THE THIRD DIMENSION IN LAND USE PLANNING

by

Frederick Roy Madgwick

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Thesis Supervisor

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on Graduate Students
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Submitted to the Department of City and Regional Planning on May 20, 1966, in partial fulfillment of the requirement for the degree of Master in City Planning.

The distribution of intensity of different land uses throughout a modern metropolitan area is so diverse as to require some standardized framework for description in order that comparison may be made between patterns found in different cities and for different points in time for a single city. The concept most useful in land use planning is determined and applied to a sample of metropolitan areas as a means of describing the distribution of the intensity of land use and the correlations between cities in their patterns of net use intensity. The results of this analysis are then assessed for their significance in the land use planning process.

The discussion is restricted to the importance of the annular method of description with little attention given to other aspects of this broad and complex subject. It extends, however, to consideration of certain of the factors which control the density of development and the manner in which these affect the use to which the method may be put. The approach is descriptive, explanatory, exploratory.

Thesis Supervisor: John T. Howard
Title: Head of Department
PREFACE

The charge that "planners tend to forget the third dimension, architects the fourth" may have had substance prior to 1950 but, as far as the planners are concerned, the amount of research devoted to the density of land use and the range of work which has been published on the subject renders the criticism now unjustified.

Harland Bartholomew, in 1932, published his classic book which, quite simply, listed the amount of land devoted to each of the more important categories of use found in a sample of sixteen central cities and six satellite cities of the U. S., a work which was in 1953 expanded, brought up-to-date and presented in a new volume "Land Uses in American Cities." It was, however, the first of these publications which filled a virtual void in the collection and comparison of this type of data and which received a great deal of attention. This work was concerned only with the numbers of acres in use, no consideration being given to the intensity with which those acres were used; thus may the impression have been given that the profession as a whole was not unduly concerned with density or intensity. If this impression lingers, it is despite the efforts of the demographers Bogue, Clark and the analysts of urban growth and structure, Blumenfeld, Winsborough, Duncan, Webber, Guttenberg and Chapin, all of whom have, particularly so since the middle of last decade, made substantial contributions to empirical definition of patterns of
intensity of use and theoretical explanations for the intensity phenomena recorded.

It is worth scrutinizing Bartholomew's approach a little more closely to determine just exactly what are its shortcomings since the following will be not only an investigation of the dimension which he omitted but also an appraisal of the validity of the manner in which he ignored the time factor in his projection techniques. The objective of his work is, he states, to "provide a reasonably reliable means of forecasting the future use of land in a community," primarily for the purpose of preparation of zoning plans; the projection process involves the determination of the relation between the amount of land per hundred population and the size of the city, the calculation of the current figures per hundred for each land use, the derivation of a "norm" by comparison with other cities and an extrapolation, based upon population projections, of future land requirements. In so doing, he makes the substantial assumption that the land needed by, say, a city A, present population 50,000, for an increment of population of 25,000 between 1940 and 1950 will be the same as that needed by the same city for the same increment if it had occurred between 1950 and 1960, or, in other words, that the amount of additional land needed is a function of the present rates of land need, the size of the present population and the size of the increment. It is patently clear, however, that the amount of additional space needed will be appreciably modified by other factors such as technology and social values, changes in which are a function of time. Maybe Bartholomew has omitted both the third and the fourth dimensions.
The method, it is suggested, would be valid only if

i) his sample was sub-classified according to similarities in industrial base, history, topography, region of the country and so on, and only cities from within the sub-category used for determining the appropriate land needs per hundred population (which it is not) and

ii) data is collected for, and comparisons made between whole urban areas

iii) the density of development of the increment to growth is dependent upon the size of the city,

yet, with these serious conceptual shortcomings, the method was found to offer appreciable guidance, at least to the accuracies demanded for zoning purposes. The examination of most aspects of projection of land use re-introduce time and again the complications of changing intensity of use with time. Bartholomew had, however, set up a method for determination of future land use requirements with some success while short-circuiting the intensity question: his approach is not strictly amenable to having the extra dimension "tacked onto" it and the concern will be primarily with examining the significance of the relationships established to the more modern land use projection methods, such as that described by Chapin. These involve the prediction of population and economic expansion and the translation of these predictions into land needs, a proportion of the growth being allocated to each part of the urban area and the land requirements being calculated at an intensity of use appropriate to the particular activity and the particular part of the city. It seems, at times, that the densities employed in these calculations
are based on insufficient understanding of what is the pattern of
densities throughout the urban area and what are the changes taking
place in this pattern. The purpose of this study is then:

1) to examine the relationship between different indices
   of intensity of land use for different purposes;
2) to determine upon a method of analysis of patterns of
distribution of intensity of use of land within the
   metropolitan area;
3) to define the pattern of distribution for a number of
   metropolitan areas, to examine these patterns for common
   characteristics, and to explain the relationships
   exhibited;
4) to present evidence as to how these patterns are
   changing in response to the intensity of use of recent
   increments to growth; and
5) to determine what is the significance of the relationships
   exposed to the process of predicting land use require-
   ments.
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PART I

THE ANALYTICAL FRAMEWORK
CHAPTER I

METHODOLOGY

The diversity in the intensity of land use within an urban area calls for the adoption of a method of analysis of its distribution such that the regularities, which would otherwise be masked by local variations, may be perceived and such that comparison is possible between different cities. It is a matter of reducing either a map or a mass of tabulated data to a form which permits the type of examination which is the purpose of this paper.

The selection of the most appropriate areal basis for analysis is the first matter to be settled: in view of the weight of research which has been performed on the assumption that the significant factor is the distance from the c.b.d., the amount of data which is made available in the form which intrinsically makes the same assumption and the failure of any other single conceptual approach to so successfully explain the phenomenon of urban structure, it is perhaps iconoclastic to question the correctness of adopting the same approach. The justification for adoption of one conceptual approach rather than another must be its greater significance in explaining the location and intensity of human activities. If this is true then historically it is irrefutable that the metropolitan center should be chosen; a system of rings about this point best describes what has been the locational
behavior of firms and of individuals and, in fact, still does so insofar as current developments are a function of the existing pattern. Modern transport technology and the social changes have introduced into the system certain factors which may be more potent as determinants of location such as the circumferential highway. Two points must be made in connection with this: firstly, that before discarding the c.b.d. as the significant point it must be established that the alternative is not itself part of the response to forces which are organized about the c.b.d. and secondly, even if the influence of the metropolitan core upon location becomes nil, the c.b.d. still remains, by reason of its historical importance in this respect, the fulcrum of any description of what exists today, so recently has it failed to occupy the determining position.

To add to a system of rings some method of describing sectoral variations improves the completeness of description and most systems of data analysis for transportation studies permit data abstraction for this dimension; the Chicago study does so, while Bogue in his mammoth study of metropolitanization includes not only analysis of sectoral differences but a classification of sectors according to those characteristics which are important in determining the location of urban activities. The present study will be restricted to the significance of analysis by "rings," with some comment upon the value of adding this further axis.

The "grain" of distribution of intensities of land use is fine and, in certain types of industrial and commercial land use, so mixed that, in order to identify the regularities in the distribution of intensity, it is necessary to adopt a certain level of
aggregation of data; failure to do so will permit individual deviant establishments to obscure what would otherwise be a regular distribution. Extending the scale of aggregation in large cities can be justified, but to apply the same yard stick to smaller metropolitan areas may result in two or more distinctive parts of the study area falling within a single group; the price of obtaining a regular pattern may be too high in terms of the information which is buried. These effects are clearly demonstrated in the curves developed for the smaller of the metropolitan areas analyzed and impose a limitation upon the size of the metropolis which may be handled in this way.

The form in which the data was available varied from city to city; townships, census tracts, traffic zones and other data collection units being included. To prepare comparable measures of the variation within any ring after aggregation is therefore not easy, though this type of analysis, at the scale of the individual unit preferably, would provide an indication of what has been lost in the aggregation process. The aggregation was done to a level which is appropriate to each of the metropolitan areas within the constraints imposed by the data collection unit. Where the unit is small, determination of rings was easy and the boundaries conform relatively well with the concentric circles, while where the units are large (such as townships in the case of Boston) the aggregation was of townships whose geographical center lies within the particular ring. Details of the treatment for each metropolitan area is given with other relevant facts relating to the data in Appendix A.
This is an investigation, in part, of the significance of this selected analytical approach to describing the distribution of intensity to land use planning and it is essential that the measure of intensity chosen be one which has meaning in this context. The alternatives available are explored in greater detail in the following chapter, but the reasons for choosing to work with net rather than gross densities are best considered at this stage. Not only is the planner more interested in net densities but, the primary purpose of this investigation being analysis of intensity, to work with gross density which may yield little information on intensity of use cannot be justified.

The technique will be, then to prepare density gradient curves, plotting the average intensity of use for a number of broad categories of land use by ring against distance from the c.b.d. The relationship exhibited by these curves between different uses and between different cities will be examined. Since the concern is partly the potential use in land use planning, efforts are made to identify how these patterns are changing: this will be done by direct comparison of the curves for a single city at different points in time where this information is available and where it is not, which is in most cases, presenting the fragmentary evidence available and concentrating on the various components of change rather than the whole pattern, to obtain some indication of what are the changes in the total situation. The examination will be of the cross-sectional data in the absence of adequate description of the pattern in a single city at different points in time.
CHAPTER II

DESCRIPTIONS OF INTENSITY OF USE

The importance of the "fact that use (be it activity, or adapted space) is an almost useless thing to know about, unless intensity (density measured somehow) is also known" is stressed by Howard in a recent review article. In the following section will be considered the indices of intensity of use, their relationships with each other and their utility in describing the intensity of human activity.

The thrust of urban land use planning techniques lies in the area of the prediction of the numbers of persons, acting in certain ways, who have to be accommodated, such as industrial and office employees, shoppers or merely residents, so the first requirement of an index of intensity is that it must involve some measure of the numbers of persons involved. Secondly, it is usually necessary that those predictions be translatable into acres of land through the medium of a series of indices of density; therefore acres, net acres, is well suited to provide the denominator of the index. Persons per acre has disadvantages in that it tells us little about the way in which these activities are "stacked up" to produce the given intensity, that is, about the structures in which the activities occur, it tells us little of the "productivity" of the land and it may tell us little of the trips which are generated by
the activity, but it does successfully permit the equation of the planner's economic and demographic projections with land requirements and is thus perhaps most valuable in the present context.

Residential

A discussion as to the most useful index of residential density is not fruitful. Not only is "persons per acre" an index which is widely available but it is well suited to the analysis in hand. To use F.A.R. or floor space per person would be unnecessarily complicating matters; the first may well be closely equatable with persons per acre while the latter adds nothing to our knowledge of intensity of use of land, only of floor-space.

Manufacturing

Problems resulting from the aggregation of industries with very different intensity characteristics are pronounced and the sub-categorization by density would permit more meaningful analysis. Activity on industrial sites being closely related to employment, however, employees per acre constitutes a useful index. F.A.R. on the other hand, describes only the physical plant and does not permit immediate translation of economic forecasts into land requirements while floor-space per employee has less significance unless F.A.R. is introduced into the equation.

In discarding these two measures as being less useful for our immediate purposes than employees per acre, their contribution to the description of the manner in which the intensity is actually arranged on the land is nevertheless important. Figure 1 demonstrates a remarkably close correspondence in measure of FAR and employees per
Comparison of Indices of Intensity of Industrial Use, Buffalo

Figure 1

Miles from c.b.d.

Floor Space per Employee

Employees per Acre

Floor Area Ratio

10 Squares to the Inch
acre for the city of Buffalo with a serious discrepancy occurring only with \( \frac{1}{2} \) mile of the c.b.d. Floor space per employee increases from the core to 2 miles as would be expected, but then, surprisingly, decreases in the ring between 2 miles and 4 miles. Coincident with this decrease is an unexpected increase in employees per acre and F.A.R.: in view of the difficulties in establishing what are the regularities when the scale of aggregation is small, no explanation is offered for the phenomenon but the fact that the two unexpected effects are coincident suggests that they are connected and may represent but two separate aspects of an accumulation, within these zones, of industry with high intensity, high F.A.R. characteristics and of a type which has characteristics similar to that associated with the core areas. Other characteristics reflect only the mathematical relationships which exist between the quantities represented.

Evidence of the relation between employees per acre and FAR for Chicago shown on Figure 2 shows that the F.A.R. exhibits a much steeper decline from a peak in the c.b.d. than does the employees per acre index. Also on this diagram is represented vehicle trips generated per acre for industrial land; the expected gap between employees per acre and trips generated per acre in central areas, the result of the greater numbers walking to work, is not in evidence due to the particular derivation of employment statistics for this metropolis. The same holds for Minneapolis-St. Paul.

Retailing

The special quality of activity in retail establishments is that its principal component is the shopper rather than the employee;
Comparison of Indices of Intensity of Industrial Use

CHICAGO

Employees per Acre
Trips per Acre
Floor Area Ratio

TWIN CITIES

DETROIT and TUCSON (Trip Generation only)
measures of shoppers are not commonly available and would, to describe total activity, have to be related to the amount of time spent by each individual in this activity. The use of this index to describe the amount of activity would be not only a complex matter but, for the purposes of this study, would be made more difficult by data limitations. There are a number of alternatives, namely:

1) sales per acre; the evidence is that there is a good linear correlation (0.92) between daily sales and daily traffic movements into customer parking lots for different times of year, though this is for only a single shopping center in metropolitan New York. Variations in sales per acre between different types of store, selling different classes of goods is clearly a constraint upon general application of sales figures to represent activity but evaluations of its utility are not available.

2) F.A.R.; a wide discrepancy exists between sales per acre of floor space between stores selling different commodities but it has been shown that the number of people attracted to a central area is closely related to the amount of floor space being used for various purposes. The suggestion is that, once the trip generation quality is equated with floor area for a city within a certain population range, this relationship holds through fluctuations in the population and in the amount and distribution of floor area devoted to that activity. The significance of F.A.R. in the c.b.d. is great, but it has to be proven valid for other sectors of metropolitan areas.

3) employees per acre; the evidence is very sparse, but the indications are that the number of employees, excepting certain limited categories of store, bears some relation to the numbers of shoppers.
Making the reasonable assumption that discrepancies will relate in some regular way to the area of the city, the adoption of this as an index of intensity of use may be justified for the purposes of comparison between cities. It is for this index that data is available so in the following analysis employees per acre is the most-used measure. From the aspect of projection of land needs, it may be argued that, retail space requirements being more a function of the disposable income of the projected population than it is of the population, sales per acre constitutes the most useful index. This will not be argued at this point, the analysis using the index most generally available.

The relation between F.A.R. and employees per acre for Toronto and for Norfolk is shown on Figure 3. The close connection which would be expected is observed for the finer scale of aggregation for Norfolk while no useful relationship is distinguishable in the case of Toronto.

Office Activities

In terms of the relationships between employment and activity, the office function is akin to industry and employment per acre remains a useful measure of intensity of use. Owing to a more constant value for floor area per employee, F.A.R. bears a more regular relation to employment per acre and is therefore an index of activity in the sense in which this term is here used. Each of the examples shown in Figure 4 have shortcomings which limit their comparative value, the employment per acre curve for Toronto being for total commercial, but areas of correspondence are demonstrated.
Comparison of Indices of Intensity of Retail Use

Toronto

Employees per Acre
Floor Area Ratio

Miles from C.B.D.

Norfolk

Employment per Acre
Floor Area Ratio
Floor Space per Employee

Miles from C.B.D.
Comparison of Indices of Intensity of Office Use

TORONTO

Employees per Acre
Floor Area Ratio

(EMPLOYMENT PER ACRE IS FOR TOTAL COMMERCIAL)

CHICAGO

Trips per Acre
Floor Area Ratio

Miles from c.b.d.
Trip Generation Characteristics

The number of persons actually visiting an area during a day will provide an index of the intensity with which it is used (assuming some degree of correspondence between these two factors for a given activity); this is the basis for using trip generation statistics as a measure of density. That pedestrian traffic is ignored may be true but the value of these indices as indicators is seen in Figures 2, 3, and 4. In Figure 5 is shown the generation rates for residential, industrial and commercial land uses in Detroit: the regularity (and correlation) between residential and industrial uses is marked while the relative weaker relationship between commercial and distance from the c.b.d., despite the "peaking" correlation at 9-11 miles for both Detroit and Chicago, is clear. An extended study of the kind performed by Davidson\(^9\) to determine the person trips generated in downtown Boston for an average day in 1950 would provide more rigorous indices for analysis of the kind proposed than do those of Detroit, but the figures are nevertheless of considerable significance.

The figures given in Table 1 below indicate the relation of trips generated in Minneapolis and St. Paul by manufacturing activities: their close relation to F.A.R. and relative independence of floor area are significant in selection of index.
Figure 5

Person and Vehicle trips per acre generated by different land uses

- Residential
- Manufacturing
- Commercial

CHICAGO

MINNEAPOLIS

TUCSON

DETROIT

Miles from c.b.d.
TABLE 1

VEHICLE TRIP GENERATION OF MANUFACTURING INDUSTRY
BY LAND AND FLOOR AREA BY DISTANCE FROM NEAREST
C.B.D. FOR TWIN CITIES, 1958

<table>
<thead>
<tr>
<th>Ring</th>
<th>Distance</th>
<th>F.A.R.</th>
<th>Trips per 1000 sq. ft. of Floor Area</th>
<th>Trips per acre of Mfg. Industry</th>
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<tbody>
<tr>
<td>1</td>
<td>Not available</td>
<td>1.41</td>
<td>2.0</td>
<td>121.3</td>
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<tr>
<td>2</td>
<td>&quot;</td>
<td>0.65</td>
<td>2.1</td>
<td>60.0</td>
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<td>3</td>
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<td>4</td>
<td>&quot;</td>
<td>0.47</td>
<td>1.5</td>
<td>30.7</td>
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PART II

THE DATA AND ITS INTERPRETATION
CHAPTER III

INTRODUCTION TO THE INTERPRETATION OF THE DATA

Accessibility

The differences in current explanations for the structural pattern of land uses and activities within the city are, as Chapin points out, "in part a function of the background, specialization and research biases of the person advancing the approach" but all have a common concern for accessibility, the keystone in the explanation of the spatial relationships to be described.

It is accessibility which is the crucial factor and it is changes in this factor which provide the key to many of the changes in land use which are identified. If the social and economic phenomena of suburbanization stem from technological advance, the distribution of activities within metropolitan areas may nevertheless be explained largely in terms of spatial economics. Accessibility recurs frequently in the explanation of both changes in use and shifts in the pattern of intensity of use.

A city is, however, a very individual entity and local conditions determine the details of the distribution of land uses: the emphasis is upon broad distributions but, in comparison, discrepancies occur which call for explanation in terms other than accessibility. It is useful, therefore, to state what are these other
factors; a check list follows:

A. Physical Setting
   i) topography as it acts as a constraint upon growth,
   ii) local natural resources,
   iii) regional climate,
   iv) political and natural boundaries,

B. Characteristics of Urban Growth
   i) size of the metropolitan area,
   ii) presence of large satellite centers close by,

C. Social and Economic Factors
   i) characteristics of local economic development,
   ii) local social patterns determined by region of the country,
   iii) changes in income and in social values,

D. Historical Factors
   i) history of the metropolis as this is reflected in the age and arrangement of the structures,
   ii) changes in technology and resulting obsolescence of plant,
   iii) timing, size and type of immigrant wave,
   iv) recessions and wars.

Two Introductory Studies

Determinations of the density of use of central cities for periods prior to the second half of last century involves guess-work but it is clear that over the turn of the century net densities were still increasing rapidly in response to rapid development within the constraints of space imposed by rudimentary transportation technology. With widespread use of the automobile, the door was unlocked and net
densities, at the broad level of generality, have been observed to be decreasing. Outside the central cities the same is not true since the suburban areas, although absorbing this growth, exhibit very different characteristics of change in net density of development, as will be demonstrated later.

A recent single study identified many of the trends which are to be examined in more detail; the study by Neidercorn and Hearle\(^{11}\) was structured in such a way that, although dealing only with central cities, they were able to make some interesting comparisons between an entire group of 22 cities for which data at 2 points in time was available and 12 of this group which had not made substantial annexations during the period. The results of their work are summarized in Tables 2 and 3.

The conclusions to be drawn are:

a) the population density of the central cities decreased and, the annexations being of low density, the amount of decrease was greater for the full sample than for the 12 constant area cities,

b) the industrial employment density decreased but the amount of the decrease was less for the full sample than for the constant area cities, indicating that the density of employment in the annexed suburbs was greater than that of the central city,\(^ {12}\) and

c) the annexed commercial land tends to be used for low density shopping areas, resulting in a reduction in the density for the full sample as against a small increase in density for the constant area cities.
TABLE 2

PERCENTAGE CHANGES IN MEAN NET DENSITIES OF LAND USE BETWEEN TWO SAMPLES OF CITIES

<table>
<thead>
<tr>
<th>Land Use</th>
<th>22 Cities</th>
<th>12 Cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>-15.7</td>
<td>-12.4</td>
</tr>
<tr>
<td>Industrial</td>
<td>-10.5</td>
<td>-14.8</td>
</tr>
<tr>
<td>Commercial</td>
<td>-5.8</td>
<td>+0.6</td>
</tr>
</tbody>
</table>

TABLE 3

CORRELATION BETWEEN NET DENSITY AND CHANGES IN NET DENSITY OF LAND USE BETWEEN TWO SAMPLES OF CITIES

<table>
<thead>
<tr>
<th>Land Use</th>
<th>22 Cities</th>
<th>12 Cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>-0.35</td>
<td>-0.57</td>
</tr>
<tr>
<td>Industrial</td>
<td>-0.81</td>
<td>-0.83</td>
</tr>
<tr>
<td>Commercial</td>
<td>-0.05</td>
<td>+0.06</td>
</tr>
</tbody>
</table>


Note: Industrial densities were calculated by dividing manufacturing employment by industrial land area. Commercial densities were obtained by dividing the sum of wholesaling, retailing and selected service trade employment as defined by the Bureau of the Census, by commercial land. Finance, insurance real estate and professional services are not included in the calculations since data on these activities are not available.
This indicates that:

a) the more densely populated cities and those with high industrial employment densities are decreasing in population and employment density more rapidly than those that have made annexations and

b) changes in net commercial employment density show no systematic relation to existing commercial density.

Figures collected by Howard\textsuperscript{13} indicate that land used per 100 population has increased for all major types of land uses, overall densities have declined in recent years and that densities tend to be lower in metropolitan areas which are

1. smaller in population
2. more recent in development.

The second study used to introduce the body of data is not new but well illustrates, for a single city, many of the trends which will be identified; the results are summarized in Table 4 which demonstrates:

a. the relatively even spread of new retail construction, at high density in the c.b.d. and steadily decreasing density away from downtown

b. office construction, at very high density, restricted to the core

c. lower density warehousing construction concentrated around the core

d. lower density factory construction around the core, although amounts are small.

The data suffers from being old and thus excludes more recent trends, but as a prelude to presentation of further evidence, it is significant.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1 in.</td>
<td>Class 1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Class 2</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
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<td></td>
<td>Class 3</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Class 1</td>
<td>1</td>
<td>-</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>1-2 in.</td>
<td>Class 2</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Class 3</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Class 1</td>
<td>1</td>
<td>-</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>2-3 in.</td>
<td>Class 2</td>
<td>1</td>
<td>-</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Class 3</td>
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<td>-</td>
<td>-</td>
<td>-</td>
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<td>Class 1</td>
<td>1</td>
<td>-</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3-4 in.</td>
<td>Class 2</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td></td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Class 1</td>
<td>-</td>
<td>4</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>4-5 in.</td>
<td>Class 2</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Class 3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Class 1</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5-6 in.</td>
<td>Class 2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Class 3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Class 1</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6-10 in.</td>
<td>Class 2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Class 3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Class 1 F.A.R. = 0.09 (?) - 0.74
Class 2 F.A.R. = 0.75 - 2.09
Class 3 F.A.R. = 2.40 - 7.80

CHAPTER IV

RESIDENTIAL DENSITY

Data for population of the cities and its distribution throughout the metropolitan area are freely available from census and other sources; this has permitted better documentation of population distribution than is the case for industrial or commercial activities. Land use data, even in this field, lag behind population data in terms of availability with the result that most studies are concerned with gross density rather than the net density which is the concern of this paper. Certain of these studies nevertheless provide indications of how the density gradient (to use Guttenberg's term) is changing.

Notable among these is the work of Blumenfeld who, for Philadelphia and Toronto, defined the changing patterns of population distribution using, among other tools, figures for gross population density for rings concentric about the central city.14 His work permitted the construction of generalized density curves representing the changing pattern, to which mathematical dimensions were later assigned,15 but the point of greatest interest stems from the fact that his curves showed the kind of irregularities which are apparent in other cities in the current sample and that he had enough data to determine how they changed over time.

37
Figure 6 offers no help in problems associated with net densities for the Philadelphia area, its value lying in the deviations from the regular exponential curve which are demonstrated, namely

a) in the zone 8-9 miles where a sharp rise is exhibited and which, despite Blumenfeld's statement that "it has almost been smoothed out in 1950" remains marked at that date. It is clear that the smoothing out process only dates from 1930 since at that time the slope of the curve between the 7-8 and 8-9 mile zone was sharper than at any other time in the period concerned by his study (note the semi-log representation!). The density difference between the two zones was 0.1 in 1900, 1.0 in 1930 and 0.5 in 1950 and, assuming that development through this period was primarily of vacant land, this provides an indication of the relative density of the increments of growth within this ring between the two periods. It is hypothesized that the net density of development was high between 1900 and 1930 and that it was low between the years 1930 and 1950.

The smoothing of the curves over time represents a filling-in between previously isolated settlements, centers which were previously satellites becoming engulfed in the tide of metropolitan expansion. If, however, Hamburg is correct and developed sites respond only very slowly to changes in accessibility, then the complete elimination of this irregularity may take a very long period of time.

b) in the zone 10-12 miles, where the "abnormality" has been fairly regularly disappearing since 1900.

Where comparable land use statistics are available for two points in time for which population data are also available then it
Gross Population Density by Zones for Philadelphia, 1900 - 1950

is possible to compare density gradients for net densities at different points in the growth of the metropolis. Such a comparison has been made for Chicago for the years 1941 and 1956 (See Figure 7.).

It is clear that here there has been no simple "upward" movement of the residential curve corresponding to the growth of total population from 3.39 million to 3.61 million, but that different parts of the curve have responded in different ways to social and economic changes. The interpretation of these curves is:

a. The decline in net population density for the city as a whole is attributed by the C.A.T.S. analysts to an increase in relative accessibility of competitive outlying areas consequent upon an increase in car ownership,

b. the increase in net density within the 4 mile ring is attributed to a small decrease in residential land and an increase in population, the result of an influx of Negroes into the central area and their inability to relocate in the suburbs,

c. beyond the 4-mile zone the expected tendency to lower density is observed, with declines averaging about 16% and being very regular. It is hypothesized that:

i) for the ring between 4 and 7 miles from the center, the fact that the population decreased may reflect a tendency for the stock to remain relatively constant while the household size decreased and

ii) for the ring between 7 and 14 miles from the center the decline is the result of new building at densities sufficiently lower than the density prior to 1941 that the overall average is reduced.
1941 and 1956 Net Residential Densities by Mile Distance Rings about Chicago

d. The reduction of the increase during the period to nil at 14 miles indicates that the mean densities of the population in 1941 and of increments to the population between 1941 and 1956 are similar, probably the result of the relatively recent date of initial development of the area. A similar pair of curves has been constructed for Pittsburgh and although, in this case, data are restricted to the city, the relationships demonstrated (in Figure 8) are comparable with those demonstrated for Chicago.

In Figure 9 are shown the density gradient curves for net population density for the 9 cities with which this study is concerned. The first objective being to identify points of similarity in the relationships involved, the cities were ranked in order of size with an appropriate adjustment for those with water frontages, and characteristics tabulated. The curves were found to be interrupted by a series of "steps" which occur with some regularity between areas; these inconsistencies have been shown in Table 5.

In his study of the pattern of gross densities for Philadelphia, Blumenfeld attributes a similar type of "step" to his method of aggregation of the data and, with its shortcomings, this might hold for the inconsistencies displayed by the data in the current study. Certainly, confidence in the data is not so high that its inadequacies can be discounted as a cause of the irregularities. There are, however, marked regularities in the pattern between cities and, since the method and extent of aggregation varied widely, this indicates that there may be some other explanation. The premise that this is due to the engulfing of previously developed
Net Residential Density per Acre by Analysis Ring
For the City of Pittsburgh, 1938 and 1958

Miles from c.b.d.

Source: Pittsburgh Area Transportation Study
Density Gradient Curves for Residential Land Uses
in the sample of Nine Metropolitan Areas

Chicago
Philadelphia
Baltimore
Boston
Twin Cities
Toronto
Buffalo
Norfolk
Tulsa
TABLE 5

CHART SHOWING THE POSITION OF "STEPS" IN POPULATION DENSITY CURVES FOR SAMPLE ON NINE METROPOLITAN AREAS

<table>
<thead>
<tr>
<th>Metropolis</th>
<th>First Step</th>
<th>Flattening</th>
<th>Second Step</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
<td>Begins</td>
</tr>
<tr>
<td>Chicago</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Philadelphia</td>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>Boston</td>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>Toronto</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baltimore</td>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>Buffalo</td>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>Twin Cities</td>
<td>$3\frac{1}{2}$</td>
<td>$4\frac{1}{2}$</td>
<td>9</td>
</tr>
<tr>
<td>Norfolk</td>
<td>$3\frac{1}{2}$</td>
<td>$5\frac{1}{2}$</td>
<td>7</td>
</tr>
<tr>
<td>Tulsa</td>
<td>$4\frac{1}{2}$</td>
<td>$5\frac{1}{2}$</td>
<td></td>
</tr>
</tbody>
</table>

*Relatively minor effect.

Note: All figures represent radius of rings about c.b.d.
satellite communities, appears to be the logical explanation, the higher densities relating to older independent urban centers, although cursory examination of the structure of the metropolitan areas reveals no obvious confirmation that this is so.

Two important regularities are observed in:

a. the slope, for different cities, of the curves (representing rate of change of net density with distance on the semi-log graph paper) between the steps, and

b. the apparent reduction in the distance from the center of the second peak with the size of the metropolitan area. If the theory of the satellite centers is correct then this last feature could reflect the variation in the distance from the major center at which a substantial satellite center is viable (and tolerable) and the size of the major center.

The evidence is that the similarities between the curves are not such as to permit the characteristics of one curve to serve as the basis for the projection of another despite regularities in

a. location of steps in the curve
b. slope of the curve between steps
c. an apparent tendency for the curve to become smoother and less irregular as the size of the metropolitan population increases.

It is suggested that:

i) the relation between density of population and age, established by Winsborough and explained by him in the correlation between the number of dwellings per structure and age of structure,
ii) the changes in density of current development consequent upon social, technological and other changes render this type of comparison inadmissible.

Given the current density gradient curve, however, and the trends which have been established, it should be possible to make some reasonable prediction of what will be the future pattern of population density. The nature of the changes are summarized in Figure 10, and may be stated as:

A - B  small rise in central city densities
B - C  fall in density to the limits of appreciable suburbanization
C - D  increase in density in rural fringe
Diagram illustrating general trends in residential density gradient

- Rise in density in center
- Recent past
- Probable future
- Decline in density
- Small decline
- Little change

Miles from c.b.d.
CHAPTER V

INDUSTRIAL DENSITY

The aggregation of persons in the process of analysis of patterns of distribution of population is a relatively straightforward operation compared with the parallel process for industrial employment: in the first case distribution is fairly even and definitions are unambiguous, a person being the unit, but in the calculation of manufacturing densities, the concern is with aggregations of plants with density characteristics as diverse as 80 sq. ft. per employee and 1485 sq. ft. per employee, of units with very different locational requirements and size characteristics. The situation is complicated by shortage of data, by wide variation in the definitions adopted between cities rendering comparability hazardous and by inexact equating of definitions for the purpose of compilation of land use and of employment statistics for a single city. With these reservations there were nevertheless apparent certain regularities in the density gradient curves obtained for the cities in the sample.

In Figure 11 are shown these curves. The first question to be asked is "Do they exhibit any regularities in degree of density with total population?" If this were true, then the curves for the large cities would lie above those for smaller cities; there is, in fact, some evidence that this is so although:
a) this evidence must be interpreted with care due to the lack of comparability.\textsuperscript{22}

b) the effect is most marked beyond 16 miles from the center.

The evidence is, however, quite inadequate to support the justification for the concept of using the \textit{level} of the curve for a larger city as the basis for projecting the future density gradient for a smaller city. The general relationships, including the regularity observed beyond 16 miles, is compatible with present densities being a function of the date of development rather than the size of the city at the time of development, the big city being bigger at any one year and growth at a particular density occurring further from the center than simultaneous growth in a smaller city.

The second question is "Is there a characteristic shape for the density gradient for cities of comparable size?" In order to facilitate this analysis, Table 6 was compiled from the curves of Figure 11 to show the location in miles from the center of certain "steps" in the curves similar, but rather more regular than those identified in the population density gradients.

The regularities are:

i) a remarkable similarity in the position of the first step, with some tendency for it to occur closer to the center in the smaller cities,

ii) an apparent tendency for the second step, in those cities where it was identified, to occur closer to the center in the smaller cities,

iii) a high degree of similarity in the slope of the curves between steps and
### TABLE 6

CHART SHOWING THE POSITION OF "STEPS" IN MANUFACTURING DENSITY CURVES FOR SAMPLE OF NINE METROPOLITAN AREAS

<table>
<thead>
<tr>
<th>Metropolis</th>
<th>First Step</th>
<th>Second Step</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Chicago</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Philadelphia</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Boston</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Toronto</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Baltimore</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Buffalo</td>
<td>3</td>
<td>4½</td>
</tr>
<tr>
<td>Twin Cities</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Norfolk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tulsa</td>
<td>3½</td>
<td>4½</td>
</tr>
</tbody>
</table>

Note: all figures represent radius of rings about c.b.d.
iv) a regularity in the density of industrial employment at the center of the city regardless of the size of the city.

The shifts of the steps appear therefore to be related to the size of the city while the level of the curve is not. In order to determine whether there is any movement of the position of the steps in a city with time it would be necessary to compare the curve for a single city at two points in time and for this the data are inadequate. The evidence is, however, that this is not so and that, with certain reservations, the density of development within a ring is related to the density which was appropriate to that ring at the time at which it was developed. In order to throw some light on this matter, whatever evidence as to:

a) what are the shifts taking place in the location of industrial activity and

b) what are the densities of these activities both before and after locational shifts

is proffered.

That there are major shifts taking place in the pattern of industrial employment densities due to developments in transportation and production technologies and taxation is clear: Vernon has shown that thirteen selected central cities have been declining in importance as manufacturing employees relative to their suburban hinterlands while from 1947 to 1954, the cities of San Francisco, Boston, Chicago, Detroit, Pittsburgh and St. Louis showed an absolute decline. The reasons for this shift show considerable agreement between studies made in different cities, obsolescence of
the multi-storied mill building with the introduction of assembly line techniques, improved transportation and consequent weakening of "external economy" effects, the call for large areas for employee automobile parking and truck loading, congestion, expansion room, shifting markets, taxes and zoning being commonly cited reasons for quitting central city plants.²⁴

The firms which have not moved are:

a. those which are "communication-oriented" for which central city sites are essential. These tend to occupy old "loft" space vacated by the migrants in the heart of the city with the result that this part of the urban area becomes increasingly specialized. Vernon indicates that the space occupied by these firms is old space and that there being ample vacancies, the construction of new industrial space has not been financially attractive inside the central city, and

b. those firms which are dependent upon the external economics of the central city, are unable to afford the move out or are tolerant of the crowded conditions: it has been pointed out that "whatever the advantages of locating close to (the central city), such advantages are confined to a very narrow band of land around the city."²⁵

The changes in location of manufacturing activity are well documented for Chicago, revealing considerable gains in the ring ten to fifteen miles from the c.b.d. and the greatest losses within five miles of the core (see Figure 12). Leon Moses observed a marked
Changes in location of manufacturing activity, Chicago, 1950 - 1959

(Net relocations by mile distance from c.b.d.)

Source: Mark Reinsberg "Growth and Change in Metropolitan Areas and their relation to Metropolitan Transportation", Northwestern University, 1961
tendency for business growth to take place on the fringe of the city as well as in the adjacent suburbs.\textsuperscript{26}

To establish that there is a decrease in the number of manufacturing jobs in the central city does not necessarily result in a decrease in density in this part of the metropolis: a knowledge of what is the amount and density of that part remaining and the amount and density of that part relocating would permit a direct calculation of the change and although precise data are sparse, there are available some important clues, namely:

1) the fact that central city construction of high density manufacturing space is considered uneconomic implies that employment density is unlikely to rise substantially, at least in the immediate future;

ii) the data available for moves of manufacturing firms from the city of Philadelphia\textsuperscript{27} (see Tables 7 and 8) which indicate that

- density of the firms remaining is constant and
- the much lower densities after relocation are found outside the city.

A rider should be added to this last statement since Schoop\textsuperscript{28} ascertained that between 1946 and 1959, firms undertaking substantial new industrial construction added over a million sq. feet of floor space within 3 miles of downtown Boston, about one third of the increment along Route 128 during the same period and established, moreover, that the intensity of use in terms of floor space per employee was somewhat lower in the central areas. It is most unlikely that density described in terms of employees per acre would tell the same story, however.
TABLE 7

TABLE SHOWING SPACE REQUIREMENTS OF NEW PLANTS
COMPARSED WITH ON SITE EXPANSIONS
AND MOVES INTO EXISTING BUILDINGS
PHILADELPHIA AND S. COUNTY AREA

<table>
<thead>
<tr>
<th>Employees Per Site</th>
<th>Site Coverage Ratio</th>
<th>Average No. of Stories</th>
<th>Floor Space Per Employee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before all moves and expansions</td>
<td>168</td>
<td>0.48</td>
<td>2.26</td>
</tr>
<tr>
<td>After expansions and moves to existing buildings</td>
<td>83</td>
<td>0.31</td>
<td>1.63</td>
</tr>
<tr>
<td>After move to new plants</td>
<td>17</td>
<td>0.12</td>
<td>1.17</td>
</tr>
<tr>
<td>Ratio of total &quot;after&quot; to &quot;before&quot;</td>
<td>0.24</td>
<td>0.40</td>
<td>0.64</td>
</tr>
</tbody>
</table>
TABLE SHOWING GROWTH OF EMPLOYMENT IN PHILADELPHIA AND 40-COUNTY AREA 1940-1954

<table>
<thead>
<tr>
<th>Group</th>
<th>Actual Growth</th>
<th>Ratio 1954/1940 (%)</th>
<th>Philadelphia % of Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phila. 4-County</td>
<td>Phila. 4-County</td>
<td>1940</td>
</tr>
<tr>
<td>I Intensive</td>
<td>22,237 23,079</td>
<td>131.3 196.1</td>
<td>75.6</td>
</tr>
<tr>
<td>II Intermediate</td>
<td>40,723 19,888</td>
<td>140.7 180.0</td>
<td>80.1</td>
</tr>
<tr>
<td>III Intermediate/Extensive</td>
<td>3,264 6,709</td>
<td>95.6 119.3</td>
<td>68.1</td>
</tr>
<tr>
<td>IV Extensive</td>
<td>2,806 14,038</td>
<td>119.5 185.4</td>
<td>46.7</td>
</tr>
<tr>
<td>All</td>
<td>62,502 63,714</td>
<td>124.1 163.7</td>
<td>72.2</td>
</tr>
</tbody>
</table>

Source: "Industrial Land and Facilities for Philadelphia"

Note: Group I includes SIC categories 21, 23, 31, 36, 37
Group II includes SIC categories 20, 27, 30, 34, 35, 38, 39
Group III includes SIC categories 22, 24 (5), 26, 28, 32
Group IV includes SIC categories 29, 33
Individual locational decisions will hinge upon many factors, one of which will be the most advantageous height for the building. A Detroit survey showed that only 10% of firms surveyed desired a plant of more than one story, of which only 25% desired 3 or more stories, these being from a specialized group including tobacco, textile and apparel manufacture and printing. The significance of the demands of this deviant group upon the location of new construction appears to be small; Dorothy Muncie's study, although now somewhat out of date, indicates that:

a) during the period covered by the survey, 1940-1944, the most intensively developed sites are concentrated in the area closest to the business center, a trait which is carried over into the equivalent tabulation of employment density with distance. (See Tables 9, 10 and 11.)

b) even within the five mile ring the low structural density is noteworthy, since it again indicates the extent to which density of new construction is a function of the date of construction.

Typical figures for more recent developments are given in a study by Boley. He found that in an area which he studied in Chicago, some 37% of plants had less than 10 employees per acre, the average being 8.5 employees per net site acre, while the site coverage averaged only 10.4% in industrial park complexes.

Further evidence of the effect of age upon the structural intensity is found in a study performed in Minneapolis. Table 12 was compiled from information abstracted from the report; the points
## TABLE 9

### PLANT CONCENTRATIONS BY TYPE OF INDUSTRY

<table>
<thead>
<tr>
<th>Miles from Central Business District</th>
<th>Type of Industry</th>
<th>Location Concentrations (in miles)</th>
<th>Total Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 5</td>
<td>Synthetic rubber</td>
<td>3-4</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Petroleum refining</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Iron and steel forgings</td>
<td>3-5</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Primary refining of aluminum</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Rolling &amp; drawing non-ferrous metals</td>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Machine tools</td>
<td>2-5</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Electrical machinery</td>
<td>1-3</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Aircraft engines &amp; engine parts</td>
<td>1-3</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Aircraft parts</td>
<td>1-3</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Scientific instruments</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>5-10</td>
<td>Blast furnaces, steel works, rolling mills</td>
<td>6-8</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Iron and steel foundries</td>
<td>Under 10</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Primary refining of magnesium</td>
<td>6-9</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Engines and pumps</td>
<td>Under 10</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Motor vehicles and parts</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Aircraft manufacture</td>
<td>5-6</td>
<td>26</td>
</tr>
<tr>
<td>10-20</td>
<td>Note: no primary concentrations in this distance zone.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-25</td>
<td>Primary refining of other non-ferrous metals</td>
<td>22-25</td>
<td>7</td>
</tr>
</tbody>
</table>

### TABLE 10

**STRUCTURAL DENSITY AND DISTANCE FROM BUSINESS CENTER**

<table>
<thead>
<tr>
<th>Per Cent of Site Covered by Structure</th>
<th>0-4 Miles</th>
<th>5-9 Miles</th>
<th>10-14 Miles</th>
<th>15-24 Miles</th>
<th>25 Miles or Over</th>
<th>Total Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 5</td>
<td>8</td>
<td>9</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>33</td>
</tr>
<tr>
<td>5-9</td>
<td>14</td>
<td>7</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>32</td>
</tr>
<tr>
<td>10-14</td>
<td>11</td>
<td>13</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>34</td>
</tr>
<tr>
<td>15-24</td>
<td>10</td>
<td>12</td>
<td>9</td>
<td>4</td>
<td>2</td>
<td>35</td>
</tr>
<tr>
<td>25-34</td>
<td>15</td>
<td>10</td>
<td>9</td>
<td>3</td>
<td>2</td>
<td>39</td>
</tr>
<tr>
<td>35-49</td>
<td>11</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>50-74</td>
<td>15</td>
<td>6</td>
<td></td>
<td>1</td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>75 or over</td>
<td>4</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Total Plants</td>
<td>88</td>
<td>63</td>
<td>38</td>
<td>18</td>
<td>13</td>
<td>220</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Employee Per Acre</th>
<th>0-4 Miles</th>
<th>5-9 Miles</th>
<th>10-14 Miles</th>
<th>15-24 Miles</th>
<th>25 Miles or Over</th>
<th>Total Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 5 per acre</td>
<td>11</td>
<td>10</td>
<td>9</td>
<td>4</td>
<td>7</td>
<td>41</td>
</tr>
<tr>
<td>5-9 per acre</td>
<td>9</td>
<td>8</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>10-14 per acre</td>
<td>10</td>
<td>9</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>29</td>
</tr>
<tr>
<td>15-24 per acre</td>
<td>13</td>
<td>12</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>35</td>
</tr>
<tr>
<td>25-49 per acre</td>
<td>12</td>
<td>10</td>
<td>9</td>
<td>1</td>
<td></td>
<td>32</td>
</tr>
<tr>
<td>50-74 per acre</td>
<td>11</td>
<td>8</td>
<td>3</td>
<td>4</td>
<td></td>
<td>26</td>
</tr>
<tr>
<td>75-99 per acre</td>
<td>10</td>
<td>4</td>
<td>1</td>
<td></td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>100 employees or more per acre</td>
<td>12</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>Total Plants</td>
<td>88</td>
<td>63</td>
<td>38</td>
<td>18</td>
<td>13</td>
<td>220</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year of Construction</th>
<th>1 Story</th>
<th>2 Story</th>
<th>3 Story</th>
<th>4 Story</th>
<th>5 Story</th>
<th>6 Story +</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior to 1880</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1880 - 1890</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>1890 - 1900</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>1900 - 1910</td>
<td>3</td>
<td>11</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>1910 - 1920</td>
<td>12</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>1920 - 1930</td>
<td>7</td>
<td>9</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>1930 - 1940</td>
<td>6</td>
<td>7</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1940 - 1950</td>
<td>20</td>
<td>5</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1950 - 1960</td>
<td>33</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

of interest are:

a. the decline in the number of multi-story buildings erected for manufacturing activities since 1920 and
b. the small amount of construction during the depression period.

Bogue, in his study of suburbanization of manufacturing activity offers more evidence on the second of these two points; in the summary of reports from local observers representing SMA's in his study, the point is clearly made that in the years of World War II the stimulus to greater production outran plant construction and an appreciable increase in employment density was the result. It is likely that, by the same token, less cataclysmic periods of economic advance and recession could have an effect upon density without an accompanying change of premises.

The relationships between the density gradients for manufacturing employment and those for residential density are not strongly marked but the following may be observed from Figure 13, in which these curves are superimposed for each city region:

a) the slope of the industrial employment density curve tends to be steeper than that representing population density, in the central areas,

b) the actual levels of density are very similar for the two factors beyond 8 miles from the center and

c) the regularity of the population curve is not matched by that for manufacturing employment, there being wide fluctuations attributed to the effects of one or a limited number of plants with exceptional use intensity
Figure 13

Comparison of Residential and Industrial Density Gradient curves for the sample of nine Metropolitan Areas

- CHICAGO
- PHILADELPHIA
- BOSTON
- TORONTO
- BALTIMORE
- TWIN CITIES
- BUFFALO
- TULSA

Note vertical scale change between cities.
characteristics and the propensity of such a group to cause substantial irregularities in the density gradient. The solution, as was indicated in the discussion of aggregation methods, lies in widening the areas of aggregation but, particular in the smaller city regions, to do so would reduce the number of data points and hence "sterilize" the curve. This effect is pronounced in the case of Buffalo, Norfolk and Tulsa. An indication of how great are the variations within a ring is given by the compilation for Chicago of the average manufacturing worker densities by distance from the CBD in each sector.

Early industrial development, with its characteristically high density of employment, generated adjacent high density housing, urban transportation being then a serious constraint upon the length of the journey to work and, as Winsborough puts it, "the type of structure composition of many parts of the city (Chicago)...established under previously existing transportation conditions...(remaining)...relatively inflexible" we would expect to find, in appropriate metropolitan areas, a correspondence in density between industrial plant and residence. This is generally true (See Figure 13.) although the relationship would appear to be not so regular that knowledge of the one permits deductions about the other.

The foregoing permits some generalizations upon what changes are occurring in the pattern of densities; these are summarized in Figure 14 and may be stated as:
Diagram illustrating general trends in manufacturing density gradient

- Little change in net density in center
- Outside the center, general decline in net density

Miles from c.b.d.
A-B density tends to remain fairly constant in the c.b.d.

B-C elsewhere it tends to decrease, the amount of decrease being greatest where current densities are greatest.

There is no justification for using the curve of the larger city as a basis for prediction of the curves for a smaller city at some point in time in the future, since it is clearly indicated that the density of use of current construction is first and foremost a function of the date of construction. Bogue notes in his work that the degree of suburbanization of manufacturing (which has connotations in terms of employment densities):

1) varies greatly from one city to the next,

2) shows no systematic relationship with measures of the suburbanization of population although the one has been observed to engender the other and

3) depends upon the date of industrialization, the late developers being much more decentralized than those with older established industry.

The suggestion then is that the body of evidence is sufficient to justify its use, not in predictions based solely on application of a curve appropriate to the predicted population of the city, but in development of a projection from:

a) the current curve and

b) the current trends in density changes.

In evaluating the meaning of these results it is particularly important that the definition of "industrial" used in the sample area
be borne in mind. Not only does it vary widely but in the nine cities, data is variously available for manufacturing alone and for manufacturing aggregated with other activities, notably wholesaling and warehousing. This combination of activities is adopted in the figures for Philadelphia, Boston, and Toronto while the wholesaling category is separated in the case of Baltimore, Tulsa and Norfolk. Employment in wholesaling activity runs well below that in manufacturing activities in most rings in most cities and no separate analysis will be made other than to determine approximately how the aggregation of this category with manufacturing will modify the patterns of manufacturing intensities displayed.

Wholesaling (and warehousing) is subject to much the same pressure for single story structures as is industry, although, the emphasis being more upon handling of goods, it is perhaps even more accentuated. Locationally, however, this group is more constrained in relocation since:

i) lower profits limit the amount of new building which can be justified,

ii) warehouses are more attached to the railroads than are most industries and

iii) it depends to a greater extent upon accessibility to a diffuse market area.

Hence decentralization has been found to be less marked in this group than it has in manufacturing activities. In Philadelphia, for instance, 40% of the city's warehouses are still located in blocks adjacent to Market St. in the heart of the city. Reinsberg states that the opposite is true for Chicago, that the exodus of warehouses
from the inner zones to the periphery proportionately exceeds that for other manufacturing activities but offers no direct evidence to support this contention. 39

The impact upon the manufacturing density when the two categories are aggregated occurs as a result of the very low densities in terms of employees per acre at which warehousing and wholesaling plants operate. In the same Philadelphia Study, it was found that 1 employee per 10,000 sq. ft. (or about 4 employees per acre) of storage space was a representative figure; this would have to be substantially adjusted to embrace both site area other than storage space and the multi-story nature of most of the structures so that the figure of 22 employees per net site acre given for Buffalo is perhaps in broad agreement. Compare this however with the floor space requirements of employees in an industry also heavily localized in the heart of Philadelphia and also occupying largely multi-story structures, the apparel industry. Where sewing is the sole activity the figure is about 80 sq. ft. per employee, rising to 200 sq. ft. per employee where manufacturing processes are involved, but still being insignificant compared with the space requirements of the wholesaling employee. To what extent these manufacturing averages will be modified by the lower wholesaling densities will be determined by the relative amounts of each and this varies among the cities for which data was obtained.

In the Baltimore c.b.d. wholesaling employment reaches 12,890 compared with industrial employment of some 2,000; in the ring between 1 and 2 miles from c.b.d., these figures have, however, become 1,610 and 50,400 respectively and in no other ring does the
wholesaling employment exceed 25% of the industrial employment. Data for wholesaling acreage in the c.b.d. was not available so that the density at which these 12,390 employees worked cannot be deduced; it is nevertheless clear that were wholesaling to be included in the same category as manufacturing, the effect would be:

i) to greatly reduce the average density of manufacturing in the c.b.d. and

ii) small outside the c.b.d. since the employment densities for the two activities become increasingly similar.

Tulsa provides another case in point. The wholesale employment runs at about 25% of industrial employment within the 4 mile ring and very much less than this proportion beyond 4 miles. The indications (see Figure 15) are that:

a) the employment density is substantially lower throughout for wholesaling employment than for industrial employment

b) aggregating the two activities would tend to lower the average employment density throughout, although this would be material only within the 4 mile ring

c) the great accumulation of wholesaling employment noted in the heart of Baltimore is missing in Tulsa reflecting perhaps different regional functions, types of hinterland, historical background and size.

Two examples provide insufficient evidence upon which to generalize but the evidence suggests that:

a) wholesale densities are lower than industrial densities,
Comparison of density gradient curves for manufacturing and wholesaling land use in selected metropolitan areas

Figure 15

Baltimore

Tulsa

Miles from c.b.a.
b) the range of wholesaling densities is less than that for industrial densities,
c) the wholesaling density gradient appears to have the same general shape as that for industry,
d) noting in Figure 15 the fact that a dip in the industrial density is accompanied by a rise in the wholesaling density and vice versa, the combination of the two would tend to flatten the density gradient curve,
e) the downtown density will be lowered by inclusion of wholesaling into the manufacturing category, the extent of modification being great where the wholesaling employment is large (as in Baltimore) and small when the opposite is true (as with Tulsa) and
f) the suburban densities will not be substantially affected by combining the two.

In the two metropolitan areas in the sample, Boston and Toronto, for which data upon wholesaling and industry are combined, it is noted (see Figure 11) that the most central densities are low in comparison to those for other cities in the sample: the low density characteristics of wholesaling may explain this phenomenon.
CHAPTER VI

DENSITY OF OFFICE ACTIVITIES

Due in part to the difficulties of collecting data on office-commercial activities, the approach adopted is less rewarding than for those other categories of human activity considered. Density gradients in terms of employees per acre have been constructed for five of the city-regions studied and in terms of F.A.R. for Chicago but it must be noted that the definitions vary so widely that the results of comparison must be suspect. The figures for Philadelphia, Baltimore and Tulsa relate purely to office employment, while those for Chicago, Toronto and Twin Cities embrace other commercial activities, details of which are given in Appendix A. With these shortcomings, Figure 16 yields the following points of interest:

a) there is no discernible pattern in the distribution of "steps," unlike the previous activities considered,

b) the overall decrease from a peak at the c.b.d. to lower suburban densities is marked, but the lower asymptote is higher than that for other activities,

c) the characteristic correspondence in the slope of the curves between "steps" is observed,

d) an unexplained but marked increase in intensity of development appears beyond the 14 mile ring in three of the four cities for which data is available at
Density Gradient Curves for Office Land Use for the sample of Nine Metropolitan Areas

Philadelphia ——— (Office only)
Baltimore ——— (Includes Services)
Toronto ——— (Includes retail and services)
Twin Cities ——— (Includes retail and services)
this distance from the c.b.d. and e) the densities are greater than those for retail activities.

The discrepancies between curves clearly renders invalid the method of "transposing" curves between cities. Neither do the relationships of the office employment density gradients with population density gradients shown in Figure 17 demonstrate any obvious relationship between the two. They appear to be largely independent except:

a) in general form,
b) at certain places the commercial employment density appears to vary in sympathy with population density, as with Philadelphia beyond 8 miles. The fact that the correspondence is not more marked reflects the greater measure of independence of population distribution of office as against retail activities,
c) the curve for Tulsa demonstrates how a finer degree of aggregation can permit a single firm or small group of firms to turn the curve into a "monster." In this case, some 400 persons are employed on a net land area of 2.7 acres in the 8-10 mile ring.
d) the abnormally high figures for the Twin Cities must reflect definitional, data-collection and other comparability differences.

An examination of what are the current shifts in office employment open up a number of insights to the future shape of the
Comparison of Density Gradient Curves for Residential and Office Land Use.

- Residential
- Office

Includes retail and services

Includes retail and services

Includes retail, services and wholesaling
curves but they are few and indefinite. The Rand study identified an increase in net density in the central cities but their definition "includes wholesaling, retailing and service uses." Bearing in mind what it has been determined is happening to the first two of these items, Neidercorn and Hearle's conclusion that "... increased employment in the service trades has offset losses in retailing and has consequently prevented commercial densities from falling" appears reasonable. Vernon produces little statistical evidence but is able to show that:

a) office employment is a sector which is growing at a rate faster than the economy as a whole,

b) office employment in the central cities is growing on the average, although he warns that the biggest cities, the regional centers, may be the only benefactors from this growth and

c) the central city share of the office employment in finance, insurance and real estate in the metropolitan area declined over the period 1947-1956, responding to the migration of certain services with population as, for example, banking becomes a "neighborhood" service.42

These trends are making themselves felt in central business district development. Examples abound. Due for completion shortly is a building of 26 stories in Atlanta and one of 42 stories in Los Angeles, while the State Street Bank (30 stories) and the John F. Kennedy Building (24 stories) both in Boston are scheduled for occupation in April 1966. Detroit went 30 years without a new office
building but three have recently been completed simultaneously.\textsuperscript{43} In Chicago there was a substantial increase in office space during the period 1945 to 1960, the result of the construction of 34 new buildings totalling 3.9 million sq. ft. of office space and the conversion of 19 existing buildings, mostly from light manufacturing, loft and retail uses, totalling 5.4 million sq. ft. of office space.\textsuperscript{44}

Total floor areas and figures for number of stories of these new buildings do not necessarily imply intense use of the site (e.g. Prudential Center in Boston) although the relationship must become closer in the area of high land values in the c.b.d. Having established the fact of a growth in the amounts of office activity in metropolitan cores, the question of the intensity of use must be examined. Here again, there is no shortage of data but to relate it in meaningful ways to the amounts of the changes is often not possible.

The F.A.R. of the new construction in Chicago between 1945 and 1960, referred to above, was 7.86\textsuperscript{45} which is very much higher than the F.A.R. (commercial) for the C.A.T.S. district No. 1. The 1955 average F.A.R. of office buildings in downtown Boston was 6.7 (median 9.5) while that of the John Hancock Building is 7.8: the significance of this density away from the "core" is modified by the lower average density of the Prudential Center development on an adjacent site (only about 3 despite the one tall tower). Post-war buildings in downtown Washington ranged from 0.5 - 12.7 with a median figure of 9.4.

Increments to the office space of the core seem likely to locate at existing or higher densities while a supply of "convertible"
space remains but that new building in this part of the city will be, in response to increasing demand for space, at appreciably higher densities. This tendency may be accentuated by the increasing amount of floor space required per employee. In the old Insurance Exchange Building in Chicago the figure was 103 sq. feet while in the new Prudential Building in that same city it had risen to 135 sq. ft.: this, however, is low compared with Vernon's 1956 figure of 188 sq. ft. for Manhattan, 47 the current Louisville c.b.d. average of 213 48 and the 1960 figure for Pittsburgh c.b.d. 166 sq. ft. per employee. 49

The suburbs have shared in the growth of office employment but it is difficult to determine at what density these employment opportunities are occurring. It seems likely that those which are consumer oriented, the local branches of the banks for instance, will be attracted to retail shopping areas and that their locational characteristics will be similar to those for retail business, though the actual employee density may differ. There are reports of appreciable migrations of employment from the core to suburban sites; these will obviously have a great effect upon the density gradient if the movement reaches large proportions, although Vernon suggests that the locational advantages of the c.b.d. are sufficiently strong for a large enough proportion of major office functions to preclude this. 50

He quotes the examples of "General Foods" moving from New York to Westchester and of Connecticut General Life Insurance transferring to a site 5 miles out of Hartford. The latter move was to a site of 280 acres to accommodate parking and the accessory services which would otherwise be available in the c.b.d. and to meet the demands of local zoning and the prestige requirements. The
exact degree of intensity of use in such situations cannot be
determined from data to hand, but clearly, it will be very much less
than that which is typical of the central city. Clark$^51$ found
that firms locating in the suburbs were required to provide some
250 sq. ft. for each employee: compare this with the floor space
requirements quoted above, allowing further for parking and the
prestige landscaping which is a part of site development in these
situations and it is clear that the intensity of site use is very much
lower than that of the city site.

How these densities relate to existing densities is not
easy to determine; it seems likely, however, that the amounts in
the outer zones are small so that the addition of a large increment
will result in a new net density similar to that of the increment.
A "typical" density gradient curve has been constructed, Figure 18,
and the effects of the identified changes shown. The curve seems
likely to change in the following ways:

A-B For those central cities with expanding office
employment, the employment density seems likely
to increase, assuming that these two factors may
be equated.

B-C In the inner suburbs the expansion of office
employment from the established commercial sub-
centers to the new shopping centers and to
"neighborhoods" should result in a decrease in
density.

C-D In the outer suburbs, which is the part of the
metropolis with land prices which would be
Diagram illustrating general trends in the density gradient curves for office land use

Increase in density in the core for cities with growing office sectors

Declining densities

Recent past

Probable future

Little evidence

Miles from c.b.d.
attractive to the large employers relocating outside the core, the evidence is thin, but the new density will be close to that of the density of the increments.
CHAPTER VII

RETAILING DENSITY

The limited information upon intensity of use of retailing areas, the doubt which exists as to which of the indices available provides the most valid measure of intensity of human activity and the relationships established between the different indices are justification for using whatever is available. For the construction of the density gradient curves, employees per acre is the measure used; these curves are represented in Figure 19 and show the following characteristics:

1) they show the same "stepping" as was noted with other elements,

2) there are no discernible regularities in the location of these steps as between cities,

3) the slope of the curve, representing the rate of change of density, shows marked similarities between steps for different cities and

4) the aggregation problems previously noted have again limited the value of the method for the smaller areas.

It is apparent that each of these curves has distinctive characteristics and that no one curve offers a meaningful guide in the projection of another.
Density Gradient Curves for the Retail land use in the sample of Nine Metropolitan Areas

Philadelphia (Retail only)
Baltimore (Retail only)
Boston (Includes offices)
Norfolk (Includes offices)
Tulsa (Retail only)

Distance from c.b.d. in miles
Examination of the retail employment density gradients as they relate to the population density gradient is, however, more rewarding. The suggestion, from the few curves available (see Figure 20), is that there is a close correlation between retail employment and population densities; in the cases of Philadelphia and Boston, the retail employment densities seem to respond in a very sensitive manner to changes in population density. The answer which comes to mind, that each is responding to an independent variable, the market value of land, would certainly require further investigation. The characteristics of the location of retail jobs in relation to population, briefly:

a) the declining role of the central city and especially of its central business district as population shifts occur,
b) the system of organization of shopping centers with a hierarchical arrangement of service areas,
c) the manner in which retail growth is concentrated relative to the distribution of income and
d) the lag between retail growth and population growth, both temporally and spatially,\(^{52}\)
appear not to have a substantial effect upon the relationship between retail employment and population density curves, although the actual shape of the curves is strongly influenced by the higher densities in the central city.

It is between the central city and the suburbs that the most dramatic changes are occurring so the extent of these changes warrants closer examination. The changes are attributed to:
Comparison of density gradient curves for retail and residential land uses

Retail

Residential

Includes services

Includes offices

Note different vertical scale
a) less rapid growth of population in the central cities,
b) less rapid growth of jobs in the central cities and
c) preference for the automobile for the journey-to-shop.

Vernon presents evidence that, in his sample of 13 major metropolitan areas, the share of the c.b.d. fell by 25% and that of the central city by 10%.\textsuperscript{53} A great volume of evidence of this change is available for many cities, the following figures for Tulsa being typical:

\begin{table}
\centering
\caption{Comparison of Retail Sales in Tulsa C.B.D. and Suburbs, 1948 to 1958\textsuperscript{54}}
\begin{tabular}{|c|c|c|c|c|}
\hline
 & c.b.d. & & Suburbs & \\
 & Sales & \% & Sales & \% \\
\hline
1948 & $103.4\ m$ & 42.0\% & $142.6\ m$ & 58.0\% \\
1958 & $113.8\ m$ & 28.2\% & $289.1\ m$ & 71.8\% \\
\hline
\end{tabular}
\end{table}

and the map (Figure 21) showing changes in the Chicago's retail establishments between 1948 and 1958 needing no further explanation. The figures for floor area added (excluding strip commercial growth) for Metropolitan Toronto between 1956 and 1964 shown in Table 14 demonstrate parallel shifts for a third metropolis from the sample. The eclipse of the "core" city has not been complete; in Washington, for instance, post-war construction of stores in the downtown has occurred, at a density of FAR of 0.38 to 2.3 (median 1.5), although
Change of Retail Establishments, 1948 - 1958, Chicago

Change in No. of Retail Establishments 1948 - 1958

- Loss of 10 stores
+ Increase of 10 stores
* Increase of 10 planned center stores

TABLE 14

TABLE SHOWING INCREMENTS TO RETAIL AND SERVICE STORE SPACE IN THE METROPOLITAN TORONTO PLANNING AREA, 1956 - 1964, BY GROUPS OF MUNICIPALITIES

<table>
<thead>
<tr>
<th>Zone</th>
<th>Floor Area Added, 1956-1964</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sq. Ft.</td>
</tr>
<tr>
<td>City of Toronto</td>
<td>308,000</td>
</tr>
<tr>
<td>9 Inner Suburbs</td>
<td>566,000</td>
</tr>
<tr>
<td>3 Outer Suburbs</td>
<td>5,085,000</td>
</tr>
<tr>
<td>Fringe Municipalities</td>
<td>734,000</td>
</tr>
</tbody>
</table>

the low density would suggest that much of this construction was outside of downtown.

Perhaps the most interesting point concerning Vernon's figures, although not elaborated upon by the author, is that they illustrate (by deduction) a growth in the share of retail employment of the central city excluding the central business district and, in all cases, an actual growth in employment. This is evident in the fact that retail sales in the city of Baltimore grew as detailed in Table 15.

SELLING AREA AND SALES FOR DOWNTOWN AND REMAINDER OF BALTIMORE, 1948 AND 1954

<table>
<thead>
<tr>
<th>Department</th>
<th>Selling Area</th>
<th>Sales/sq.ft.</th>
<th>Selling Area</th>
<th>Sales/sq.ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stores Only</td>
<td>000's sq. ft.</td>
<td>000's sq. ft.</td>
<td>000's sq. ft.</td>
<td>000's sq. ft.</td>
</tr>
<tr>
<td>Downtown</td>
<td>1,254</td>
<td>$ 87</td>
<td>1,254</td>
<td>$ 88</td>
</tr>
<tr>
<td>Remainder</td>
<td>283</td>
<td>$ 82</td>
<td>499</td>
<td>$ 92</td>
</tr>
</tbody>
</table>

Further support is given to this contention by figures for the construction of planned shopping centers. They are by no means restricted to what are usually called suburban areas. Eleven of the "planned shopping centers" built in the Boston metropolitan area up to 1963 were within 5 miles of downtown Boston, while a similar situation holds for Chicago. The importance of this phenomenon is that these planned centers had characteristically low floor-area ratios and correspondingly low figures for employment per acre. Valuable clues as to how these factors change, in space and in time,
have been obtained from data collected for a study of planned shopping centers in the Boston area: the results of this analysis are shown in Table 16.

Identified by the authors of the study as of interest are:

a) the largest centers are built from 14-18 miles from downtown Boston,

b) centers falling into the next category by size are located principally in the 7-10 mile zone,

c) 20 of the 70 planned centers covered by the study are within 1 mile of the circumferential Route 128.

From the further analysis, may be added:

d) there is a marked relationship between FAR of the planned center and the distance from the c.b.d.,

e) the differences in FAR between planned centers in the central and suburban locations is less than the difference in employee density between all retail establishments close to the center and in suburban locations (by comparison with Figure 20) and

f) the variation of FAR with year of construction is irregular, the high for the period 1944-54 probably being attributable to the greater proportion of the construction which occurred in central areas during this period.

While this sheds light upon what is currently happening to densities outside the c.b.d. there are few data offering positive evidence regarding changes in the heart of the metropolis. Vance states that "...in the post-war period virtually all growth of the commercial structure has taken place outside the city core. Concentra-
TABLE 16

TABLE SHOWING CHARACTERISTICS OF PLANNED SHOPPING CENTERS CONSTRUCTED IN THE BOSTON AREA 1944-1962, ANALYZED BY AGE AND DISTANCE FROM C.B.D.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Site Area</td>
<td>Floor Area</td>
<td>Site Area</td>
<td>Floor Area</td>
<td>Site Area</td>
</tr>
<tr>
<td>0 - 4</td>
<td>643 138</td>
<td>180 63</td>
<td>200 70</td>
<td>655 95</td>
<td>1,678 366</td>
</tr>
<tr>
<td>5 - 8</td>
<td>595 300</td>
<td>2,095 630</td>
<td>390 85</td>
<td>252 80</td>
<td>3,332 1,095</td>
</tr>
<tr>
<td>9 - 12</td>
<td>141 32</td>
<td>2,358 412</td>
<td>2,221 223</td>
<td>9,740 1,265</td>
<td>14,460 1,932</td>
</tr>
<tr>
<td>13 - 16</td>
<td>500 39</td>
<td>7,461 1,159</td>
<td>2,801 398</td>
<td>2,483 409</td>
<td>13,245 2,005</td>
</tr>
<tr>
<td>17 - 20</td>
<td>3,398 577</td>
<td>488 105</td>
<td>2,934 308</td>
<td>1,049 190</td>
<td>7,869 1,180</td>
</tr>
<tr>
<td>21</td>
<td>- 1,960</td>
<td>46 420</td>
<td>81 1,423</td>
<td>230 3,803</td>
<td>357 0.094</td>
</tr>
</tbody>
</table>

Totals by Age

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5,277</td>
<td>1,086</td>
<td>14,452</td>
<td>2,415</td>
<td>8,966</td>
</tr>
</tbody>
</table>

F.A.R. by Age

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.206</td>
<td>0.167</td>
<td>0.130</td>
<td>0.145</td>
<td></td>
</tr>
</tbody>
</table>


Note:
2. All areas in 000's of sq. ft., gross area.
tion on that area (the core) alone would give us a picture of the realities of the pre-war world."\(^{59}\) This appears to be substantially justified although limited amounts of new construction have been recorded in Kansas City and other c.b.d.'s mostly of department store type.\(^{60}\) The general trend, however, is clearly towards restricted "core" construction for retailing, the increasing specialization of downtown types of retail business and a loss of the proportion of the business of the metropolitan area at its center.

The density of any retail activity in the core is constrained by the high land costs with the result that there can be no really low density activity of this kind and, moreover, competition for land remains fierce in the c.b.d. to the extent that no reduction of density is likely in the immediate future.

A relevant point made by Simmons\(^{61}\) is that, despite the rash of planned centers, the numbers of new unplanned centers is also increasing, but that their locational requirements now include car accessibility and parking; the density of this type of development can therefore reasonably be expected to be below that of the traditional small unplanned center.

It has been stated it is not sufficient simply to apply curves between cities in making projections, but knowledge of the existing density gradient and the circumstantial evidence collected does permit the formulation of an educated guess as to the direction in which it is moving. These trends are summarized in Figure 22 which shows:

A-B Little change expected, although there may be some slight increase in density in the core,
Diagram illustrating general trends in retailing density gradient curves.

- Recent past
- Probable future
- Little change: small rise in density in the core indicated
- Marked decline here
- Smaller decline
- Little change
with rising land values (See the Rand tables, p. and loss of small retail stores.

B-C Area of substantial decrease as new planned and unplanned shopping centers with typical densities well below those of the traditional centers replace this latter category.

C-D Area of smaller decrease, a large proportion of development being built to current standards.

D-E Area of predominantly new development, with little change of density with time.

It should be noted that an aggregation of development to new standards such as that likely to follow construction of a circumferential highway, may cause an irregular drop in density. The same effect may be produced by the cycle of growth and decay as it is described by Simmons, where "...dings of centers mature and decline as the pattern of residential succession moves outwards," a statement which he makes based upon the "interceptor" theory along radial routes. There is no empirical evidence to show that this affects retail employment density, but insofar as density is related to time, it would not be surprising if this resulted in a "step" downwards in the curves and that these steps tended to migrate outwards.
PART III

EVALUATION AND CONCLUSION
CHAPTER VIII

SUMMARY AND CONCLUSION

Comparison of curves representing the distribution of each of the activities for a number of the metropolitan areas yield the following identifiable features:

a) the "steps" observed in the curves show some correspondence between cities and a tendency to occur closer to the center in the curves representing population and industrial density,

b) there is a correspondence in the rate of decrease of intensity with distance from the c.b.d. between cities for residential industrial, office and retail land uses,

c) the intensity of use of industrial land in the cores of the metropolitan areas studied showed similarities without regard to the size of the metropolis,

d) office intensities were higher in suburban areas than were the other land uses considered and

e) the relationship between distribution of residential and retailing land use intensity is close.

These demonstrated relationships do not permit the construction of a curve for a city, knowing its characteristics and
those for cities whose curves are to hand, such is the very individual nature of each city. Neither, by the same token, is correlation between cities of the same size and characteristics evidence enough to project this common curve as the curve for a city growing to the same size and characteristics.

Comparison of the curves representing residential intensity distribution with those representing the distribution of the intensity of other land uses yields the following:

a) retail intensity curves closely resemble population curves, the industrial gradients show some correspondence with population intensity beyond 8 miles from the c.b.d. and proportionately more intense use of land within this ring while, despite certain apparently delicate responses for office and residential intensities, this curve is of a "flatter" kind and

b) the regularity of the industrial intensity curve is less than that for population, limiting the use of one for the projection of the other.

The value of the correspondence between retail and population intensities facilitates the use of a linear calculation of retail land use requirements.

The collection of data as to the intensity of current increments to each of the categories of land use indicate that:

a) in the c.b.d. small increases in intensity of use are probably occurring in residential, office and retailing activities but that industrial density is changing little,
b) in the central cities outside the c.b.d. all land uses exhibit substantial decreases in intensity and
c) in suburban areas, intensities are changing little but show a tendency to decline.

It is suggested that the changes which have until recently affected intensity have been responses to "natural" forces but that growing powers of public intervention, especially that of urban renewal, now permit the manipulation of these intensities of land use to such a degree that the consequences of these natural forces may be substantially modified.

The question raised by these conclusions is that of the proportional influence of size of the city and of time as determinants of intensity of use of an increment to the particular urban activity under examination. The evidence which has been presented is not inconsistent with the following:

that, at any point in time, there are a series of measures of intensity of use, each appropriate to a different part of a metropolitan area, at which it is economical for a particular type of activity to locate, that the distribution of these points will be determined by the size and the structure of the city, and that the distribution will change over time. If, however, the constraints upon locational decisions change, then, at any one time, one particular intensity is likely to be most appropriate and the bulk of growth most likely to occur at that density and in those parts of the
metropolitan area where this density is most favorably obtained. If then the locational constraints and requirements change in a systematic way over time, the density of increments to growth will not only be a function of time but will produce a pattern which is a function of those systematic changes.

The effect of existing density upon the density of increments occurs in three ways:

i) the density of existing stock changes slowly, even upon changes in use,

ii) existing density implies a pattern of activity which may influence the density of increments and

iii) the cost of a site, in competition with adjacent intensive uses, will influence the intensity with which it is used.

The complete replacement of the stock in a fully developed area is unlikely; increments may affect the density but the changes are likely to be so slow in relation to the growth in the population of the metropolitan area that the application of curves between cities is not justified.

It is less easy to tie mean net density gradient curves to time. Omitting for the moment the effect of increments upon the mean density in any ring, the density is closely related to the density which was appropriate to that ring at the time of development.

That appropriate density, however, is a function of the size of the city at that time, due to the operation of the principles described by the spatial economists. The separation of, firstly, the factors of
time and size and, secondly, of the amending influence of increments subsequent to initial total development, is not possible with the evidence to hand but it is clear that the shape of the density gradient curve cannot be directly equated with the present population of the metropolis, only with the history of the growth of the population. This is not to say, however, that the intensity of an increment in the metropolitan core is independent of the present metropolitan population.
CHAPTER IX

APPLICATION OF THE METHOD

The qualities of this type of analysis which are important in an assessment of its value are:

a) the curves give a total picture but this is not the sole basis for locational decisions by firms and individuals who are concerned perhaps more with their particular increment and with current increments. The gradient curve tells little of the density of current increments,

b) any type of aggregation will hide wide variations in the intensity of use, but the annular method used masks also sectoral variations which may have regularity. The average intensity for a particular ring bears no predictable relation to the intensity of any increment so even a broad allocation process is not materially aided by the curve. A sectoral differentiation in conjunction with the rings would refine the method and should be made a part of analysis of this kind and

c) the curve is composed only of averages. The problems of designing a system which embraces amounts of land as well as the intensity with which it is used were
touched on: this approach does not rate well in this respect.

The use of information prepared in the form appropriate to this type of analysis in a land use projection situation is, then, restricted to prediction of densities.

Where the time-span is short or medium a possible procedure might be:

a) construct the existing residential gradient curve,

b) examine the trends and project the curve to the projection date,

c) determine the extent of present residential development in each zone and the extent of possible development by the projection date,

d) where the zone is fully developed assume that the density will not change,

e) where it is vacant, apply to the zone a density determined from the projected density gradient curve for the ring in which it lies and

f) where it is partly developed, assume that there will be no change in that part which is developed and apply the density of current increments in the ring to the part which is undeveloped.

The allocation process is then continued until the projected population is accommodated according to projected locational preference criteria, permitting a determination of the annular location and the amounts of residential land needed at the projection date. The basis
for proceeding in this way is the belief that the density gradient curves are an expression of the resultant of the complex forces operating upon the area and that to vary substantially from the curve needs strong justification.

Two things become clear:

i) that in the short or medium term plan, the allocation process requires a more refined analysis of density than that of rings about the c.b.d.; the aggregation obscures differences which may be of the greatest significance to the standards applied to an individual zone and

ii) that the process is applicable to an activity such as residential use which covers the largest part of the land area of the metropolis. In the case of other land uses "spotted" in the residential development, they are more selective in their location and the allocation process cannot be performed in the same sweeping manner.

The Chicago Area Transportation Study staff predicted density of employment of industrial increments by ring but, although constructing the 1956 density gradient curve, they did not use it in any strictly defined way to do so, the figures at which they finally arrived for each rings appearing to fall into the "educated guess" category.63 The important point here is that the regularities shown by residential intensity are not duplicated in the case of industry and the use of the curve as a basis for prediction of the intensity of increments is therefore not justified.
The rationale for use of the office activities density gradient curve for prediction of the density of increments seems to be greater provided that the areal units of analysis are small. Within the central city a regular relationship exists between density and distance from the c.b.d. and although this offers no help in the determination of where growth shall be, it is of the greatest value otherwise in the process of land allocation since it permits the translation of projections of floor space or employees into land requirements. The appropriate procedure might be:

a. project office floor space needs for the projection date,

b. determine what will be the locational requirements of office activities at the projection date,

c. project the density gradient curve for the projection date and

d. allocate the required floor space according to b. and c. above.

Should office activities become less constrained in their locational preferences, then the value of this approach becomes less: in any case, its validity is greatest only for the central city where the regularities are most marked and where investment is quick to respond to market pressures.

The quality which limits the use of the curve in the short-term situation is that it describes the mean density rather than incremental density. This ceases to be so serious a shortcoming, however, if the time span is increased to very long range. This
offers the time and opportunity for response to the forces acting
towards changes in density and, to a degree, justifies the use of the
mean value of total development within a ring rather than the density
of increments to that development. A procedure might be:
  a) construct existing density gradient curve,
  b) project the locational requirements of the activity
     at the projection date,
  c) examine trends, project probable changes and con-
     struct a density gradient curve for the projection
     date,
  d) project total needs for that activity at the projec-
     tion date and
  e) allocate land according to (b) and (c) to meet (d).
Such long range forecasts are hazardous and this does not remove the
elements of chance which remain in (b), (c), and (d), but the
procedure does provide a more rational basis for the determination
of densities in the allocation process than more unfounded guesses.

The value of the curves in simulation models is remarked
upon in their discussion of the conceptual framework of one
particular type of urban model by Row and Jurkat,64 while the data
represented by the curve constitute an input into a Rand model
designed specifically for research into the relationships between
transportation and land use.65 This model is, significantly,
recursive in time, predicting absolute values of the land use para-
meters instead of increments of change.
CHAPTER X

REFINEMENT OF THE METHOD

The use of mean net density places certain constraints upon the applicability of the method to land use planning; it is not suggested that any other concept be substituted for to do so would blunt this still further as an instrument for the planner. There are, however, several means by which it could be made more effective, namely:

a) further research to establish more precise relationships between the pattern of intensity, time and the population of the metropolis. Approaches might include:

i) the preparation of data to show annular and sectoral densities of land use by age,

ii) comparison of the annular population changes with densities of other uses,

iii) comparison of the distribution of intensity of land use with the history of the development of the metropolis (by maps) and

iv) construction of density gradients for the mean density of increments, within specified periods, by distance from the c.b.d.
These and other research proposals may be limited by lack of comparable data;

b) refinement of the method by the introduction of a sectoral breakdown of the rings; this would have been possible with part of the cities of the present sample but the scope was limited to exclude this refinement,

c) the manipulation of the material by computer. The advantages of this would be great, enabling re-organization of the data to determine what is the most meaningful system of aggregation and size of zone for each land use.
NOTES AND REFERENCES

Preface


4. For example, estimated workers per acre in wholesaling activities in Buffalo in 1985 is 30 compared with 22 in 1964, while all the evidence is that employee densities are decreasing in this industry. (Source: *Planning Proposals, Buffalo Master Plan*, p. 183.)

Chapter 1.


Chapter 2.


Chapter 3


110
12. Explained by differences in character of the cities making annexations and those not: the average density of the 12 cities may, for instance, have been greater to begin with than the average for the full sample.


Chapter 4.


15. A negative exponential curve has been fitted to this distribution - by Clark, C., "Urban Population Densities," *Journal of the Royal Statistical Society, Series A*, 114 (1951), 490-496.
- (See also Hans Blumenfeld, "Are Land Use Patterns Predictable?" A.I.P. Journal, May 1959, p. 63.


17. City of Chicago alone. The population of the C.A.T.S. study area, which includes more suburban areas, showed a growth from 4.17 million in 1940 to 5.20 million in 1956.

18. This finding is in apparent agreement with the findings of Duncan that large urban areas are nearing a limit of deconcentration that they are now "congesting," but note that increments to growth are still locating in the rural fringe. The two processes operate simultaneously.

19. Those cities with freedom to expand in all directions would be expected to show characteristics similar to those for cities with a smaller population which front a lake or ocean. In ranking the cities, the population of those constrained in this way was increased by a factor which seemed appropriate to the geographical setting of each metropolitan area.


Chapter 5


22. The figures for Chicago are based on "first work trips" and should be increased by 15% - 20% to represent approximate employment densities: this will accentuate the dominant position of Chicago densities. (See C.A.T.S. "Land Use Forecast," p. 113.)

24. See, for example,
- Ibid., pp. 53-54.


26. Leon N. Moses, "Transportation and the Spatial Distribution of Economic Activity within Metropolitan Areas," The Transportation Center, N. W. University.

27. From *Industrial Plant Location Data*, Philadelphia 1957, p. 252.
Note: - error in Group II (Floor Space)
- possibility that distortion arises in that the firms locating are more likely to be those that are growing and are heavily overcrowded prior to the move, so that the employment density in the city will be exaggerated upwards and that in the suburbs after the move exaggerated downwards.


31. Ibid., Tables 18 (p. 20) and 20 (p. 21).


33. E. M. Kitagawa and Donald J. Bogue, "Suburbanization of Manufacturing Activity within Standard Metropolitan Areas," Scripps Foundation and Population Research and Training Center, 1955, p. 120.


36. Evidence of "suburbanization" of wholesaling is given in Real Estate Research Corp. *Analysis of Wholesale Trade, Warehousing*
and Distribution Facilities in Chicago, 1963. Additional data on the relocation from multi-story to single-story structures is offered on p. 36.


38. Ibid.

39. Mark Reinsberg, "Growth and Change in Metropolitan Areas and Their Relation to Metropolitan Transportation," The Transportation Center, N. W. University, 1965, p. 10.


Chapter 6.

41. Neidercorn and Hearle, op. cit., p. 10.

42. Vernon, op. cit., pp. 57-60.

43. Time Magazine, April 8th, 1966, p. 89.

44. This despite a decline in the amount of Central Area office-space per person in the Chicago Metropolitan Area from 8.15 sq. ft. in 1940 to 7.09 sq. ft. in 1960. P. 9 of "Chicago-Central Area Office Space Study," 1961, Real Estate Research Corp. for Chicago City Planning Department.

45. Ibid., p. 9.

46. Ibid., p. 56.


48. Louisville City Planning Department, "Louisville C.B.D. 1960." But it must be noted that at this time Louisville was losing office employment which may have affected the space per employee.


50. Vernon, op. cit., pp. 56-60.


Chapter 7.

52. James Simmons, "The Changing Pattern of Retail Location," Univ.
of Chicago Research Paper No. 92. Chicago 1964, pp. 11, 14 and 118.

53. Vernon, op. cit., p. 46.


56. Simmons, op. cit., p. 104.

57. The two factors may not be directly equated but, with all the vagaries of the relationships resulting from degree of specialization, nature of goods, etc., the statement is substantially justified.


61. Simmons, op. cit., p. 145.

62. Simmons, op. cit., p. 149.

Chapter 9.

63. Hamburg and Sharkey, op. cit., p. 113.


65. This does not pretend to predict land use in a metropolitan area and is a research tool only. See Traffic Research Corporation "Review of Existing Land Use Forecasting Techniques," 1963, p. 33.
APPENDIX A

TABULATED DENSITIES FOR THE 9-CITY SAMPLE
CHART SHOWING THE GROUPS OF USES
FOR WHICH DATA IS AVAILABLE
BY METROPOLITAN AREA

<table>
<thead>
<tr>
<th></th>
<th>Retail</th>
<th>Services</th>
<th>Offices</th>
<th>Wholesale Selling</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philadelphia</td>
<td>Separate</td>
<td>-</td>
<td>Separate</td>
<td>-</td>
<td>Separate</td>
</tr>
<tr>
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</tr>
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</table>
BALTIMORE

1. Sources

Population -


Land Use and Employment Statistics

From unpublished tabulation (print-out) of "1962 Data on the Baltimore Region" (BMATS Internal Zones only). From unpublished tabulations of "L. U. characteristics for all areas outside BMATS Gordon lines, 1962," supplied by Regional Planning Council.

2. Data Collection Units and Aggregation

Planning Districts used by BMATS and later adopted by Regional Planning Council. Aggregated into rings using centroids of district to determine ring for the whole district.

3. Definitions

No problems.

4. Comparability of Data

Good for time; all data relate to 1962. Other data for floor space were collected but not used.
### Table of Densities for Land Use for Baltimore

<table>
<thead>
<tr>
<th>Ring</th>
<th>Ring Dimensions</th>
<th>Population Density Person/Acre</th>
<th>Intensive Industrial Density Emp./Acre</th>
<th>Wholesaling Density Emp./Acre</th>
<th>Total Commercial Empl. Acre</th>
<th>Office Density Empl./Acre</th>
<th>Retailing Density Empl./Acre</th>
<th>Total Industrial Density Empl./Acre</th>
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<td>573</td>
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<td>44</td>
<td>25.9</td>
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<td>25+</td>
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</tr>
</tbody>
</table>

1 - Partial data only. Must be interpreted with care.
BOSTON

1. Sources

Population, Land Use Total

From "Land Use in Greater Boston 1960" Table in Land Use Report No. 1 of Greater Boston Economic Study Commission, pp. 33-38.
Residential Land Use - Sum of cols. la, lb and lc
Retail - Services L.U. - Col. 2a.
Manufacturing and Wholesale Land Use - Col. 32

Employment

From 1958 Census of Business
Retail Trade (Area Statistics) Table 102
Selected Service (Area Statistics) Table 102
Whole Trade (Area Statistics) Table 102

From 1958 Census of Manufacturers
Area Statistics, (Massachusetts) Table N9. 3.

2. Data Collection Units and Aggregation

Townships aggregated by the ring in which the centroid falls.

3. Definition

"Retail and Services" (Land Use) includes "accessory parking, service area and landscaping."
"Manufacturing" (Land Use) includes "industry, warehousing, bulk storage, power plants and accessory service and parking areas."

"Retail and Services" (Employment) includes paid employees and active proprietors, Nov. 1958, in the following S.I.C. groupings,

52, 53, 54, 55, 56, 57, 58, 59, 70 (except 702, 704)
72, 73, 75, 76, 78, 79

"Manufacturing" (Employment) includes all workers and active proprietors in manufacturing and wholesaling (SIC Group 50) establishments.

4. Comparability

Population and Land Use were measured in 1960, employment towards the close of 1958.
There are discrepancies in definition between land use and employment but these appear not to be large enough to invalidate the general relationships established.
TABLE OF DENSITY OF LAND USES FOR BOSTON

<table>
<thead>
<tr>
<th>Ring No.</th>
<th>Dimensions of Ring (Miles)</th>
<th>Residential Density Pers./Acre</th>
<th>Manufacturing Density Emp./Acre</th>
<th>Retail Density Emp./Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 - 4</td>
<td>82.3</td>
<td>26.3</td>
<td>67.1</td>
</tr>
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<td>2</td>
<td>4 - 6</td>
<td>39.0</td>
<td>16.5</td>
<td>32.0</td>
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<td>3</td>
<td>6 - 8</td>
<td>22.6</td>
<td>21.5</td>
<td>11.5</td>
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<td>4</td>
<td>8 - 10</td>
<td>12.6</td>
<td>21.7</td>
<td>15.2</td>
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<td>10 - 12</td>
<td>12.5</td>
<td>27.3</td>
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<td>12 - 14</td>
<td>8.7</td>
<td>7.8</td>
<td>10.5</td>
</tr>
<tr>
<td>7</td>
<td>14 - 16</td>
<td>9.7</td>
<td>10.4</td>
<td>10.7</td>
</tr>
<tr>
<td>8</td>
<td>16 - 18</td>
<td>6.5</td>
<td>4.6</td>
<td>4.2</td>
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</tbody>
</table>
BUFFALO

1. Sources


Residential Land Use


Industrial Land Use, Employment, Floor Space and Densities

For central areas .. "Buffalo Master Plan" (Provisional Copy only) Table 57, p. 174 "Districts of Industrial Firms by Ring"

For whole study area, data from "Niagara Frontier Transportation Study," Vol. I, "The Basis of Travel," Figure 3.

Commercial Densities and Residential Densities outside Center

Same as second source in above paragraph.

2. Data Collection Units and Aggregation

Table No. 1 - by rings for city of Buffalo
Table No. 2 - by "Communities" and "District," the whole unit being aggregated to the ring in which its centroid falls.
Table No. 3 - traffic zones aggregated to rings.

3. Definitions

"Commercial" Land Use in Table 3 refers to the sum of Retail, Wholesale and Service activities.

4. Comparability

For data presented in each of the tables is internally comparable.
### TABLES OF DENSITY OF LAND USE FOR BUFFALO

1. **Industry in Central Areas**

<table>
<thead>
<tr>
<th>Zone No.</th>
<th>Ring Dimensions</th>
<th>Emp./Acre</th>
<th>F.A.R.</th>
<th>Fl. Sp./Empl.</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>0 - ½</td>
<td>177</td>
<td>1.23</td>
<td>303</td>
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<td>2</td>
<td>½ - 1</td>
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<td>1.45</td>
<td>418</td>
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<td>427</td>
</tr>
<tr>
<td>5</td>
<td>2 - 2½</td>
<td>70</td>
<td>0.97</td>
<td>603</td>
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<td>6</td>
<td>2½ - 3</td>
<td>39</td>
<td>0.42</td>
<td>462</td>
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<td>8</td>
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<td>66</td>
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<td>447</td>
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<td>75</td>
<td>0.57</td>
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<td>375</td>
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<tr>
<td>12</td>
<td>5½ - 6</td>
<td>-</td>
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TABLES OF DENSITY OF LAND USE FOR BUFFALO
(CONTINUED)

2. Residential Density in Central Areas

<table>
<thead>
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<th>Ring No.</th>
<th>0-1</th>
<th>1-2</th>
<th>2-3</th>
<th>3-4</th>
<th>4-5</th>
<th>5-6</th>
<th>6-7</th>
<th>7-8</th>
<th>8-9 Miles</th>
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<tr>
<td>Resid. Density</td>
<td>77.8</td>
<td>89.9</td>
<td>71.1</td>
<td>51.0</td>
<td>41.9</td>
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<td>23.4</td>
<td>15.7</td>
<td>16.1</td>
</tr>
<tr>
<td>Persons/Acre</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Densities for All Land Uses for Whole Study Area

<table>
<thead>
<tr>
<th>Ring No.</th>
<th>Center Dimension of Ring</th>
<th>Residential Density Persons/Acre</th>
<th>Manufacturing Density Employees/Acre</th>
<th>Commercial Density Employees/Acre</th>
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<td>0</td>
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<td>200+</td>
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<td>1½</td>
<td>88</td>
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<td>2</td>
<td>3½</td>
<td>57</td>
<td>20</td>
<td>15</td>
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<td>30</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>10½</td>
<td>15</td>
<td>29</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>14½</td>
<td>19</td>
<td>14</td>
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<tr>
<td>7</td>
<td>23</td>
<td>11</td>
<td>8</td>
<td>7</td>
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</table>
CHICAGO

1. Sources

Population, Land Use, Floor Area, First Work Trips

C.A.T.S. reports and publications, data refers to 1956.

2. Data Collection Units and Aggregation

C.A.T.S. Traffic Zones aggregated according to C.A.T.S. classification for Table 1.
For Table 2, aggregation by ring done by C.A.T.S. staff.

3. Definitions

"Commercial" - includes retail, service and wholesale activities. The "first work trips" substituted for employment represent an estimated 85% of employment.

4. Comparability

Direct.
TABLES OF DENSITIES OF LAND USES FOR CHICAGO

1. F.A.R.'s by C. A. T. S Rings

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<td>24 +</td>
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<td>0.005</td>
<td>0.005</td>
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TABLES OF DENSITIES OF LAND USES FOR CHICAGO
(CONTINUED)

2. Persons per Acre by 2 mile Rings

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<th>Ring No.</th>
<th>Dimensions of Ring</th>
<th>Residential Density Persons/Acre</th>
<th>Manufacturing Density First work trips/Acre</th>
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</thead>
<tbody>
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<td>2 - 4</td>
<td>136</td>
<td>123</td>
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<td>85</td>
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<td>8 - 10</td>
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<td>31</td>
</tr>
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<td>10 - 12</td>
<td>36</td>
<td>22</td>
</tr>
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<td>15</td>
<td>26 - 28</td>
<td>8</td>
<td>8</td>
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</table>
NORFOLK

1. Sources

Population

From tabulation for 1965 estimated population by c.t. supplied by Dept. of C.P. Norfolk.

Residential Land Use

From "Land Use Statistics - 1965) by Dept. of City Planning, Norfolk Table 1, "Land Use by C.T." Aggregate of all residential categories except "Hotel-Motel."

Other Land Uses

Same source, sum of "manufacturing" and "non-manufacturing" categories for industry.
Same source, column "Commercial - Intensive" for retail (and office).
Same source, column "Commercial - Extensive" for wholesaling and auto services.

Employment and Floor Areas

Tabulation "Number of Activities, Employment and Sq. footage by 2 digits S.I.C. No. by Census Tract, City of Norfolk, Va." provided by Dept. of City Planning, Norfolk.

2. Data Collection Units and Aggregation

Census Tracts for City of Norfolk, aggregated into rings using the centroids of the tract to determine the ring of the whole tract.

3. Definitions

Retailing includes office activities.
Wholesaling includes auto sales and related services.
Industry includes manufacturing only.

4. Comparability

All data refers to 1965
The land use data was classified according to a system which differs from the S.I.C. classification used for the floor area and employment statistics. The Norfolk C.P. Dept. has a key for conversion from one scale to the other and although this is not a precise conversion, it permits the manipulation of data sufficient to establish valid relationships for the purpose of this study.

Certain of the data is "raw" and a warning is attached by the supplier (Norfolk City Planning Dept.) that it must be interpreted with care.
### TABLE OF DENSITIES OF LAND USE FOR NORFOLK

<table>
<thead>
<tr>
<th>Zone No.</th>
<th>Ring Dimensions</th>
<th>Population Density Pers/Acre</th>
<th>Industrial Density</th>
<th>Wholesaling Density</th>
<th>Retailing Density</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Emp/Acre</td>
<td>F.L.Sp/Emp</td>
<td>Emp/Acre</td>
</tr>
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<td>7-8</td>
<td>26.5</td>
<td>320.0</td>
<td>133.0</td>
<td></td>
</tr>
</tbody>
</table>

1 - The strangeness of these figures suggests that there is something wrong with the data for total area of land use. This column has not therefore been used in the analysis.
PHILADELPHIA

1. Sources

All data is abstracted from App. VI to Vol. 2 of the Penn-Jersey Transportation Study Report "1975 Projections," the following tables:

- "Employment by Projection Groups - Superdistricts, 1960 and 1975"
- "Land Area in Land Use Projection Groups, 1960 and 1975"

2. Data Collection Units and Aggregation

Data Collection Superdistricts classified according to the rings defined by the Penn-Jersey Transportation Study.

3. Definitions

No problems.

4. Comparability

Direct.
<table>
<thead>
<tr>
<th>Ring No.</th>
<th>Dimension of Ring</th>
<th>Residential Density Persons/Acre</th>
<th>Industrial Density Empl/Acre</th>
<th>Office Density Empl/Acre</th>
<th>Retailing Density Empl/Acre</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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<td>138.2</td>
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<td>112.3</td>
<td>38.3</td>
<td>149.3</td>
<td>73.5</td>
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<td>4-6</td>
<td>51.0</td>
<td>21.7</td>
<td>151.2</td>
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<td>6-8</td>
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<td>21.3</td>
<td>87.2</td>
<td>30.4</td>
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<td>8-10</td>
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<td>14.3</td>
<td>64.6</td>
<td>12.0</td>
</tr>
<tr>
<td>6</td>
<td>10-13</td>
<td>11.9</td>
<td>7.3</td>
<td>29.9</td>
<td>9.4</td>
</tr>
<tr>
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<td>13-16</td>
<td>10.8</td>
<td>10.5</td>
<td>24.8</td>
<td>14.9</td>
</tr>
<tr>
<td>8</td>
<td>16-20</td>
<td>13.3</td>
<td>9.4</td>
<td>47.3</td>
<td>15.3</td>
</tr>
<tr>
<td>9</td>
<td>20-25</td>
<td>11.8</td>
<td>3.6</td>
<td>42.0</td>
<td>10.3</td>
</tr>
<tr>
<td>10</td>
<td>25+</td>
<td>22.6</td>
<td>19.3</td>
<td>72.2</td>
<td>20.4</td>
</tr>
</tbody>
</table>
TORONTO

1. Sources

Population

From Table 6, Distribution of Population by Municipality, 1951, 1958, 1980” p. 34 of Official Plan.

Land Use

From Table 42, "Distribution of Land Uses by Municipality, 1958-1980" p. 131 of Official Plan

Employment (Industry and Commercial)


"Industrial" is the sum of columns

Primary
Manufacturing
Construction
Wholesale Trade

"Commercial" is the sum of columns

Retail Trade
Finance, Real Estate, Insurance, Business Service
Personal and Business Services

Retail Area of Land Use, Employment and Floor Space

From Table 32 "Distribution of Retail Floor Space and Land, 1956 and 1980" p. 101 of Official Plan

Office Area of Land Use, Employment and Floor Space


2. Data Collection and Aggregation

By municipality and group of municipality, aggregated according to the position of the centroid.

3. Definitions

Refer to para 1 above.

4. Comparability of Data

The data relates to different time bases, the most significant discrepancy being between Employment (1960) and Land Use (1958), the two variables used to determine intensity of use in employees per acre. Other indices namely Residential Density (1958), Retail Intensity (1956) and Office Intensity (1958) are each calculated from co-terminous data.
### Tables of Densities of Land Use for Toronto Metropolitan Area

#### By Rings

<table>
<thead>
<tr>
<th>Zone No.</th>
<th>Ring Dimension</th>
<th>Population Density Persons/Acre</th>
<th>Industrial Density Emp/Acre</th>
<th>Commercial Density Emp/Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-4</td>
<td>53.0</td>
<td>74.4</td>
<td>98.1</td>
</tr>
<tr>
<td>2</td>
<td>4-6</td>
<td>33.7</td>
<td>32.7</td>
<td>41.8</td>
</tr>
<tr>
<td>3</td>
<td>6-8</td>
<td>33.7</td>
<td>36.1</td>
<td>33.3</td>
</tr>
<tr>
<td>4</td>
<td>8-10</td>
<td>17.0</td>
<td>17.5</td>
<td>39.5</td>
</tr>
<tr>
<td>5</td>
<td>10-12</td>
<td>17.8</td>
<td>9.7</td>
<td>24.3</td>
</tr>
<tr>
<td>6</td>
<td>12-16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>16-20</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### By Groups of Municipalities

<table>
<thead>
<tr>
<th>Ring of Municipalities</th>
<th>Office Density FAR</th>
<th>Retail Density FAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>City of Toronto</td>
<td>2.6</td>
<td>0.45</td>
</tr>
<tr>
<td>Nine Inner Suburbs</td>
<td>0.2</td>
<td>0.36</td>
</tr>
<tr>
<td>Three Outer Suburbs</td>
<td></td>
<td>0.25</td>
</tr>
<tr>
<td>Fringe Areas</td>
<td>0.1</td>
<td>0.13</td>
</tr>
</tbody>
</table>

1 - Classification by Toronto Metropolitan Area Planning Board.
1. Sources

Population and Residential Areas


Land Use totals and employment

From preliminary tabulation of TS-1 Trip Generation factors (1964 data) for Tulsa Metropolitan Area. The sum of categories

- $I_1$: Low or limited nuisance activities
- $I_2$: Substantial nuisance activities
- $I_3$: Hazardous or noxious activities for industry
- $I_4$: Non-manufacturing activities

from sum tabulation, category

- $C_1$: Retail and Personal Services for retailing

...from same tabulation, category

- $I_5$: Wholesaling and Warehousing Activities for wholesaling

...from same tabulation, category

- $C_3$: Business and Professional Offices for office activities

2. Data Collection Units and Aggregation

Community Statistical Planning Areas defined by the Tulsa Metropolitan Area Planning Commission for residential data and "districts" defined by the same body for all other land uses. Aggregated into rings on the basis of the centroid of the district.

3. Definitions

Refer to para. 1 above.

4. Comparability

The data is all dated 1964 and is fully comparable in respect of time. The residential data is separated from other land uses, being classified by community rather than district: at no stage do the manipulative processes applied to the two groups of figures impinge upon each other so there is no conflict. The tabulation of trip generation Factors are, however, in a "raw" state and in abstracting and aggregating from this table, certain ambiguities and gaps were identified. Where these ambiguities were not explained the data was omitted, but the risk remains, that other less obvious discrepancies were undetected. The relationships which have been established must therefore be viewed with reserve.


<table>
<thead>
<tr>
<th>Zone No.</th>
<th>Ring Dimensions</th>
<th>Population Density Persons/Acre</th>
<th>Industrial Density Empl/Acre</th>
<th>Wholesaling Density Emp/Acre</th>
<th>Office Density Emp/Acre</th>
<th>Retail Density Empl/Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-2</td>
<td></td>
<td>204.9</td>
<td>53.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2-3</td>
<td>16.4</td>
<td>29.2</td>
<td>9.5</td>
<td>43.7</td>
<td>17.0</td>
</tr>
<tr>
<td>3</td>
<td>3-4</td>
<td>11.5</td>
<td>14.7</td>
<td>9.2</td>
<td>46.6</td>
<td>21.2</td>
</tr>
<tr>
<td>4</td>
<td>4-5</td>
<td>7.1</td>
<td>20.1</td>
<td>1.2</td>
<td>10.0</td>
<td>6.3</td>
</tr>
<tr>
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<td>5-6</td>
<td>9.3</td>
<td>12.4</td>
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<td>16.1</td>
<td>14.5</td>
</tr>
<tr>
<td>6</td>
<td>6-8</td>
<td>7.0</td>
<td>9.8</td>
<td>1.8</td>
<td>19.5</td>
<td>9.0</td>
</tr>
<tr>
<td>7</td>
<td>8-10</td>
<td>4.2</td>
<td>8.1</td>
<td>0.1</td>
<td>148.1</td>
<td>0.51</td>
</tr>
<tr>
<td>8</td>
<td>10-12</td>
<td>1.4</td>
<td>21.0</td>
<td>0.2</td>
<td>3.6</td>
<td>12.2</td>
</tr>
</tbody>
</table>

1 - Calculated from a very small total.
TWIN CITIES

1. Sources:

   Land Use "Twin Cities Area Transportation Study," Vol. I, Table 30
   "Generalized Land Use by District," p. 90

   Employment District figures for employment were lacking so the
   Trip destinations to each area were used. These were
   taken from "Person Trip Destination by Land Use by
   District (Daily Average)," Table 28 of the above
   volume.

2. Data Collection Unit and Aggregation

   Planning Districts aggregated according to the location of the
   centroid of each district.

3. Definitions

   Manufacturing - excludes non-manufacturing industry, transportation
   and communications

   Commercial - retailing, services, wholesale, distribution and
   contracting activities.

4. Comparability

   All figures date to 1958. The substitution of trips generated for
   employment affects the comparability of this data with that for
   other metropolitan areas.
# Table of Densities of Land Use for Twin Cities Area

<table>
<thead>
<tr>
<th>Ring No.</th>
<th>Dimensions of Ring</th>
<th>Residential Density Pers/Acre</th>
<th>Manufacturing Density Trips/Acre</th>
<th>Commercial Density Trips/Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-1</td>
<td>108.1</td>
<td>282.4</td>
<td>435.1</td>
</tr>
<tr>
<td>2</td>
<td>1-2</td>
<td>48.8</td>
<td>56.4</td>
<td>156.2</td>
</tr>
<tr>
<td>3</td>
<td>2-3</td>
<td>38.2</td>
<td>46.8</td>
<td>217.6</td>
</tr>
<tr>
<td>4</td>
<td>3-4</td>
<td>20.6</td>
<td>32.1</td>
<td>251.1</td>
</tr>
<tr>
<td>5</td>
<td>4-5</td>
<td>25.2</td>
<td>23.8</td>
<td>158.6</td>
</tr>
<tr>
<td>6</td>
<td>5-6</td>
<td>20.0</td>
<td>35.7</td>
<td>165.8</td>
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<tr>
<td>7</td>
<td>6-8</td>
<td>15.6</td>
<td>88.5</td>
<td>188.4</td>
</tr>
<tr>
<td>8</td>
<td>8-10</td>
<td>11.9</td>
<td>6.0</td>
<td>110.4</td>
</tr>
<tr>
<td>9</td>
<td>10-12</td>
<td>10.9</td>
<td>18.9</td>
<td>122.8</td>
</tr>
<tr>
<td>10</td>
<td>12-14</td>
<td>12.8</td>
<td>15.2</td>
<td>104.2</td>
</tr>
<tr>
<td>11</td>
<td>14-18</td>
<td>9.4</td>
<td>47.4</td>
<td>110.0</td>
</tr>
</tbody>
</table>

1 - Note the high figures, due to the fact that trips per acre rather than employees per acre are represented, and for commercial land use this will be much higher than the employee trips. This is less true for manufacturing employment.
APPENDIX B

ADDITIONAL DATA ON TRIP GENERATION RATES
FOR SELECTED METROPOLITAN AREAS
### CHICAGO

**TABLE OF TRIP GENERATION RATES PER ACRE**

**BY LAND USE TYPES, CHICAGO, 1956**

<table>
<thead>
<tr>
<th>Zone</th>
<th>Distance from c.b.d. (Miles)</th>
<th>Residential</th>
<th>Commercial</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBD</td>
<td>0</td>
<td>2120</td>
<td>2069</td>
<td>3343</td>
</tr>
<tr>
<td>I</td>
<td>1.5</td>
<td>213</td>
<td>182</td>
<td>229</td>
</tr>
<tr>
<td>II</td>
<td>4.1</td>
<td>123</td>
<td>118</td>
<td>78</td>
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<tr>
<td>III</td>
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<td>104</td>
<td>141</td>
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<tr>
<td>IV</td>
<td>8.6</td>
<td>66</td>
<td>208</td>
<td>50</td>
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<td>V</td>
<td>11.7</td>
<td>42</td>
<td>176</td>
<td>26</td>
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<td>VI</td>
<td>15.8</td>
<td>30</td>
<td>129</td>
<td>14</td>
</tr>
<tr>
<td>VII</td>
<td>23.4</td>
<td>19</td>
<td>122</td>
<td>14</td>
</tr>
</tbody>
</table>

"Summary Comparison of Trip Generation Rates for Chicago and Detroit" by John R. Hamburg, p. 4.

**Note:** Figures represent the average number of weekday person trips per acre.
DETROIT

TABLE OF TRIP GENERATION PER ACRE BY LAND USE TYPES

<table>
<thead>
<tr>
<th>Ring No.</th>
<th>Dimensions of Ring</th>
<th>Average Weekday Person Trips Per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0 m</td>
<td>Residential 733</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Commercial 1797</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industrial 153</td>
</tr>
<tr>
<td>1</td>
<td>0.2 m</td>
<td>Residential 186</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Commercial 207</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industrial 209</td>
</tr>
<tr>
<td>2</td>
<td>2.0 m</td>
<td>Residential 65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Commercial 194</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industrial 92</td>
</tr>
<tr>
<td>3</td>
<td>4.5 m</td>
<td>Residential 56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Commercial 218</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industrial 48</td>
</tr>
<tr>
<td>4</td>
<td>7.5 m</td>
<td>Residential 42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Commercial 280</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industrial 38</td>
</tr>
<tr>
<td>5</td>
<td>10.5 m</td>
<td>Residential 26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Commercial 325</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industrial 36</td>
</tr>
<tr>
<td>6</td>
<td>16.5 m</td>
<td>Residential 14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Commercial 182</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industrial 8</td>
</tr>
</tbody>
</table>

### TABLE OF PASSENGER VEHICLE DESTINATIONS PER ACRE OF VARIOUS LAND USES FOR MINNEAPOLIS, 1958

<table>
<thead>
<tr>
<th>Ring</th>
<th>Distance from c.b.d. (miles)</th>
<th>Residential</th>
<th>Industrial</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-2</td>
<td>38</td>
<td>50</td>
<td>210</td>
</tr>
<tr>
<td>2</td>
<td>2-4</td>
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<td>113</td>
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<td>5</td>
<td>8-10</td>
<td>9</td>
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<td>86</td>
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<tr>
<td>7</td>
<td>12-14</td>
<td>9</td>
<td>7</td>
<td>122</td>
</tr>
<tr>
<td>8</td>
<td>14-16</td>
<td>9</td>
<td>5</td>
<td>96</td>
</tr>
<tr>
<td>9</td>
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<tr>
<td>10</td>
<td>18-20</td>
<td>7</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>20-22</td>
<td>5</td>
<td>3</td>
<td>-</td>
</tr>
</tbody>
</table>


Note: "Industrial" is presumed to include manufacturing and non-manufacturing industries although this is not defined in the report.
TABLE FOR VEHICLE TRIP DESTINATIONS
BY LAND USE AND RING, TUCSON, 1965

<table>
<thead>
<tr>
<th>Ring No.</th>
<th>Dimensions</th>
<th>Residential Trips/Acre</th>
<th>Total Business Trips/Acre</th>
<th>Light and Heavy Industry Trips/Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 - 3/4 m</td>
<td>16.82</td>
<td>93.44</td>
<td>17.67</td>
</tr>
<tr>
<td>2</td>
<td>3/4 - 2 m</td>
<td>15.28</td>
<td>96.83</td>
<td>10.29</td>
</tr>
<tr>
<td>3</td>
<td>2 - 5 m</td>
<td>9.95</td>
<td>86.30</td>
<td>7.92</td>
</tr>
<tr>
<td>4</td>
<td>5 - 10 m</td>
<td>1.66</td>
<td>20.40</td>
<td>4.61</td>
</tr>
<tr>
<td>5</td>
<td>10 - 14 m</td>
<td>1.02</td>
<td>10.79</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>c.b.d.</td>
<td>22.28</td>
<td>301.49</td>
<td>-</td>
</tr>
</tbody>
</table>

ACKNOWLEDGEMENTS

In the course of collection of the data on which this analysis is based, some 150 planning agencies were contacted from over half of whom helpful and interested replies were forthcoming. In not all of these were the data sufficient to satisfy the requirements of this study, but in all cases the writer wishes to acknowledge the debt owed to the directors for their encouragement and, in some cases, the very substantial amount of staff time which they have authorized in collection and processing of statistics.

It is particularly wished to thank those agencies which provided the data actually used in the study, namely:

Baltimore Regional Planning Council
Eastern Massachusetts Regional Planning Project
Buffalo Division of Planning
Transportation Planning Section of New York Department of Public Works
Chicago Area Transportation Study
Norfolk City Planning Commission
Philadelphia City Planning Commission
Penn-Jersey Transportation Study
Metropolitan Toronto Planning Board
Tulsa Metropolitan Area Planning Commission
Twin Cities Area Transportation Study
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