The Spatial Structure of the Metropolitan Regions of Brazil

Yoon Joo Lee

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of the Metropolitan Regions of Brazil

Yoon Joo Lee

The World Bank
Washington, D.C., U.S.A.
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Yoon Joo Lee, on the research staff of the World Bank’s Development Economics Department when this paper was written, is now with the U.S. Agency for International Development.

Library of Congress Cataloging in Publication Data

Lee, Yoon Joo, 1944-
The spatial structure of the metropolitan regions of Brazil.

(World Bank staff working papers ; no. 722)
1. Brazil--Population density--Case studies. 2. Labor supply--Brazil--Case studies. 3. Metropolitan areas--Brazil--Case studies. I. Title. II. Series.
HB2233.L43 1985 304.6'2'0981 85-3206
ABSTRACT

Using published census data, this paper describes the spatial structure of the eight metropolitan regions of Brazil during 1940-1980. The analysis shows that the experience of these regions is similar to what has been observed in the developed as well as some other developing countries. The growth of population and employment in these areas has been rapid but its speed has been associated with the size of the region. Both population and employment in large metropolitan regions have deconcentrated, while they have concentrated in the smaller regions. Employment is spatially more concentrated than is population. Large establishments in manufacturing tend to be located in the periphery of cities. The reverse trend is observed for commerce establishments.
Ce document décrit, en utilisant les données des recensements qui ont été publiées, l'organisation dans l'espace des huit agglomérations brésiliennes durant la période 1940-80. Il en ressort que dans leur cas, l'évolution observée est semblable à celle des agglomérations des pays développés comme de certains autres pays en développement. L'accroissement de la population et du nombre d'emplois y a été rapide, mais proportionnellement à la dimension de la zone urbaine. La population tout comme l'emploi se sont concentrés dans les petites agglomérations alors que l'on observait le phénomène inverse dans les grandes. L'emploi est plus concentré dans l'espace que la population. Les grandes entreprises industrielles ont tendance à s'implanter à la périphérie des villes, à la différence des entreprises commerciales.
EXTRACTO

Utilizando datos de censos publicados, en este documento se describe la estructura espacial de las ocho regiones metropolitanas del Brasil durante el periodo de 1940-80. El análisis muestra que la evolución de estas regiones es semejante a la observada tanto en las naciones desarrolladas como en algunos países en desarrollo. En ellas el crecimiento de la población y el empleo ha sido rápido, pero esa rapidez ha guardado relación con el tamaño de la región. La población y el empleo se han desconcentrado en las regiones metropolitanas grandes, pero se han concentrado en las más pequeñas. El empleo está más concentrado espacialmente que la población. Los grandes establecimientos manufactureros suelen estar ubicados en la periferia de las ciudades; en cambio entre los establecimientos comerciales se observa la tendencia contraria.
<table>
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<tr>
<th>Table</th>
<th>Title</th>
</tr>
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</tr>
<tr>
<td>2</td>
<td>Population Density of Eight Metropolitan Regions</td>
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</tbody>
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This paper forms part of a large program of research grouped under the rubric of the "City Study" of Bogota, Colombia, which was conducted at the World Bank with the collaboration of Corporacion Centro Regional de Poblacion, Bogota. The goal of the City Study was to increase our understanding of the workings of five major urban sectors—housing, transport, employment location, labor markets, and the public sector—in order that the impact of policies and projects can be assessed more accurately.

The author would like to thank Gregory K. Ingram, Kyu Sik Lee, and other members of the City Study research staff at the World Bank and at the Corporacion Centro Regional de Poblacion in Bogota for comments on the work presented here, with particular application to Anna Sant'Anna, who organized and supervised the collection of the census data and Rakesh Mohan, who edited the final manuscript.

Other City Study papers dealing with the urban spatial structure include:


I. INTRODUCTION

This paper investigates the growth and distribution of population and employment in the eight metropolitan regions of Brazil: Sao Paulo, Rio de Janeiro, Porto Alegre, Recife, Belo Horizonte, Salvador, Fortaleza, and Curitiba. Specifically it attempts to decide whether the growth and distribution of population and employment of these regions exhibit strong regularities and deconcentration observed in most developed and other developing countries.

The main body of this paper is composed of four sections. Section II discusses the growth and distribution of population and compares them among and within the metropolitan regions. Section III examines the deconcentration of employment and establishment in the manufacturing industry and commerce. Section IV presents estimated population and employment density gradients and compares them among the regions and changes in gradients over time. Section V summarizes the findings of this study.

II. TRENDS OF POPULATION GROWTH AND STRUCTURES IN METROPOLITAN REGIONS

The eight regions being studied are three metropolitan regions (Fortaleza, Recife, Salvador) located in the northeast which is generally poor and less developed and five metropolitan regions (Rio de Janeiro, Belo Horizonte, Sao Paulo, Curitiba, Porto Alegre) in the southeast where economic growth has been fast. Except for Curitiba, all the regions had a population of more than one million in 1970. These metropolitan regions were created to
centralize planning and public service delivery for large urban areas of the country and to provide a revenue sharing system among the municipalities within these regions. Belem is not studied in this paper due to data problems.

The first problem was to construct a consistent boundary of metropolitan regions over the time period being studied (1940-1980 census years). Census data were used for municipalities in each region and it was possible to roughly define the same geographic regions for the previous years as in 1970 (see Table 1 in Annex). Each region is divided into two areas, city and ring, to study the spatial structure of the metropolitan regions. City is defined as the municipality at the core of the region and the rest of the region is defined as ring.

The metropolitan regions are very important in Brazil. The total population of the eight regions in 1970 was more than twenty-three million, roughly one-fourth of the total population of the country. The growth of population in the eight regions has been faster than the nation as a whole. Table 1 shows that between 1940 and 1980, the total population of the eight regions more than quadrupled while the nation's population less than tripled. With this rapid growth, the population share of the eight regions to the nation increased from 15.9 percent to 28.9 percent during the same period.

The population growth in the eight regions has been rapid but its magnitude varies among the regions and the time periods observed. For all regions except for Sao Paulo and Curitiba, the growth rate in the fifties was higher than in any other decade. While large regions like Sao Paulo and Rio de Janeiro show higher growth rates in the forties than in the sixties or seventies, smaller regions like Fortaleza, Salvador and Curitiba show larger growth rates in the sixties and seventies. Regions like Recife and Salvador
<table>
<thead>
<tr>
<th>Metropolitan Regions</th>
<th>Population Estimated Annual Growth Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sao Paulo</td>
<td>1,568</td>
</tr>
<tr>
<td>Rio De Janeiro</td>
<td>2,364</td>
</tr>
<tr>
<td>Porto Alegre</td>
<td>673</td>
</tr>
<tr>
<td>Recife</td>
<td>554</td>
</tr>
<tr>
<td>Belo Horizonte</td>
<td>346</td>
</tr>
<tr>
<td>Salvador</td>
<td>424</td>
</tr>
<tr>
<td>Fortaleza</td>
<td>289</td>
</tr>
<tr>
<td>Curitiba</td>
<td>325</td>
</tr>
<tr>
<td>Total</td>
<td>6,543</td>
</tr>
<tr>
<td>Brazil</td>
<td>41,236</td>
</tr>
</tbody>
</table>

Source: Census of Demography, Brazil, 1940-1980.
Annual Statistics of Brazil, 1973

The population figures of 1940-70 in this table and other parts of this paper are resident population living in private dwelling units. In other words, they exclude population in public institutions such as hospitals, mental institutions, military units, etc. The total of this population in the eight metropolitan regions in 1970 was about 3.9 percent of the total resident population in private dwelling units. The population of 1980 and in parentheses for 1970 are total residents. The annual population growth rates during 1970-80 are computed using the corresponding figures.
experienced stable growth of population while Curitiba and Belo Horizonte went through wide variations in their growth rates. Close analysis shows that the growth rate is large when the population of the regions ranges from 400,000-1,500,000. This growth pattern is consistent with the typical growth pattern observed in other countries, i.e., average growth rates decline slightly with size.

In addition, population growth has not been distributed evenly within the metropolitan regions. The average growth rate in the rings of the eight regions is 4.8 percent, while the rate in the cities is slightly less than 4.0 percent. For the large regions, population in rings has grown faster than that in the cities. For the small regions, the reverse trend is observed.

Table 2 shows that the share of population in the cities has been stable in the forties and fifties and has decreased since then. It also indicates that large regions tend to deconcentrate and small regions tend to concentrate. The two largest regions, Sao Paulo and Rio de Janeiro have experienced large amounts of deconcentration during the last four decades. The two smallest regions, Fortaleza and Curitiba, went through rapid concentration during 1940-1970 and stabilized since then. While the percent of people living in the city of Sao Paulo decreased from 84.6 in 1940 to 67.5 in 1980, the same figures of Curitiba increased from 43.4 to 66.3. In medium regions like Porto Alegre and Recife, the share of the city population remained steady. Careful examination of Tables 1 and 2 reveals that population tends to concentrate until the size of the region reaches about one million and remains stable when it ranges from 1 million to 1.5 million. When the population grows more than 1.5 million, the region tends to deconcentrate.
Population densities both in the cities and the rings of all metropolitan regions have increased but their magnitudes vary. Although the density in the cities of large regions like Rio de Janeiro and Sao Paulo has grown at a smaller rate than that in rings, the density in the cities of small regions, Fortaleza and Curitiba for example, has increased faster than that in the rings. Of the eight regions, Recife experiences the highest densities both in the city and ring. Curitiba has the lowest densities. In Curitiba, however, the density in the city increased by more than ten times while the density in the ring remained almost at the same level. In Porto Alegre, densities of both city and ring went up by a similar growth rate. (see Table 2 in Annex.)

**TABLE 2: PERCENT OF POPULATION IN CITIES OF EIGHT METROPOLITAN REGIONS**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sao Paulo</td>
<td>84.6</td>
<td>82.0</td>
<td>79.8</td>
<td>72.7</td>
<td>67.5</td>
</tr>
<tr>
<td>Rio de Janeiro</td>
<td>74.6</td>
<td>71.5</td>
<td>64.9</td>
<td>59.2</td>
<td>56.0</td>
</tr>
<tr>
<td>Porto Alegre</td>
<td>40.4</td>
<td>43.5</td>
<td>44.4</td>
<td>44.3</td>
<td>40.4</td>
</tr>
<tr>
<td>Recife</td>
<td>62.9</td>
<td>64.0</td>
<td>64.3</td>
<td>59.4</td>
<td>51.4</td>
</tr>
<tr>
<td>Belo Horizonte</td>
<td>64.0</td>
<td>71.4</td>
<td>76.3</td>
<td>75.8</td>
<td>69.2</td>
</tr>
<tr>
<td>Salvador</td>
<td>68.4</td>
<td>74.9</td>
<td>79.6</td>
<td>79.7</td>
<td>79.5</td>
</tr>
<tr>
<td>Fortaleza</td>
<td>69.0</td>
<td>68.7</td>
<td>77.3</td>
<td>82.2</td>
<td>82.2</td>
</tr>
<tr>
<td>Curitiba</td>
<td>43.4</td>
<td>45.8</td>
<td>58.1</td>
<td>65.5</td>
<td>66.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>69.4</td>
<td>70.7</td>
<td>69.2</td>
<td>66.0</td>
<td>62.6</td>
</tr>
</tbody>
</table>

Source: Census of Demography, Brazil, 1940-1970.
Table 3 shows the distribution of the general population and migrants living for less than one year in the metropolitan regions. The share of migrants in cities is higher than that of the general population in the two smallest regions only, Fortaleza and Curitiba. For the rest of the regions, migrants are more likely than the general population to live in rings and this reinforces the overall deconcentration trend. Column 3 of this table shows the share of total migrants out of total population. Slightly less than five percent of the population are migrants and the share of migrants does not seem to have any relationship with the size of cities.

**TABLE 3: DISTRIBUTION OF POPULATION AND MIGRANTS, 1970**

<table>
<thead>
<tr>
<th>Metropolitan Regions</th>
<th>Percent Residing in City</th>
<th>Percent of Migrants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Population</td>
<td>Migrants</td>
</tr>
<tr>
<td>Sao Paulo</td>
<td>72.7</td>
<td>53.2</td>
</tr>
<tr>
<td>Rio de Janeiro</td>
<td>59.2</td>
<td>41.8</td>
</tr>
<tr>
<td>Porto Alegre</td>
<td>44.3</td>
<td>32.0</td>
</tr>
<tr>
<td>Recife</td>
<td>59.4</td>
<td>36.7</td>
</tr>
<tr>
<td>Belo Horizonte</td>
<td>75.8</td>
<td>60.9</td>
</tr>
<tr>
<td>Salvador</td>
<td>79.7</td>
<td>71.1</td>
</tr>
<tr>
<td>Fortaleza</td>
<td>82.2</td>
<td>87.6</td>
</tr>
<tr>
<td>Curitiba</td>
<td>65.5</td>
<td>71.1</td>
</tr>
<tr>
<td>Total</td>
<td>66.0</td>
<td>50.8</td>
</tr>
</tbody>
</table>

1/ Migrants are defined as non-native residents living for less than one year in the municipios of the metropolitan regions.

2/ Percent of non-native residents living for less than one year in the municipios of the metropolitan regions out of total population in that region.

Source: *Census of Demography, Brazil, 1970.*
III. SPATIAL DECONCENTRATION OF EMPLOYMENT AND ESTABLISHMENTS

The previous section discussed the growth and the distribution of the population in the eight metropolitan regions, with special emphasis on the concentration - deconcentration of the population over time. This section is concerned with the redistribution of employment and establishments of manufacturing and commerce in these regions.

In 1970, more than one third of the total labor force in the eight metropolitan regions was engaged in manufacturing and about 13 percent was in commerce. The growth of total employment in these industries, as in the case of population, has been rapid. Growth in commerce, however, has been faster than that in manufacturing. Between 1940 and 1970, total employment in commerce almost quadrupled (from 189,000 to 747,000) while that in manufacturing grew almost three-fold (from 495,000 to 1,550,000). In addition, the growth in commerce shows small variance among the regions, while the growth in manufacturing has a large variance. As expected, the growth of employment in both industries has a relationship with that of population. Employment in manufacturing and commerce in Sao Paulo and Fortaleza, for example, had grown more than six times during 1940-1970. Both regions have experienced higher than average growth rates of population. Rio de Janeiro and Curitiba have experienced a modest growth rate both in employment and population.

Table 4 shows that, both in manufacturing and commerce, the aggregate share of cities in total employment of the eight regions has decreased over time. In manufacturing employment, the share of cities decreased from 81.8 percent in 1940 to 68.0 percent in 1970. In commerce, it decreased from 89.4
to 82.9 in the forties and stabilized since then. Also, employment in both
industries has been spatially more concentrated than population. The speed of
deconcentration of employment, however, has been much faster than that of
population. In addition, employment in commerce has been spatially more
concentrated than that in manufacturing. This observation is consistent with
what has been experienced in the developed and other developing countries
(Mills, 1972, and Mills and Song, 1977).

The speed of spatial deconcentration of employment has varied among
the metropolitan regions. The large regions have experienced rapid
deconcentration while the small regions have remained stable. The share of
employment in manufacturing in the city of Sao Paulo, the largest region,
decreased from 97.2 percent in 1940 to 71.0 percent in 1970. The same figure
of Curitiba, the smallest region, decreased from 74.9 percent to 73.0 percent
during the same period.

The table also shows that the share of establishments in manufactur-
ing in the cities of eight regions was stable (73.8 percent in 1940 and 71.1
percent in 1970), while the share in commerce decreased from 80.5 percent in
1940 to 71.9 percent in 1970. The total employment in manufacturing in the
eight regions was spatially more concentrated than establishments in 1940 and
1950. In 1970, however, employment was less concentrated than establish-
ments. In commerce, total employment was more concentrated than establish-
ments throughout the period being studied. This indicates that larger
establishments in manufacturing were located in cities and smaller establish-
ments were in rings during the forties and fifties and the trend reversed in
the sixties, i.e., larger establishments were located in rings. In commerce,
large establishments tended to be located in the cities for all periods. This
tendency may be due to externalities. The agglomeration effect in commerce
may be more important for larger establishments than for the smaller ones.
### TABLE 4: SPATIAL DECONCENTRATION OF EMPLOYMENT

<table>
<thead>
<tr>
<th>Region</th>
<th>MANUFACTURING INDUSTRY</th>
<th>COMMERCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sao Paulo</td>
<td>97.2 (94.9)</td>
<td>83.8 (84.4)</td>
</tr>
<tr>
<td>Rio de Janeiro</td>
<td>83.2 (68.1)</td>
<td>80.8 (80.8)</td>
</tr>
<tr>
<td>Porto Alegre</td>
<td>55.5 (35.0)</td>
<td>43.6 (21.9)</td>
</tr>
<tr>
<td>Recife</td>
<td>56.3 (67.8)</td>
<td>59.3 (64.1)</td>
</tr>
<tr>
<td>Belo Horizonte</td>
<td>47.8 (68.5)</td>
<td>55.9 (72.9)</td>
</tr>
<tr>
<td>Salvador</td>
<td>77.5 (76.5)</td>
<td>87.9 (70.7)</td>
</tr>
<tr>
<td>Fortaleza</td>
<td>88.9 (67.3)</td>
<td>86.6 (62.9)</td>
</tr>
<tr>
<td>Curitiba</td>
<td>74.9 (60.3)</td>
<td>72.4 (48.0)</td>
</tr>
<tr>
<td>Total</td>
<td>81.8 (73.8)</td>
<td>77.0 (69.5)</td>
</tr>
</tbody>
</table>

1/ Employment includes all establishments regardless of their size.

The employment data for 1960 were partially published but are not available for this study.

2/ Figures in parentheses are percent of establishments in cities.

Source: Census of Industry, Brazil, 1940-1970.
IV. POPULATION AND EMPLOYMENT DENSITY FUNCTIONS

Though the data analyzed in the previous sections can reveal the broad trend of the growth and redistribution of population and employment, they are subject to limitations. First of all, the distinction between the city and the ring does not provide a unique measure of spatial deconcentration since the percent of the land area included in the city differs greatly among the metropolitan regions (see Table 1 in Annex). Second, the boundaries of some cities have changed over time, mainly because the city was subdivided and part of it became a separate municipality or annexed to another municipality. Though the changes in the boundaries of these cities have been adjusted, there are still some variations in the definition over time to the extent that it is not possible to construct exactly the same boundaries for four decades. Thus, it is desirable to have a measure of deconcentration that does not depend upon the historical or political criteria of the city boundary locations. Third, the city and ring dichotomy yields data aggregated across space. For some purposes, it would be desirable to measure changes in location patterns within the cities and within the rings. Also, the descriptive tables presented in the previous sections do not allow easy and clear cross-regional comparisons of deconcentration. These limitations can be surmounted by employing the commonly used assumption that population densities decline exponentially with distance from the center.

\[ D(x) = D_0 e^{-bx} \]

where \( D(x) \) is density of the population at distance \( x \) from the city center, \( b \) is the gradient (i.e., description of how rapidly the density function falls
off with distance), and $D_0$ is the intercept (i.e., population at the city center).

The parameters obtained from the functions, $D_0$ and $b$, can be used to characterize the distribution of population within the metropolitan regions and provide insights about the urban spatial structure. The larger $b$ is, the faster density falls with distance, which suggests that $b$ can be used as a measure of deconcentration. In other words, the share of total population within a given distance from the center is uniquely related to $b$. These density functions are easy to compare both among cities and points in time. It is thus not difficult to study whether there are regularities in the density either by comparing different cities or different countries at a given time or by observing a city or a country over time.

Two most commonly used methods to estimate the exponential density function are the ordinary least-square and the two-point estimate technique. If data is available on population and distance from the center for a large number of small land areas, census tracts in the U.S., for example, ordinary least-squares regressions can be used. Alternatively, since the function is a two-parameter curve, we can estimate the gradient and central density using only information on the population and the area of the city and the ring. This technique called two-point estimate was first developed and later modified by Mills (1972), and evaluated by White (1977)4/. In the absence of the information required for regression estimation, the two-point estimation procedure has an obvious advantage and was adopted for this study.

Table 5 displays how the estimated density gradient and central density vary across the regions and how they change over time. Change in the density gradient over time shows three different patterns depending on the
size of the regions. In large metropolitan regions like Sao Paulo and Rio de Janeiro, the gradient flattens slowly and in small regions like Fortaleza and Curitiba, it becomes steeper rapidly. In regions of medium size (Porto Alegre and Belo Horizonte), the value of the gradient remains almost constant. Also the absolute value of the gradient shows a wide variance among the regions: from 0.0646 in Rio de Janeiro in 1980 to 0.2675 in Belo Horizonte in 1960. The central density or the intercept \(D_0\) increases in all metropolitan regions over time and the rate of growth is higher in small regions. Central density in Sao Paulo and Rio de Janeiro is high but the gradient is low. In Recife and Belo Horizonte, both the density and gradient are high. It is interesting to note that while the gradient in Sao Paulo and Rio de Janeiro decreases over time, the central density increases. This observation suggests that the effects of the rapid growth of population have more than offset the effects of the deconcentration. In addition, while the value of gradient shows a pattern of relationship with the size of the regions, central density does not seem to have any association with it. Large regions tend to be associated with low gradient and smaller regions tend to have high gradient.

Comparison of the gradients and densities among the countries reveals interesting information. The average density gradient of the eight metropolitan regions in Brazil computed for three decades (1950-1970) is 0.151, which is higher than the average gradient of 0.132 computed for the twelve cities of the United States by Ingram and Carroll (1981). While the average gradient in Brazil increases from 0.148 in 1950 to 0.171 in 1970, the same figure in the U.S. decreases, from 0.153 to 0.113. During the same period the average central density in the U.S. also decreases, from 13,504 to 9,670. In Brazil, it increases from 5,111 to 13,074. As observed, the values
of the average gradient and the average density of Brazil in 1970 are much higher than those of the U.S. However, the density of the eight metropolitan regions of Brazil is much lower than that of the twelve Korean metropolitan areas estimated by Mills and Song (1977) or the twelve Indian metropolitan areas computed by Mills and Tan (1980).  

Estimation of the population density gradients has been one of the popular procedures to describe the shifts in the structures of cities. The number of previous studies on the population density function in developed countries are countless and a few studies have been made in developing countries in recent years. Estimation of density function for employment, however, is scarce in developed countries and virtually non-existent in developing countries. One reason for this scarcity is that employment data are not easily available, especially in developing countries. This study calculates the employment density function using the same technique as the one used to estimate population density gradient. It provides a useful descriptive summary and an interesting comparison between the deconcentration of population and that of employment.  

Table 6 shows the employment density gradient and the central density in manufacturing and commerce. As in the case of the population density function, the slope of the gradient varies among the regions depending on the size of the regions. The gradient also declines over time in large regions like Sao Paulo, Rio de Janeiro, and Porto Alegre and increases in small regions such as Salvador and Curitiba. With this opposite movement of the slope, the average density gradient of the eight regions has remained constant over time, 0.169 in 1940 and 0.161 in 1970. Central density, however, increases in almost all regions.
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sao Paulo</td>
<td>$D_0$</td>
<td>5,498</td>
<td>9,792</td>
<td>13,296</td>
<td>16,579</td>
<td>21,641</td>
</tr>
<tr>
<td></td>
<td>$b$</td>
<td>0.1481</td>
<td>0.1386</td>
<td>0.1314</td>
<td>0.1148</td>
<td>0.1022</td>
</tr>
<tr>
<td>Rio de Janeiro</td>
<td>$D_0$</td>
<td>7,054</td>
<td>8,745</td>
<td>10,289</td>
<td>11,127</td>
<td>12,855</td>
</tr>
<tr>
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<td>$b$</td>
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<td>0.0786</td>
<td>0.0695</td>
<td>0.0646</td>
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<td>$D_0$</td>
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<td>1,990</td>
<td>3,291</td>
<td>4,354</td>
<td>5,374</td>
</tr>
<tr>
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<td>$b$</td>
<td>0.0981</td>
<td>0.1050</td>
<td>0.1070</td>
<td>0.1067</td>
<td>0.0981</td>
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<tr>
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<td>$D_0$</td>
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<td>9,217</td>
<td>14,077</td>
<td>16,503</td>
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</tr>
<tr>
<td></td>
<td>$b$</td>
<td>0.1990</td>
<td>0.2052</td>
<td>0.2061</td>
<td>0.1874</td>
<td>0.1591</td>
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<tr>
<td>Belo Horizonte</td>
<td>$D_0$</td>
<td>2,439</td>
<td>4,628</td>
<td>10,356</td>
<td>17,643</td>
<td>22,048</td>
</tr>
<tr>
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<td>$b$</td>
<td>0.2101</td>
<td>0.2426</td>
<td>0.2675</td>
<td>0.2650</td>
<td>0.2323</td>
</tr>
<tr>
<td>Salvador</td>
<td>$D_0$</td>
<td>1,214</td>
<td>2,133</td>
<td>3,950</td>
<td>18,181</td>
<td>28,140</td>
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<tr>
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<td>$b$</td>
<td>0.0810</td>
<td>0.0957</td>
<td>0.1082</td>
<td>0.1941</td>
<td>0.1935</td>
</tr>
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<td>0.2357</td>
<td>0.2358</td>
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<tr>
<td>Curitiba</td>
<td>$D_0$</td>
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<td>2,752</td>
<td>5,145</td>
<td>9,244</td>
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<tr>
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<td>$b$</td>
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<td>0.1320</td>
<td>0.1668</td>
<td>0.1912</td>
<td>0.1935</td>
</tr>
<tr>
<td>Average</td>
<td>$D_0$</td>
<td>3,204</td>
<td>5,111</td>
<td>8,237</td>
<td>13,074</td>
<td>17,375</td>
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<tr>
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<td>0.1483</td>
<td>0.1596</td>
<td>0.1706</td>
<td>0.1599</td>
</tr>
</tbody>
</table>

1/ Density gradients in this Table and the following tables were calculated using technique described in L.J. White, "How Good Are Two Point Estimates of Urban Density Gradients and Central Densities?", Journal of Urban Economics, Vol. 4, No. 3 (July, 1977).

2/ Parameters from $Density = D_0 e^{-bx}$ where $x$ is distance from center in kilometers; $D_0$ is central density in persons/km².

Source: Census of Demography, Brazil, 1940-1970.
The density gradient of commerce in Table 6 shows a similar pattern of change over time to manufacturing. While in large regions like Sao Paulo and Rio de Janeiro the gradient becomes flatter, it becomes steeper in small regions. Central density in commerce also increases in most of the cases displayed in the table. The gradient in commerce has higher value than that in manufacturing for most of the metropolitan regions. The average gradient of 0.229 in commerce is compared to 0.166 in manufacturing. This observation provides evidence that employment in commerce in general is more concentrated in the center of the city than that in manufacturing. The employment density gradient in manufacturing is slightly higher than the population density gradient. The average density gradient in manufacturing is slightly higher than the population density gradient. The average density gradient in manufacturing is 0.166 and the same figure for population is 0.151. This observation supports the statement made at the beginning of this section that employment is located closer to the city center than is population. Also commerce is more concentrated to the center than manufacturing.
### TABLE 6: EMPLOYMENT DENSITY GRADIENTS

<table>
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<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>San Paulo D</td>
<td>D</td>
<td>1,692</td>
<td>1,203</td>
<td>1,801</td>
<td>386</td>
<td>250</td>
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<td>0.1104</td>
<td>0.2191</td>
<td>0.1801</td>
<td>0.1543</td>
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<td>Rio de Janeiro</td>
<td>D</td>
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<td>986</td>
<td>918</td>
<td>490</td>
<td>300</td>
<td>719</td>
</tr>
<tr>
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<td>0.1107</td>
<td>0.0980</td>
<td>0.1377</td>
<td>0.1144</td>
<td>0.1000</td>
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<tr>
<td>Porto Alegre</td>
<td>D</td>
<td>129</td>
<td>131</td>
<td>230</td>
<td>118</td>
<td>65</td>
<td>384</td>
</tr>
<tr>
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<td></td>
<td>0.1176</td>
<td>0.1107</td>
<td>0.0980</td>
<td>0.1377</td>
<td>0.1144</td>
<td>0.1000</td>
</tr>
<tr>
<td>Recife</td>
<td>D</td>
<td>325</td>
<td>501</td>
<td>570</td>
<td>432</td>
<td>249</td>
<td>976</td>
</tr>
<tr>
<td>b</td>
<td></td>
<td>0.1763</td>
<td>0.1872</td>
<td>0.1990</td>
<td>0.3745</td>
<td>0.2745</td>
<td>0.2811</td>
</tr>
<tr>
<td>Belo Horizonte</td>
<td>D</td>
<td>102</td>
<td>141</td>
<td>280</td>
<td>146</td>
<td>171</td>
<td>1,106</td>
</tr>
<tr>
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<td>0.1333</td>
<td>0.1800</td>
<td>0.1683</td>
<td>0.3470</td>
<td>0.3360</td>
<td>0.3861</td>
</tr>
<tr>
<td>Salvador</td>
<td>D</td>
<td>60</td>
<td>116</td>
<td>228</td>
<td>110</td>
<td>79</td>
<td>922</td>
</tr>
<tr>
<td>b</td>
<td></td>
<td>0.1525</td>
<td>0.1366</td>
<td>0.1404</td>
<td>0.1615</td>
<td>0.1382</td>
<td>0.2613</td>
</tr>
<tr>
<td>Fortaleza</td>
<td>D</td>
<td>86</td>
<td>171</td>
<td>445</td>
<td>114</td>
<td>130</td>
<td>590</td>
</tr>
<tr>
<td>b</td>
<td></td>
<td>0.2813</td>
<td>0.2633</td>
<td>0.2592</td>
<td>0.2934</td>
<td>0.2712</td>
<td>0.2980</td>
</tr>
<tr>
<td>Curitiba</td>
<td>D</td>
<td>41</td>
<td>132</td>
<td>306</td>
<td>17</td>
<td>43</td>
<td>472</td>
</tr>
<tr>
<td>b</td>
<td></td>
<td>0.1445</td>
<td>0.2181</td>
<td>0.2206</td>
<td>0.1476</td>
<td>0.2103</td>
<td>0.3148</td>
</tr>
<tr>
<td>Average</td>
<td>D</td>
<td>405</td>
<td>423</td>
<td>597</td>
<td>227</td>
<td>161</td>
<td>774</td>
</tr>
<tr>
<td>b</td>
<td></td>
<td>0.1689</td>
<td>0.1683</td>
<td>0.1610</td>
<td>0.2352</td>
<td>0.2089</td>
<td>0.2449</td>
</tr>
</tbody>
</table>

1/ The density gradients for 1960 are missing because the employment data for this year are not available.

2/ The figures in 1970 exclude both the employment and the land area of the two municipalities: Jose de Melo, Lagoa Santa.

Source: Census of Industry, Brazil, 1940-1970.
As a comparison, Table 7 displays employment density function parameters for the twelve U.S. cities, estimated using aggregate employment data of all industries. The absolute magnitudes of the density gradients in the U.S. cities are significantly less than those observed in the eight metropolitan regions of Brazil. Out of the twelve U.S. cities, in only two cities are the density gradients larger than 0.2 (Washington, D.C. and Denver), and in four of the cities, the parameters are less than 0.1.

Compared to this observation, in four of the eight regions of Brazil, the density gradients of commerce in 1970 are higher than 0.2 and no gradient is lower than 0.1. In manufacturing industry, three gradients in 1970 are higher than 0.2 and only two gradients are lower than 0.1. The average gradient of the twelve U.S. cities is 0.1381. The average gradients of manufacturing and commerce in the eight regions are 0.152 and 0.231 respectively.

V. CONCLUSION

This paper has been concerned with the changing spatial structure of the eight metropolitan regions of Brazil from 1940 to 1980. The rapid growth of population in these regions during the past decades may slow down a little in the next decades. Analysis of the previous experiences shows that the growth rate of population is high when the size of a region ranges from 0.4 to 1.5 million people. In 1980, all the regions had a population of more than 1.5 million.

A cross regional comparison shows that at a given time large metropolitan regions tend to have flatter density functions than small regions. While the large regions experience deconcentration over time, the small ones first go through concentration. The trend of deconcentration of
population and employment in large regions may continue in the future but the concentration in small regions may decline. The patterns of shift in employment density function and population density function are found to be similar. Regions with a steep population density gradient tend to be associated with a high employment density gradient. Regions experiencing deconcentration in population also go through spatial deconcentration in employment. In addition, close examination of the pace of deconcentration and concentration of population and employment suggests that redistribution of population is more rapid than that of employment.

A few studies made recently on the developed and the developing countries (Ingram and Carroll, 1981; Mills and Tan, 1978; Mills and Song, 1977; and Mohan and Villamizar, 1982), show that the distribution of population within cities is fairly regular and that deconcentration is observed not only in the developed countries but also in the developing countries. They also show that land use in the cities of Asia and Latin America is more compact than that of the cities of North America. In general, the results of the present study are similar to what have been found in other studies. However, this does not mean that this general conclusion can be applied to all of the individual regions. As shown in the tables of the previous sections, there are many exceptions. Various factors affect density patterns in an urban area: the local characteristics of housing construction, the mix of various industries, scarcity of land, structure of transportation system, the rate of growth in real income and population, and car ownership. Since these factors are different among the cities and among countries, the pattern of density may also be different.
### TABLE 7: EMPLOYMENT DENSITY GRADIENTS OF ALL INDUSTRIES IN TWELVE U.S CITIES (1970)

<table>
<thead>
<tr>
<th>City</th>
<th>Parameter</th>
<th>1970</th>
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</thead>
<tbody>
<tr>
<td>New York</td>
<td>D</td>
<td>14,485</td>
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<td></td>
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<td>0.0918</td>
</tr>
<tr>
<td>Boston</td>
<td>D</td>
<td>8,250</td>
</tr>
<tr>
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<td>b</td>
<td>0.1723</td>
</tr>
<tr>
<td>Washington, D.C.</td>
<td>D</td>
<td>9,398</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>0.2169</td>
</tr>
<tr>
<td>Philadelphia</td>
<td>D</td>
<td>7,246</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>0.1983</td>
</tr>
<tr>
<td>Chicago</td>
<td>D</td>
<td>6,524</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>0.0818</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>D</td>
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</tr>
<tr>
<td></td>
<td>b</td>
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<tr>
<td>Houston</td>
<td>D</td>
<td>2,762</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>0.1482</td>
</tr>
<tr>
<td>San Diego</td>
<td>D</td>
<td>2,025</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>0.1088</td>
</tr>
<tr>
<td>Denver</td>
<td>D</td>
<td>4,072</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>0.2285</td>
</tr>
<tr>
<td>Phoenix</td>
<td>D</td>
<td>1,422</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>0.1975</td>
</tr>
<tr>
<td>Miami</td>
<td>D</td>
<td>5,838</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>0.1881</td>
</tr>
<tr>
<td>San Jose</td>
<td>D</td>
<td>709</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>0.0310</td>
</tr>
<tr>
<td>Average</td>
<td>D</td>
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</tr>
<tr>
<td></td>
<td>b</td>
<td>0.1400</td>
</tr>
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</table>

**Note:** The high values of the central densities in this table are due to the fact that the density function was estimated using the figures of total employment of all industries.


1/ The Municipio in Brazil is the smallest government unit comparable to the county in the U.S. The number of municipios in the nation was 4,362 in 1972, and they showed a great variation in area and population. The municipio has both an executive branch headed by a mayor (prefeito) and a legislative branch called camara de vereadores. The municipio council legislates on matters of local interest such as budgeting, local taxes, city plan and it controls the mayor. For more details, see Area Handbook for Brazil, Thomas E. Weil, et al, third edition, 1975, p. 229.

2/ The boundaries of the metropolitan regions defined in this paper are slightly larger than the official definitions used for census data. Since the boundaries of the metropolitan regions are defined by the collection of municipalities and the boundaries of some municipalities have been changed over time, it is not possible to construct a consistent and exactly the same boundary for four decades as the official definition.

3/ The employment figures being discussed in this paper includes all establishments regardless of their size. The Census of Industries for 1960 was published partially and the quality of the published data is poor. Anyway, those data were not available for this study.

4/ The result of the White study is that the properties of the two-point estimates depend somewhat on the fraction of cities that are included in the inner and outer divisions. However, the extent of the bias is not great for the density gradient. He concludes that, overall, two-point estimates perform about as well as ordinary least squares.
Comparison of the density function among the countries should be made very carefully, especially when the function is computed using different estimation techniques. In computing the density gradient for the twelve cities of the U.S., Ingram and Carroll (1981) used the two-point estimate technique, the same method used in this study. Mills and Tan (1980) estimated the function for Korea and India by ordinary least square regressions. They also estimated the gradient for the four regions of Brazil, which are the same regions being studied in this paper: Sao Paulo, Rio de Janeiro, Recife and Belo Horizonte. The author compared the results of their study of these regions with those of this study. The differences in the results of the two studies are not large. The author therefore feels that it is reasonably safe to make comparison among the results obtained by different studies.

The twelve Korean metropolitan areas included in the study by Mills and Song (1977) were Seoul, Busan, Daegu, Gwangju, Incheon, Daejeon, Cheongju, Andong, Suwon, Cheonan, Gangreung and Samcheonpo. The average density gradients for these areas for 1966, 1970 and 1973 were 0.701, 0.670 and 0.639, respectively. The twelve Indian metropolitan areas included in the study by Mills and Tan (1980) were Poona City, Howrah, Hubli, Gaya, Dharwar, Madras, Bombay, Jamshedpur, Hyderabad (Old City), Secunderabad, Bangalore and Bangalore Civil and Military Section. The average density gradients for these areas for 1951 and 1961 were 0.672 and 0.652, respectively.

The disaggregated employment data of manufacturing and commerce of these cities are not readily available.
ANNEX

Table 1: LAND AREA OF THE EIGHT METROPOLITAN REGIONS
(in km²)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sao Paulo</td>
<td>8,238</td>
<td>8,241</td>
<td>8,295</td>
<td>8,240</td>
<td>18.1</td>
</tr>
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<td>Center</td>
<td>1,565</td>
<td>1,565</td>
<td>1,565</td>
<td>1,493</td>
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<tr>
<td>Periphery</td>
<td>6,673</td>
<td>6,676</td>
<td>6,730</td>
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<tr>
<td>Rio de Janeiro</td>
<td>7,856</td>
<td>7,856</td>
<td>7,708</td>
<td>7,708</td>
<td>15.2</td>
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<td>1,171</td>
<td>1,171</td>
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<td>20,064</td>
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<td>2.7</td>
</tr>
<tr>
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<td>497</td>
<td>497</td>
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</tr>
<tr>
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<td>19,578</td>
<td>20,028</td>
<td>18,100</td>
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<td>2,201</td>
<td>2,201</td>
<td>2,201</td>
<td>2,201</td>
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<td>1,992</td>
<td>1,992</td>
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<td>4,656</td>
<td>4,561</td>
<td>7.3</td>
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<td>335</td>
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<td>4,321</td>
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<td>3,147</td>
<td>3,403</td>
<td>8.6</td>
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<tr>
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<td>3,590</td>
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<td>3,590</td>
<td>9.4</td>
</tr>
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<td>336</td>
<td>336</td>
<td>336</td>
<td></td>
</tr>
<tr>
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<td>3,254</td>
<td>3,254</td>
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</tr>
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<td>16,409</td>
<td>16,391</td>
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<td>2.6</td>
</tr>
<tr>
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<td>1,084</td>
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<tr>
<td>Periphery</td>
<td>15,325</td>
<td>15,978</td>
<td>15,960</td>
<td>16,279</td>
<td></td>
</tr>
</tbody>
</table>

1 Percent of the land area of the central city in 1970 out of the total metropolitan region.
## ANNEX

### Table 2: POPULATION DENSITY OF EIGHT METROPOLITAN REGIONS

(By Region by Year: Per Square Kilometers)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sao Paulo</td>
<td>190</td>
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Source: Census of Demography, Brazil, 1940-1970.
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pages.
$5.

The Transformation of Urban
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W. Paul Strassmann
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to upgrade the existing housing stock
than to replace it with new construc-
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not only be expected and tolerated,
but should even be fostered as means
to increase production in an important
field, to generate employment, and to
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housing. This study shows how the
housing stock in Cartagena was up-
graded during the 1970s by owner oc-
cupants and, to a lesser extent, by
landlords. The principal conclusions
are supported by extensive economet-
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experts and authorities.
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Rakesh Mohan

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Harold B. Dunkerley, coordinating editor, with the assistance of Christine M.E. Whitehead

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