. These researchers share the view that transportation mobility, rather than residential location, is the key determinant of the degree to which low-income workers seeking economic opportunities are faced with spatial barriers. Their findings imply that both the conventional analytical approach and the conventional policy response to the problem of spatial mismatch, which focus on the geographic location factor, need modification.

What has caused this disparity? A close examination of the research design in each case suggests that the disagreement may be attributed in part to the different ways in which economic opportunities are measured. Some researchers, Kasarda (1995) and Raphael (1998), for example, use employment changes (growth, decline, and relocation) as the basis for analyzing spatial distribution of job opportunities and spatial variation in job accessibility. Others, Shen (1998) for example, use employment levels instead. Given the fact that new jobs are spatially much more dispersed than pre-existing jobs, it is not surprising that Kasarda (1995) and Raphael (1998) find the central city to be a disadvantaged residential location with respect to employment access, whereas Shen (1998) finds the opposite to be true.

Which approach is preferable? If the research objective is to understand variations in access for all less-educated workers, employment levels should undoubtedly provide an appropriate measure of opportunities. On the other hand, if the objective is to understand variations in access for only those less-educated workers who are unemployed and are seeking jobs, neither approach will be entirely appropriate. Employment opportunities for job seekers consist of two categories of job openings —those coming from new jobs (employment growth) and those coming from turnover. Data on employment changes capture growth but not turnover, whereas data on employment levels capture turnover but not growth.[1] Neither measure alone provides a complete picture of the total economic opportunities for less-educated job seekers.

Because unemployed workers are the primary target of antipoverty policy in general and of current welfare reform in particular, it is imperative to study job openings. It is essential to investigate the spatial distribution of job openings that are suitable for less-educated workers and, subsequently, to reexamine patterns of spatial variations in employment accessibility.

Research Methodology

The research methodology used in this study has three main components: (1) estimation of the number of job openings, (2) measurement of accessibility of job openings, and (3) analysis and visualization of spatial patterns of job openings and accessibility. Each of these components will be described and discussed.

Estimation of the Number of Job Openings

The objective here is to obtain information on intrametropolitan distribution of job openings, at an adequate level of spatial resolution. Given the fact that governmental agencies in charge of economic censuses do not collect spatially disaggregated data on job openings, alternative ways to obtain the information need to be explored. One conceivable approach is to draw a probability sample from all employers in a metropolitan area and conduct a questionnaire survey. Based on the responses, the researcher can find out the number, education and skill requirements, and other characteristics of job openings in various geographic locations within the metropolitan area. However, in order to gather the data at a satisfactory level of spatial resolution, a very large sample is needed, which would in turn necessitate large amounts of financial and time resources. Therefore, this approach is often not practical.

A similar but more realistic approach is to survey only those employers who are actively seeking employees through job advertisements in newspapers, Web sites, and other media. Compared with the previous approach, it requires a smaller sample and simplifies the sampling procedure. A good example of an application of this approach is found in a recent study of economic opportunities and job accessibility in Metropolitan Atlanta (Rich & Coughlin, 1998). The researchers sent questionnaires to approximately 3,000 employers who were advertising job openings in the newspaper and received 750 completed responses. The data obtained from the survey enabled them to gain useful insights into the composition and spatial distribution of job openings. The primary shortcoming of this approach is that it excludes from the sample all employers who do not advertise their job openings. By excluding an unknown number of employers who are actually hiring, this approach does not usually lead to a systematic measurement of spatial variations in accessibility of job openings.

Another alternative, which can lead to a systematic measurement of spatial variation in accessibility of job openings, is to estimate the number of job openings for different geographic locations within the metropolitan area. The estimation is based on spatially disaggregated data on both employment levels and employment changes. This approach does not require a survey of employers and therefore is much more economical than the previous ones. Its major shortcoming, obviously, is that the resulting data consist of estimates rather than observations. In spite of the shortcoming, however, this method is useful because the estimates depict a relatively complete picture of spatial patterns of job openings in a metropolitan area, which can complement insights gained from a survey of employers. The details of this approach are described in the following paragraphs.

Job openings consist of opportunities created by employment growth and opportunities created by turnover. Job openings ($O_{i(t)}$) in geographic location i at time t can be expressed by the following equation:

$$O_{i(t)} = O_{i(t)}^{growth} + O_{i(t)}^{turnover} \quad (1)$$

where

$O_{i(t)}^{growth}$ is the number of job openings that come from net employment growth, and

$O_{i(t)}^{turnover}$ is the number of job openings that come from turnover, in geographic location i at time t.

It is important to note that employment growth can have a negative value (due to employment decline and/or relocation), which means that $O_{i(t)}^{growth}$ can be negative.

Estimating job openings is a flow-stock problem. The stock of job openings at any given time is a function

of two flows of jobs, one from employment growth and the other from turnover, which come into and exit the stock. In order to quantify these two components, it is essential to estimate the average rates of employment growth and turnover, as well as the average duration of job vacancies. Using the month as the unit of measurement for time, the product of the monthly employment growth and the vacancy duration yields the value of the first component of the total number of job openings. The product of the monthly turnover and the vacancy duration yields the value of the second component of the total number of job openings.

Under normal macroeconomic conditions, average vacancy duration in the U.S. is roughly 0.5 month, or 15 days.[2] Assuming that the employment level increases or decreases by a constant amount every month during a given time period, job openings due to employment growth can be estimated as follows:

$$O_{i(t)}^{growth} = \frac{E_{i(t)} - E_{i(t')}}{(t - t') \times 12 \text{ months}} \times 0.5 \text{ month} \quad (2)$$

where
t is the ending point (year) of the time period;
t′ is the starting point (year) of the time period;
$E_{i(t)}$ is employment level in geographic location i at the ending time; and
$E_{i(t')}$ is employment level in geographic location i at the starting time.

Estimating the number of job openings created by turnover is more challenging. The difficulty is caused by the lack of systematically collected data on turnover. However, there are some available data that are useful for making sound estimates. Until 1981, the U.S. Bureau of Labor Statistics (BLS) conducted annual surveys on turnover in the manufacturing sector. The data indicated that the average *monthly* turnover rate was roughly 4%, if all components (quits, discharges, and layoffs) were taken into consideration; it was close to 3% if only quits and discharges were taken into consideration. It is important to note that the latter figure is more relevant to this study because quits and discharges lead to job openings, whereas layoffs do not.

Some recent studies have provided more updated data on turnover. Anderson and Meyer (1994) calculated an average *quarterly* turnover rate of 23% across all industries. Their figure suggests a monthly rate that is considerably higher than the figure reported by the BLS. However, Anderson and Meyer include the portion of turnover caused by layoffs. If this portion were excluded from their calculation, the resulting turnover rate would be reduced. Holzer (1996), on the other hand, indicates that the average *annual* turnover rate across manufacturing, retail, and service sectors is roughly 21%. Holzer's calculation is based on quits and discharges only. If converted into a monthly rate, this figure would probably be not far off from the figure reported by the BLS.[3]

Therefore, it is reasonable to assume that under normal macroeconomic conditions, quits and discharges create a *monthly* turnover rate of 3% as reported by the BLS. A later section will address the question of how using different turnover rates might affect the results. Job openings created by turnover are estimated as follows:

$$O_{i(t)}^{turnover} = 3\% \text{ per month} \times E_{i(t)} \times 0.5 \text{ month} \quad (3)$$

Measurement of Job Accessibility

Over the last four decades, urban researchers have developed many alternative accessibility indicators. The demand-adjusted indicator, proposed initially by Weibull (1976) and extended recently by Shen (1998), is especially suited for measuring job seekers' level of accessibility. The following two equations are, therefore, used to calculate accessibility for job seekers who are, respectively, automobile drivers and captive public transit riders:

$$A_i^{auto} = \Sigma_j \frac{O_{j(t)} \times f(C_{ij}^{auto})}{\Sigma_k [\alpha_k P_{k(t)} \times f(C_{kj}^{auto}) + (1 - \alpha_k) P_{k(t)} \times f(C_{kj}^{tran})]} \quad (4)$$

$$A_i^{tran} = \Sigma_j \frac{O_{j(t)} \times f(C_{ij}^{tran})}{\Sigma_k [\alpha_k P_{k(t)} \times f(C_{kj}^{auto}) + (1 - \alpha_k) P_{k(t)} \times f(C_{kj}^{tran})]} \quad (5)$$

where
A_i^{auto} and A_i^{tran} are accessibility scores for job seekers who are automobile drivers and captive public transit riders, respectively, living in location i; i = 1, 2, ..., N;
$O_{j(t)}$ is the number of job openings in location j at time t; j = 1, 2, ..., N;
$f(C_{ij}^{auto})$ and $f(C_{ij}^{tran})$ are impedance functions for automobile drivers and public transit riders, respectively, traveling between i and j;
α_k is the percentage of households in location k that own at least one motor vehicle;
$P_{k(t)}$ is the number of job seekers living in location k at time t; k = 1, 2, ..., N; and
$f(C_{kj}^{auto})$ and $f(C_{kj}^{tran})$ are impedance functions for automobile drivers and public transit riders, respectively, traveling between k and j.

Equations 4 and 5 together reflect essentially each worker's proximity to the job openings for which he or she is qualified, relative to the number of workers competing for these positions. Proximity is measured by required travel time, which is determined jointly by travel distance and travel mode.

An adequate measure of the number of job seekers living in each location is the number of unemployed workers living in that location. Because the focus of this study is on economic opportunities and job access for less-educated workers, it is desirable to estimate the number of unemployed workers in each location who are seeking positions that require relatively little formal training. Unfortunately, this type of information about unemployed workers is usually not available for small geographic areas. Therefore, an estimation is made, which involves two basic steps. First, less-educated job seekers are defined as people who seek positions in sales, service, and labor-intensive occupations.[4] Second, the number of less-educated job seekers living in each location is approximated on the basis of one of two assumptions. One assumption is that the occupational distribution of unemployed residents resembles the occupational distribution of employed residents for which information is available. The other assumption is that all unemployed workers residing in each location are seeking jobs that require relatively little education. It is important to note that both assumptions have some weakness, as the former likely understates the proportion of the unemployed that compete for job openings suitable for less-educated workers, whereas the latter likely overstates it. But these weaknesses will not cause any major concern if the two assumptions lead to consistent results.

It is also essential to estimate the number of job openings in each location that are suitable for less-educated workers. As an approximation, only jobs in sales, services, and labor-intensive occupations are included in the calculation of job openings.

Available data on automobile ownership only measure the overall percentage of households in each location that have one or more motor vehicles; they do not provide any information about the level of automobile ownership among less-educated job seekers. Once again, there are two basic approaches to making an approximation. The first approach is to assume that job seekers living in each location have the same level of automobile ownership as the rest of the residents. The other approach is to assume that all job seekers have the same level of automobile ownership (for example, 50%) regardless of where they live.

There are many possible ways to specify the travel impedance function. To make the analysis transparent, this study uses the travel time threshold function, which has the simplest form. With a threshold travel time of C, the value of $f(C_{ij}^{auto})$ is 1 when C_{ij}^{auto} is less than C; it is 0 otherwise. The value of $f(C_{ij}^{tran})$ is similarly assigned. To determine whether the results are sensitive to the definition of the threshold time, three alternative values of C—15, 30, and 45 minutes—are used.[5]

Shen (1998) shows that the expected value of accessibility scores calculated using Equations 4 and 5 equals the ratio of the total number of opportunities to the total number of opportunity seekers in the metropolitan area. In the context of this study, the expected value is the ratio of the sum of job openings to the sum of job seekers ($A = O / P$, where $O = \Sigma_j O_{j(t)}$ and $P = \Sigma_k P_{k(t)}$). The ratio provides a benchmark for examining how the accessibility of job openings varies among residential locations and between travel modes. Note that here and in the remainder of this article, for the sake of simplicity, the term *job openings* will denote job openings suitable for less-educated job seekers, and the term *job seekers* will denote less-educated job seekers, unless otherwise noted.

Visualization of Spatial Patterns of Job Openings and Accessibility

When a metropolitan area is represented by a large number of locations (zones), visualization through mapping becomes highly effective for identifying spatial patterns of job openings and accessibility. Geographic Information Systems (GIS) provide an effective tool for this purpose. The three-dimensional (3-D) representation capability of GIS is especially powerful in visualizing variables that show highly skewed spatial distributions, such as employment and people in a metropolitan area. Two sets of maps will be produced. The first set depicts the spatial distributions of job openings created by employment growth, job openings created by turnover, and the sum of these two components. The second set shows the spatial distribution of job seekers and the locations of opportunity-rich and opportunity-poor areas.

Because the geographic size of these locations (zones) varies substantially, spatial distributions of job openings and job seekers are best visualized through density maps. In 3-D representation, densities of job openings and job seekers are depicted by heights. The volumes, each a multiplication of height and area, realistically depict the spatial distributions of job openings and job seekers.

The Case Study, the Data, and Computation

The Boston Metropolitan Area was examined as the case study. A total of 775 transportation analysis zones[6] spatially represent this metropolitan area, which covers more than 2,000 square miles of land and accommodates more than 4 million people.

Because 1990 was the most recent year in which spatially disaggregated employment data were systematically collected, the year 1990 is considered in this study as the ending point (t) of the time period of concern. The

starting point (t′) of the time period is 1980. The length of the time period, which is the denominator of Equation 2, is 120 months. It is important to note that the average for this 10-year period is not an ideal estimator of current monthly job growth, but is an approximation necessitated by the lack of more recent data. Nevertheless, it is appropriate because the rate and the spatial distribution of employment growth in the Boston Metropolitan Area did not change fundamentally during the decade. The same reasoning applies to the use of employment levels in 1990 for the estimation of current monthly turnover (quits and discharges).

Data on employed workers by occupation by residential location, for 1980 and 1990, are extracted from the U.S. Census Bureau's Summary Tape Files 3A (STF3A). Also extracted from STF3A are data on unemployment and automobile ownership by residential location. Data on employment by occupation by work location, for 1980 and 1990, originate from the U.S. Census Bureau's Journey-to-Work tabulations. Zone-to-zone travel-time matrices for automobile and public transit, essential for calculating travel impedance for each mode, are obtained from the Central Transportation Planning Staff, which is in charge of transportation planning in the Boston Metropolitan Area.

Accessibility scores are calculated using a program written in the C language. Maps are generated using the GIS software ArcView 3-D Analyst.

Primary Findings

Composition of Job Openings

It is useful to look first at the overall picture of job openings in the Boston Metropolitan Area. Between 1980 and 1990, the whole metropolitan area added roughly 390,000 jobs. Based on Equation 2, it is estimated that on a typical day during the time period, there were roughly 1,630 job openings due to employment growth. It is also estimated that only 18% of these openings—approximately 290 new positions—were in sales, services, and labor-intensive occupations,[7] suitable for less-educated job seekers.

The corresponding figures of job openings created by turnover, which are estimated using Equation 3, are much greater. On a typical day in 1990 there were roughly 31,280 job openings due to quits and discharges! Almost one third of them—approximately 10,400 positions—were in occupations suitable for less-educated job seekers.

Altogether, on a typical day in 1990, there were an estimated 32,910 job openings in the Boston Metropolitan Area. Roughly 30% of them (10,690 positions) were suitable for less-educated job seekers. Table 1 summarizes these results. What is striking in these figures is that growth, in comparison with turnover, was only a minor source of job openings. It accounted for merely 5% of total job openings and less than 3% of job openings in sales, services, and labor-intensive occupations. Therefore, if an empirical study of job openings focused exclusively on employment growth, it would inevitably depict only part of the picture and very likely lead to incorrect conclusions.

Spatial Distributions of Job Openings and Job Seekers

Table 2 describes the intrametropolitan distribution of job openings on a typical day in 1990 that were suitable for less-educated workers and the distribution of less-educated job seekers. Several important observations can be made. First, opportunities created by employment growth are spatially much more dispersed than opportunities created by turnover. Only 6.9% of the new jobs are located in the central city, whereas 20.4% of turnover jobs are located in the central city. This is broadly consistent with observations made previously by numerous researchers, and indicates that the Boston case shares a fundamental similarity with other U.S. metropolitan areas.

Second, because turnover is the dominant contributor of job openings, the spatial distribution of opportunities reflects primarily the distribution of turnover. Of all job openings in the Boston Metropolitan Area suitable for less-educated workers, 20.0% are located in the central city. This percentage is similar to the one that Rich and Coughlin (1998) found in Atlanta through their survey of employers.

TABLE 1. Estimated job openings in the Boston Metropolitan Area on a typical day in 1990.

Job openings	Positions created by growth	Vancancies created by turnover	Total number of job openings
Total	1,630	31,280	32,910
Suitable for less-educated workers	290	10,400	10,690

TABLE 2. Intrametropolitan distribution of less-educated job seekers and job openings suitable for them on a typical day in 1990.

	Entire Boston Metropolitan Area	Within the City of Boston	Outside the City of Boston
Positions created by growth	290	20 (6.9%)	270 (93.1%)
Vacancies created by turnover	10,400	2,120 (20.4%)	8,280 (79.6%)
Job openings for less-educated workers	10,690	2,140 (20.0%)	8,550 (80.0%)
Less-educated job seekers	50,480	10,650 (21.1%)	39,830 (78.9%)

Third, less-educated job seekers are slightly more concentrated in the central city than are the job opportunities suitable for them. Specifically, 21.1% of less-educated job seekers in this metropolitan area are located in the central city, in comparison with 20.0% of job opportunities. The issue of whether or not this implies that central-city residents have a disadvantage in access to economic opportunities will be addressed later.

The spatial distribution of job openings suitable for less-educated job seekers is depicted in more detail in three maps, Figures 1, 2, and 3, which are directly comparable to one another because they use the same data classification and visual presentation. Figure 1 displays the density (height) and number (volume) of positions created by employment growth in each zone. Figure 2 portrays the density and number of vacancies created by

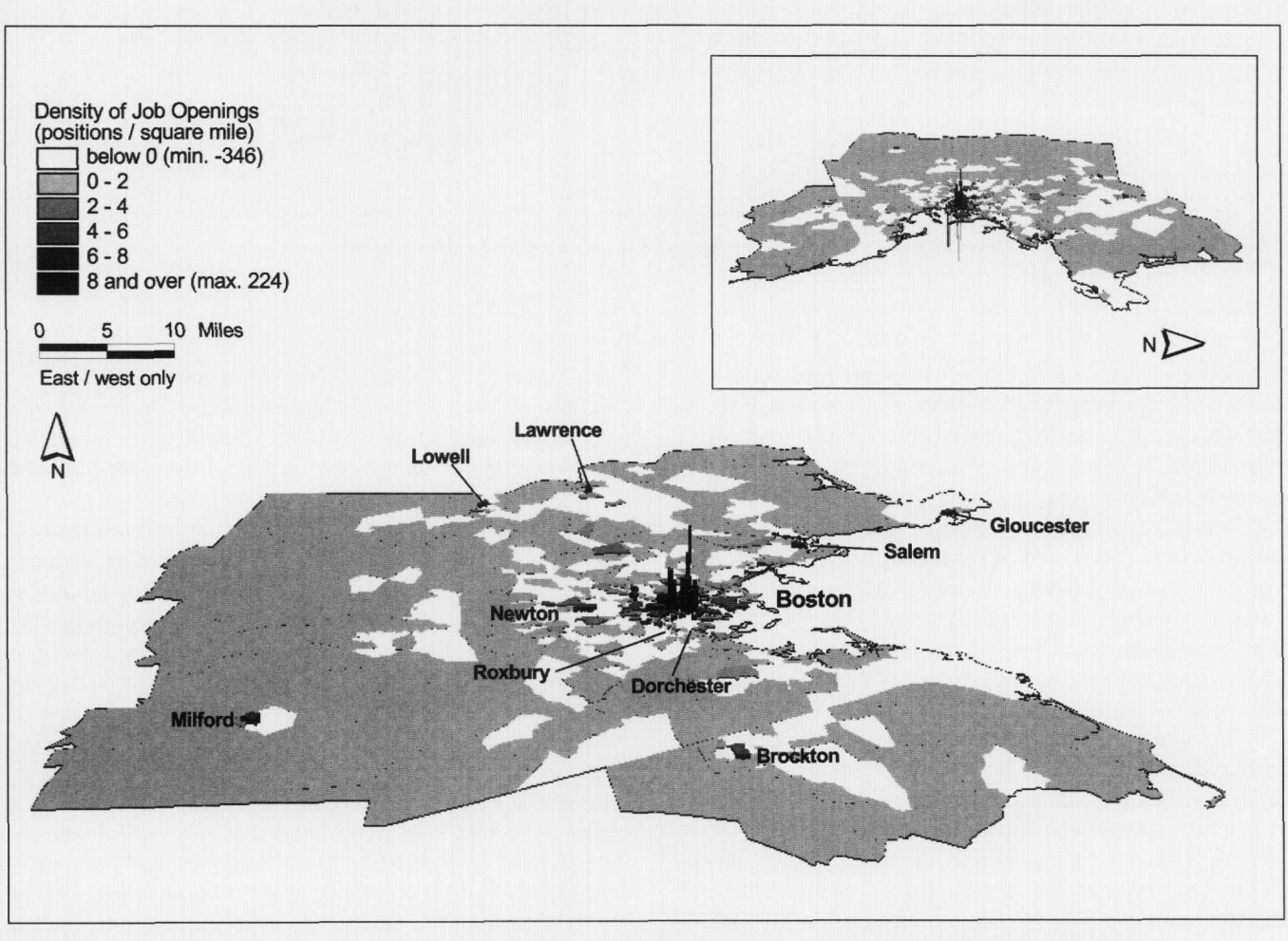

FIGURE 1. Perspective view showing density of less-skilled job openings due to employment changes.

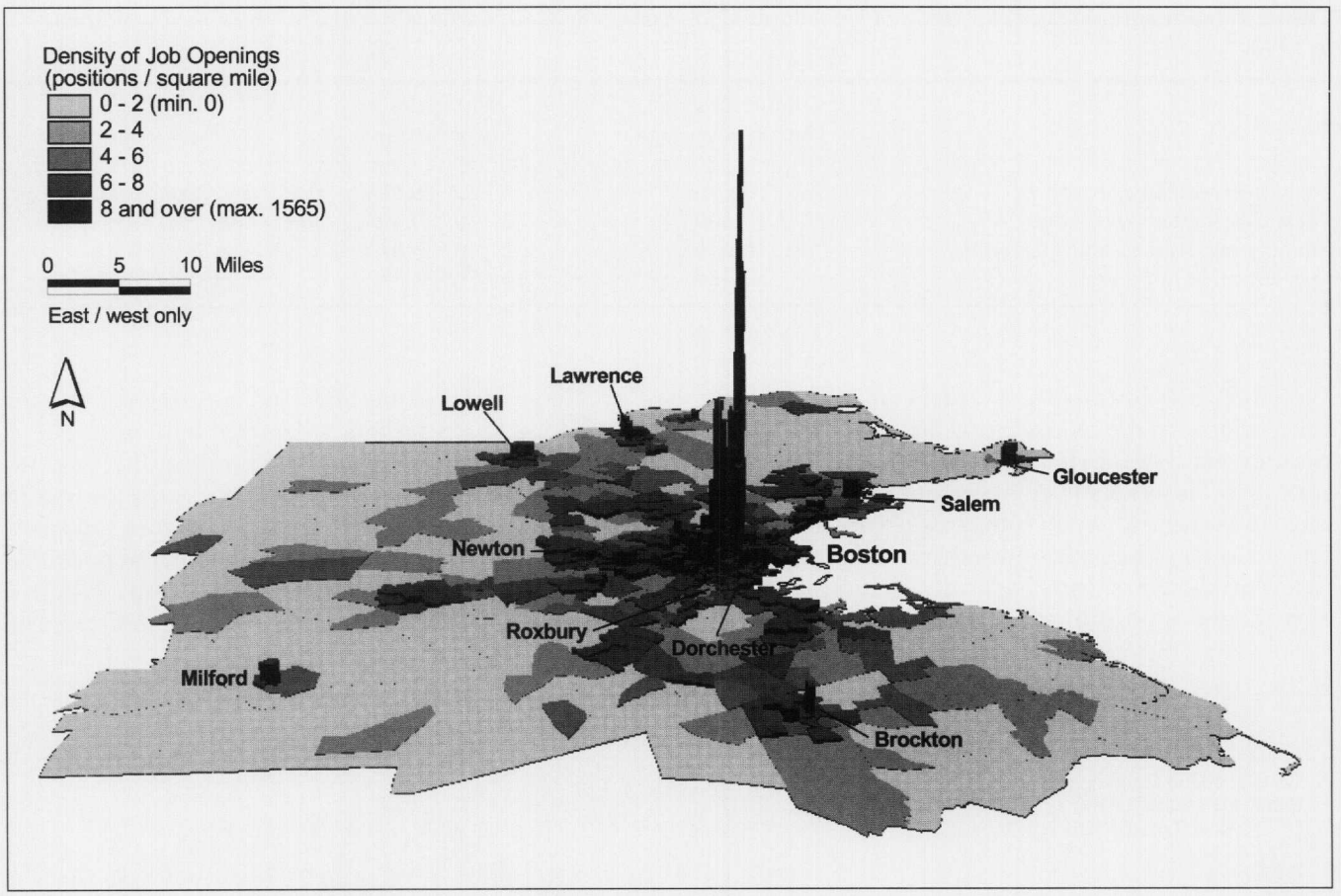

FIGURE 2. Perspective view showing density of less-skilled job openings due to turnover.

turnover in each zone. Obviously, new jobs were spatially more dispersed than vacancies in pre-existing jobs. In fact, Figure 1 shows that job growth was negative in a considerable percentage of zones in the central city, most of which are located in or near low-income neighborhoods. But Figure 2 shows that densities of vacancies created by turnover were rather high in most central-city zones. Overall, as shown in Figure 3, job openings were highly concentrated in the central city. The great majority of suburban zones had low densities of job openings. Only a small number of them showed moderate densities.

The spatial distribution of less-educated job seekers is displayed in Figure 4. The numbers shown on this map are calculated on the basis of the assumption that the occupational distribution of unemployed residents resembles the occupational distribution of employed residents. On a typical day in 1990, there were an estimated 50,480 less-educated job seekers in the Boston Metropolitan Area.[8] Obviously, job seekers were highly concentrated in the central city. However, a number of neighborhoods in low-income far-suburban towns, especially the declining manufacturing cities of Lawrence and Lowell located near the northern boundary, also had very high densities of job seekers.

Figure 5 shows the ratio of job openings to job seekers in each zone. For the metropolitan area as a whole, there were estimated 10,690 job openings in sales, services, and labor-intensive occupations and 50,480 seekers of such positions; therefore, the average ratio was roughly 0.2. Zones with a higher ratio were opportunity rich; zones with a lower ratio were opportunity poor. This map indicates clearly that the central business district (CBD) and a considerable number of suburban zones were opportunity-rich areas, whereas many central-city low-income neighborhoods and several poverty enclaves in far-suburban manufacturing cities were the most pronounced opportunity-poor areas. It is especially worth noting that the CBD, which is located not far from many low-income neighborhoods in or near the

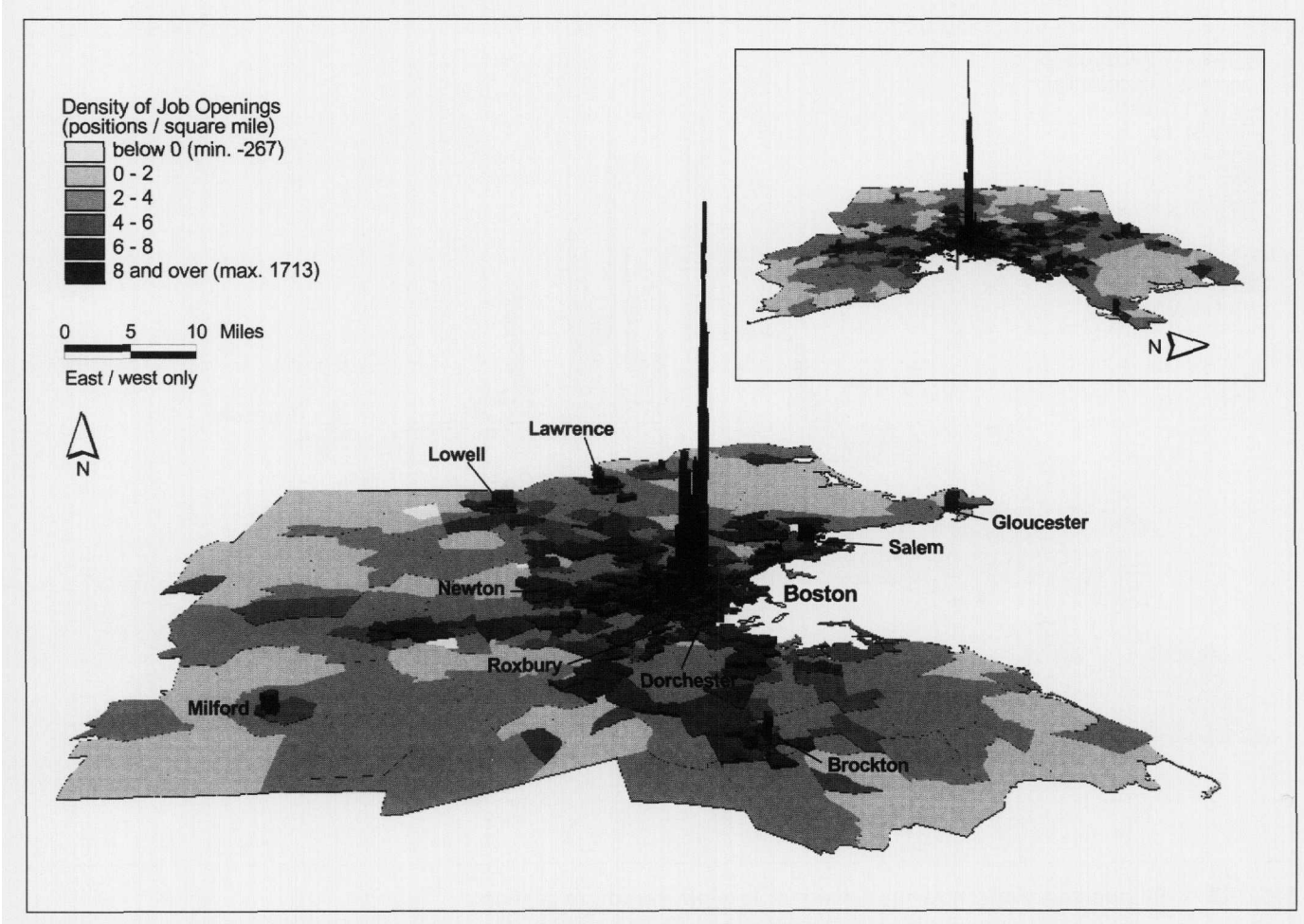

FIGURE 3. Perspective view showing density of less-skilled job openings in total.

central city, was extremely opportunity rich. It is also worth noting that most of the opportunity-rich suburban zones were located not far from the central city.

Spatial Variations in Accessibility of Job Openings

It is clear that job seekers living in central-city low-income neighborhoods and suburban poverty enclaves did not find many local opportunities. But this does *not* necessarily mean that they had a low level of job accessibility. Accessibility depends not only on the number of opportunities located within their neighborhoods but also on their distance from employment centers (such as the CBD) and the travel mode and relative speed. For example, a job seeker living in an opportunity-poor central-city zone may have a relatively high level of job accessibility if the CBD is not far away. On the other hand, a job seeker living in an opportunity-rich suburban area may have a relatively low level of job accessibility if he or she does not own a car and does not have access to good public transit service.

Accessibility of job openings for job seekers living in each zone and commuting by each mode was measured systematically using Equations 4 and 5. The results were also depicted visually, although the maps are not shown here due to space considerations. Some summary statistics are reported in Table 3. All these results were obtained by calculation based on the assumption that the threshold travel time is 30 minutes.

The results indicate that if job seekers traveled by car and were willing to commute for up to 30 minutes, they would have a relatively high level of accessibility of job openings as long as they did not reside at the periphery of the metropolitan area. In fact, 542 out of the 775 zones were accessibility-rich for job seekers who traveled by car (i.e., they had accessibility scores higher than the expected value of 0.2). It is especially important to note that central-city low-income neighborhoods, in com-

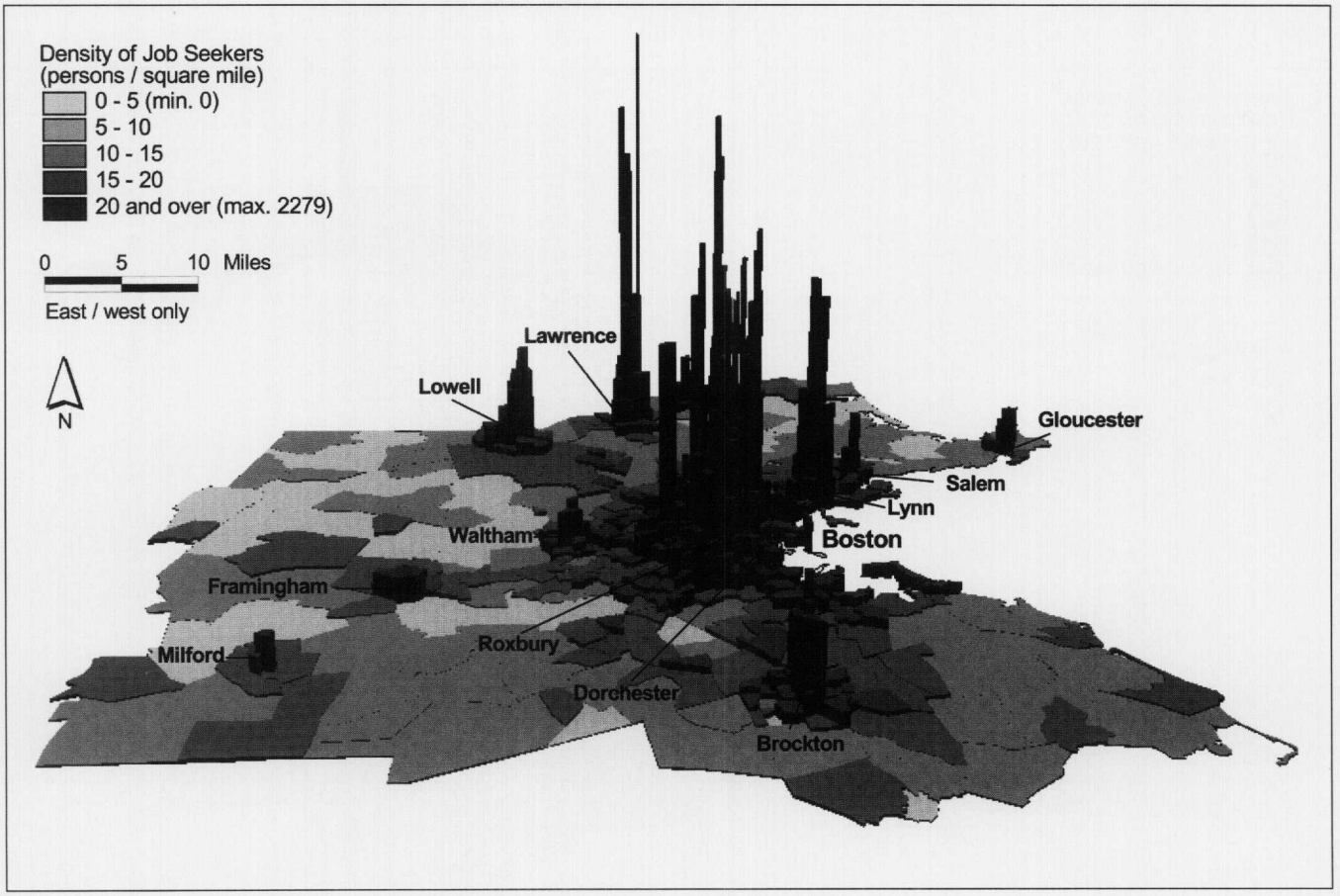

FIGURE 4. Perspective view showing density of less-educated job seekers.

parison with a great majority of peripheral and suburban locations, still had some advantage in accessibility of job openings. This finding is consistent with what was reported in Shen (1998). However, the results also show that there was a large cluster of zones in the wealthy west suburbs that had a high average level of accessibility of job openings.[9] These zones were the locations of many new firms, especially firms in the fast-growing high-tech industry. The location advantage of these zones is more pronounced when accessibility is measured on the basis of job openings instead of employment levels.

On the other hand, the results indicate that if job seekers were willing to commute for up to 30 minutes but were dependent on public transit, they would have a very low level of accessibility of job openings almost anywhere they lived. Only two zones, both located in the CBD, were accessibility-rich for job seekers who relied on public transit. The average accessibility score for public transit-dependent job seekers was merely 0.03. These results confirm another finding of Shen (1998): Travel mode, rather than residential location, is the predominant factor in determining accessibility in contemporary U.S. metropolitan areas. Furthermore, the results indicate that the central city, including most zones located in low-income neighborhoods, still showed a slightly higher average level of accessibility of job openings than did the majority of peripheral and suburban locations. In addition, they suggest that spatial variation in the level of accessibility for public transit-dependent job seekers reflected the alignment of the transit network.

TABLE 3. Accessibility of job openings by travel mode (travel threshold time assumed to be 30 minutes).

Travel mode	Average score of accessibility	Number of accessibility-rich zones
Automobile	0.31	542
Public transit	0.03	2

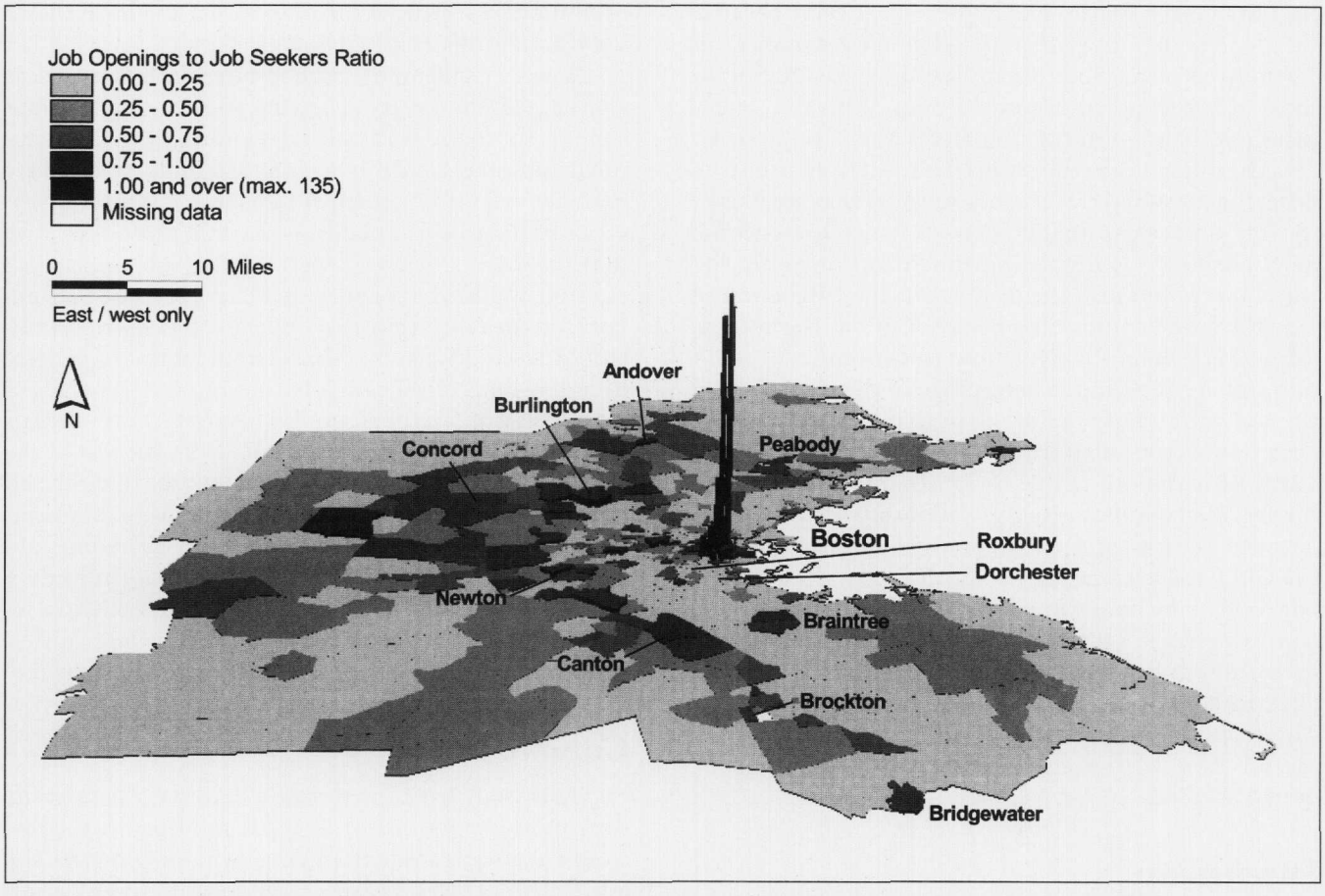

FIGURE 5. Perspective view showing ratio of less-skilled job openings to less-educated job seekers.

Although some suburban employment centers had good public transit service and therefore were among the better residential locations for job seekers who depended on public transportation, the majority of suburban zones were simply inappropriate as residential locations for people who did not have a car.

Sensitivity to Alternative Assumptions

Four alternative assumptions were tested and the results compared with those we have just described. First, different turnover rates were used to estimate job openings. Even if the monthly turnover rate were significantly lower, for example 2%, employment growth would still be a relatively minor source of job openings in the Boston Metropolitan Area.

Second, job seekers were estimated on the basis of the alternative assumption that all unemployed workers were willing to take positions in sales, services, and labor-intensive occupations. The resulting spatial distribution of less-educated job seekers, and subsequently spatial variations in accessibility of job openings, did not change appreciably.

Third, level of auto ownership in each zone was estimated with the alternative assumption that a fixed percentage of less-educated job seekers owned one or more motor vehicles regardless of their location. Assuming that the level of auto ownership among job seekers was 50% in every zone, the measurement of accessibility was repeated. The outcome was quite similar.

Finally, the alternative threshold travel times of 15 minutes and 45 minutes were used to generate accessibility scores. The results were quite sensitive to the specification of threshold travel time. With the shorter threshold of 15 minutes, there were many more local variations in accessibility of job openings. Most importantly, a high number of low-income zones in the central city had much lower accessibility because many opportunity-rich locations—especially the CBD—were more than 15 minutes away. On the other hand, a considerable number of suburban zones, including many in

the northwest suburbs, had higher accessibility because they tended to be opportunity-rich and were more than 15 minutes away from unemployed workers living in most of the opportunity-poor zones. With the longer threshold of 45 minutes, the effects were the opposite.

The difference in the results obtained from using the different threshold travel times suggests that accessibility for job seekers living in central-city low-income neighborhoods is highly dependent on not only the travel mode, but also the distance to the CBD and the job-search and commuting behavior. While the average job seekers are probably willing to commute 30 to 45 minutes, a considerable percentage of them—especially women with young children—probably want to work near home, with a short commute (Hanson & Pratt, 1995; Rosenbloom & Burns, 1993). In the case of the Boston Metropolitan Area, given the spatial proximity between central-city low-income neighborhoods and the CBD, the average job seekers living in these neighborhoods may have some location advantage in access to job openings.[10] But for those who can only commute up to 15 minutes, living in these neighborhoods translates into a disadvantage in access to job openings. Therefore, this study has revealed more complexity in central cities' location characteristics than has previously been discussed.

Discussion

One may argue that the employed also search for jobs, and therefore the stock of job seekers should include not only unemployed job seekers, but also some fraction of employed workers. This is true; but no matter what percentage of the employed were included in the analysis, it would only have strengthened the finding that living in the central city still offers less-educated job seekers some advantage with regard to access to job openings. The reason is that employed workers are not nearly as highly concentrated in the central city as unemployed job seekers are. Adding any fraction of the employed to the pool of job seekers would make the job openings/job seekers ratio in the central city relatively more favorable than the same ratio in the suburbs. The exclusion of employed job seekers from the analysis should not affect other findings of this study.

One may also argue that given the booming economy of the 1990s, the importance of employment growth in creating job openings is underestimated in this study. It is certainly true that a large number of jobs have been created during the past several years, and that the number of estimated job openings due to growth would be greater if more recent employment data were available for the zones. But even if we doubled the pace of employment growth, turnover would still be the dominant source of job openings.

A more challenging issue to be addressed concerns alternative definitions of less-educated workers and jobs suitable for them. Because of data limitations, less-educated job seekers and job openings suitable for them are both defined rather broadly in this study. If more disaggregated data were available, one would most likely find that the least-educated/lowest-income job seekers, for example welfare recipients, are relatively more concentrated in the central city than indicated in Figure 4. Similarly, one would also find that certain kinds of opportunities, such as child care jobs, are more decentralized than what is shown in Figure 3. Therefore, if the job market differentiates welfare recipients from the rest of the less-educated job seekers, it may be the case that for welfare recipients, the central city is a relatively disadvantaged residential location in comparison with some suburban neighborhoods. However, in any case, the finding that accessibility differentials attributed to residential locations are small in comparison with accessibility differentials attributed to transportation modes remains valid.

Conclusion

This study has shown clearly that in the case of the Boston Metropolitan Area, most job openings come from turnover rather than employment growth. The estimation of the number of job openings on a typical day in 1990 indicates that turnover accounted for approximately 95% of all job opportunities for unemployed workers and an even higher percentage of the opportunities suitable for those with little formal education. Employment growth is a minor source of job openings.

Although a large portion of employment growth is in the suburbs, on a typical day the number of job openings created by this growth is small. Furthermore, these opportunities are spatially dispersed over a very large territory. On the other hand, pre-existing employment—the primary source of job openings—is still highly concentrated in the central city (i.e., the City of Boston). Consequently, job openings, including ones that require little education, are still relatively concentrated in commercial and industrial areas of the central city.

Less-educated workers who seek jobs are also relatively concentrated in the central city—more specifically, in its low-income residential neighborhoods. On balance, low-income residential neighborhoods in the central city are mostly opportunity-poor, as there are generally more job seekers than job openings in such areas. However, these neighborhoods are located reasonably close to opportunity-rich commercial and industrial areas of Boston, including the CBD, which is extremely

opportunity-rich. They are also not far from some opportunity-rich suburban locations.

For less-educated job seekers who are willing to spend about 30 minutes commuting, residing in the central city of the Boston Metropolitan Area still gives a small amount of location advantage in access to job openings. The 1990 zone-to-zone travel time data indicate that 30 minutes of travel by either car or subway would take residents of low-income neighborhoods in the central city to some opportunity-rich commercial and industrial areas located nearby. The analysis has shown that, for average job seekers (i.e., those who are able to commute for up to 30 minutes), the central city as a residential location offers somewhat higher job accessibility than the majority of suburban and peripheral areas. On the other hand, for those who can only work near home and therefore cannot access opportunities located outside their low-income neighborhoods, the opposite is true.

Most importantly, the analysis has demonstrated that accessibility differentials among locations within the metropolitan area are rather modest when compared to accessibility differentials between travel modes. Measurement of accessibility of job openings in 1990 has shown that for job seekers who travel by car, most residential locations will allow them to have an accessibility level higher than average. On the other hand, for job seekers who depend on public transit, the great majority of residential locations are associated with an accessibility level substantially lower than the average.

These findings have important methodological implications. First and foremost, in any study of spatial patterns of job openings and access in a U.S. metropolitan area, employment growth should not be used as the sole empirical basis for identifying job opportunities. In the case of the Boston Metropolitan Area, a study that neglects job turnover in effect overlooks 95% of the picture! Furthermore, this incomplete picture is biased, because the spatial pattern of employment growth presents an overly optimistic view of economic opportunities in the suburbs and an overly pessimistic view of opportunities in the central city. To be sure, in comparison with the Boston case, some other metropolitan areas may have a relatively higher pace of employment growth and more intrametropolitan employment relocations. However, given the high level of labor mobility in this country, it is unlikely to find any case where employment growth is the primary source of job openings. Focusing exclusively on employment growth/decline, a popular approach taken by many researchers, will inevitably generate misleading results.

Second, in measuring job seekers' accessibility of employment opportunities, those who can travel by automobile should be distinguished from those who depend on public transportation. A study that mixes these two groups will inevitably lead to an outcome which understates the level of access for the former and overstates it for the latter. It is critical for urban researchers to remember that a high percentage of less-educated job seekers, and an even higher percentage of welfare recipients, do not own an automobile. Unfortunately, most published studies of spatial mismatch and labor participation in U.S. metropolitan areas fail to recognize the enormous gap in employment accessibility between people who have an automobile and people who do not have this option.

Third, in assessing spatial obstacles faced by job seekers, those who have a normal commute time constraint should be distinguished from those who have a more stringent one. A study that does not make this distinction will underestimate the spatial disadvantage resulting from having a small time budget for commuting. It is important for researchers to keep in mind that a very high percentage of the unemployed, especially adult welfare recipients, are single mothers who bear many domestic responsibilities, which may prevent them from commuting far from home.

The fourth and final methodological implication is that, in analyzing intrametropolitan variations in access to job openings, the data should be processed at an adequate level of spatial resolution to capture differences among central-city neighborhoods and among suburban locations. In the case of the Boston Metropolitan Area, although low-income residential neighborhoods in the central city are opportunity-poor, they are spatially proximate to some opportunity-rich areas, especially the CBD, and therefore still offer a small advantage in location to those job seekers who are willing to commute beyond their neighborhoods. Whether or not this is true in other metropolitan areas should be examined in future research. Careful examination using spatially disaggregated employment, demographic, and travel data is the only approach for answering the question.

The findings of this study also have major policy implications. One is that residential dispersal is unlikely to be an effective strategy for removing spatial barriers to access to employment opportunities for low-income persons. To be sure, as Wolpert (1999) observes, central cities are both havens and traps for the neediest population groups, and the haven quality has been eroding relative to the trap. However, as far as access to job opportunities is concerned, central cities are probably still superior to most suburban locations. The Boston case study has shown that, contrary to the prevailing view, job seekers would most likely face similar—if not greater—spatial ob-

stacles by relocating from the central city to the suburbs. Of course, this general conclusion may not apply to some special groups of job seekers. For example, central-city residents who are searching for positions in household services, which are relatively concentrated in wealthy suburban areas, may find some suburbs more desirable as residential locations. But for the majority of less-educated job seekers, residential dispersal would not improve accessibility.

One may argue that because Boston is one of a relatively small number of American cities that remain strong centers of metropolitan economies, the concentration of job openings in the central city is most likely lower for most other cases. Even so, it does not mean that residential dispersal would be an effective strategy in other U.S. metropolitan areas. Given the fact that turnover, rather than employment growth, is the primary source of job openings, there is no reason to expect other cases to show significantly higher concentrations of employment opportunities in suburban locations.

This is not to deny the importance of establishing a nondiscriminatory suburban housing market. Such a market would allow a healthy residential mobility for low-income households and enable them to optimize their residential location by choosing freely between the central city and the suburbs. For example, central-city residents who have found jobs in the suburbs can benefit from moving closer to their employment location. Furthermore, suburban housing offers a wide range of potential benefits, including school quality, safety, and opportunity for exposure to mainstream cultural and social environments (Rosenbaum, 1995). However, the belief that the suburbs are generally better locations for less-educated job seekers in regard to job access and that suburban housing can effectively connect them to suitable opportunities is the result of misperception, which needs correction.

Another important policy implication is that great efforts need to be made to improve the transportation mobility of job seekers who are currently dependent on public transit. These job seekers have a major disadvantage in competing for job opportunities. Because very few residential areas have enough location advantage to make up for their mobility disadvantage, the challenge is to devise innovative approaches to reducing the gap in transportation mobility. There is an emerging consensus among urban researchers that transportation policy must be directed toward low-income people who are unable to benefit from the mobility of automobiles (Blumenberg & Ong, 1998; Ong, 1996; Shen, 1998; Wachs & Taylor, 1998). However, researchers have not reached agreement on what actual transportation services and programs should be provided.

A view widely shared among transportation researchers in the U.S. is that automobiles, provided through public subsidy, can enhance employment accessibility most effectively for low-income persons (Ong, 1996; O'Regan & Quigley, 1998). This view is based on the common observation that in a dispersing metropolitan economy, more and more employment opportunities are beyond the reach of public transit-dependent people. Indeed, as the results of this study have shown, even the relatively well developed public transportation system in the Boston Metropolitan Area cannot provide adequate accessibility to job seekers. Undoubtedly, the potential role of automobiles in helping low-income people access job opportunities is worth exploring. However, before advocating subsidized automobile ownership as a new strategy, transportation researchers must first gain a better understanding of public transit dependency in U.S. metropolitan areas; they must also carefully analyze its likely economic efficiency and social equity impacts. They must then redefine the role of public transit in light of the proposed change. It is encouraging to see that some important steps have been taken to understand the positive effects of public transit on labor participation in U.S. metropolitan areas (Sanchez, 1999).

Public transportation will at least continue to serve people who cannot drive due to physical, mental, and financial limitations. Because the central city and high-density transportation corridors are where public transit service is most efficient, bringing suitable jobs to central-city locations is a highly desirable policy strategy for helping public transit-dependent people search for and commute to jobs. This strategy would certainly enhance the employment accessibility of low-income central-city residents, who constitute a high percentage of the total public transit-dependent population in a metropolitan area. Furthermore, it would offer the greatest employment accessibility contribution to public transit-dependent people throughout the metropolitan area, provided that the central city is the center of the metropolitan public transit system. Transportation mobility improvement and job creation can be complementary antipoverty strategies.

Current welfare reform presents a great challenge to urban researchers, because we need to help policymakers identify various barriers to economic well-being and design strategies for removing those barriers. On the other hand, it also provides an opportunity for reexamining, and perhaps reshaping, important aspects of antipoverty policy. This study has shown that in order to help job seekers in general, and welfare recipients in particular, to access economic opportunities in the contemporary U.S. metropolitan area, we must now rethink strategies

for removing spatial barriers. Increasingly, it is the ability to overcome spatial separation, not the residential location per se, that is the primary determinant of an individual's position in the economic geography of a metropolitan area (Shen, 1999).

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NOTES

1. Data on employment levels captures turnover as long as turnover rates do not vary systematically within a metropolitan area.
2. An empirical study by Abraham (1983) and more current information provided to the author by the labor economist Harry Holzer (personal communication, July 1998) both indicate that half a month is a reasonable estimate of the average vacancy duration in the United States. To be sure, vacancy duration can vary substantially among job categories, regions, and time periods. Everything else being equal, a longer vacancy duration means that a larger pool of job openings accumulates. However, vacancy durtion does not affect the relative importance of net employment growth and turnover, nor does it influence intrametropolitan distribution of job openings.
3. If there were no multiple turnovers during a year, the 21% annual rate reported by Holzer (1996) could be converted into a monthly rate of 1.75% (i.e., 21% ÷ 12). Since many jobs have multiple turnovers during a year, the monthly turnover rate is considerably higher than 1/12 of the annual turnover rate. See Anderson and Meyer (1994) for a more thorough discussion of this issue.
4. The Standard Occupational Codes (SOC) for these occupations are SOC 243-302 (sales), SOC 403-472 (services), SOC 473-502 (farming, forestry, and fishing), and SOC 703-902 (construction and machine operation).
5. These different threshold travel times represent different assumptions about how far workers are willing to commute. The same alternative values were used in other studies, including the work by Ellwood (1986). Generally speaking, 30 minutes is considered the average commute duration. In the Boston Metropolitan Area, the average is approximately 25 minutes, which is reasonably close. The lower bound, 15 minutes, is considered a commute duration 1 standard deviation below the average. The upper bound, 45 minutes, is considered a commute duration 1 standard deviation above the average. It is important to compare results obtained using these alternative assumptions because different workers have different job-searching and commuting behaviors. For example, women, especially those who have young children to take care of, tend to make short trips (Hanson & Pratt, 1995; Rosenbloom & Burns, 1993). This implies that women with dependent children tend to look for jobs that are located close to home.
6. The 1980 geographic boundary contained 775 zones, but the 1990 boundary was expanded to 787 zones. This study focuses on the 775 zones that are included in both 1980 and 1990 data.
7. The estimated number of available new positions on a typical day would be roughly 440 if the decline in manufacturing jobs, estimated to be −150 (−300/month × 0.5 month), were not taken into account.
8. When the census was taken in 1990, there were roughly 137,210 unemployed workers living in the 775 zones. It is estimated that approximately 50,480 of them would seek positions in sales, services, and labor-intensive occupations.
9. Most of these zones are located in the towns of Newton, Waltham, and Wellesley.
10. During the peak hours, the largest low-income neighborhoods in Boston—Roxbury and Dorchester, for example—are about 20-30 minutes away from the CBD by automobile, and 30-50 minutes away by public transit.

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