

CHANGING URBAN POPULATION DENSITY
GRADIENTS IN TAIPEI

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ABSTRACT

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By

Michael Arthur Graff

The purpose of this study is to investigate the proposition that a difference exists in urban population density patterns found in different parts of the world. The point of departure for the study is a set of conclusions concerning a dichotomy involving features characterizing the population density gradient patterns for Western and non-Western cities. Western cities have been found to be characterized by central densities that first rise and then fall, along with density gradient slopes that decline as the cities grow. This combination of density gradient pattern features has not been found in non-Western cities. There, central densities continually increase and density gradient slopes remain constant over time. These differences in population density gradient patterns have been concluded to be due to socio-economic differences between the peoples inhabiting Western and non-Western cities.* Such a conclusion is not, however, supported by general observations of urban growth

and development patterns found in cities in non-Western nations experiencing rapid economic development.

In order to test the validity of the proposed Western - non-Western dichotomy, appropriate data were collected and used to derive a density gradient pattern for a non-Western city in a rapidly developing nation. The metropolitan area of Taipei, Taiwan, Republic of China, was selected for study precisely because it is a non-Western city in both locational and cultural terms. It is also located in a country that has experienced rapid economic development in the post-World War II era. Analysis of the data revealed that a Western density gradient pattern has appeared in Taipei since 1950 and that its population growth characteristics are similar to those of Western cities. Corollary relationships between density gradient slopes, time and population growth rates were also found to be both strong and significant. The possible connection between appearance of a Western density gradient pattern and economic development was investigated by means of correlation analyses involving density gradient parameters and twenty-one measures of economic development. The findings of these analyses indicate that there is a significant relationship between development and the appearance of a Western density gradient pattern.

On the basis of these findings it was concluded that Taipei has become a city of the Western type in terms

of its population density gradient pattern characteristics, and that the appearance of the Western pattern was associated with the rapid development of Taiwan's economy. In concert with these conclusions it is recommended that the concept of the Western - non-Western dichotomy be replaced by one emphasizing stages in economic development as an explanation for the differences that have been noted among cities of the world.

* B.J.L. Berry, J. W. Simmons and R. J. Tennant, "Urban Population Densities: Structure and Change," Geographical Review, Vol. 53 (1963), pp. 389-405.

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Michael Arthur Graff

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1976

To George, Mildred and Irene

May the coming years contain as many
happy landmarks as the past

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CHAPTER I

INTRODUCTION

In the post-World War II era scholars have turned their attention to the processes of urbanization and urban growth. Locations and conditions favorable to the appearance of cities have been examined and the growth of cities has been traced.¹ One facet of the urbanization process that has engaged the attention of social scientists in several disciplines is change in the spatial distribution of urban population over time. The purpose of this study

¹Arthur E. Smailes, The Geography of Towns (Chicago, Aldine Publishing Co., 1968), especially chapters one and two dealing with the origins and bases of "Olden and "Modern" towns; Walter Christaller, Die Zentrallen Orte in Suddeutschland (Jena: Gustav Fisher, Verlag, 1933); E. L. Ullman, "A Theory of Location for Cities," American Journal of Sociology, Vol. 46 (1941), pp. 853-864; C. D. Harris and E. L. Ullman, "The Nature of Cities," Annals of the American Academy of Political and Social Science, Vol. 242 (1945), pp. 7-17; Lewis Mumford, The City in History (New York: Harcourt, Brace and World, 1961). Studies dealing with the growth of cities include: Kingsley Davis, "The Origin and Growth of Urbanization in the World," American Journal of Sociology, Vol. 60 (1955), pp. 429-437, Henri Pirenne, Medieval Cities, trans. F. D. Halsey (Garden City, N. Y.: Doubleday, 1958); F. W. Boal, "Technology and Urban Form," Journal of Geography (April, 1968), pp. 229-236; A. M. Voorhees, "Urban Growth Characteristics," Urban Land, December, 1961, as reprinted in Putnam, Taylor and Kettles (eds.), A Geography of Urban Places (Toronto: Methuen, 1970), pp. 81-86; James H. Johnson (ed.), Suburban Growth (New York: John Wiley and Sons, 1974).

is to examine the proposition that a difference exists in urban population density patterns characterizing Western and non-Western cities.

Studies of urbanization and urban growth have been carried out by academicians and members of planning agencies, but both have tended to focus their attention mainly upon cities in the industrialized Western nations. The findings of these investigations have been of considerable use in attempting to plan and promote the orderly growth of cities. However, with the concentration of attention on Western cities, change in the spatial distribution of urban population in developing countries has been, comparatively speaking, neglected. In addition, the findings of studies conducted in Western nations have, on occasion, been stated to be inapplicable to cities in the developing world.² The effect of the comparatively limited research

²Boal, op. cit., p. 236; B. J. L. Berry, J. W. Simmons and R. J. Tennant, "Urban Population Densities: Structure and Change," Geographical Review, Vol. 53 (1963), pp. 389-405. Studies indicating that questions concerning urbanization in developing nations are, at best, unanswered include: Rhoads Murphey, "Urbanization in Asia," Ekistics, Vol. 21 (1966), pp. 8-17; N. S. Ginsburg, "Urban Geography in non-Western areas," in P. M. Hauser and L. F. Schnore (eds.), The Study of Urbanization (New York: John Wiley and Sons, 1965), pp. 311-346. A general review of the urbanization process is provided in G. Breese, Urbanization in Newly Developing Countries (Englewood Cliffs, N. J.: Prentice-Hall, 1966). More recently, Breese has provided a collection of papers, none of which contain a clear affirmation of the existence of similarities in the urbanization processes in Western and non-Western countries. G. Breese (ed.) The City in Newly Developing Countries (Englewood

on the spatial dynamics of population growth in cities of the developing world, and stated restrictions on the applicability of research findings in Western cities, has been to leave a gap in the literature related to urban growth. The goal of this study is to narrow that gap and provide new insight into the population distribution aspect of urban growth in the developing world.

Urban Population Density Patterns

The differences in population densities found throughout urban areas is a topic that has received considerable attention during the last twenty-five years. In 1951, Colin Clark developed a mathematical model describing the relationship between population density and distance from the center of a city. Briefly, the model states that population density decreases exponentially with distance from the city center. The model is represented by the equation:

$$PD_x = PD_c e^{-bx} \quad (1)$$

where: PD_x = population density at distance x
 x = distance from the city's center

Cliffs, N. J.: Prentice-Hall, 1969). For an extensive bibliography dealing with the topic of general urbanization in developing countries see Stanley D. Brunn, Urbanization in Developing Countries: An International Bibliography, L.A.S.C. Research Report No. 8 (East Lansing, Michigan: Latin American Studies Center and The Center for Urban Affairs, Michigan State University, 1971).

PD_c = density at the center of the city

e = the base of natural logarithms

b = the population density gradient slope

A linear relationship that can be described by means of a simple linear regression equation may be obtained by performing a logarithmic transformation on density data. This procedure results in a change in the form of the model such that:

$$Y = a + bx \quad (2)$$

where: Y = the natural logarithm of population
density at distance x

x = distance from the city center

a = the natural logarithm of population
density at the city center

b = a negatively signed value representing
the slope of the population density
gradient

The value of the density gradient slope (b) indicates the rate of change in population density with a unit change in the distance (x) variable. A large value for the slope is indicative of a rapid decline in population density when moving away from the center of a city. A city having a large slope value would be compact and relatively limited

in areal extent. Conversely, a small slope value indicates a dispersed and areally extensive city.³

Clark's model has undergone a series of applications, evaluations and improvements.⁴ While the improvements have been aimed at making the model conform more closely to the real world, the general relationship described by equation (2) has been found to be representative of the distance decay function associated with population density in cities throughout the world. Applications have, therefore, tended to rely on the basic form set forth by Clark in preference to the later and more complex versions of the model.

Two findings connected with the application of Clark's model have been the subject of repeated evaluation. First, when the model has been used to derive population density gradient parameters for a city at different points in time, both the slopes (b values) and central densities

³Colin Clark, "Urban Population Densities," Journal of the Royal Statistical Society, Series A, Vol. 114 (1951), pp. 490-496. A population density gradient is a simple linear regression line depicting both the level of population density at varying distances from the center of a city and the rate at which population density decreases as distance from the city center increases.

⁴B. E. Newling, "The Spatial Variation of Urban Population Densities," Geographical Review, Vol. 59 (1969), pp. 242-252; K. E. Haynes and M. I. Rube, "Directional Bias in Urban Population Density," Annals of the Association of American Geographers, Vol. 63 (1973), pp. 40-47.

(a values) have been found to differ. The differences have usually indicated an increase in the areal extent of the city and changes in the concentration of population in the center of the city.⁵ Second, when the density gradients of cities in the Western and developing worlds have been compared over time, considerable differences have been noted. Density gradient slopes for Western cities tend to decrease in value, indicating rapid increase in the areal extent of these cities. At the same time, central densities first increase and then decrease. The slope values for cities in the developing world, however, have been found to remain virtually constant over time while central densities have steadily increased. This situation is indicative of increasing population concentration in the central portions of cities in the developing world and very little increase in their areal extent.⁶

Figure 1 illustrates the differences between Western and non-Western cities in terms of density gradients and central densities over time. The Western Pattern graph shows the general trend that has been found to characterize Western cities. The graphs for London and Chicago illustrate this trend with actual density gradients for two

⁵Clark, op. cit.

⁶Berry, Simmons and Tennants, op. cit., pp. 400-403.

Figure 1

Population Density Gradient Patterns
 Western Pattern, Poona, London,
 Calcutta and Chicago⁹

⁹In all graphs such as those appearing in Figure 1, the time series progression of the regression lines representing the population density gradients will always follow the same basic sequence. The line representing the density gradient at the earliest point in time will always be that which crosses the X (distance) axis closest to the Y (density) axis. The latest line will always be that which crosses the X axis farthest from the Y axis or highest above the X axis at its rightmost extremity. The graph for Calcutta amply illustrates the pattern. The shortest line, closest to the origin of the graph represents the density gradient in 1881, while the longer line ending above the X axis at a distance of six miles represents the gradient for 1951.

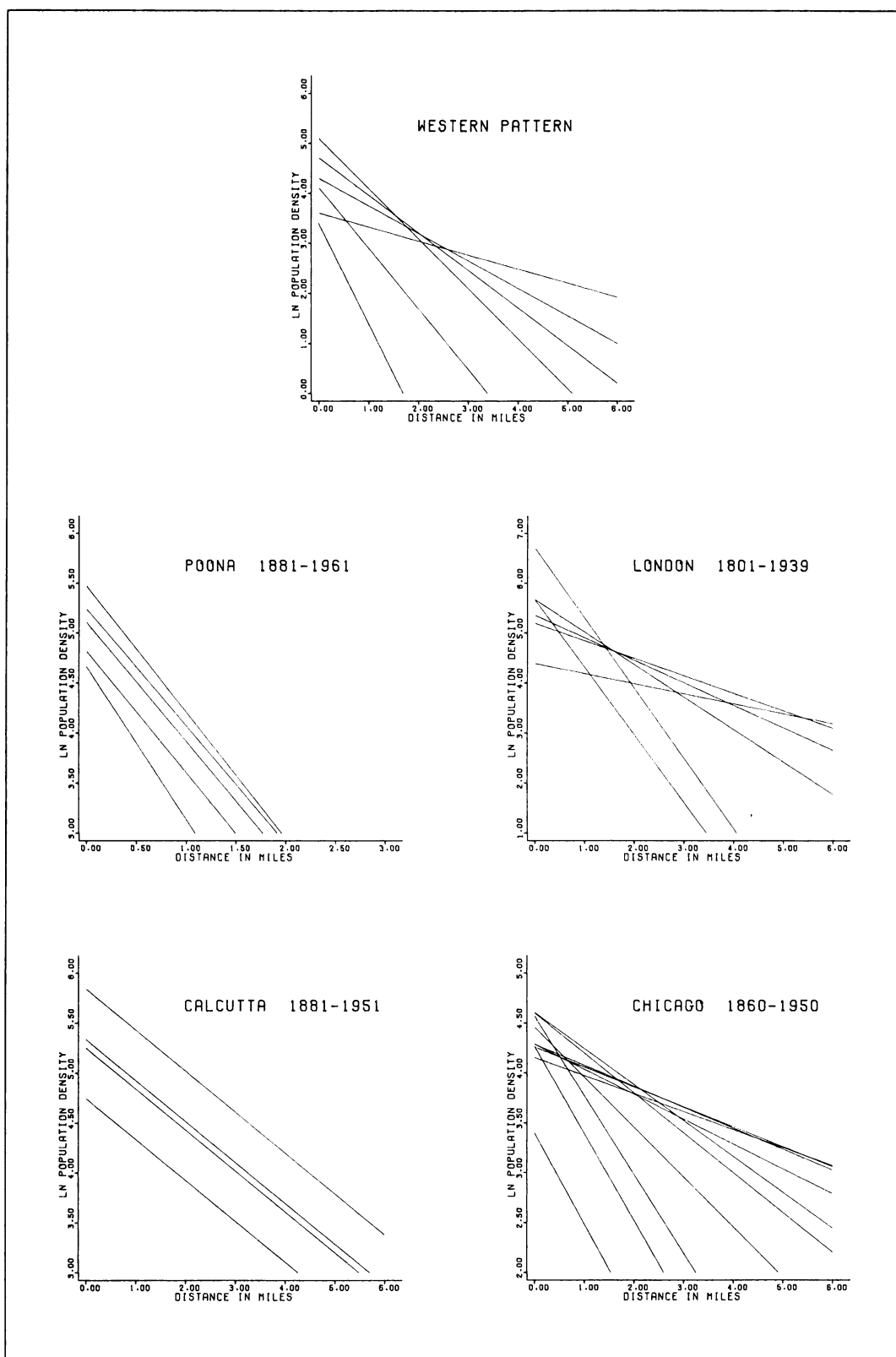


Figure 1.

Western cities, while the non-Western pattern is illustrated by the graphs based on data for Poona and Calcutta, India. Table 1 contains density gradient parameters associated with the lines appearing in each of the graphs in Figure 1.⁷

The differences between cities in the developing and Western worlds, as reflected by changes in their population density gradient parameters, have been attributed to several causes. In the Western case, changes in the availability of inexpensive mass transportation have been credited with making it possible for people to live farther from their jobs and for industry to locate more freely.⁸ Therefore, the degree to which such transportation is, or becomes, available, affects the rate at which the density gradients change and a city increases in areal extent. In the absence of inexpensive transportation, people, business, and industry

⁷Data sources: Western Pattern - hypothetical values selected to illustrate the ideal Western pattern; London - Clark, op. cit., p. 494; Chicago and Calcutta - Berry, Simmons and Tennant, op. cit., pp. 399, 401; Poona - derived by the author from data contained in J. E. Brush, "Some Dimensions of Urban Population Pressure in India," in W. Zelinsky, L. A. Kosinski and R. M. Prothero (eds.), Geography and a Crowding World (New York: Oxford University Press, 1970), p. 295. All central density (a) and slope (b) values are in natural logarithmic form.

⁸G. H. Wehrwein, "The Rural Urban Fringe," Economic Geography, Vol. 18 (1942), pp. 217-228; Colin Clark, "Transport - Maker and Breaker of Cities," Town Planning Review, Vol. 28 (1957-1958), pp. 237-250; idem., "The Location of Industries and Population," Town Planning Review, Vol. 35 (1964), pp. 195-218; Boal, op. cit.

Table 1

Population Density Gradient Parameters for
Western and non-Western Cities

<u>Western Pattern</u>		
	a	b
	3.4	-2.00
	4.1	-1.21
	5.1	-1.00
	4.7	- .75
	4.3	- .55
	3.6	- .28

<u>Poona 1881-1961</u>		
Year	a	b
1881	4.67	-1.52
1931	4.81	-1.21
1941	5.11	-1.19
1951	5.24	-1.17
1961	5.47	-1.26

<u>Calcutta 1881-1951</u>		
Year	a	b
1881	4.75	- .41
1901	5.25	- .41
1921	5.34	- .41
1951	5.84	- .41

<u>London 1801-1939</u>		
Year	a	b
1801	5.67	-1.35
1841	6.68	-1.40
1871	5.67	- .65
1901	5.35	- .45
1921	5.19	- .35
1939	4.38	- .20

<u>Chicago 1860-1950</u>		
Year	a	b
1860	3.40	- .91
1870	4.26	- .87
1880	4.57	- .79
1890	4.46	- .50
1900	4.61	- .40
1910	4.61	- .36
1920	4.29	- .25
1930	4.29	- .21
1940	4.26	- .20
1950	4.15	- .18

will tend to remain tightly clustered in compact cities characterized by high and ever-increasing population density. Other factors have been introduced to account for the presence or absence of change in population distribution, including modifications in the desirability or "utility" of various locations within an urban area and differences in the demand for land in the city and on the urban fringe.¹⁰

Clark cited differences in transportation systems as the reason for disparities between Western and non-Western cities, but Berry, Simmons and Tennant disagreed with this explanation. Noting the differences in density gradient patterns over time for cities like Chicago and Calcutta, they concluded that Western and non-Western cities do not grow in a like manner. They held that socio-cultural differences between Western and non-Western societies operate to affect the demand for land, with preferences for central city residential location in non-Western societies acting to reduce the demand for land on the urban periphery. These societal preferences, in turn, restrict the areal growth of cities and necessitate steady increases in central city population

¹⁰E. Casetti, "Urban Population Density Patterns: An Alternate Explanation," Canadian Geographer, Vol. 11 (1967), pp. 96-100, discusses the role of variations in the perceived "utility" of locations as a factor affecting population distributions. Berry, Simmons and Tennant, op. cit., pp. 402-404, focus their attention on differences in demand for particular urban locations.

densities. The analysis and conclusions of Berry, Simmons and Tennant were first published in 1963.¹¹ Since that time they have gained widespread acceptance, appearing in a work on urban systems, a collection of readings on population geography, and a text on urban geography.¹² In addition, their study is frequently cited in the literature dealing with population density.¹³ As yet, their conclusions have not been seriously tested.¹⁴

¹¹Berry, Simmons and Tennant, op. cit.

¹²B.J.L. Berry and F. E. Horton, Geographic Perspectives on Urban Systems (Englewood Cliffs, N. J.: Prentice-Hall, 1970), pp. 288-293; G. J. Demko, H. M. Rose and G. A. Schnell (eds.), Population Geography: A Reader (New York: McGraw-Hill, 1970), pp. 181-193; R. M. Northam, Urban Geography (New York: John Wiley and Sons, 1975), pp. 275-277.

¹³J. E. Brush, "Spatial Patterns of Population in Indian Cities," Geographical Review, Vol. 58 (1968), pp. 362-391; idem., op. cit. (footnote 9), p. 289; R. C. Treadway, "Social Components of Metropolitan Population Densities," Demography, Vol. 6 (1969), pp. 55-74; C. W. Pannell, T'ai-Chung, T'ai-Wan: Structure and Function (Chicago: Department of Geography, University of Chicago, 1973), p. 115; A. M. Guest, "Urban Growth and Population Densities," Demography, Vol. 10 (1973), pp. 53-69; idem., "Population Suburbanization in American Metropolitan Areas," Geographical Analysis, Vol. 7 (1975), pp. 267-283.

¹⁴B. E. Newling, "Urban Population Densities and Intra-Urban Growth," Geographical Review, Vol. 54 (1964), pp. 440-442, cites Clark's data and states that they ". . . suggest that the Western/non-Western dichotomy proposed by Berry, Simmons and Tennant is not a tenable hypothesis. . . ." This comment on the hypothesis did not discourage its republication in 1970 by Berry and Horton, op. cit., and by Demko, Rose and Schnell, op. cit. On the other hand, J. E. Brush, "Some Dimensions of Urban Population Pressure in India," op. cit., provides two examples that tend to support Berry, Simmons

The Problem

The disparity between the conclusions of Clark on the one hand and Berry, Simmons and Tennant on the other poses a problem for city planners in the developing world. If the findings of Berry, Simmons and Tennant are valid and accepted at face value, the growth of cities in the non-Western, developing world can be expected to differ from that experienced in the Western world. Population will become increasingly concentrated within the relatively static confines of existing cities. Such a situation will present planners with a set of problems unlike those encountered in the Western world. For example, public utilities and services will have to be designed to function within a relatively small area and at the same time meet the needs of a large, highly concentrated population. More importantly, however, many of the generalizations about the growth of urban centers in the Western world will be of little use in planning for the orderly growth of non-Western cities, for the pattern of urban growth in the Western world has been one of areal expansion and decreasing concentration of population, business and industry in association with improvements

and Tennant. This support is diluted, however, by the nature of the examples selected, behavior of the economically advantaged segment of the population, and artificial restrictions on urban expansion that are noted.

in transportation systems. In short, the findings noted above raise the question of whether urban planners in developing countries should plan for increasing concentration and congestion, or for the more typical Western-world process of urban sprawl.

If it can be shown that the patterns of urban growth in Western and non-Western cities are basically similar, we may expect that non-Western cities will encounter problems similar to those found in Western cities. The experiences and findings of planners in the developed world will, therefore, constitute a valuable fund of knowledge that can be drawn upon and used as a guide by planners and officials in developing countries. Problems that may appear in connection with urban growth could be anticipated, ameliorated, and perhaps entirely circumvented.

Hypotheses

The research discussed on the following pages was designed to test two hypotheses. The first of these is that cities in the developing world will, with the passage of time, experience the same kinds of changes in population density patterns that have characterized Western cities. There is reason to believe that cities in developing countries are experiencing pressures and influences similar to those encountered in Western cities during the middle and

late nineteenth century. For example, at a basic demographic level Hoselitz found,

that the demographic trend in India's large cities in the last half-century resembles rather closely that of the large cities in European countries. In the first fifty years of this century the population living in Indian cities which now have more than one lakh [million] population almost tripled. This record compares roughly with that of Belgium, Austria and Germany in the first half of the nineteenth century, and exceeds the rate of growth of population of large cities in Hungary, Ireland and Scandinavia in the same period.

Similarly, the rate of growth of city population in India during the twentieth century does not fall behind comparable growth rates in European countries during the period of their most rapid urbanization.¹⁵

In addition to gross similarities in urban growth rates, there are similarities in the spread and effect of technological advances. The advent of the steam engine in the 1800's and its adaption to the needs of industry and transportation made possible the decentralization of industry in London and Manchester, England.¹⁶ The effects of this decentralization on the population density and areal

¹⁵B. F. Hoselitz, "The Role of Urbanization in Economic Development: Some International Comparisons," in D. J. Dwyer (ed.), The City in the Third World (New York: Harper and Row, Barnes and Noble Import Division, 1974), p. 175.

¹⁶Clark, "Transport - Maker and Breaker of Cities," op. cit., pp. 243-245; F. Vigier, Change and Apathy: Liverpool and Manchester During the Industrial Revolution (Cambridge, Mass.: M. I. T. Press, 1970), pp. 19-25, 156-161.

extent of these cities are evident in the changes in their density gradients between 1840 and 1900 (Figure 1). The application of electric power to transportation and industry, and the increasingly widespread use of trucks, buses and automobiles have contributed to the further expansion of these cities and dispersal of their populations.¹⁷

Similar changes in the technology of transportation and industry have appeared in developing nations, especially since the end of World War II. Oxcarts and pedicabs are being replaced by trucks, buses, automobiles and motorcycles. Industries that have sprung up since 1945 have, as in Western countries, been increasingly able to locate outside of the central city and still be assured of the availability of labor, transport, power and other amenities. The main difference between the Western and non-Western nations in terms of technological advance is that the non-Western countries have been able to adopt state-of-the-art technologies without having to invest years of time and effort in their development. As a result, the non-Western nations have had

¹⁷A system of equations involving land rent, employment densities and residential densities evaluated by Niedercorn suggests that, ". . . improvements in the movement of persons have played a significant role in transforming the core-dominated city to the sprawling metropolis of today." J. H. Niedercorn, "A Negative Exponential Model of Urban Land Use Densities and its Implications for Metropolitan Development," Journal of Regional Science, Vol. II (1971), p. 325.

the opportunity to advance economically at a much faster pace than was possible in Europe and North America.¹⁸

Consideration of these recent developments in non-Western nations leads to the second hypothesis. As noted, much of the growth of Western cities has been associated with expansion of industrial production and improvement in transportation facilities; i.e., economic development. It seems reasonable, therefore, to expect that economic development in non-Western nations will be accompanied by urban growth similar to that found in Western nations. Hence, it is hypothesized that as non-Western nations develop economically the pattern of urban growth characterizing Western cities will appear in non-Western cities. With the passage

¹⁸The rise of Japan from the status of a feudal, agricultural country to that of a world industrial power between the time of the Meiji Restoration in 1868 and World War I amply illustrates this proposition. The rapidity of Japan's economic development was facilitated to a large extent by the ready availability for purchase of machines, man-power and know-how. In the span of a half century Japan's role in world affairs changed from that of a potential market to be "opened" for Western trade to that of a colony-holding world power whose actions and desires had to be given careful consideration by the Western nations in times of both war and peace. J. K. Fairbank, E. O. Reischauer and A. M. Craig, East Asia: Tradition and Transformation (Boston: Houghton Mifflin, 1973), pp. 484-557, 648-735. In more recent, post-World War II, times the Republic of China (Taiwan) has gone through a similarly rapid process of economic development. There, too, rapid change from a predominantly agricultural economy to one based on industry and commerce has been facilitated by the opportunity to purchase new technologies instead of having to invent and develop them. N. H. Jacoby, U. S. Aid to Taiwan (New York: Frederick A. Praeger Publishers, 1966).

of time, central city population densities will first increase and then decrease, and the slopes of the density gradients will decline.

An examination of the relationships among changes in population density patterns, improvements in transportation and industrial expansion in a non-Western city will provide evidence for testing the validity of the hypothesis. The results of such an examination are expected to indicate that cities in non-Western countries grow under the influence of long term economic development as have cities in the developed Western nations.

Methodology

The urban area of Taipei, Taiwan, Republic of China, was selected as the subject of investigation for this study. Data related to the population of Taipei and the surrounding area were gathered during ten months of field work in Taipei. The data were collected from unpublished records of the Division of Household Registration, Ministry of Interior. Raw population figures were converted to natural log of population density values, arrayed with corresponding distance values, and used to derive a series of population density gradients for the 1950-1972 period using Clark's model.

The derivation of the central density (a) and density gradient slope (b) values was an elementary procedure

involving use of simple least-squares regression analysis. Selecting the portion or subset of the data for the general metropolitan area to use in the analysis was, however, a more involved process. The city of Taipei is considerably overbounded and includes large areas of mountainous, sparsely populated terrain. At the same time the city limits of Taipei do not include all important, heavily urbanized portions of the metropolitan area. Hence, the city boundary did not serve as an accurate guide in defining the urban domain of Taipei. Reliance was placed instead on computer-generated isarithmic maps of population density, an examination of shifts in the population-weighted mean centers of administrative districts, and consideration of maps and field notes in determining the specific area to be analyzed.

Following completion of the evaluation of population density patterns, attention is focused upon the relationships between density gradients and variables measuring changes in transportation and economic development. Variables considered in conjunction with the density gradient values for the 1952-1972 period include per capita availability of various modes of transportation, make-up of the labor force, various economic indicators and demographic characteristics commonly associated with modernization and economic development. While it had been hoped that a multiple regression and correlation analysis of these data would be possible, high levels of interaction among

independent variables precluded such an approach.

Evaluation of the relationships is therefore limited to an examination of trends in the data and simple correlation analysis.

Study Site

Several factors led to the selection of Taipei as the study site. Foremost among them is the fact that Taipei is a metropolitan center in a decidedly non-Western country. The natural setting of the city also closely approximates the physical requirements of Clark's basic population density model. Taipei is situated in a broad, level basin offering opportunities for areal expansion in all directions. The presence of the Tan Shui, Kee Lung and Hsin Tien rivers has somewhat hampered areal growth, but these impediments have been overcome with the construction of rail and highway bridges.¹⁹

A further reason for selecting Taipei is that it has changed from a traditional agricultural-administrative center to a modern industrial-commercial city. Prior to the Sino-Japanese War of 1895, Taipei functioned as an agricultural trade center and the seat of the provincial

¹⁹Cheng-Siang Chen, The City of Taipei, Research Report No. 71 (Taipei, Fu-min Geographical Institute of Economic Development, 1956): idem., Cities and Rural Towns of Taiwan, Research Report No. 48 (Taipei: Institute of Agricultural Geography, 1953).

government. During the Japanese occupation of Taiwan from 1895 to 1945, the city served as headquarters for the colonial government and Japanese companies involved in the processing of agricultural products and their export to Japan. Since the end of World War II, Taipei has become a center of industrial production, transportation and international trade as well as the seat of the national government of the Republic of China.²⁰ During the latter period the population of the city increased rapidly, rising from 595,000 to 1,926,000 between 1950 and 1972.²¹

The availability of accurate and detailed data also favored the selection of Taipei as the study site. The Chinese have maintained a population register for Taiwan since the late 1940's. The records include detailed data

²⁰Chen Shao-Hsing, "The Trend of Urbanization and the Formation of a Metropolitan Area in Taiwan During the Last Decade," National Taiwan University Journal of Sociology, Vol. 1 (1963), pp. 59-77; Lung Kwan-Hai, "A Comparative Study of the Population Growth of Taiwan's Five Largest Cities During the Last Twenty Years," National Taiwan University Journal of Sociology, Vol. 5 (1969), pp. 113-130; Yukon Feng, "Urbanization Policy & Metropolitan Planning in Taiwan," Industry of Free China, May, 1966, pp. 20-30, and June, 1966, pp. 23-42.

²¹Derived by the author from data contained in the records of the Division of Household Registration, Ministry of Interior. The figures cited are for the sixteen districts (Ch'u) which make up the city of Taipei. The population of the Taipei Metropolitan Area, including the city and thirteen districts (Shih, Chen and Hsiang) in the surrounding area increased from 803,000 to 2,915,000 during the same period.

based on small observational units similar to census tracts in the Standard Metropolitan Statistical Areas of the United States. The abundance of data, somewhat unusual in the developing world, facilitates the application of Clark's model not only on the basis of aggregated data grouped by concentric rings, but also on the basis of disaggregated data and by sectors within the city. The high level of accuracy in the data increases the probability of arriving at valid conclusions concerning the hypotheses.²²

The following chapters present in more detail a description of the city, data used for analytical purposes, the results of the analyses and conclusions that relate directly to the hypotheses. Chapter II deals with the development of Taiwan and the location, growth and present condition of Taipei. In Chapter III attention is focused on the acquisition, verification and manipulation of data. Analysis of the data and the results obtained are discussed in Chapters IV and V. Finally, conclusions concerning the hypotheses and their implications, along with two recommendations, are presented in Chapter VI.

²²Alden Speare, "An Assessment of the Quality of Taiwan Migration Registration Data," Taiwan Population Studies, Working Paper No. 12, Population Studies Center, University of Michigan, March, 1971 (mimeographed).

CHAPTER II

TAIWAN AND TAIPEI

The Physical Setting

The island of Taiwan lies astride the Tropic of Cancer about 160 kilometers off the coast of the Chinese mainland (Figure 2, A). It is midway between Shanghai and Hong Kong on the mainland and the island metropolitan centers of Osaka, Japan, and Manila in the Philippines. The island itself is roughly elliptical in shape, with the long north - south axis extending from 25° 38' to 21° 45' north latitude, a distance of almost 400 kilometers. The shorter east - west axis extends from 122° 6' to 120° 1' east longitude, making the island approximately 160 kilometers in width at its widest point. The area of Taiwan is 35,854 square kilometers, similar in size to the Netherlands (36,160 square kilometers) and half the size of Ireland (70,284 square kilometers).

The topography of Taiwan is marked by sharp contrasts. Almost half of the island's area is made up of mountains that rise steeply out of the Pacific Ocean on the west and extend from the northern to the southern capes (Figure 2, B). The highest point is the summit of Yu Shun

Figure 2

The Location and Topography of Taiwan

Panel A: Location

Panel B: Topography

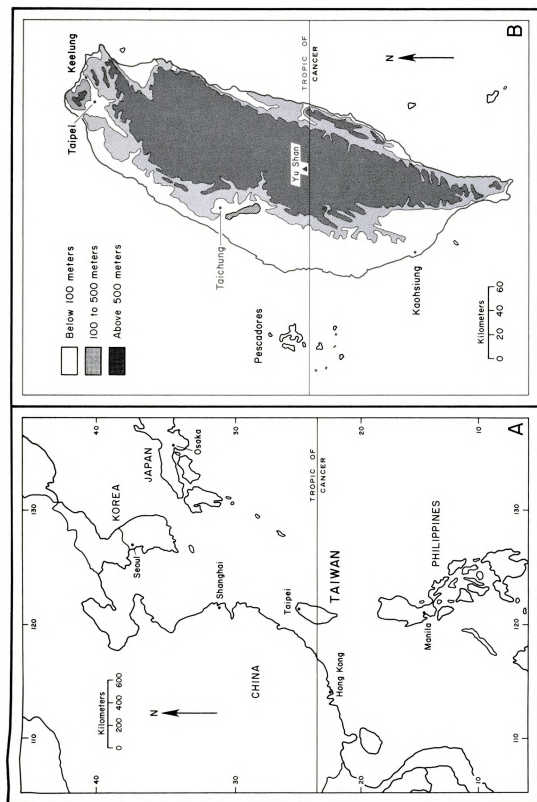


Figure 2.

(Jade Mountain) 3,950 meters above sea level and located on the Tropic of Cancer at 121° east longitude. In total, forty-five percent of the island lies above 500 meters in elevation and less than one-third of the island's area is below 100 meters. With the exceptions of the Taitung Rift Valley on the eastern side of the central mountain range, the Ilan Plain at the northeastern corner of the island, and the Taipei Basin at the northern end, Taiwan's lowlands are concentrated in the coastal plain that extends the length of the western side of the island. The lowland areas are crossed by numerous streams and rivers that rise in the mountains and run to the sea in a generally radial pattern. It is these well-watered lowlands, especially the coastal plain and Taipei Basin, that have attracted and sustained the population of Taiwan through the centuries.²³

Taiwan: Growth and Development

The peopling of Taiwan has been a process extending over more than two millenia. It has been suggested that the

²³The latitude and longitude coordinates for Taiwan are given in: Council for International Economic Cooperation and Development, Taiwan Statistical Data Book, 1973 (Taipei, Executive Yuan, 1973), p. 3. A detailed discussion of the geologic and topographic features of Taiwan is contained in: Chiao-Min Hsieh, Taiwan - ilha Formosa (Washington, D. C.: Butterworths, 1964), pp. 3-120. The National War College, National Atlas of China (Yang Ming Shan, Taiwan: National War College, 1972), Vol. 1, "Taiwan," contains a series of maps depicting topographical, geologic, climatic, land use and other characteristics of the island.

prehistoric inhabitants came to the island via the Philippines as part of Asian mainland migration to the islands of the Pacific. Archaeological evidence has also been found indicating origins in northern China and the possibility of direct migration across the Taiwan Straits. Whatever their origins, the first visitors to Taiwan to record their observations reported the presence of people on the island. Official recorded history begins in 1430 A.D. with the report of a ship-wrecked officer to the Chinese government concerning his treatment by inhabitants of the island. From that time onward the history of events and developments on Taiwan becomes more detailed and complete.²⁴

Official Chinese interest in Taiwan was limited and sporadic until the latter half of the seventeenth century. In the interim between its "discovery" and incorporation into the administrative structure of China as a prefecture of Fukien Province in 1683, Taiwan served as a base for pirates, a European foothold on the doorstep of China, and the last stronghold of partisans following the collapse of the Ming dynasty. Chinese activity prior to the arrival of Europeans was focused on controlling pirates who raided Chinese shipping

²⁴Robert C. Suggs, The Island Civilizations of Polynesia (New York: New American Library, 1960), pp. 59-66; Kwang-Chih Chang, "A Brief Survey of the Archaeology of Formosa," Southwestern Journal of Anthropology, Vol. 12 (1956), pp. 371-386; James W. Davidson, The Island of Formosa (New York: Macmillan, 1903), pp. 2-8.

and coastal villages from Taiwan. Toward this end a naval base was established in the Pescadores, a group of small islands off the southwest coast of the island. No attempt was made, however, to extend control to Taiwan itself, even though it was the destination of a steady stream of migrants from the mainland.

In 1557 the Portuguese succeeded in establishing a permanent point of entry to China at Macao. The Spanish firmly established themselves in Asia with the founding of Manila in 1571. Not to be outdone or excluded from the lucrative trade with China, the Dutch attempted to drive the Portuguese from Macao. After several unsuccessful attempts, they gave up the effort and settled on Taiwan in 1622. Over the next forty years they engaged in trade with China, extracted considerable wealth from Taiwan and set about the conversion of the native population to Christianity. This latter undertaking was vigorously pursued but had little lasting effect on the target population. Migration from the mainland of China to Taiwan was considerable during the period of Dutch colonization. The movement was spurred in part by Dutch policies aimed at increasing the population of the island and in part by the turmoil associated with the collapse of the Ming dynasty. The end of the Ming dynasty in 1644, followed by the successful takeover of China by the Manchus, was to bring an end to Dutch control of Taiwan.

The fall of the Ming dynasty was followed by years of fighting as the Manchu government gradually gained control over all of China. By the late 1650's all but a few of the Ming supporters had been converted to the new government, exterminated, or driven into enclaves on the Pacific coast. In 1661 the remaining Ming partisans left for Taiwan, complete with a large army and fleet. There they besieged the Dutch and succeeded in driving them from the island in 1662. The victorious refugees set up an autonomous kingdom which lasted until 1683 when final surrender was made to the overwhelming might of the Manchu forces. Following the surrender, Taiwan was officially made a part of the Chinese empire, being given the status of a prefecture under the authority of the governor of Fukien Province.²⁵

During the 200 years following official inclusion in the Chinese empire Taiwan remained a backwater, frontier area. A steady stream of migrants continued to flow in from the mainland. As a result of this movement the aboriginal inhabitants of the island were pushed off the western coastal

²⁵The developmental history of Taiwan through 1683 was drawn from more detailed accounts in Davidson, op. cit., Hsieh, op. cit., and W. G. Goddard, Formosa: A Study in Chinese History (London: Macmillan, 1966). The activities of the Dutch are described from contemporary records in William Campbell, Formosa Under the Dutch (London: Kegan Paul, Trench, Trubner and Co., 1903). The Ming dynasty from peak to collapse, and the rise of the Manchu (Ching) dynasty are discussed in Fairbank, Reischauer and Craig, op. cit., pp. 177-230.

plain and into the hills and mountains. Recurrent revolts and rebellions marked relationships between the settlers and officials sent to administer the prefecture. Taiwan came to be known as a trouble plagued area suitable for the posting of bothersome court officials who, in turn, used their position on the island to exploit the local population. This situation came to a rather sudden end with the advent of war between France and China in 1884.²⁶

Throughout the eighteenth and early nineteenth century Britain and France competed for control over Oriental markets, mainly those of India. The French were forced out of India at the close of the eighteenth century and turned to southeast Asia in search of markets and a route into China. By the 1860's France had gained a protectorate over Cambodia and the cession of Southern Cochinchina (South Vietnam) from Annam, a tributary state under the claimed suzerainty of China. A dispute over China's claim to suzerainty in the area and French access to Southwestern China via the Red River valley led to a declaration of war by China in 1884. Part of the French reaction was the capture of Keelung, a port city thirty kilometers northeast of Taipei, and the blockade of Taiwan. This action forcefully brought the value of Taiwan, important in the tea and camphor trade, to the attention of the Chinese government. As

²⁶Davidson, op. cit., pp. 63-202.

a result Taiwan's status was raised to that of a separate province of China, the capital was moved from Tainan at the southern end of the island to Taipei, and a governor was appointed.²⁷

With the elevation to provincial status came a flurry of activity centered at the provincial capital of Taipei and aimed at modernizing the island. A railroad was built linking Taipei to Keelung and other northern cities. A telegraph system was established and Taipei became the first Chinese city to have an electricity generating plant. The modernization trend ended, however, with the appointment of a new governor in 1891 and did not resume until after Japan took control of Taiwan in 1895.²⁸

Official Japanese interest in Taiwan was activated in 1872 by the deaths of shipwrecked seamen at the hands of Taiwanese aborigines. Upon failure to obtain redress from the Chinese government, a military expedition was launched

²⁷Ibid., pp. 219-242; J. L. Christian, "Anglo-French Rivalry in Southeastern Asia: Its Historical Geography and Diplomatic Climate," Geographical Review, Vol. 31 (1941), pp. 272-282; Hosea B. Morse, The International Relations of the Chinese Empire (New York: Longmans, Green and Co., 1918), Vol. II, "The Period of Submission, 1861-1893," pp. 340-367. Events and conditions in the Taipei area during the blockade are described in John Dodd, Journal of a Blockaded Resident in North Formosa (Hong Kong: Daily Press, 1888) as reprinted by Ch'eng Wen Publishing Co., Taipei, 1972. The war was settled in 1885 with France gaining control of all of what is now Vietnam.

²⁸Davidson, op. cit., pp. 243-256; Goddard, op. cit., pp. 129-139.

in 1874 which resulted in better treatment for later shipwreck victims and aroused fears in China that Japan held designs on Taiwan. Two decades later the fears were proven to be well founded when Japan insisted upon cession of Taiwan as part of the settlement of the Sino-Japanese war in 1895. The arrival of Japanese forces in June of 1895 marked the beginning of a fifty-year period of growth and development in Taiwan's economy.²⁹

The period of Japanese colonial rule (1895-1945) saw the implementation of modern organizational techniques, development of commercially oriented agriculture, renewal and widespread expansion of communication and transportation systems, and the beginnings of industrialization in Taiwan. Banditry, internecine warfare and depredations of the aborigines were suppressed. Social welfare programs were instituted that resulted in improved literacy levels and a decline in the death rate, brought about largely by improved sanitation measures and control of diseases such as malaria, cholera and plague.³⁰

²⁹Davidson, op. cit., pp. 123-159, treats the 1874 expedition in considerable detail. Equally detailed attention is given to the Japanese' arrival and occupation of the island in 1895 (pp. 257-370). Morse, op. cit., Vol. III, "The Period of Subjection, 1894-1911," pp. 2-55, discusses events leading up to the war, conduct of the war and peace negotiations, and the outcome. Also see Goddard, op. cit., pp. 140-157.

³⁰Jacoby, op. cit., pp. 71-84; Hsieh, op. cit., pp. 262-183; Goddard, op. cit., pp. 158-167; Anthony Y. C.

One of the more important features of Japanese rule was the effective termination of migration from the mainland. The flow of peasant farmers from the mainland was replaced, in part, by an influx of administrators, businessmen and technically skilled workers from Japan who took up leadership positions in the economy.³¹ Under their guidance Taiwan was converted from a frontier province to a rich agricultural colony that annually sent large quantities of rice and sugar to Japan. In addition, the decades of peace and stability associated with the colonial period afforded the opportunity to develop the social and physical infrastructure on the island that would provide a foundation for post-World War II development and industrialization.³²

Koo, The Role of Land Reform in Economic Development (New York: Frederick A. Praeger, Publishers, 1968), pp. 8-26; Chang Han-Yu and R. H. Myers, "Japanese Colonial Development Policy in Taiwan, 1895-1906--A Case of Bureaucratic Entrepreneurship," Journal of Asian Studies, Vol. 17 (1963), pp. 433-449. Agriculture received the most attention from the Japanese colonial government. R. H. Myers and A. Ching, "Agricultural Development in Taiwan Under Japanese Control," Journal of Asian Studies, Vol. 23 (1964), pp. 555-570; Samuel Pao-San Ho, "Agricultural Transformation Under Colonialism: The Case of Taiwan," Journal of Economic History, Vol. 28 (1968), pp. 313-340. Also see A. J. Grajdanzev, Formosa Today (New York: Institute of Pacific Relations, 1942).

³¹G. W. Barclay, Colonial Development and Population in Taiwan (Princeton, N. J.: Princeton University Press, 1954), pp. 10-17, 65-72.

³²Jacoby, op. cit.

When Taiwan was returned to Chinese control in 1945 industrial capacity was greatly reduced. Agricultural production was down considerably from pre-war peak levels, largely due to the absence of fertilizer previously imported from Japan. Industrial facilities and the transportation system had suffered war damages and general deterioration due to a lack of maintenance. A shortage of technically trained manpower developed immediately following the war due to the repatriation of Japanese nationals and the preoccupation of the Chinese government with the civil war on the mainland. The national government's move to Taiwan in 1949, however, once again focused attention on the island.³³

The large civilian migration that accompanied the movement of the national government to Taiwan helped alleviate the shortage of administrative and technically trained personnel caused by the repatriation of Japanese. In 1949 a land reform program was initiated that resulted in the transfer of land ownership from the government and landlords to individual farmers.³⁴ Beyond the basic goal of changing land tenure patterns the reform has been credited with

³³Events and conditions on Taiwan immediately following its return to Chinese control are described, in an emotional and critical manner, in G. H. Kerr, Formosa Betrayed (Boston: Houghton Mifflin, 1965).

³⁴Hui-Sun Tang, Land Reform in Free China (Taipei: Chinese - American Joint Commission on Rural Reconstruction, 1954); Koo, op. cit., pp. 28-122.

fostering increased agricultural production and modernization of rural social structures.³⁵

On a more general level, the United States started an aid program in 1951 designed to improve not only agricultural production, but also the basic facilities needed to promote general economic development. Over a period of fifteen years the aid program helped provide the roads, power plants and technological ability that today support an expanding and increasingly industrially based economy.³⁶ The variety of goods produced for export has expanded beyond

³⁵Hsieh, op. cit., p. 286; Y. L. Hsueh, "Doubling the Rice Crop," Free China Review, Vol. 14, No. 10 (1964), pp. 27-31; Jacoby, op. cit., pp. 109-110. Bernard Gallin presents the opinions and reactions of farmers in one village (1957-58 data) to the results of the land reform program in Hsin Hsing, Taiwan: A Chinese Village in Change (Los Angeles: University of California Press, 1966), pp. 88-126.

³⁶Jacoby, op. cit., describes the U. S. aid effort, both strong and weak points, and claims that the 1951-1965 aid period constituted a ". . . watershed between tradition and modernity" (p. 103). A summary of Taiwan's progress based on comparisons between 1952 and 1966 industrial output data is provided by Chen Kao-tang in "The Fruits of Industry," Far Eastern Economic Review, Vol. 55, No. 7 (February 16, 1967), pp. 243-246. Taiwan's continuing economic development in the face of diplomatic reversals is discussed by William Glenn in "Isolation: A Spur to Taiwan," Far Eastern Economic Review, Vol. 83, No. 5 (February 4, 1974), pp. 44-46. Statistical data related to the aid period may be found in Directorate-General of Budgets, Accounts and Statistics, National Income of the Republic of China: National Accounts in Taiwan for 1951-1967 (Taipei: Executive Yuan, 1968). Current figures are regularly published in the Economic Statistics sections of Industry of Free China (Tzu Yu Chung-Kuo Chih Kung Yeh).

the basic rice and sugar to include canned pineapple, mushrooms and asparagus from the agricultural sector, and manufactured goods ranging from textiles and footwear to sophisticated electronics and telecommunications equipment.³⁷ Perhaps more important, the benefits of economic development are within the reach of the general population.³⁸ Demand for more and better housing spurred a building boom that started in the mid-1960's and continues unabated today. Incomes have increased to the point that items like refrigerators and television sets, previously considered luxuries, are found in more and more homes. Indeed, Premier Chiang Ching-kuo said at the close of 1973 that when a recently initiated series of infrastructure improvement projects is completed the Republic of China will join the ranks of the developed nations.³⁹

³⁷Overall Planning Department, EPCEY, "The Electronics Industry in Taiwan," Industry of Free China, Vol. 42, No. 1 (July, 1974), pp. 21-34.

³⁸Jacoby, op. cit., pp. 101-102.

³⁹"Premier Says: ROC Becoming Developed Nation," The China News (Taipei), December 26, 1973, p. 4. The premier's statement was preceded by a similar comment by the chairman of the Economic Planning Commission. "ROC to Join Ranks of Developed Nations," The China News (Taipei), October 2, 1973, p. 4. The anticipated change in status became the topic of repeated comments. Cf., P. Jay King, "'Developed Nation' Status Symbol in Sight," The China News (Taipei), May 28, 1974, pp. 1, 4. The infrastructure projects include railway electrification, construction of an island-long, north-south freeway, port facilities at Taichung, integrated steel mill and shipyard at Kaohsiung, and

The development of Taiwan over the last ninety years, and especially since the end of World War II, illustrates the speed with which change can occur in a developing nation. Growth and change also occurred in the cities of Taiwan as the island's economy was developing. The city of Taipei, subject of this study, rose from a small riverside village to become the dominant metropolitan center on the island as the island itself moved from obscurity to prominence on the world scene.

A description of the growth of the city will help in understanding the population distribution patterns that have appeared and exist today.

The Growth of Taipei

Taipei is located on the east bank of the Tan Shui River in the approximate geographic center of the Taipei Basin. The basin is irregular in shape and bordered by mountains on the north, east and south, and by a tableland on the west. It extends approximately twenty-five kilometers from east to west and nineteen kilometers from north to south at the 100 meter contour. The margins of the basin are

international airport at Taoyuan to the southwest of Taipei. These and other projects are included in the current four year plan. "Targets and Basic Policies Under the Republic of China's Sixth Four-Year Plan (1973-1976) for Economic Development of Taiwan," Industry of Free China, Vol. 39, No. 4 (April, 1973), pp. 8-38.

sharply defined by the abrupt rise of mountains that are so steep as to preclude most construction activities and the building of roads.

The floor of the Taipei Basin is drained by the Tan Shui River and its tributaries. Over the years these rivers and streams deposited a fine alluvial soil well suited to irrigated rice cultivation. The agricultural potential of the basin attracted settlers who established the village of Meng Chia near the junction of the Tan Shui and Hsin Tien rivers in the early eighteenth century (Figure 3). In 1788 trade was opened between northern Taiwan and the Chinese mainland, and Meng Chia became an increasingly important center as more junks sailed up the Tan Shui to load agricultural products for shipment. Through the eighteenth and first half of the nineteenth centuries the village grew until it rivaled in importance the prefectural capital at the southern end of the island. In 1853, however, a dispute among rival groups in Meng Chia resulted in the departure of one of the groups. These people moved about two kilometers downstream and established the settlement of Ta Tao Chen (Figure 3). At about the same time the bed of the Tan Shui River began to fill with silt, restricting, and eventually ending, river traffic to Meng Chia. Ta Tao Chen gradually replaced Meng Chia as a trade center as mainland and foreign demand for locally produced tea and camphor increased. Tea processing and packing factories grew in

Figure 3

Taipei Central Urban Area

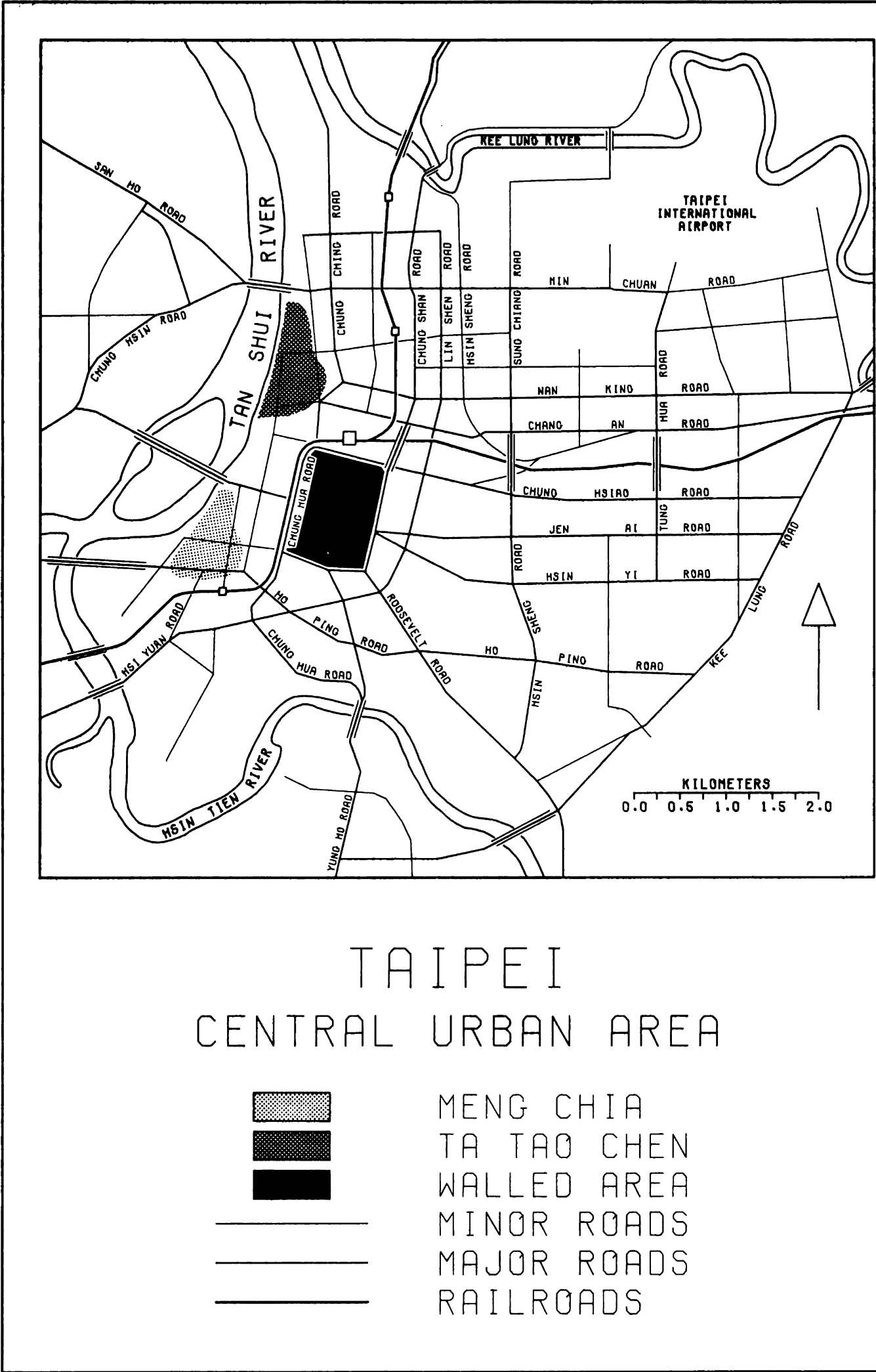


Figure 3.

Figure 3

Taipei Central Urban Area

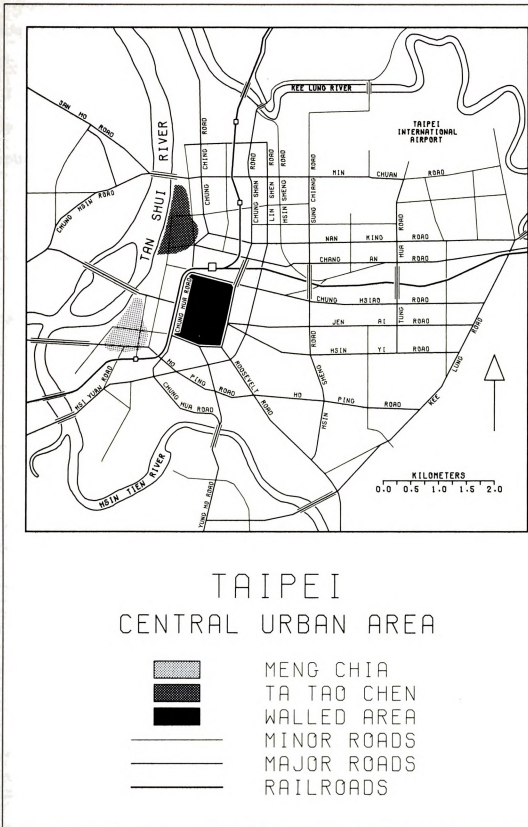


Figure 3.

number and several foreign firms set up business in the new settlement.⁴⁰ At the time of the French blockade of Taiwan in 1884-1885 the combined populations of Ta Tao Chen and Meng Chia had grown to somewhere between 60,000 and 70,000 persons.⁴¹

The late 1870's brought an administrative reorganization of northern Taiwan. The imperial prefect moved his office and residence to Meng Chia and began to build the new administrative center at Taipei. By the end of 1879 gates for what was to become a walled city had been erected and the prefect was able to move into his new residence.⁴² The city wall itself was not built until after the Sino-French War that ended in 1885, and with the return of peace, work went ahead on the wall and other improvements to the city. Streets were rearranged and paved, electric lighting installed and Taipei was connected with the rest of the island and the outside world by means of a telegraphic

⁴⁰Cheng-Siang Chen, The City of Taipei, op. cit., pp. 5-7.

⁴¹Davidson, op. cit., p. 227; Dodd, op. cit., p. 165; G. L. Mackay, From Far Formosa (New York: Fleming H. Revell Co., 1895), p. 113, gives figures of 45,000 (Meng Chia) and 30,000 (Ta Tao Chen) but the exact date to which his figures apply is uncertain. Data relating to the import and export trade of northern Taiwan for the 1886-1909 period have been collected from British consular reports and reprinted in Annual Report on the Trade of North Formosa, 1886-1909 (Taipei: Ch'eng Wen Publishing Co., 1972).

⁴²Davidson, op. cit., p. 211.

communication system. With the elevation of Taiwan to provincial status in 1885 and seating of the provincial capital at Taipei in 1891 the future growth of the city as an administrative, industrial and commercial center was assured.

Arrival of the Japanese in 1895 marked an end to Chinese guidance of growth in Taipei. The wall around the official center of the city was torn down and replaced by wide boulevards resting on its base. A sewage system was installed and a dike built along the Tan Shui River as a flood control measure. The railroad linking Taipei with the port at Keelung was rebuilt along with the station on the north side of the previously walled area (Figure 3). By 1920, when Taipei was officially made a municipality, the three originally distinct communities had coalesced to form a solid urban core. At the end of World War II the built-up portion of the city covered the area from the Tan Shui River to Hsin Tien River on the south. Much of the growth, especially in the southern and southwestern part of the city, was due to the development of a residential area by the Japanese colonists.⁴³

Taipei has continued to expand during the thirty years that have elapsed since Taiwan was returned to Chinese

⁴³Cheng-Siang Chen, The City of Taipei, op. cit., pp. 6, 8.

control in 1945. Today the urbanized area includes virtually all land bounded by the Kee Lung, Tan Shui and Hsin Tien Rivers that is below 100 meters in elevation. In addition, growth has expanded the urbanized area to include contiguous portions of the basin beyond the administrative limits of the city. Considerable amounts of land to the south and west of Taipei are being converted from agricultural to urban uses. Much of the easily converted flat land within a radius of ten kilometers of the Taipei railway station has, in fact, already been put to use for industrial and residential purposes. This is particularly true of the area to the south and southwest of the city limits. Completion of the north-south freeway, traversing the northern and western sides of the basin, can be expected to contribute to westward expansion of the urbanized area. Given the trend in urban growth that has appeared over the last quarter century it seems highly probable that urban land uses will eventually cover the entire basin.

Population Growth and Expansion Trends in Taipei Today

The city of Taipei as it exists today reflects its development over the past two centuries. The area encompassing the original village of Meng Chia is characterized by narrow streets, old two and three story brick structures, and a high level of congestion. Ta Tao Chen has continued to be an important commercial sector of the city. In



addition, small industries producing a variety of goods have located in the area and new, multistory office buildings are replacing older structures.⁴⁴ The old walled area is the site of many governmental offices, financial institutions and military compounds.⁴⁵ It also contains most of the downtown shopping center for the city, is adjacent to the entertainment district, and is the focus of the public transportation system. In short, the previously walled area now contains the central business district and is marked by an emerging skyline made up of tall office buildings, stores and hotels.

New centers of commercial and industrial activity have emerged as the older portion of the city has experienced change and redevelopment. An industrial area astride the railway line leading to Keelung and to the east of Tung Hua

⁴⁴Pannell, *op. cit.*, pp. 85-88, elaborates on the traditional urban structure described as a "shophouse." The ground floor is used as a shop or small factory while upper floors provide living accommodations. In Meng Chia (today known as the Wan Hua district) this type of structure predominates and there has been relatively little replacement with newer, taller buildings. In the Ta Tao Chen area many of the traditional shophouses have been replaced by three, four and five story structures. The ground floors are still used for business and industrial purposes, but the upper floors are used more for business offices than for residential purposes. The ongoing replacement of older buildings is particularly noticeable along Chung Ching Road.

⁴⁵A sixty acre area abutting the southeast corner of the old walled portion of the city, occupied by military compounds, is scheduled to "... become the Chinese version of New York Rockefeller Center." "Ying Pien Plan Taking Shape," China News (Taipei), February 2, 1974, p. 4.

Road developed during the Japanese occupation. More recently a new commercial zone housing the offices of import-export firms, shippers, insurance companies and other enterprises has appeared to the east of Chung Shan Road between Nan King and Chung Hsiao Roads (Figure 3). Concurrently, a tourist-oriented area containing hotels, souvenir shops and airline offices developed along Chung Shan Road. At the same time a zone of small industrial operations, ranging from printing to machine shops, grew up to the west of Chung Shan Road with a mixture of offices and warehousing facilities extending north of Min Chuan Road.

Residential development in Taipei has also been considerable, with the southern and southeastern portion of the city, bordered by the Hsin Tien River and Kee Lung Road, undergoing great change. Multi-unit apartment buildings three and four stories in height have replaced single family dwelling units built by the Japanese.⁴⁶ Roads have been widened and are now lined with stores and office buildings.

⁴⁶Cheng-Siang Chen, The City of Taipei, op. cit., p. 12. Also see Barclay, op. cit., pp. 121-122. More recent descriptive materials dealing with land use in Taipei are generally lacking. The absence of contemporary descriptive works is largely due to the difficulties involved in obtaining data suitable for use in land use studies. Pannell, for example, had to carry out a sample survey in order to obtain data for his study of Tai-Chung's land use pattern. Pannell, op. cit., pp. 98-103. Similar studies could and should be undertaken in Taipei to provide an updated picture of the city's land use structure and changes that have taken place since the early 1950's.

Finally, residential land uses expanded onto land previously used for agricultural purposes, out to the eastern and southern margins of the basin. Similar structure replacement and land use change has occurred in the southwestern part of the city, and in an arc around the Taipei International Airport which is bounded by the Kee Lung River to the north and east.

Urban growth has also occurred in the area to the west and south of the municipal boundary of Taipei formed by the Tan Shui and Hsin Tien Rivers. The area on the west bank of the Tan Shui River contains a mixture of residential and industrial land uses, with industrial activity concentrated along Chung Hsin Road and extending to the southwestern end of the Taipei Basin. Agriculture still predominates on the far western side of the basin, but even there factories and apartment buildings are appearing in increasing numbers.

The south bank of the Hsin Tien River, particularly the Yung Ho Road area, is a recently developed and still growing residential district. It is somewhat unique among districts in the metropolitan area in that evidence of overall development planning is clearly visible. Broad avenues lace the area, making movement within the district easy in comparison to recently developed residential zones in Taipei proper. The area is hemmed in, however, by an industrial

area on the southeast and older residential-industrial land uses to the west.

Many of the changes that have taken place in Taipei, especially since the end of World War II, are reflected by changes in population throughout the city. Inner portions of the city have generally lost population while suburban areas have experienced considerable growth. An appreciation for the types of change that have occurred may be gained by examining population density trends in six sample tracts within Taipei (Figure 4). The tracts selected for examination represent a range of population growth trends in the city and take into account both tract size and location in terms of distance from the city center located at the main railroad station (Table 2).

The Fu Pei tract is located in the northwest section of the formerly walled central part of the city (Figure 3). This particular area lies within the central business district and has had a steady decrease in population since the early 1950's. The trend toward depopulation of the tract has been spurred by the replacement of old, two and three-story shophouses with multi-story office buildings. In addition, most of the remaining shophouses have been converted to commercial uses. Structures that used to contain residential units on the upper floors are today largely devoted to business enterprises. The combined effect of shophouse replacement and the conversion of former dwelling

Figure 4

Population Density Trends in Selected Tracts

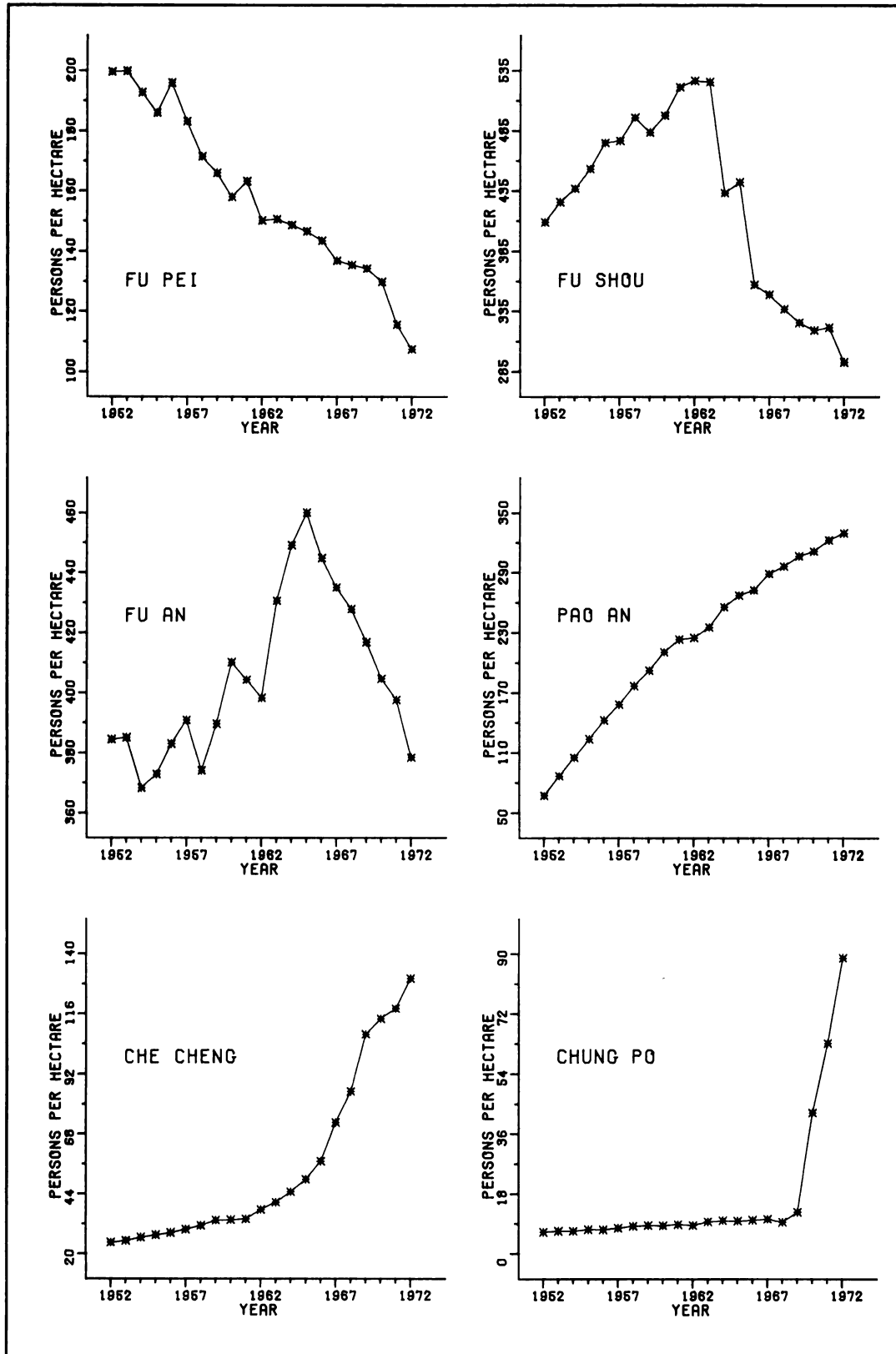


Figure 4.

Table 2

Sample Tracts:
Location, Size and Population Characteristics

Tract	Distance ^a (meters)	Area (ha)	Population Density ^b		
			1952	1972	Net Change
Fu Pei	290	9.7	199.5	107.4	-46.2%
Fu Shou	870	2.0	408.8	292.6	-28.4%
Fu An	1490	3.3	384.4	378.3	-1.6%
Pao An	3100	76.7	67.2	329.7	390.6%
Che Cheng	4440	60.8	24.5	130.1	431.0%
Chung Po	7030	108.7	6.6	89.0	1248.5%

^aDistance is measured from the main railroad station on the north side of the walled area to the center of each tract.

^bPopulation density is stated in persons per hectare.

units to commercial uses has been to reduce the availability of housing in the central business district and bring about a forty-six percent net decrease in the tract population between 1952 and 1972.

A little farther to the west, and on the edge of the central business district, lies the Fu Shou tract. Population rose throughout the 1950's and then began a decline that was at first precipitous and then, late in the 1960's, slowed to a pace similar to that found in the Fu Pei tract. The rapid decline in population that started in 1962 was brought about by the demolition and replacement of old,

one and two-story structures that had housed family operated businesses. Today the Fu Shou tract contains a mixture of commercial and entertainment establishments and is undergoing a continuing shift away from the traditional combination of business and residence in the same low-rise structure.

The Fu An tract lies south of the Fu Shou tract and on the northeastern edge of Meng Chia, the site of the original settlement that has become Taipei (Figure 3). There, too, structure replacement has led to a decline in population as residential units have decreased in number or been converted to commercial uses. The changes, however, have been less dramatic than in the more central portions of the city, reflecting the lower desirability of this congested and more remote section of the central business district and higher levels of resistance to displacement exerted by the inertia of a larger number of persons living in the area. Even though population decline in this inner city tract has been slower in coming and less dramatic in its net effects on population size, it is evident that a long term decrease in population is under way and likely to continue as the central business district expands.

In moving away from the inner city and toward the suburban areas a much different trend in population and residential structure change is found. While the innermost portions of Taipei generally experienced net decreases in population, the population in suburban areas increased

throughout the study period. The rate and period of maximum growth was not the same, however, in all suburban locations. In addition, changes in the landscape associated with increases in population were different from those found in the central part of the city. In the Pao An tract, about 1500 meters north of Ta Tao Chen, population growth was relatively steady over the twenty-year period under consideration. The increased numbers of people were accommodated by replacement of single-family dwellings and the conversion of agricultural and vacant land to residential uses.

The Che Cheng tract, located four and a half kilometers east of the railroad station, experienced a similar type of growth until the mid-1960's when the construction of free-standing, comparatively widely separated, high-rise apartment buildings was started. This tract and nearby areas today are marked by several clusters of apartment buildings and associated local office building complexes. This recent growth has resulted in the creation of secondary business and residential nodes at several major intersections and the rise of commercial strips along the major thoroughfares. In the mid-1970's, previously vacant land between major roads was rapidly being filled in with additional apartment buildings and businesses aimed at serving the needs of existing populations and anticipated new arrivals.

Population growth and residential expansion has been a more recent development in suburban fringe areas, with much of this area devoted to agricultural production through the late 1960's. Residential development on the suburban fringe has been quite different from that found in the middle suburban zone as exemplified by the Che Cheng tract. Block long apartment buildings four and five stories in height distinguish the most recently developed neighborhoods, and it is not uncommon to find the water of irrigated rice paddies lapping at the foundations of the newest buildings. In places like the Chung Po tract located seven kilometers to the east of the railroad station such construction activity is followed by a rapid increase in population density (Figure 4). Another distinguishing characteristic of the more recently developed residential areas is the absence of office buildings. Only daily necessities such as food and household oriented goods and services are provided by the local businesses. In many ways the most recently built and populated neighborhoods bear the strongest resemblance to the middle-class residential suburbs as they are known in the developed Western world.

Like most growing cities, Taipei suffers from the effects of rapid urbanization. Foremost and most visible among the problems is that of traffic congestion. Streets and roads are clogged, especially during the morning and evening rush hours, due to the increasing number and use

of motor vehicles. Considerable effort and money has been invested to alleviate the problem, but thus far only with mixed results. Streets have been widened, oxcarts and pedicabs banned from the inner city, and under and overpasses constructed to reduce the conflict between vehicular and pedestrian traffic. The problem is far from solved, however, and in the summer of 1974 the bus system was reorganized to improve service and reduce congestion in the downtown area.⁴⁷

A further problem facing the city concerns water supply and runoff disposal. Large scale pumping of groundwater has led to subsidence and the threat of saltwater invasion of the groundwater supply.⁴⁸ Water drawn from the Hsin Tien River is threatened by industrial pollution.⁴⁹

⁴⁷The traffic situation is a topic of continual editorial comment and criticism in the local press. A study of the bus system was conducted in the early 1970's and a restructuring of the system carried out in 1974. National Taiwan University Graduate School of Civil Engineering, Public Transportation Route Study (Ta Chung Yun Shu Lu Hsein Yen Chiu Kuei Hua) (Taipei: Transportation Bureau, Taipei City Government, September, 1973). Also see "City Gov't Discloses Bus Rerouting Plan," China News (Taipei), June 4, 1974, p. 4.

⁴⁸"Taipei Sinks 16 CM. A Year," China News (Taipei), November 15, 1973, p. 4. The lowest groundwater level in Taipei is almost 46 meters below sea level. "To Help Prevent Sinking of Taipei Basin," China News (Taipei), January 26, 1974, p. 4.

⁴⁹At one time a plan to annex the area containing the Hsin Tien watershed to the city was considered. "Taipei Wants to Annex Wulai, Hsintien," China News (Taipei),



Expansion of the built-up area and multiplication of paved roads and sidewalks have increased problems in handling runoff. The problem is most pronounced during the typhoon season when torrential downpours drench the area. Local flooding is not uncommon in Taipei and widespread flooding often occurs on the undiked, western side of the Tan Shui River.

Other problems include those associated with building on highly plastic alluvial soils in a seismic area, provision of public services, and noise and air pollution. Soil conditions effectively limit the height of buildings without extensive and costly foundation preparation.⁵⁰ The demand for public services far exceeds supply. For example, the availability of telephones is limited to the extent that telephone numbers are offered for sale via the classified want-ad sections of both Chinese and English language

October 24, 1973, p. 4. An expansion of the city's water-works was started in 1974 with the goal of ending chronic water shortages. "No Shortage of Tap Water By 1975, Mayor Says," China News (Taipei), January 17, 1974, p. 4.

⁵⁰Construction of caisson-like retaining walls is frequently required in order to prevent collapse of excavations for apartment house basements. Construction of buildings over five stories in height generally requires the deep driving of piles and very heavily reinforced and massive foundation works. These problems have not slowed the rise and spread of tall buildings. "High Rise Buildings Continue To Increase," China News (International Airmail Edition), February 20, 1976, p. 1.

newspapers. Noise associated with the flow of traffic is most pronounced during the rush hours and provides a constant background din throughout the day.⁵¹ The ever-increasing number of motor vehicles adds not only to the noise level but also to the air pollution problem. Taipei, like many other motorized cities, wears a brown blanket of smog, especially during the warm part of the year. The presence of numerous industrial plants in the basin only adds to the problem.

Along with modifications in the physical make-up of the city and general problems of urbanization have come changes in population distribution. From a town of less than 100,000 persons in the 1880's, Taipei has grown into a metropolitan center containing more than two million people. Detailed data were collected in order to facilitate an analysis of changes in population density distributions that occurred in the city during the 1950-1972 period.

⁵¹Main street noise levels range from 72 to 90 decibels and are increasing. "Noise Level Reaches Danger Point Here," China News (Taipei), June 10, 1974, p. 1.

CHAPTER III

DATA ACQUISITION AND MANIPULATION

The Taipei Metropolitan Area was defined for the purposes of this study as including twenty-nine administrative districts in part, or entirely within the Taipei Basin.⁵² The selection of districts for inclusion in the general metropolitan area was done on the basis of map study and field work involving extensive travel within the basin. The present City of Taipei is made up of districts 1 through 16 and its administrative boundary is marked by the bold line in Figure 5. The remaining thirteen districts (numbers 17

⁵²Use of the term 'district' to describe the 29 administrative areas is somewhat misleading in that the Chinese terms Chu, Chen, Hsiang and Shih indicated in Figure 5 imply administrative differences. Only districts within and under the jurisdiction of Taiwan's major cities are labeled Chu. The remaining terms are used in conjunction with county administered areas. Units designated Shih have populations exceeding 100,000 persons, advanced commerce and industry, good communication services and sound internal administrative organs. The Chen (urban townships) are the lowest level county administered urban units. They are distinguished primarily by populations under 100,000 and absence of features required for classification as Shih. Units labeled Hsiang (rural townships) generally have smaller populations and contain large areas of mountainous terrain and/or lands used for agricultural purposes. The term 'district' will be used throughout the discussion when referring to the administrative units shown in Figure 5. See Pannell, op. cit., pp. 46-51, for a more detailed discussion of the administrative hierarchy.

Figure 5

Administrative District Boundaries in
The Taipei Metropolitan Area

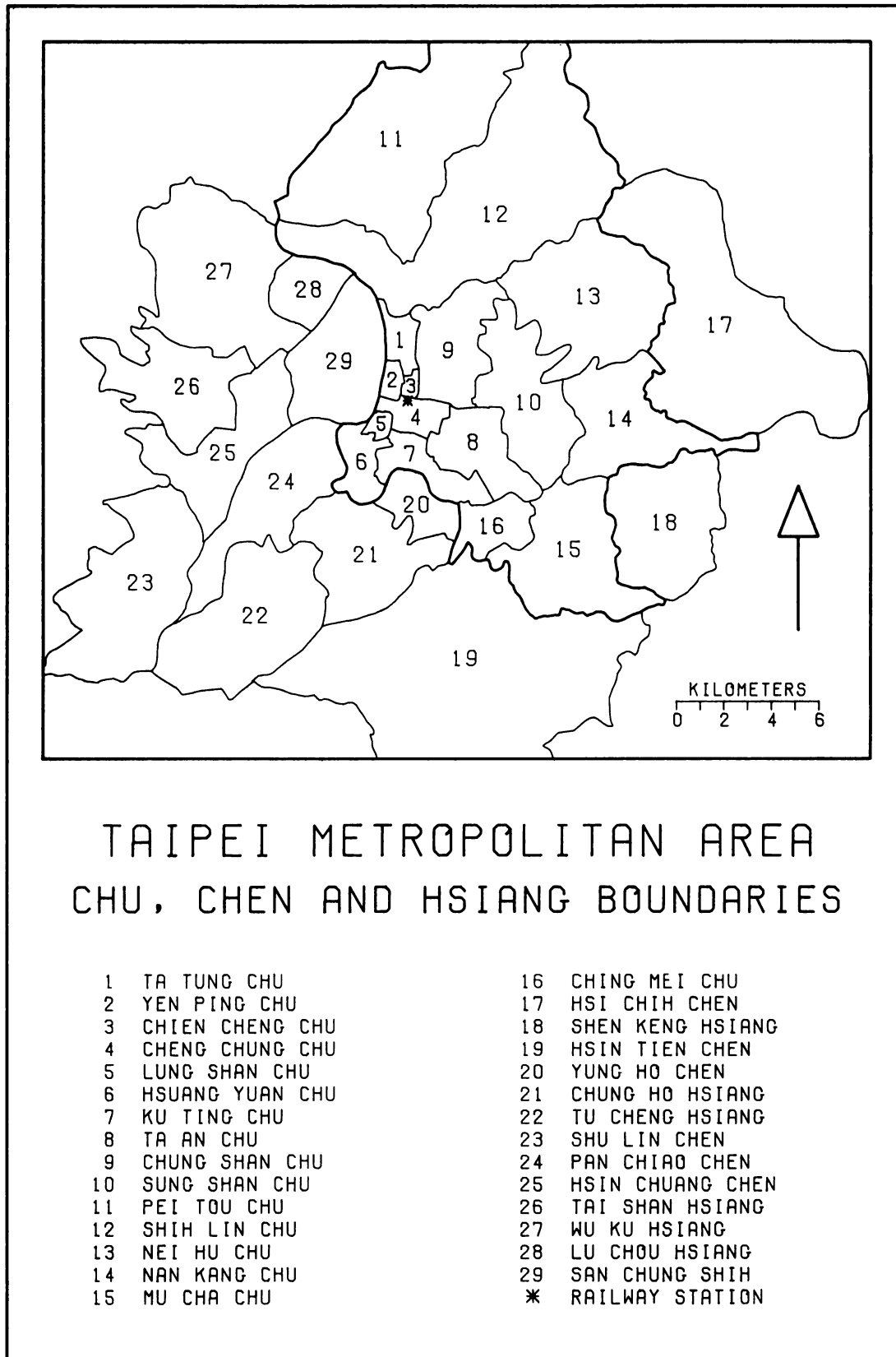


Figure 5.

through 29) are under the administrative jurisdiction of Taipei County.

The City of Taipei, as originally incorporated by the Japanese in 1920, consisted of districts 1 through 9. District 10 was annexed to the city in 1938, thus bringing the industrial zone under city control.⁵³ No further additions to the city's territory were made until 1967 when Taipei was shifted from provincial jurisdiction to that of the national government. Six districts (11 through 16) were added to the city at that time, bringing its area to a total of 272 square kilometers. Between a quarter and a third of this area lies above 100 meters in elevation, with the bulk of the mountainous terrain located in the northern parts of districts 11, 12, and 13.

Each of the administrative districts is subdivided into smaller units that will be described here as tracts.⁵⁴ The tracts vary in size from less than one hectare in the

⁵³The area shown in Figure 3 approximates the area encompassed by districts 1 through 10, plus districts 20 and 29 in Figure 5.

⁵⁴Urban districts (Chu, Chen and Shih) are subdivided into smaller units titled Li, generally translated as 'precinct.' Rural districts (Hsiang) are subdivided into Tsun, or villages. Each of these subunit's areal size is related to its population size. When the population comes to exceed a certain number in a Li or Tsun it is supposed to be divided to create a new unit. Strict adherence to the division criteria is not practiced, however, and there is considerable variation in the number of persons present in each unit. Pannell, op. cit., pp. 51-59.

inner city to well over one thousand hectares in the peripheral mountainous areas. At the end of 1972 the metropolitan area contained 944 tracts, 608 of which were located within the administrative boundaries of Taipei (districts 1 through 16). The 944 metropolitan area tracts were used as observational units for the collection of data related to population density.

Area Data

Three pieces of information were used from each tract in order to derive population density gradient parameters. Tract populations and areas were needed to compute density values. Measures of the distance separating each tract from the city's center were required in order to evaluate the density-distance relationship. Acquisition of tract area data proved to be the most tedious portion of the data gathering process.

A set of maps showing tract boundaries within the city of Taipei was obtained from the city government.⁵⁵ Similar maps showing tract boundaries within county administered districts were secured from the respective district

⁵⁵Civil Affairs Bureau, Tai-pei Shih Ko-chu Hsing-Cheng Chu-yu Tu (Taipei City Administrative Boundary Maps), (Taipei: Taipei City Government, June, 1970). A more recent and updated version of these maps has been commercially printed as Tai-pei Shih Fen-chu Ti-tu (Taipei City District Maps), (Taipei: Nan Hua Publishing Co., 1974).

headquarters offices. Tract area data were available only for districts 24 and 29 (Figure 5) and it was therefore necessary to derive tract areas for the remainder by means of planimeter measurement on the district maps.⁵⁶ The accuracy of the measurements was checked by summing tract areas within each district and comparing the sum with the published district area.⁵⁷ Differences between published district area and summed tract areas greater than five percent of the published area value led to remeasurement of the tracts. Measurement errors of less than five percent were distributed among the tracts in proportion to individual tract areas. This procedure was repeated for each district where area data were unavailable. Total measurement error (under plus over measurement) for the 608 tracts in Taipei City was 1.97 percent of the city area. For the metropolitan area as a whole the total error was 2.19 percent. A sample of tracts from districts 24 and 29 were also measured and the derived area values were virtually identical to those supplied with the maps.⁵⁸

⁵⁶The instrument used for making the measurements was an SE 10 Tamaya, Model 663, compensating planimeter (#22376), produced by the Sokkisha Company of Tokyo, Japan.

⁵⁷Department of Civil Affairs, Household Registration Statistics of Taiwan, Republic of China 1963-1964 (Nantou, Taiwan: Taiwan Provincial Government, June, 1965), Part II, Table 7, pp. 82-93.

⁵⁸Map scale problems were encountered during the area measurement work. In some cases the representative

Two area values were obtained for tracts bordering the Kee Lung, Tan Shui and Hsin Tien Rivers. One value represented all area within the tract boundaries. The second represented only area utilized for urban purposes. Almost all of the Hsin Tien, and the eastern bank of the Tan Shui, Rivers are diked. In some areas, especially along the Hsin Tien River, large amounts of land may not be used because they lie between the dike and the riverbed. The need for, and use of, the second area value was related to the prohibition of construction between dikes and the riverbed. With a few exceptions, there are no structures anywhere between dike and riverbed along the diked portions of the rivers.⁵⁹ Undiked portions of the Tan Shui and Kee Lung

fractions were found to be incorrect, and in others there were no indications of scale on the maps. The problems were solved by deriving exact representative fractions from the planimeter readings, rounding the figures to commonly encountered values, and then checking them by measurements in the field. Field checking involved the use of a 50 meter tape, repeated pacing over medium distances, and repeated use of taxi cab odometer readings over distances greater than one kilometer. The accuracy of the scale factors thus obtained was further substantiated when a single scale base map was constructed using the variously scaled district maps. Pantograph settings based on the corrected or new representative fractions yielded correct matching of map features common to adjacent districts.

⁵⁹ The exceptions to this pattern include training courses associated with driver education schools, a plant processing sand and gravel dredged from the Hsin Tien River, and the wholesale fruit, vegetable and poultry market for the city. All of these activities are located high on the floodplain and immediately adjacent to the dikes. Some of the floodplain land, including the island in the Tan Shui

Rivers exhibit a similar absence of buildings close to the banks. Such regulated non-use land areas were excluded from the area values in computing population densities.

Distance Data

The second element of the data set needed in order to derive density gradient parameters consisted of measures of distance. The acquisition of such measures required cartographic work, field observation and computation. The cartographic work involved preparation of a single basemap showing district and tract boundaries. A pantograph was used to convert the variously scaled district maps to a common scale of 1:15,000.⁶⁰ Once the basemap had been prepared it was traced onto graph paper divided into one millimeter intervals. Using the graph paper, center points were marked in each tract and the corresponding X, Y location coordinates recorded.

A center point was assigned to each tract on the basis of the apparent center of population. Assignment of center points was relatively easy within the inner portion

River, is used for agricultural purposes. None of this land is used for residential purposes, not even by squatters.

⁶⁰A PG-84 pantograph (#2302) produced by the Fuji Company of Tokyo was used in making the 1:15,000 basemap. The work was later checked by means of an optical enlarger-reducer. Only minor errors were found, but none were large enough to require relocation of center points.

of Taipei and the densely settled portions of the county administered districts. The tracts tended to be quite small and with few exceptions the physical centers coincided with population centers.⁶¹ The assignment of center points to tracts in outlying areas, however, required the expenditure of considerable time for field observation of settlement patterns. Numerous trips were made into less heavily settled zones on the mountainous periphery of the metropolitan area and to the agriculturally dominated area on the western side of the basin. As expected, population concentrations were found at crossroads, bridging points and near land areas devoted to agricultural uses.⁶² The end product of this work was a series of X, Y location coordinate values defining tract center points based upon population concentration.

A center point for the entire metropolitan area was needed in order to facilitate distance computation

⁶¹Exceptions to this general pattern included tracts containing the downtown public park, the railway station with its associated switching area, military compounds, and similar readily identifiable areas. Center points for tracts containing such features were assigned on the basis of observed population concentrations.

⁶²General agreement was found to exist between the locations of population concentrations on the one hand, and officially designated bus stops and street patterns appearing on district maps on the other hand. A number of ad hoc bus stops not shown on route maps were found and recently built-up areas not appearing on district maps were discovered.

procedures. Several locations were considered as possible reference points from which distance to tract centers could be measured. Use of the peak value intersection proved impossible due to repeated changes in its location during the 1950-1972 period. City Hall was ruled out due to a change in its location that came about with the construction of a new facility.⁶³ Two long standing central structures, the Presidential Office Building and the main railroad station, were also considered. The Presidential Office Building, located in the center of the formerly walled portion of the city, was dropped from consideration because it is somewhat removed from the central business district. The railroad station, lying between the walled area and Ta Tao Chen, was finally settled upon as the metropolitan area center point.

The Taipei Railway Station possesses several characteristics that make it suitable for use as a center point for the Taipei Metropolitan Area. It is a structure that is centrally located and has not experienced locational change, thus providing a constant reference point for the

⁶³The City Council chambers are now located at the intersection of Chung Shan and Chung Hsiao Roads. The city government offices with which most people have dealings are located approximately 500 meters north of the railway station on Chang An Road (Figure 3). Both sites are considerably removed from the central business district.

entire period under study. It is also the focus for not only commuter and long distance rail passenger service, but also the focal point for provincial and city bus systems. Highway bus terminals are located on the eastern and western sides of the station while the street in front of the railway station is lined on both sides with stops for intra-urban buses. Finally, the station is immediately adjacent to the downtown area and serves as a focal point through or past which the great majority of people pass on their trips to the central business district.

With the metropolitan area center point selected and tract center points defined, derivation of the distance values became a straightforward computational procedure. The X, Y location coordinate values for the tract and metropolitan area center points were used to obtain straight line distance values via the following formula:⁶⁴

$$\text{Distance} = \sqrt{(X_t - X_c)^2 + (Y_t - Y_c)^2} \cdot (.015)$$

Where X_t = tract center point X coordinate

X_c = metropolitan area center point X coordinate

Y_t = tract center point Y coordinate

Y_c = metropolitan area center point Y coordinate

.015 = conversion factor yielding distance in kilometers

⁶⁴The formula represents an application of the Pythagorean theorem which equates the hypotenuse length of a right triangle to the sum of the squared lengths of the orthogonal sides, e.g., $A^2 + B^2 = C^2$.

All but twelve of the tracts were found to be within fifteen kilometers of the railroad station, and the most distant tract is located 17.7 kilometers to the southwest of the city's center.

Population Data

Population data were obtained from year-end registration reports prepared by the household registration departments in each of the district administrative offices. The household registration system used on Taiwan provides a data base comparable to a population register where the basic unit of registration is the household. Various demographic characteristics are recorded for each household, including the number of persons registered as living there.

The data are aggregated by tract and recorded in monthly, quarterly and annual reports. Prior to the preparation of the year-end annual reports, district officials visit each household to correct and update registration records. The year-end reports form the basis for demographic data published by the Ministry of the Interior in annual editions of the Taiwan Demographic Fact Book. Because tract data are aggregated to the district level for publication, it was necessary to visit each of the district offices to obtain tract level data.

Year-end annual reports were reviewed and data recorded for the number of persons registered as living in

each tract for each year during the 1950-1972 period. While the reports were found to be virtually complete, several instances occurred where individual values were either missing from the reports or illegible. In most cases it was possible to obtain missing values by consulting related tables in the reports.⁶⁵ Three of the districts (numbers 5, 7 and 10 in Figure 5) did not have records for 1950. The 1950 tract values for these districts were estimated by dividing the published population value among the tracts in proportion to the number of persons living in each tract in 1951.

The most serious missing data problem was encountered in the records for the Chung Shan district (number 9 in Figure 5). Reports for the 1950-1968 period were unavailable due to their destruction in a typhoon related flood. Efforts to locate copies of the missing year-end reports at other governmental offices proved unsuccessful and it was therefore necessary to estimate tract populations for the entire nineteen-year period. The estimates were made on the basis of tract population data for 1969, the earliest year for which tract data could be obtained. The published

⁶⁵ Summations across age-sex breakdowns within the reports provided the bulk of the missing values. Others were obtained by consulting the monthly and quarterly reports. In a few cases it was necessary to use linear interpolation between values for preceding and succeeding years in order to get an estimate for a missing value.

district population value for each year was divided among the tracts according to the proportion of the district population found in each tract in 1969. This estimating procedure had important repercussions on the results of the analysis and led to the discovery of an interesting feature of the population density gradient model.

A check on the correctness of the data gathered was made by comparing the sum of tract population values to the published district values. Ideally, the sums and published values should have been identical; however, slight differences were found. Tract sums were 0.54 percent greater than the district level values over the entire metropolitan area for the 1950-1972 period. The tract sums for districts under city administration (districts 1 through 16) were 0.74 percent greater than the published values, while those for districts under county administration (districts 17 through 29) were 0.07 percent less than the published district population values. The differences in the sums are attributable in part to corrections made in published figures not reflected in the original year-end reports and in part to errors made during the process of recording, coding and punching the data onto computer cards.⁶⁶ These errors

⁶⁶The data recording sheet for each tract was examined for anomalous values prior to the final coding of the data. Several errors resulting from the transposition of digits and misreading of the reports were corrected as

were considered irreducible since complete elimination of error could not be achieved without resorting to a full review of the year-end reports.

Aggregation and Transformation

During the 1950-1972 period tracts throughout much of the Taipei Metropolitan Area experienced not only population increases, but also underwent subdivision for administrative purposes. In 1950 there were 662 tracts in the metropolitan area. By the end of 1972 the number of tracts had risen to 944. This forty-three percent increase in the number of tracts led to a problem in terms of data continuity: No data were available for the newer tracts for the years preceding their creation.⁶⁷

The data continuity problem was solved by combining data for the newly created tracts with that of the parent tracts. Population values for each year were added to obtain a complete time series of values for the parent

a result of this procedure. The coding forms themselves were routinely double-checked with the field data forms to ensure that they were free from error. The punched cards were verified prior to their use as input for analytical purposes.

⁶⁷The Yung Ho district (20) was itself created by division of the Chung Ho district (21) in 1958. Since it was possible to separate and distinguish data for the 1950-1957 period for the Yung Ho district it has been treated as a separate district for purposes of this discussion.

tracts. Area values for the new tracts were similarly added to parent tracts to yield tract areas as they existed in 1950. New center points were assigned to the reconstructed parent tracts and distance values recomputed. The result of combining parent and new tracts was a set of data associated with units of observation that remained constant throughout the 1950-1972 period.

Data for the 662 time constant tracts were prepared for analysis in two forms. The first of these consisted of aggregating the data by concentric rings, each 500 meters in width and centered on the Taipei Railway Station. Tracts whose center points fell within a given ring had their population assigned to that ring. The population density within each ring was computed using the aggregated population data and ring area. The values were then transformed to the natural logarithm of density for analysis in conjunction with distance from the railway station to the middle of each ring. The second method of data preparation involved the computation of population densities for each tract and their transformation to the natural logarithmic base. The values for each of the years were arrayed with the distance values for analysis.

Demographic, Transportation and Economic Data

Demographic, transportation and economic data were collected in order to illustrate the connection between the

demographic transition, economic development and the emergence of a Western density gradient pattern. The demographic data consisted of dependency ratios and crude birth and death rates.⁶⁸ Measures of the availability of various types of transportation (bicycles, motorcycles, automobiles, trucks and buses) were obtained so that the transportation-gradient pattern relationship could be evaluated.⁶⁹ Finally, economic and employment data were secured on the theory that economic development involves a shift in employment from agriculture to other activities and that per capita incomes increase as economic development occurs.⁷⁰

Data for a total of twenty-one variables made up the array of information analyzed in conjunction with the density gradient parameters. These data were drawn from a variety of sources including the 1972 edition of the Taiwan Demographic Fact Book, the Transportation and Communication Information quarterly, and the Taiwan Statistical Data

⁶⁸G. J. Stolnitz, "The Demographic Transition: From High to Low Birth Rates and Death Rates," in Ronald Freedman (ed.), Population: The Vital Revolution (Garden City, N. Y.: Doubleday, 1964), pp. 30-46.

⁶⁹Clark, "Transport--Maker and Breaker of Cities," op. cit.

⁷⁰Paul Ke-Chih Liu, Interactions Between Population Growth and Economic Development in Taiwan (Institute of Economics Monograph Series No. 7. Taipei: Academia Sinica, August, 1973).

Book.⁷¹ Two shortcomings of the data are noteworthy. In the case of data pertaining to the number of motorcycles registered, there was a change in the reporting system in 1967. From 1952 through 1967 only motorcycles having an engine displacement of fifty cubic centimeters or more were reported as registered, thus understating the number of machines actually in use. Since 1966 the data include all motorcycles regardless of engine displacement. Although the increase in the number of machines reported created by the change in reporting system is rather large, the values will be treated as a single series for analytical purposes. The other shortcoming is the absence of data for all but the birth and death rate variables for 1950 and 1951. The evaluation of the relationship between density gradient parameters and development indicators was therefore limited to the 1952-1972 period. The variables used for analysis in conjunction with density gradient parameters are discussed in more detail in Chapter V. The data values for each of the variables are listed in Appendix B.

⁷¹Taiwan Demographic Fact Book (Tai-wan Jen-kou Tung-chi), (Taipei: Ministry of the Interior, September, 1973); Transportation and Communications Information (Chiao-tung Yun-shu Tzu-liang), (Taipei: Transportation Planning Board, Ministry of Communications); Council for International Economic Cooperation and Development, Taiwan Statistical Data Book, 1973 (Taipei: Executive Yuan, 1973).

Reiteration of Hypotheses

The density and distance data formed the basis for testing the hypothesis that population density patterns for Taipei, a non-Western city, exhibit the same kind of changes that have occurred with the passage of time in Western cities. The testing of this hypothesis through analysis of the density and distance data is discussed in Chapter IV. Density gradient parameters describing the density gradient pattern for Taipei are, in turn, used to test the second hypothesis, that the appearance of a Western type of urban population density gradient pattern is associated with economic development. Descriptions of the trends in data for the economic development indicators are presented, along with the results of simple correlation analyses, in Chapter V. Conclusions based upon the results of the analyses, and recommendations related to the Western - non-Western dichotomy and future research, are contained in Chapter VI.

CHAPTER IV

POPULATION DENSITY GRADIENTS: ANALYSIS AND FINDINGS

Population Growth and Weighted Mean Centers

In light of the supposed characteristics of non-Western cities, there is a feature of Clark's population density gradient model that deserves consideration before undertaking the data analysis. Berry, et al., maintained that:

In the West central densities rise, then fall; in non-Western cities they register a continual increase. In the West density gradients fall as cities grow; in non-Western cities they remain constant.⁷²

The time-constant gradient and constantly increasing central density situation described for non-Western cities can come about in only one way: addition of the same number of persons at all points in an urban area. However, since Clark's model is exponential in form and rendered linear by means of logarithmic transformation of population density values, the required form of population change is actually multiplicative, deriving from the fact that the addition of logarithmic values corresponds to multiplication of arithmetic

⁷²Berry, Simmons and Tennant, op. cit., p. 401.

values.⁷³ The addition of a logarithmic value at all points corresponds to multiplication by a single arithmetic value at all points, and the single value so applied is the growth rate of the population under consideration. Thus the non-Western city can be expected to have the same population growth rate throughout its entire area and within its component parts. Different growth rates in various parts of a city may indicate a Western type of city. Therefore, a simple examination of population growth rates may be employed to determine whether or not a city is of the non-Western type.

Another characteristic of the non-Western city may be deduced from the nature of Clark's model. Since identical growth rates at all points mark the non-Western city, we may expect that there will be no change in its population weighted mean center, or in the weighted mean centers of the city's component parts over time. This phenomenon will occur since application of the same growth rate at all locations will result in increasing the population weights proportionally for all points. Such proportional increases in all weights will yield no change in population weighted mean centers even though considerable growth occurs. The Western type of city with its various growth rates, however, may be

⁷³Federal Electric Corporation, Logarithms (New York: John Wiley and Sons, Inc., 1972), pp. 98-108.

expected to exhibit shifts in weighted mean centers with the passage of time.⁷⁴

Data for the Taipei Metropolitan Area indicate two population growth trends within the general study area. In general, there was a much more rapid increase in population during the 1950-1972 period in the metropolitan area than in Taiwan Province (Table 3). Taipei's growth was due not only to population increase within the city, but also to urbanization of the island's population, a process that has continued for some time on Taiwan.⁷⁵ Second, and more importantly, figures for the ten districts comprising Taipei in 1950, the sixteen districts within its boundary in 1972, and the county administered districts in the metropolitan area show that the rate of population change was not the same over the entire region. Growth rates based on tracts whose center points lie within six kilometers of the Taipei

⁷⁴See Appendix A for a more detailed discussion of the relationships between growth rates, population weighted mean centers and density gradients.

⁷⁵Alden Speare, "Urbanization and Migration in Taiwan," Taiwan Population Studies, Working Paper No. 11, Population Studies Center, University of Michigan, March, 1971; idem., "The Determinants of Migration to a Major City in a Developing Country: Taichung, Taiwan," in Essays on the Population of Taiwan (Taipei: The Institute of Economics, Academia Sinica, February, 1973), pp. 167-188; C. W. Pannell, "Urbanization and City Growth in Taiwan," Journal of Geography, Vol. 72 (1973), pp. 11-20; Lung, op. cit.; Shao-hsing Chen, op. cit.

Table 3

Population Change 1950-1972^a

Area ^b	1950 ^c Population	1972 Population	Net Change	Percent Change
Taiwan Province	7,554,399	15,289,000	7,734,601	102
Taipei Metropolitan Area	802,939	2,914,947	2,112,008	263
City Districts 1-10	495,197	1,471,830	976,633	197
City Districts 1-16	595,085	1,925,569	1,330,484	224
County Districts 17-29	207,854	989,288	781,434	376
Tracts Within 6 Km. Radius	577,271	1,964,553	1,387,282	240

^aYear-end data^bDistricts referred to are those shown in Figure 4^cExcluding military personnel

Railway Station illustrate the changes that occurred in this more regularly shaped area.

Compound rates of population change further illustrate the differences between gross components of the metropolitan area (Table 4). Going one step farther, the data for individual districts show that growth rates varied considerably throughout the metropolitan area (Table 5). In addition, the spatial distribution of growth rates is similar to that found in Western cities in that the rate of population change was very low throughout the 1950-1972 period in districts containing the historical core of the city (districts 2 through 5). In fact, in the late 1960's population began to decrease in the central area, with the earliest declines starting in 1965 at the tract level. Districts immediately adjacent to the central area (districts 1, 6 through 9, and 29) experienced high but declining growth rates as suburban growth occurred. The other more peripheral districts generally had stable or increasing rates of growth associated with the development of new residential areas. The Yung Ho district (20) is the most outstanding case among this group.

Given the nature of the population growth rates, it is not surprising that considerable changes in the locations of population weighted mean centers occurred. During the twenty-two-year period under study, the mean center for the metropolitan area moved 330 meters to the southeast of

Table 4
Compound Rates of Population Change*

Area	Time Period			
	1952-72	1952-57	1957-62	1962-67
Taiwan Province	3.26%	3.58%	3.51%	2.92%
Taipei Metropolitan Area	6.04%	6.40%	5.40%	5.51%
City Districts 1-10	5.08%	6.14%	5.62%	4.70%
City Districts 1-16	5.48%	5.98%	4.79%	5.00%
County Districts 17-29	7.35%	7.59%	7.00%	6.72%
Tracts Within 6 Km. Radius	5.73%	6.62%	5.22%	5.51%
				4.42%

* Periodic compound rates based on year-end data

Table 5

Compound Rates of Population Change by District in Percent. *

District	No.	Time Period				
		1950-72	1952-57	1957-62	1962-67	1967-72
Ta Tung	1	5.57	8.07	4.99	3.44	1.34
Yen Ping	2	0.15	0.93	0.76	0.50	-0.74
Chien Cheng	3	1.54	1.58	0.71	0.99	-0.95
Cheng Chung	4	1.95	1.96	0.89	0.99	-1.46
Lung Shan	5	0.91	3.47	0.48	0.66	-1.16
Hsuang Yuan	6	6.95	9.46	7.63	6.22	4.35
Ku Ting	7	5.05	7.12	4.70	4.17	1.89
Ta An	8	9.18	10.22	4.81	6.36	5.34
Chung Shan	9	4.96	7.65	6.85	5.76	3.18
Sung Shan	10	8.61	8.32	9.49	9.88	10.28
Pei Tou	11	6.95	4.90	5.43	4.93	8.95
Shih Lin	12	7.22	3.90	6.03	7.80	8.71
Nei Hu	13	7.37	4.33	5.51	9.31	7.16
Nan Kang	14	6.42	5.87	5.07	5.30	5.43

Table 5
(Continued)

District	No.	Time Period				
		1950-72	1952-57	1957-62	1962-67	1967-72
Mu Cha	15	7.38	9.60	7.32	4.86	8.59
Ching Mei	16	7.49	6.75	7.12	4.16	12.45
Hsi Chih	17	4.38	3.28	4.09	3.23	4.13
Shen Keng	18	2.09	2.03	3.71	1.48	2.01
Hsin Tien	19	7.48	8.09	7.53	5.46	5.06
Yung Ho	20	13.46	18.74	12.86	9.98	10.11
Chung Ho	21	8.84	7.70	7.01	10.51	12.20
Tu Cheng	22	3.98	4.15	4.74	4.51	4.27
Shu Lin	23	4.88	2.92	3.63	3.88	5.56
Pan Chiao	24	8.55	7.56	7.90	4.15	12.11
Hsin Chuang	25	5.98	4.09	3.31	5.48	12.06
Tai Shan	26	4.87	3.29	3.01	6.29	8.34
Wu Ku	27	5.41	2.22	2.72	9.22	4.92
Lu Chou	28	3.86	1.96	3.86	3.55	7.05
San Chung	29	8.62	13.86	9.10	8.80	5.85

* Periodic compound rates based on year-end data

the Taipei Railway Station. The shift was largely due to rapid and extensive residential development in the eastern and southern portions of the city. Each of the districts in the metropolitan area also experienced a shift in its population weighted mean center (Table 6). Net shifts in mean centers during the 1950-1972 period are illustrated in Figure 6. The arrows indicate the direction in which the centers moved, while the length of the solid portion of each arrow shaft is proportional to the distance of the move. The circle appearing in Figure 6 has a radius of six kilometers and is centered on the railway station. It can be seen to mark a boundary between districts whose centers moved away from the station and those whose centers generally moved toward the station. Additional comments concerning the area bounded by the circle will be presented along with the discussion of population density gradients.

The case of the Chung Shan district (9) is the most interesting and illuminating, in terms of population weighted mean centers, of any in the metropolitan area. It will be recalled that population values were estimated for the tracts in this district by proportionally allocating population among tracts on the basis of the 1969 proportional distribution.⁷⁶ This resulted in all tracts having

⁷⁶See Chapter III, pp. 69-70.

Table 6
Changes in Population Weighted Mean Centers*

District	No.	Time Period				
		1950-72	1952-57	1957-62	1962-67	1967-72
Ta Tung	1	242	76	60	34	21
Yen Ping	2	21	15	15	15	15
Chien Cheng	3	21	0	0	15	15
Cheng Chung	4	114	15	21	45	42
Lung Shan	5	21	15	15	21	0
Hsuang Yuan	6	375	47	67	138	142
Ku Ting	7	251	76	109	54	34
Ta An	8	646	181	54	135	168
Chung Shan	9	62	0	0	0	62
Sung Shan	10	345	109	15	108	183
Pei Tou	11	303	106	54	128	266
Shih Lin	12	513	64	148	129	342
Nei Hu	13	192	42	62	21	47
Nan Kang	14	129	108	67	64	30

Table 6
(Continued)

District	No.	Time Period				
		1950-72	1952-57	1957-62	1962-67	1967-72
Mu Cha	15	399	150	15	108	200
Ching Mei	16	215	34	76	62	109
Hsi Chih	17	128	101	21	30	60
Shen Keng	18	34	45	0	15	34
Hsin Tien	19	855	262	242	150	196
Yung Ho	20	30	138	67	34	157
Chung Ho	21	196	67	47	138	151
Tu Cheng	22	321	34	171	54	64
Shu Lin	23	605	64	85	159	234
Pan Chiao	24	295	101	159	240	340
Hsin Chuang	25	230	54	81	117	128
Tai Shan	26	153	47	21	91	150
Wu Ku	27	510	30	34	384	106
Lu Chou	28	181	30	15	34	101
San Chung	29	366	81	42	96	242

* Distance of shift in meters

Figure 6

Taipei Metropolitan Area
Net Shift in Population Weighted Mean Centers,
By District, During the 1950-1972 Period*

*The arrows indicate the direction in which population weighted mean centers moved, and the solid portion of each arrow shaft is proportional to the distance of the move. The circle has a radius of six kilometers and is centered on the Taipei Railway Station.

See Figure 5, p. 59, for an index map of the Administrative Districts.

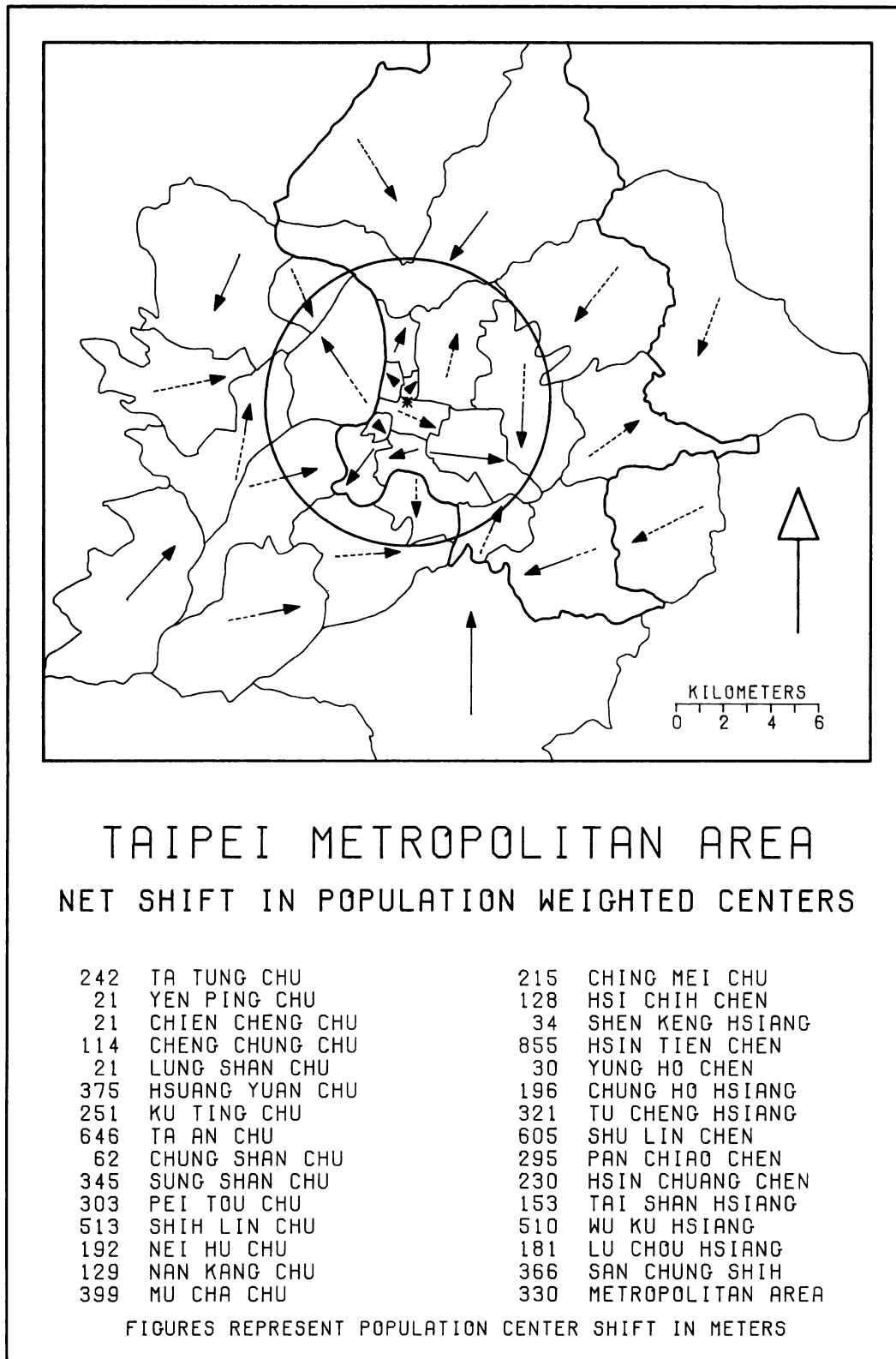


Figure 6.

a population growth rate identical to that of the district in each year during the 1950-1969 period. As expected, the district population weighted mean center remained in the same location from 1950 through 1969. All of the sixty-two meter change in the district's mean center location occurred between 1969 and 1972, the period for which tract data were directly available. This finding, although based on artificially induced conditions, amply illustrates the validity of the relationship between growth rates and population weighted mean centers described earlier. It also points to the existence of constant density gradients and continually increasing central densities postulated for non-Western cities.

Population Density Gradients

The first step in the computation of density gradient parameters involved the aggregation of tract data into concentric rings each 500 meters in width. Tracts whose center points fell within a given ring had their entire population assigned to that ring. Population densities were then calculated using complete ring areas in the computations. A set of thirty population density and associated distance values for each year from 1950 through 1972 was thus obtained. Density and distance values were also obtained for rings 300 and 400 meters in width for the

area within a radius of fifteen kilometers from the railway station.

Although the procedure used in deriving ring based density and distance values was relatively simple and straightforward, the results obtained were less than ideal. The use of ring areas in computing density values did not allow for the unpopulated river and flood plain areas; therefore, population densities for these areas were generally understated. Another problem arose due to the assignment of an entire tract's population to the ring in which its center point was located. This led to situations in which population was in part misallocated among the rings and tended to disassociate population and tract areas. When computing population density values these two problems were alleviated, but not entirely solved, by repeating the aggregation procedure and using the sums of areas for tracts within rings in place of the ring areas. A more realistic set of data was obtained and the existence of a problem anticipated on the basis of field observations was confirmed.

In the course of field work carried out in the Taipei Metropolitan Area the presence of several secondary settlement nodes was observed. These nodes are scattered over the basin floor at distances of six to ten kilometers from the central business district and contain agglomerations of administrative offices, businesses and residential

structures. They are, in effect, suburban nodes of settlement toward which the more centrally located urban core of Taipei is expanding. Due to their somewhat isolated nature, the secondary nodes of settlement had an adverse effect on the general trend of density values. Densities based upon concentric rings alternated between highs and lows beyond a distance of six kilometers from the center point. The fluctuations were much more noticeable in the 300 and 400 meter rings and appeared not only in terms of the ring based data, but also when tract data were arrayed in scatter diagrams.

To eliminate the distorting effects of the secondary settlement nodes on the generally decreasing trend in density values with distance away from the city's center, it was necessary to truncate the study area to include only the area within the urban field of Taipei. The truncation was carried out on the basis of three considerations: marginal population density, shifts in population weighted mean centers and the location of the 100 meter contour. A density of ten persons per hectare (2590 persons per square mile) was selected as the marginal density and computer drawn isarithmic maps were examined to determine the location of the appropriate isopleth.⁷⁷ It was found that the

⁷⁷ Although the selection of this value was rather arbitrary, it is similar to marginal densities found useful in studies of Western cities. Stewart found it ". . .

isopleth for ten persons per hectare in 1950 enclosed an area on the floor of the basin almost entirely below 100 meters in elevation, excluded the agriculturally dominated western side of the basin and lay between Taipei proper and the secondary settlement nodes. On the map for 1972, this isopleth was closely approximated by that for one hundred persons per hectare, indicating a general increase in the base level population during the study period.

The isarithmic maps were then overlain on one showing the actual locations of population weighted mean centers. The ten persons per hectare isopleth on the 1950 map was found to effectively separate districts whose centers had moved toward the city's center. The area circumscribed by the ten persons per hectare isopleth in 1950 was therefore considered as that containing the urban field of Taipei. In order to eliminate some remaining minor secondary settlement nodes and allow for the area expanding

plausible to assume a standard density of about 2000 people to a square mile at the edge of a city, regardless of its size." J. Q. Stewart, "Urban Population Densities," Geographical Review, Vol. 43 (1953), p. 576. Newling found that city population estimates based on a marginal density of 2000 persons per square mile were more accurate than those based on a marginal density of zero persons per square mile. B. E. Newling, "Urban Growth and Spatial Structure: Mathematical Models and Empirical Evidence," Geographical Review, Vol. 56 (1966), pp. 216-220. The computer mapping routine used to prepare the isarithmic maps is described in R. I. Wittick, "GEOSYS: An Information System for the Description and Analysis of Spatial Data," Technical Report 74-53, Computer Institute for Social Science Research, Michigan State University, October, 1974.

tendency of the computer mapping routine, the indicated area was slightly reduced and standardized to a circle having a radius of six kilometers (Figure 6). This not only resulted in the elimination of tracts having densities less than ten persons per hectare, but the secondary settlement nodes as well, and reduced the number of tracts in the data set from 662 to 448.⁷⁸

The density data based on rings 500 meters in width were logarithmically transformed and regressed on distance values to obtain density gradient parameters. The results obtained are summarized in Table 7.

Table 7
Density Gradient Parameters*
Based on Concentric Rings 500 Meters in Width

Year	Slope (b)	Intercept (a)	Correlation (r)
1952	-.642	6.213	-.942
1957	-.583	6.372	-.938
1962	-.509	6.426	-.927
1967	-.420	6.431	-.893
1972	-.298	6.279	-.847

* All b and r values significant at the .001 level

⁷⁸R. C. Martin, "Spatial Distribution of Population: Cities and Suburbs," Journal of Regional Science, Vol. 13 (1973), pp. 269-278, using data for seven United States cities, demonstrated that city and suburban areas are

The density gradient slope (b) values declined steadily throughout the entire 1950-1972 period. Central density (a) first increased and then decreased, with the highest value occurring in 1964. The correlation (r) between density and distance fell throughout the period, but remained significantly different from zero at the .001 level, as did the slope values. The trends in density gradient parameters thus match those postulated for Western cities and indicate that Taipei is not a non-Western city in terms of its post-war population density gradient pattern. Similar results were obtained when data based on rings 300 and 400 meters in width were analyzed.

An attempt was made to divide the city into sectors and analyze ring based data for each sector. While the density gradient parameters obtained were similar to those for the entire study area, problems arose in the assignment of tract data to ring sectors closest to the city center point. Assignment of whole tracts to sectors within rings led to misrepresentation of densities within two kilometers of the center point. Further analysis of density distributions in terms of concentric rings was therefore abandoned in favor of analysis on the basis of individual tracts.

characterized by distinctly different density gradient parameters. The differences were attributed to variations in income, age of dwellings and mortgage interest and tax rate structures.

Population density values were computed for each year from 1950 through 1972 for each of the 448 tracts whose center points lay within six kilometers of the city center point. The density values were logarithmically transformed and regressed on distance values associated with the individual tracts. The study area was also divided into four quadrants centered on the railway station and density gradient parameters derived for each quadrant. The parameters obtained for the four quadrants taken as a single area, and each quadrant individually, are shown in Table 8.

An examination of the density gradient parameters shows that in each case the slope (b) of the density gradient declined continuously throughout the 1950-1972 period. This finding fits the description for the Western type of city, not the description for the non-Western type. The central density (a) values also indicate that Taipei is a city of the Western type. The values first increase and then decrease, with the highest values occurring in 1964 and 1965. The density gradient patterns associated with the parameters are illustrated in Figure 7. The gradient for 1950 is represented by the line closest to each graph's origin. Succeeding years are represented by the progression of lines from left to right, with the top, or rightmost, line representing 1972.

Table 8
Density Gradient Parameters
Based on All Tracts Within a Radius of Six Kilometers

	Four Quadrants Together		North-east Quadrant		South-east Quadrant		South-west Quadrant		North-west Quadrant	
	b	a	b	a	b	a	b	a	b	a
1950	-.710	6.789	-.488	6.069	-.586	6.144	-.797	7.096	-.898	7.492
1951	-.714	6.894	-.507	6.137	-.627	6.507	-.801	7.196	-.898	7.559
1952	-.699	6.887	-.497	6.132	-.614	6.553	-.790	7.201	-.886	7.529
1953	-.689	6.928	-.497	6.204	-.601	6.589	-.776	7.236	-.869	7.546
1954	-.676	6.953	-.492	6.261	-.580	6.591	-.760	7.247	-.858	7.560
1955	-.662	6.964	-.486	6.292	-.547	6.548	-.743	7.257	-.846	7.574
1956	-.649	6.986	-.483	6.343	-.522	6.528	-.724	7.269	-.834	7.590
1957	-.637	6.993	-.478	6.377	-.509	6.536	-.714	7.278	-.817	7.569
1958	-.623	7.002	-.479	6.448	-.479	6.492	-.694	7.271	-.799	7.553
1959	-.605	7.000	-.462	6.462	-.459	6.479	-.675	7.268	-.782	7.542
1960	-.597	7.021	-.455	6.483	-.461	6.511	-.656	7.271	-.770	7.563
1961	-.584	7.026	-.449	6.512	-.448	6.510	-.639	7.261	-.752	7.556
1962	-.572	7.031	-.442	6.551	-.439	6.515	-.620	7.247	-.736	7.542
1963	-.558	7.040	-.434	6.559	-.414	6.494	-.620	7.236	-.725	7.552
1964	-.549	7.064	-.433	6.649	-.405	6.520	-.587	7.240	-.713	7.557
1965	-.533	7.062	-.425	6.675	-.387	6.510	-.567	7.222	-.691	7.542
1966	-.509	7.026	-.415	6.684	-.362	6.472	-.537	7.155	-.658	7.485
1967	-.497	7.031	-.411	6.709	-.347	6.472	-.525	7.154	-.637	7.477
1968	-.476	7.006	-.404	6.726	-.325	6.445	-.496	7.097	-.605	7.430
1969	-.447	6.967	-.393	6.739	-.284	6.380	-.461	7.029	-.565	7.373
1970	-.420	6.921	-.375	6.704	-.272	6.372	-.420	6.954	-.526	7.313
1971	-.401	6.898	-.366	6.706	-.254	6.345	-.395	6.912	-.497	7.274
1972	-.379	6.850	-.350	6.667	-.232	6.293	-.357	6.838	-.475	7.231

Figure 7

Density Gradient Patterns Based
on Data for 448 Tracts

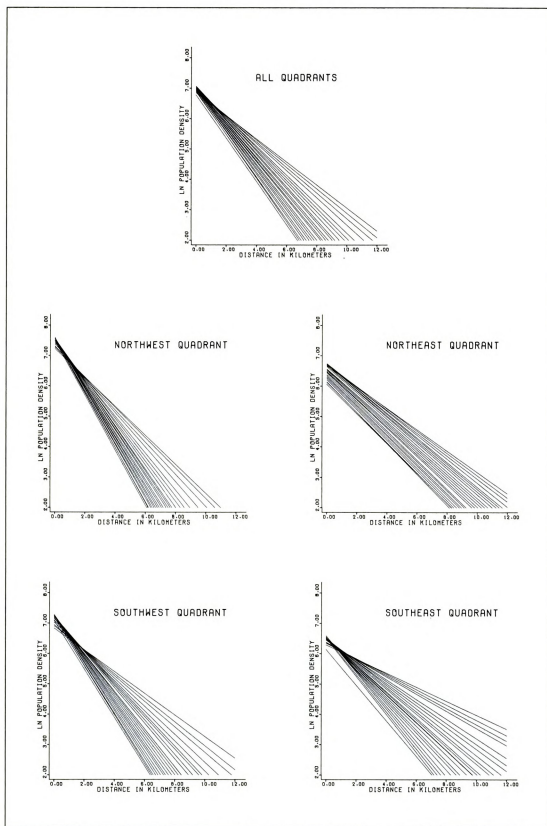


Figure 7.



The patterns shown in Figure 7 illustrate the level of population density to be expected in the absence of secondary settlement nodes in the metropolitan area out to a distance of twelve kilometers. Figure 8, on the other hand, focuses on the inner city portion of the patterns and shows more clearly the sequence of gradients. Two features of the diagrams are noteworthy. In all cases the gradients for the earliest years tend to be parallel, a condition indicative of a non-Western city. However, the parallel nature of the gradients started to disappear in the late 1950's. By the mid-1960's, parallelism in the gradients completely disappeared as slopes decreased at a faster rate and central densities began to decline. The period of change in density gradient patterns corresponds to the period of rapid economic development that occurred between 1955 and 1965.

The second noteworthy feature of Figure 8 is the gradient pattern shown for the northeast quadrant of the study area. There the pattern is comprised of a lengthy series of parallel gradients, with a change in the pattern occurring only after 1969. This anomalous situation can be tied directly to the estimated population values for tracts within the Chung Shan district. As was noted earlier, proportional allocation of population among tracts results in identical growth rates for all tracts. As the population grows in succeeding years these identical growth

Figure 8

Inner City Portions of Density Gradient
Patterns Based on Data for 448 Tracts

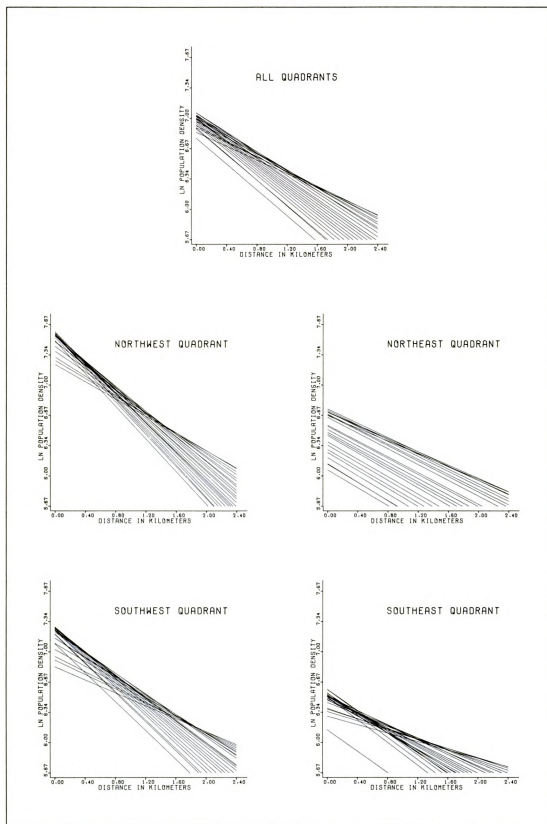


Figure 8.

rates are the values, in logarithmic form, added to the logged density values. Addition of identical values, in turn, results in increasing the intercept (a) value while leaving the slope (b) unchanged. Since 72 of the 125 tracts in the northeast quadrant are in the Chung Shan district, the effect of estimating missing values for those tracts by proportional allocation of population was quite pronounced. Inclusion of the five southernmost Chung Shan district tracts in the southeast quadrant had a lesser, though still noticeable, effect on parameters derived for that area.

The validity of the contention that proportional allocation of population (i.e., identical growth rates at all locations) results in parallel population density gradients was tested by removing the Chung Shan district tracts from the data set and recomputing the gradient parameters. Table 9 contains the new sets of parameters, and associated density gradient patterns are illustrated in Figure 9. The range of gradient slope (b) values for the northeast quadrant increased slightly and the year in which the highest central density (a) occurred changed from 1969 to 1965. The gradient pattern for the northeast quadrant shown in Figure 9 is considerably different from that appearing in Figure 8. The long series of parallel gradients is absent and the pattern bears a closer resemblance to those for the other quadrants. Failure of a more

Table 9
Density Gradient Parameters Based on All Tracts,
Except Those in the Chung Shan District, Within a Radius of Six Kilometers

Year	Four Quadrants Together		North-east Quadrant		South-east Quadrant		South-west Quadrant		North-west Quadrant	
	b	a	b	a	b	a	b	a	b	a
1950	-.727	6.941	-.483	6.518	-.581	6.107	-.797	7.096	-.898	7.492
1951	-.734	7.090	-.521	6.762	-.627	6.510	-.801	7.196	-.898	7.559
1952	-.718	7.086	-.509	6.781	-.616	6.565	-.790	7.201	-.886	7.529
1953	-.707	7.118	-.507	6.819	-.602	6.598	-.776	7.236	-.869	7.546
1954	-.692	7.129	-.497	6.824	-.581	6.595	-.760	7.247	-.858	7.560
1955	-.676	7.134	-.488	6.835	-.548	6.550	-.743	7.257	-.846	7.574
1956	-.662	7.149	-.483	6.865	-.522	6.527	-.724	7.269	-.834	7.590
1957	-.649	7.147	-.475	6.871	-.509	6.532	-.714	7.278	-.817	7.569
1958	-.632	7.134	-.469	6.857	-.477	6.478	-.694	7.271	-.799	7.553
1959	-.613	7.125	-.447	6.859	-.457	6.462	-.675	7.268	-.782	7.542
1960	-.604	7.145	-.438	6.876	-.459	6.494	-.656	7.271	-.770	7.563
1961	-.590	7.142	-.429	6.881	-.445	6.489	-.639	7.261	-.752	7.556
1962	-.576	7.135	-.417	6.886	-.435	6.489	-.620	7.247	-.736	7.542
1963	-.560	7.135	-.406	6.907	-.409	6.466	-.602	7.236	-.725	7.552
1964	-.549	7.147	-.402	6.933	-.400	6.488	-.587	7.240	-.713	7.557
1965	-.532	7.138	-.391	6.943	-.382	6.476	-.567	7.222	-.691	7.542
1966	-.506	7.091	-.377	6.924	-.357	6.435	-.537	7.155	-.658	7.485
1967	-.492	7.091	-.370	6.929	-.341	6.435	-.525	7.154	-.637	7.477
1968	-.469	7.056	-.361	6.930	-.319	6.406	-.496	7.097	-.605	7.430
1969	-.437	7.007	-.345	6.925	-.278	6.340	-.461	7.029	-.565	7.373
1970	-.411	6.964	-.332	6.894	-.265	6.333	-.420	6.954	-.526	7.313
1971	-.392	6.939	-.326	6.903	-.247	6.302	-.395	6.912	-.497	7.274
1972	-.368	6.887	-.306	6.843	-.226	6.252	-.357	6.838	-.475	7.231



Figure 9

Inner City Portions of Density Gradient Patterns
Based on the Data Set Excluding The
Chung Shan District Tracts

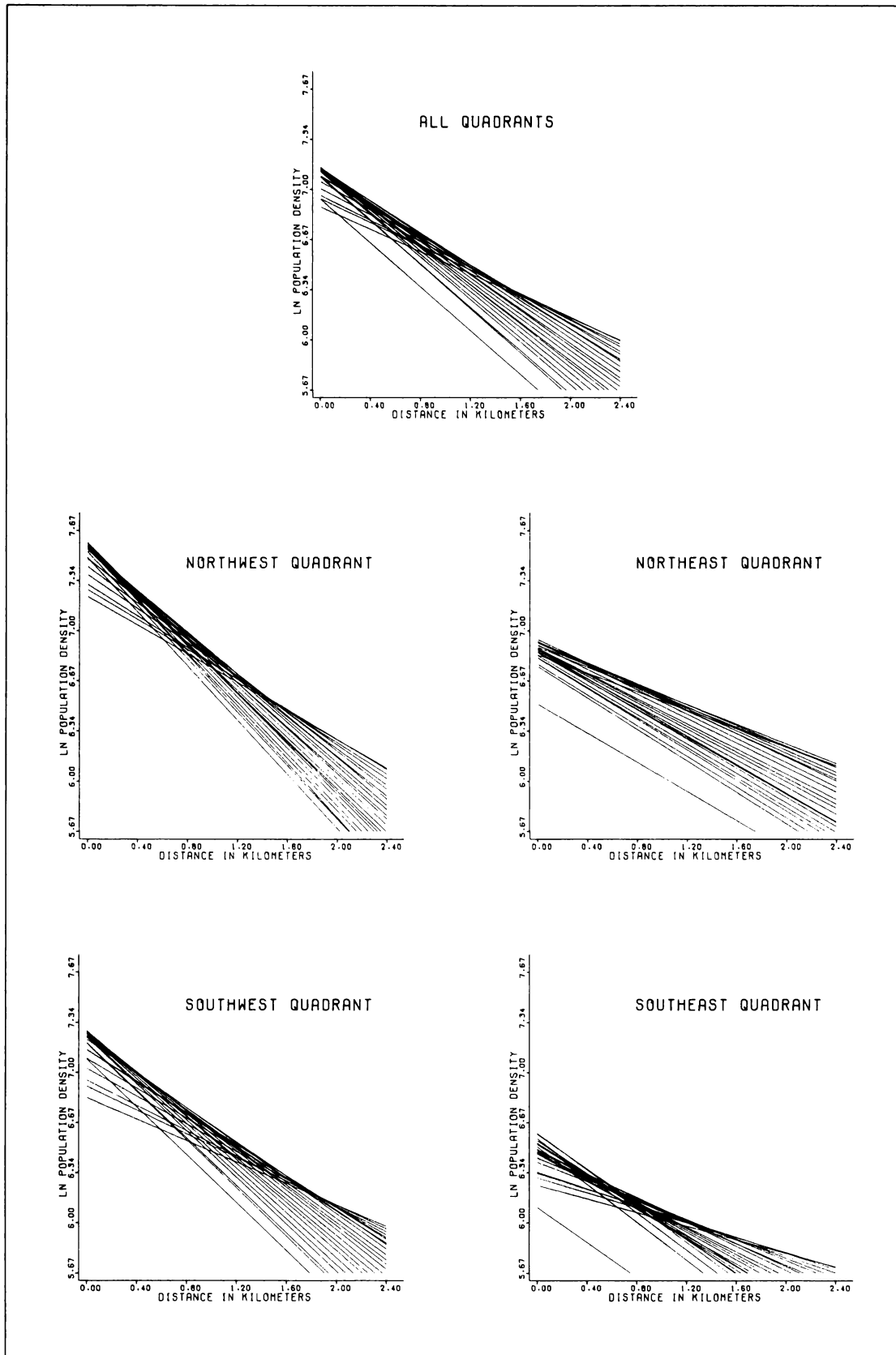


Figure 9.



pronounced pattern to appear is largely due to deletion of most data for the inner and middle portions of the quadrant brought about by the removal of Chung Shan district tracts from the data set.

While the effects of removing Chung Shan district tracts from the data set were most pronounced in the northeast quadrant, there were lesser effects on parameters for the study area as a whole and the southeast quadrant. The range of slope (b) values for the study area was somewhat expanded and higher central density (a) values prevailed throughout the 1950-1972 period. The effects were less marked in the southeast quadrant, which contained only five of the 77 tracts in the Chung Shan district. The range of slope values remained essentially unchanged while central densities were generally somewhat lower. All of these findings, especially those related to the northeast quadrant of the study area, support the statement that a non-Western density gradient pattern can appear only when population growth rates are identical throughout an urban area.

Trends in central density (a) values for the study area as a whole, and the four quadrants, are illustrated in Figure 10.⁷⁹ It can be readily seen that the trends

⁷⁹The central density trends illustrated are based on the logarithmic intercept (a) values contained in Table 8.



Figure 10

Trends in Central Densities Through Time

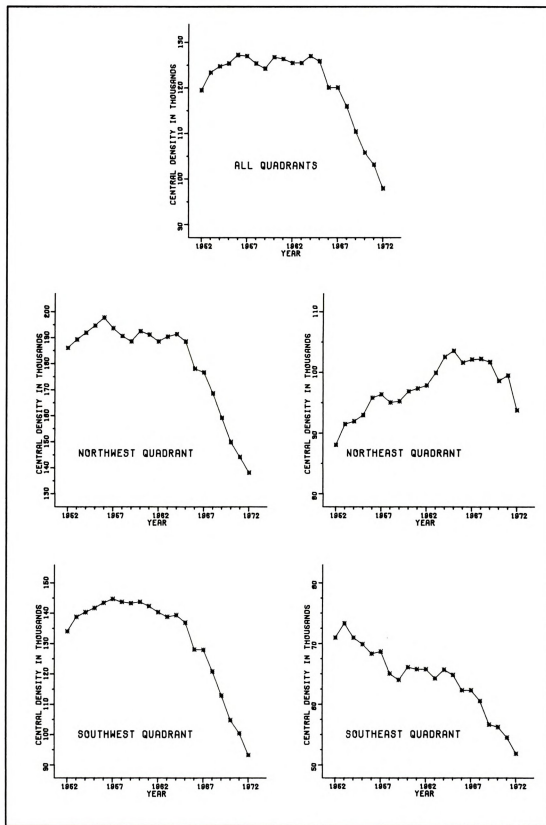


Figure 10.

are not of the continuously increasing type postulated for non-Western cities, but instead show the increasing and then decreasing trend characteristic of Western cities. Taken together, the trends in both slope (b) and central density (a) values discussed and illustrated here strongly indicate that Taipei, a city that is locationally and culturally non-Western, has experienced a pattern of growth and expansion like that of Western cities. This finding is supported by the results obtained from the analysis of three corollary relationships.

Corollary Relationships

In 1966 Bruce Newling defined three relationships associated with Clark's density-distance model and decline in the slopes of density gradients with the passage of time.⁸⁰ The first relates density gradient slopes to time in the form of the equation:

$$b_y = b_1 e^{-cy}$$

where: b_y = the slope of the density gradient in year y

b_1 = the slope of the density gradient in year 1

e = the base of natural logarithms

⁸⁰Newling, "Urban Growth and Spatial Structure: Mathematical Models and Empirical Evidence," op. cit., pp. 213-215.



c = the rate of change in the slope

y = a given year

Under logarithmic transformation the equation becomes linear in the form $\ln b_y = \ln b_1 - cy$ and indicates that the slopes of density gradients decline at a decreasing rate with the passage of time.

The value of c in the equation should be zero for a non-Western city since the density gradient slopes for non-Western cities are expected to remain constant over time. The coefficient of correlation, indicating the strength of the relationship, should also be zero. When density gradient slope values shown in Table 9 for the study area were analyzed, the value for c was found to be $-.03$ and a correlation coefficient of $-.98$ was obtained. Both values are significantly different from zero at the .001 level, indicating that the change in slope over time for Taipei is significantly different from the constant values situation expected for a non-Western city. Similar results were obtained for each of the four quadrants, as is shown in Table 10.

The second corollary relationship concerns the connection between population growth rates and distance from the center of the city. Since the number of persons living near the center of a city is usually quite large, a major increase in population is required in order to obtain a high percentage increase. Conversely, the small

Table 10
Slope-Time Relationships

Area	c	r	F
Four Quadrants Together	-.030	-.975	404.32
Northeast Quadrant	-.023	-.977	440.83
Southeast Quadrant	-.044	-.976	421.81
Southwest Quadrant	-.034	-.965	284.34
Northwest Quadrant	-.027	-.959	240.46

number of people living at the periphery means that a small addition to the population will yield a very large percentage increase. The relationship, called by Newling "... the rule of allometric intraurban growth," is one involving increasing population growth rates as distance from the city's center increases.⁸¹ It may be represented by the equation:

$$(1 + g_d) = (1 + g_0) e^{cd}$$

where: $(1 + g_d)$ = the growth rate at distance d

$(1 + g_0)$ = the growth rate at the city's center

e = the base of natural logarithms

c = rate of change in the rate of growth

d = distance from the center of the city

⁸¹Ibid., p. 214.

With logarithmic transformation of growth rate values the equation becomes linear in the form:

$$\ln(1 + g_d) = \ln(1 + g_0) + cd$$

and indicates that the population growth rate increases at an increasing rate with distance away from the center of the city. Since a non-Western city must have identical growth rates at all locations in order to possess a non-Western density gradient pattern, such a city may be expected to exhibit no relationship between growth rate and distance. The rate of change in the growth rate with distance away from the city's center (c) will be zero, as will the correlation coefficient.

To determine whether the growth rate characteristics of Taipei match those for a non-Western city, growth rates for five periods were computed, logarithmically transformed and regressed on distance values. Data for all 448 tracts in the study area were used. The results of the analyses are displayed in Table 11.

All of the c values are significantly different from zero at the .001 level, as are the values for the correlation (r) coefficients. Not only do the results indicate that Taipei's growth rate characteristics match those expected for Western cities, but they also demonstrate that the relationship increased in strength with the passage of time. Most of the increase took place during the rapid economic development period extending from



Table 11
Growth Rate--Distance Relationships

Period	c	r	F
1952-1956	.050	.319	50.53
1956-1960	.052	.350	62.26
1960-1964	.048	.432	102.33
1964-1968	.073	.540	183.59
1968-1972	.098	.543	186.49

1955 through 1965. It would appear that a connection exists between development and the improvement in the growth rate-distance relationship.

The third of Newling's relationships centers on the link between population growth rates and densities. Having noted the decline in population density and increase in growth rates with distance away from the city's center, it would seem reasonable to suspect the existence of a relationship between the two dependent variables. Indeed, a relationship does exist and can be readily explained on an intuitive basis. Because areas having high population densities are already heavily populated, addition of a very large number of people would be required to yield a high growth rate. Such high density areas are found in the inner portions of a city where there is relatively little

opportunity to increase population density by more than a small amount. At the edge of the city, however, densities are generally low and ample opportunity exists for housing additional population through new residential construction. Growth rates in this part of a city, therefore, tend to be high. Newling reduced the connection between low population densities and high growth rates to the form of the equation:

$$(1 + g_d) = GD_d^{-k}$$

where: $(1 + g_d)$ = the growth rate at distance d

G = the growth rate when density is zero

D_d = the density at distance d at the start of the time period to which the growth rate applies

$-k$ = the rate of change in the growth rate as density increases

d = distance from the center of the city

With logarithmic transformation of the growth rate and density values the equation becomes linear in the form:

$$\ln(1 + g_d) = \ln G - k(\ln D_d)$$

which indicates that as population density increases at the start of the time period to which the growth rate applies, the growth rate during the period decreases.

As has been shown, non-Western cities may be expected to have identical growth rates at all locations within their boundaries. Hence, it may be anticipated that a value of zero for the k parameter will be associated with



a non-Western city. This will occur because location-constant growth rates will exist regardless of differences in population densities at the beginning of any particular time period. The correlation coefficient will also be zero since for the non-Western city there is, in effect, no relationship between growth rates and densities.

Logarithmically transformed population growth rate and density values were submitted to regression analysis to learn if the growth rate-density relationship for Taipei matched the Western or non-Western expectations. Growth rates for five successive periods were regressed on the densities prevailing at the start of each period. The results of the analyses are shown in Table 12. Both the

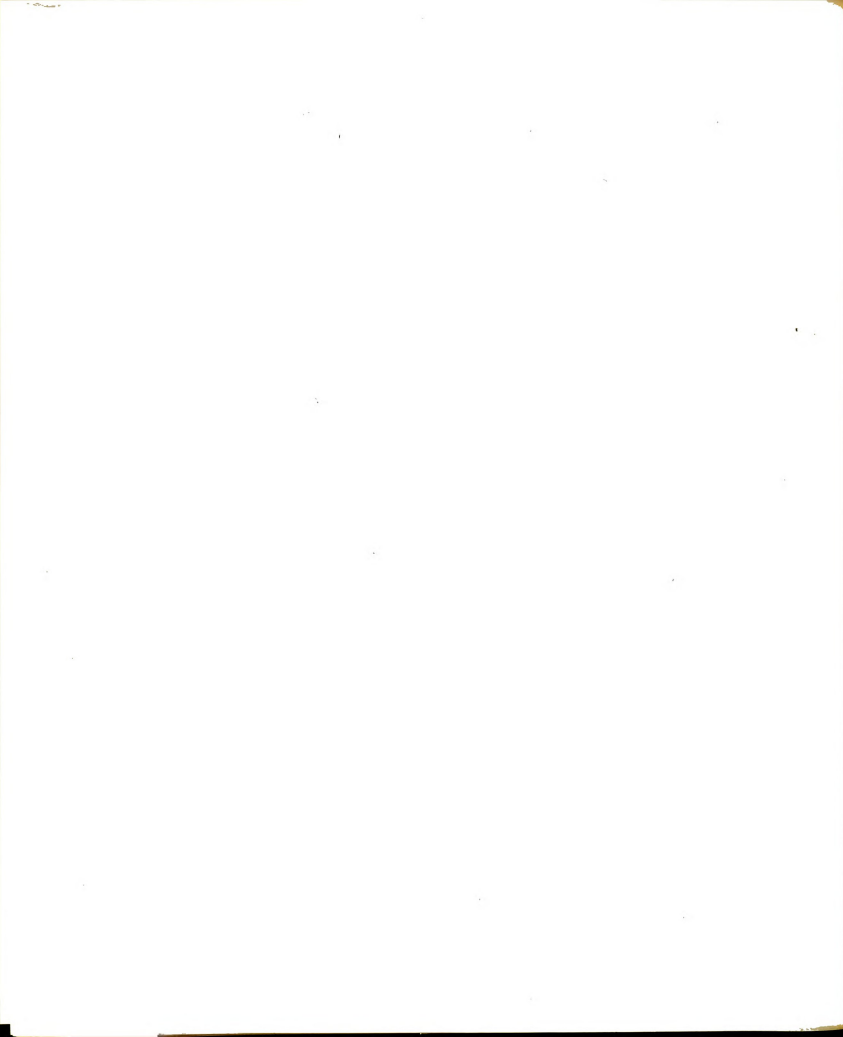
Table 12
Growth Rate--Density Relationships

Period	G	k	r	F
1952-1956	.618	-.077	-.476	130.66
1956-1960	.592	-.080	-.488	139.41
1960-1964	.536	-.068	-.513	159.29
1964-1968	.699	-.102	-.599	249.57
1968-1972	.910	-.142	-.571	215.76

k values and the correlation (r) coefficients are significantly different from zero at the .001 level, once again indicating that Taipei is a city of the Western type. In addition, the values for G, the rate of population growth expected when density is zero, indicate a strong increase in growth rates at the edge of the city during the last two periods. This trend, indicative of urban expansion, corresponds with the period following the end of United States economic aid programs and shift of Taiwan's economy to a self-sustaining basis.

The corollary relationships discussed here, together with trends in density gradient parameters evaluated earlier, indicate that Taipei should be classified among the Western cities on the basis of longitudinal trends in its population characteristics. Population growth rates varied throughout the metropolitan area and population weighted mean centers shifted considerably during the 1950-1972 period. Both of these findings are contrary to those characterizing non-Western cities. Density gradient parameters exhibited trends associated with Western cities, not the constant gradient slopes and continually increasing central densities characterizing non-Western cities. Finally, tests for the presence of corollary relationships showed conclusively that the trends in gradient slopes and growth rate features of Taipei are those of a Western city. It now remains to be seen whether the appearance of a

Western density gradient pattern in Taipei can be linked to Taiwan's post-war economic development. Evaluation of the relationships between indicators of economic development and density gradient parameters will provide evidence on which to base a decision concerning the hypothesis that the appearance of a Western type of urban population density gradient pattern is associated with economic development.



CHAPTER V

DENSITY GRADIENT--ECONOMIC DEVELOPMENT RELATIONSHIPS: ANALYSIS AND FINDINGS

Economic development in the Western world has been associated with change in several characteristics of both populations and economies. These have included changes in demographic characteristics, technology, economic indicators and employment patterns. The purpose here is to briefly review changes that have occurred in Taiwan and attempt to link them to the density gradient pattern for Taipei.

At the beginning of this investigation it was hoped that sufficient data could be obtained to allow a multiple regression analysis of the relationships between density gradient parameters and variables measuring change in Taiwan's economy. Suitable data were available on an annual basis, but only for the relatively short 1952-1972 period. The small number of annual observations ($n = 21$) available for entry into such an analysis would, therefore, constitute a limiting consideration on an evaluation of results. A more serious problem was encountered, however, that effectively precluded meaningful analysis by means of a multiple regression model: the development, growth and expansion of Taiwan's economy has been so broad based and

all-encompassing that a high degree of association exists between potential independent variables.⁸² Use of such variables in a multiple regression analysis could be expected to yield meaningless, and perhaps misleading, results. Multivariate analysis was therefore rejected in favor of simple linear correlation analysis of individual relationships between density gradient parameters and selected independent variables described in the following paragraphs. The results of the analyses are presented in the last section of the chapter.

Demographic Trends

Historically, one of the most consistent changes associated with economic development has been the demographic transition. It involves a decline in death rates followed at a later time by a decline in birth rates.⁸³ Population growth is comparatively rapid in the period between the beginning of the decline in death rates and the start of the decline in birth rates. The rapid increase in population occurs because, with lowered death rates, more people survive childhood and live for longer periods.

⁸²Coefficients greater than $\pm .90$ characterized the simple correlation (r) matrix generated from data for a broad group of independent variables.

⁸³Stolnitz, op. cit.

Before a decline in birth rates sets in, age structure is heavily weighted in favor of the younger age groups. The young come to constitute a less dominant proportion of the population as birth rates decline. This variation in age structure is reflected by change in the dependency ratio and modifications in the form of age-sex pyramids for a population.

The dependency ratio indicates the number of persons in age groups zero through fourteen years and sixty years of age and over for each one hundred persons in the population between fifteen and fifty-nine years of age. When birth and death rates are both high the dependency ratio is relatively low since many children die before reaching adulthood and few adults survive to reach old age. With a decline in death rates more children survive infancy and more adults reach old age. The result is an increase in the dependency ratio as the youthful and elderly proportions of the population become larger. A decline in birth rates brings a reduction in the number of children born and a decline in the dependency ratio.

Modifications in a population's age structure indicated by the dependency ratio can be depicted by means of an age-sex pyramid. Prior to a decline in birth rates the pyramid has a broad base representing younger people. It narrows rapidly toward the peak which represents the older age groups. As birth rates fall and death rates continue

to decrease, the base of the pyramid narrows and its middle portion broadens, reflecting both the lower birth rates and a higher rate of survivorship.⁸⁴

Data for Taiwan show that the demographic transition has been under way for some time. Death rates started declining in the decade following the arrival of the Japanese on the island in 1895, and moved steadily downward after the worldwide influenza epidemic of 1918 (Figure 11). Birth rates, on the other hand, did not begin to fall until the late 1950's. Since that time birth rates have steadily decreased and the rate of natural increase (births minus deaths) has declined from a high of 36.8 per thousand population in 1956 to 19.4 in 1972.

A change in the age structure of Taiwan's population accompanied the shift from high to low birth and death rates. In 1952 the youngest group, those under fifteen years of age, made up 42.4 percent of the population while the eldest portion, those sixty years of age and over, accounted for only 4.1 percent. The dependency ratio in 1952 was 86.8, rose to 100.9 in 1962, and then fell during the following decade to 76.4 in 1972. By the end of 1972 the youngest group's share of the population had decreased

⁸⁴G. T. Trewartha, A Geography of Population: World Patterns (New York: John Wiley and Sons, Inc., 1969), pp. 117-127; J. I. Clark, Population Geography (New York: Pergamon Press, 1965), pp. 66-68.

Figure 11

Rates of Birth, Death and Natural Increase
on Taiwan Between 1906 and 1972

* Based on quinquennial averages for the 1906-1950 period, and annual figures for the 1950-1972 period.

Data Sources: Chang Te Tsui, Long-Term Projections of Supply, Demand and Trade for Selected Agricultural Products in Taiwan (Taipei: National Taiwan University, 1970), p. 18.
1972 Taiwan Demographic Fact Book (Taipei: Ministry of the Interior, 1973), pp. 34-35.

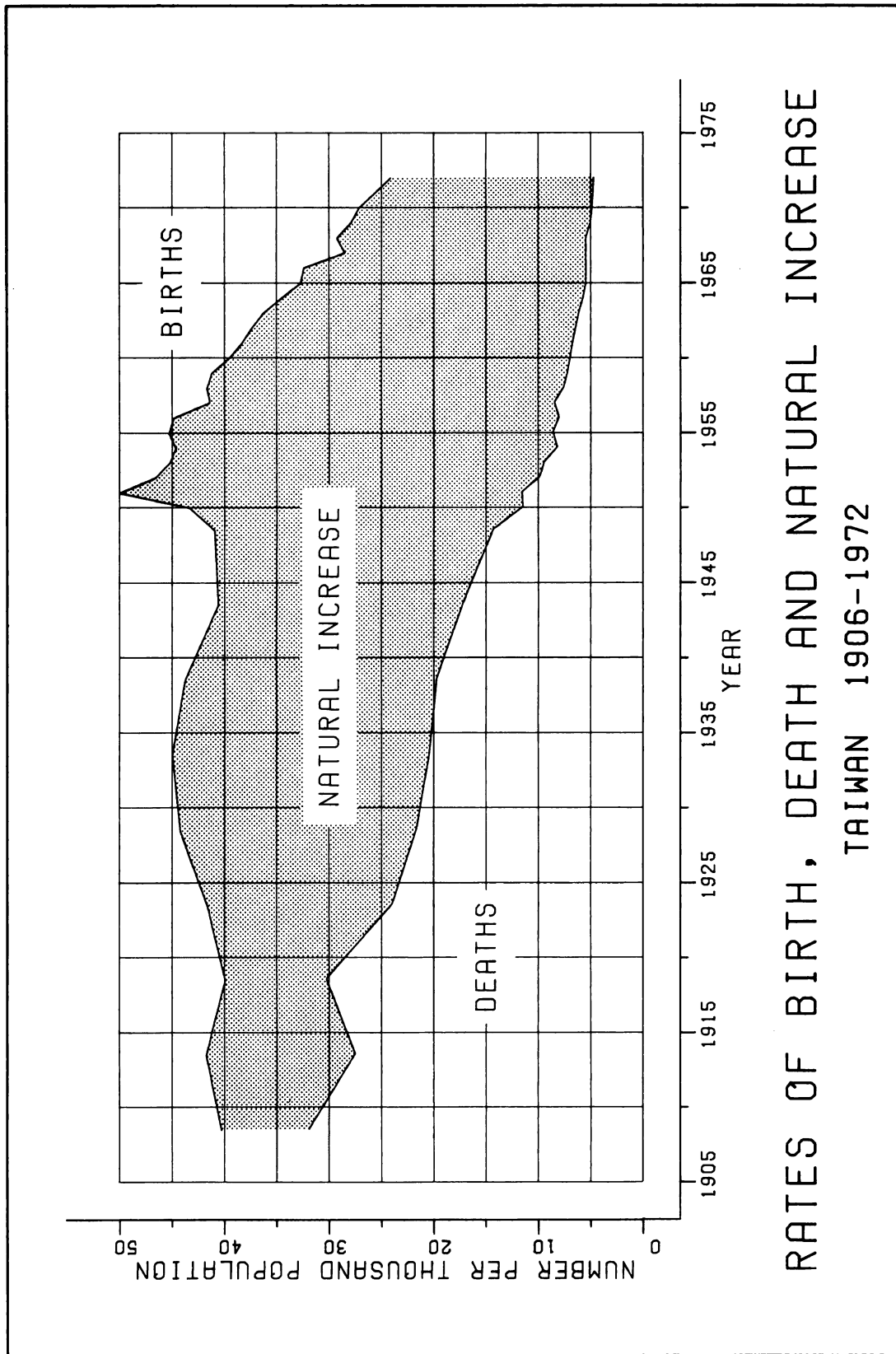
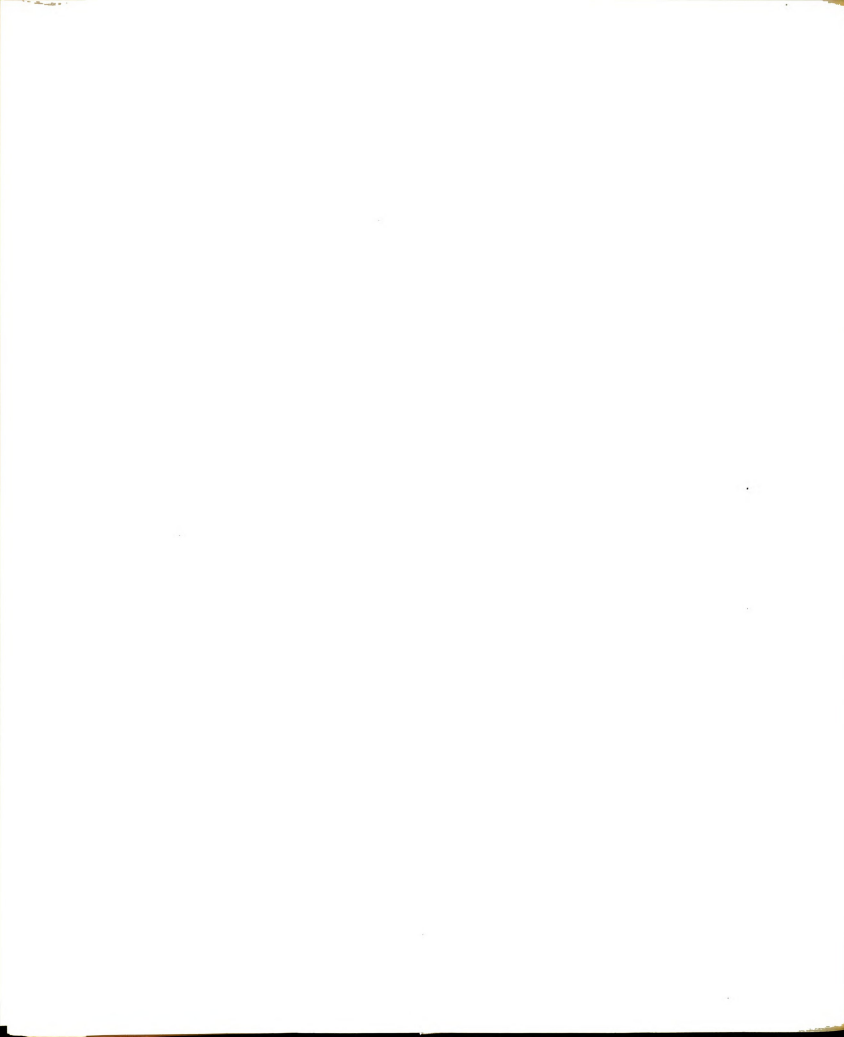


Figure 11.



to 37.9 percent, while the eldest group had increased its share to 5.4 percent. Figure 12 contains age-sex pyramids for 1952 and 1972 illustrating the changes that have occurred in Taiwan's age structure during the post-World War II era. The base of the pyramid narrowed considerably and its middle portion expanded, approximating the changes that characterized Western nations.⁸⁵

Changes in Modes of Transportation

Modification in the technological base of a country may be evaluated in a number of ways. Attention will be focused on transportation technology useful in the movement of people and goods since the concern here is with changes in population distribution, not the means or methods of production. Also, Clark emphasized the importance of affordable transportation as a factor related to declines in density gradient parameters and the spreading out of Western cities.⁸⁶ Thus the absence of modernization or expansion of the transportation system may be indicative

⁸⁵The bulge in the male side of the 1972 pyramid is due to the inclusion of military personnel in the population data. Prior to 1969 military personnel were excluded from all demographic data for security reasons.

⁸⁶Clark, "Urban Population Densities," op. cit., p. 495; idem., "Transport - Maker and Breaker of Cities," op. cit.

Figure 12

Age-Sex Pyramids for Taiwan in 1952 and 1972

Data Source: Based on data contained in the 1972 Taiwan Demographic
Fact Book (Taipei: Ministry of the Interior, 1973),
pp. 40-43.

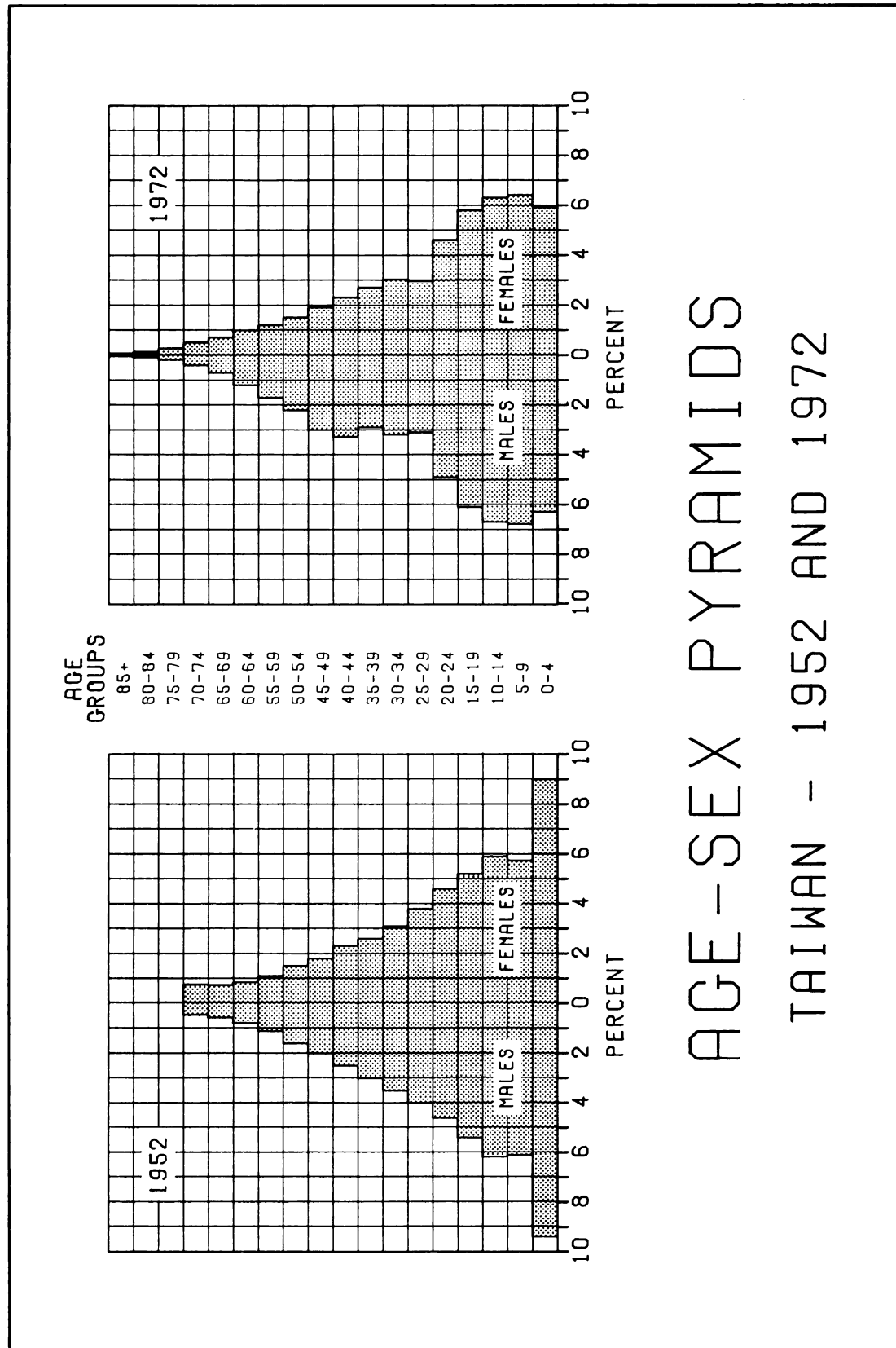


Figure 12.

of a non-Western nation or one whose economy has not become developed.

On-scene observation of the vehicular mix in Taiwan, buttressed by general availability measures related to various types of transportation, indicate that there has been a great change in modes of transportation. In 1964, the streets of major cities like Taipei were dominated by vehicles that utilized human and animal power. Bicycles and pedicabs flooded the streets along with ox-carts, man-hauled freight carts and peddled lunch wagons. Buses, trucks, automobiles and motorcycles were present, but their numbers were far outweighed by the muscle powered vehicles. By 1974 pedicabs and ox-carts had disappeared, the bicycle population visibly diminished, and the number of motorcycles, automobiles, buses and trucks increased dramatically. Arcaded sidewalks previously occupied by bicycles and lunch stands had been converted to parking strips for motorcycles, and itinerant lunch wagons relegated to the residential areas. In short, the period from the mid-1960's to the mid-1970's was a time in which there was a shift away from the more traditional transportation modes to motorized vehicles.

The most important change occurred in the area of personal transportation vehicles. Through the 1950's and into the mid-1960's the number of registered bicycles per thousand population increased steadily until a turning

point was reached in 1967 and the number of bicycles in use started a rapid decline (Figure 13). At about the time that bicycle registrations leveled off, the number of registered motorcycles per thousand population began a steady increase and continued at a rate approximating that of bicycles in the 1950's.⁸⁷ By 1972 the number of motorcycles per thousand population (62.62) was almost identical to the number of bicycles per thousand population (63.21) in 1952. This change in modes of personal transportation, readily visible on the streets and roads of Taiwan, represented an important modification of the population's mobility. Not only did individual travel become more speedy, but the length of trips in terms of distance and the carrying capacity of personal vehicles also increased.⁸⁸ The advent of the motorcycle marked a decrease in dependence on public transportation and increased individual freedom to locate without regard to bus schedules and services. In this way

⁸⁷The break in the motorcycles per thousand population series shown in Figure 13 is due to a change in vehicle registration criteria. Through 1966 only motorcycles having an engine displacement of fifty cubic centimeters or more were registered. From 1966 onward all motorcycles, regardless of engine displacement, were registered.

⁸⁸Motorcycles are used not only for individual transportation, but also as family vehicles and for the hauling of goods. It is not uncommon to see families of four or five persons riding a single motorcycle, or one burdened with tall stacks of boxes or bags.

Figure 13

Bicycles, Motorcycles and Automobiles
Per Thousand Population

Data Source: Transportation and Communications Information
(Taipei: Transportation Planning Board,
Ministry of Communications), various quarterly
editions.

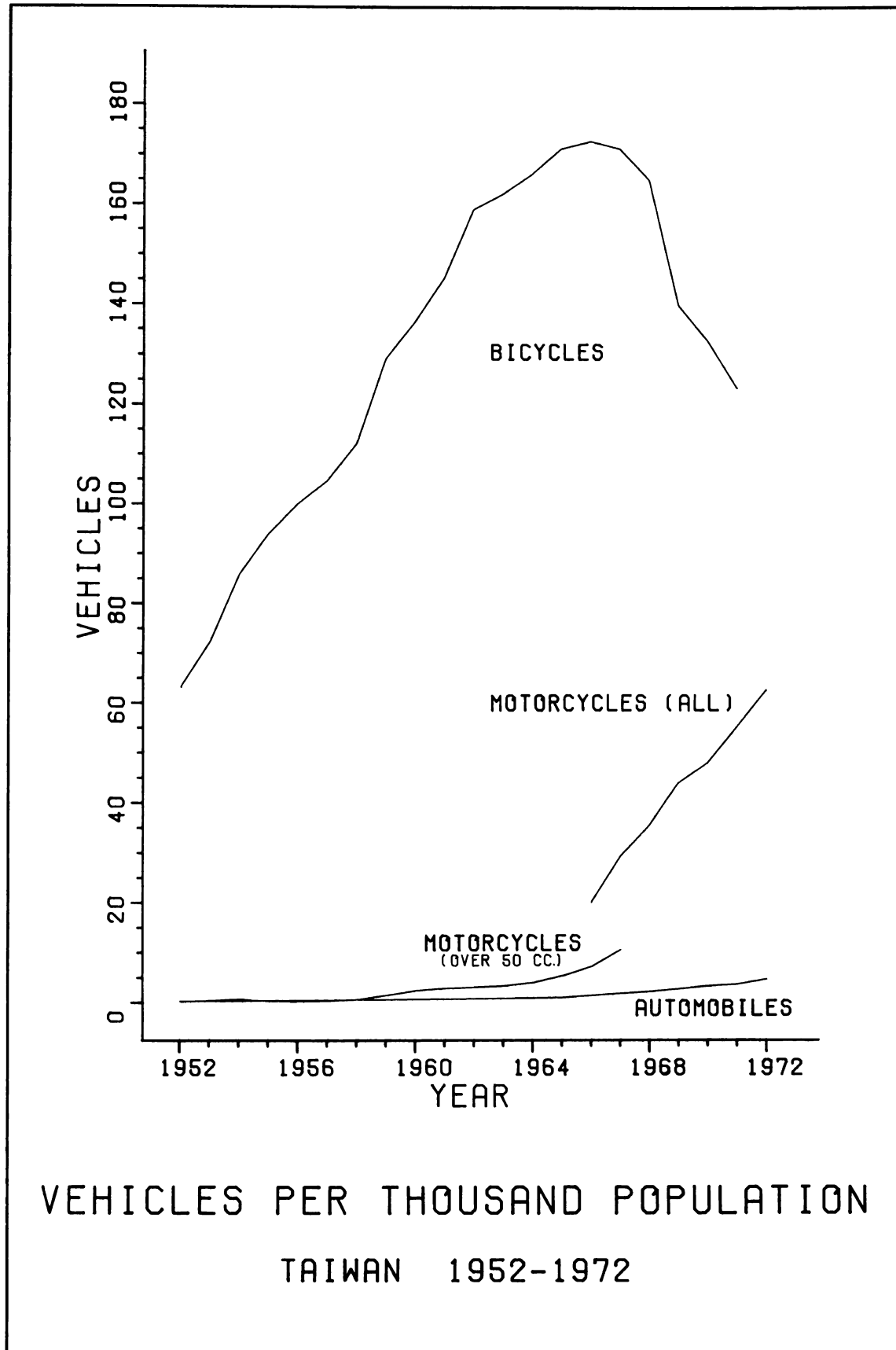


Figure 13.

the motorcycle played a role similar to that of the automobile in Western nations in facilitating the areal growth of cities.

Relatively little growth has occurred in the number of privately owned automobiles in use. This is largely due to the high initial purchase price and high cost of operation involved in owning an automobile. Another consideration discouraging automobile ownership is that downtown parking facilities are extremely limited and garages in residential areas almost non-existent.⁸⁹ The automobile owner is faced with parking problems at every turn while the motorcycle owner can park his machine almost anywhere, including the stairwells and hallways of apartment buildings at night.

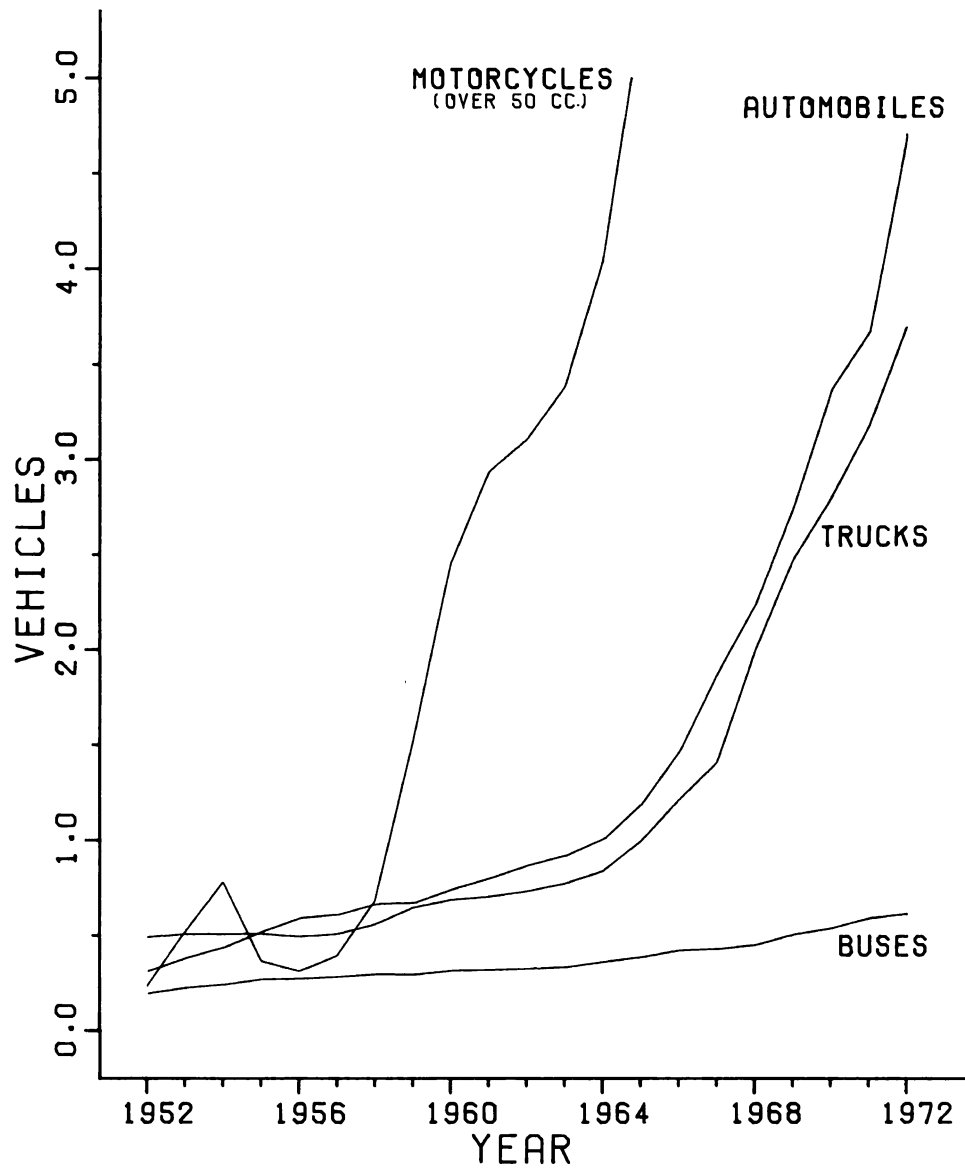
Despite the problems associated with ownership, there has been an upward trend in the number of automobiles per thousand population similar to that for motorcycles in the late 1950's (Figure 14). Most of the new vehicles,

⁸⁹The parking problem is of such magnitude that municipal authorities ordered the use of basements in high rise buildings for parking, and the opening of parking lots is a newsworthy event. "Basement Parking," China News (Taipei), October 5, 1973, p. 4; "Private Parking Lot Opens in Theater Row," China News (Taipei), October 25, 1973, p. 4. Even though problems continued to exist, automobile registrations increased sixty-four percent between 1972 and 1974, rising from 4.71 to 7.73 automobiles per thousand population. Motorcycle ownership also increased, going from 62.62 to 90.64 per thousand population in the 1972-1974 period, an increase of forty-five percent.

Figure 14

Motorcycles, Automobiles, Trucks and
Buses Per Thousand Population

Data Source: Transportation and Communications Information
(Taipei: Transportation Planning Board,
Ministry of Communications), various quarterly
editions.



VEHICLES PER THOUSAND POPULATION

TAIWAN 1952-1972

Figure 14.

however, are being used as taxi cabs and must be counted as part of the public transportation system. The rate of increase in the number of trucks per thousand population has closely paralleled that for automobiles, especially since 1960. The rise in the number of trucks in use not only brought about the demise of ox and man-hauled carts, but also brought increasing congestion to Taiwan's highways. The island-long freeway presently under construction is aimed at reducing the congestion and speeding the flow of trucked freight. Finally, the slow but steady increase in the number of buses per thousand persons indicates increasing mobility for the population. It is possible to reach virtually any point in the Taipei Metropolitan Area by bus while access to other parts of the island is easily gained by highway bus, rail or domestic airline.

All of the modifications in the transportation system indicate dramatic change in Taiwan's economy. The overall transportation system has been modified and become motorized, and considerable numbers of individuals have been able to upgrade their personal means of transportation. This in itself is a strong indication that the benefits of economic development have reached the middle class in the form of increased income and purchasing power. Without such increases people would be unable to afford investment in motor vehicles, new housing outside of the inner city, or amenities like refrigerators, clothes washers and

television sets, all of which have become increasingly available and commonly owned during the last twenty-five years.

Economic Structure, Employment and Income

Economic development in Western nations has usually been accompanied by changes in the structure of the economy and the labor force as well as general increases in per capita income. These changes have commonly involved a decline in the proportion of the labor force engaged in agriculture and concomitant increases in other sectors, especially industry and services. The shifts are brought about by modifications in the nation's economic structure which include expansion of industrial production and movement away from dependence on agricultural products as earners of export income. At the same time, service industries geared to the needs of an urban-industrial economy grow. The result is an expansion of the labor force in the industrial and service sectors of the economy and a decrease in the share of the force held by the agricultural sector. Increases in per capita income, in both raw and real terms, usually accompany such changes in labor force structure and indicate an increasing ability to meet the costs of urban-industrial living, as well as the amenities associated with a modern economy.

The record for Taiwan shows that its economy has undergone considerable change and development. The general index of industrial production rose from 100 in 1952 to 1701 in 1972, with the manufacturing index rising from 100 to 2015. During the 1952-1972 period the composition of exports underwent a dramatic reversal. Raw and processed agricultural products made up 95.2 percent of all exports by value in 1952, while industrial products accounted for less than five percent. By 1972 the composition of exports had turned around to the point where industrial products accounted for 82.9 percent of all exports and agricultural products only 17.1 percent. Finally, the share of net domestic product held by agriculture dropped from 35.7 percent to 15.7 percent, while industry's share increased from 17.9 to 36.6 percent.⁹⁰

While Taiwan's economic structure was changing to an industrial base there also occurred a general rise in per capita income and a restructuring of the labor force. The increase in incomes totaled 867 percent in raw terms, and 272 percent in terms of real income at constant prices adjusted for change in the terms of trade.⁹¹ This

⁹⁰Taiwan Statistical Data Book, 1973, op. cit., pp. 21, 47, 68.

⁹¹Ibid., p. 20.

represents an annual compound growth rate of 5.13 percent in real per capita income.

The restructuring of the labor force involved a decline in agriculture's share of the employed population and an increase in the proportions working in the industrial, service and transportation sectors. During the period under consideration employment in agriculture fell by one-third, from 61.0 percent of the labor force in 1952 to just under forty percent in 1972 (Table 13). At the

Table 13
Sectoral Proportions of the Labor Force^{*}

Sector	<u>Year</u>				
	1952	1957	1962	1967	1972
Agriculture	.610	.582	.553	.530	.399
Industry	.093	.104	.115	.123	.198
Transportation	.022	.028	.030	.033	.038
Commerce	.085	.084	.089	.090	.081
Services	.190	.202	.213	.224	.284

* The figures are based on the population aged twelve years and over for the 1950-1967 period, and on persons aged fifteen years and over from 1968 onward.

Source: Council for International Economic Cooperation and Development, Taiwan Statistical Data Book, 1973 (Taipei: Executive Yuan, 1973), pp. 8-9.

same time industrial employment more than doubled to reach 19.8 percent of the labor force in 1972. Services and transportation also increased their share of the labor force while the commerce sector experienced a small net decline. A comparison of employment structure existing in 1952 and 1972 clearly shows the growth of sectors associated with an urban-industrial economy (Figure 15).

Simple Correlation Analyses

Data for density gradient parameters and twenty-one independent variables were analyzed. The density gradient parameters used were the slope (b) and intercept (a) values obtained for Taipei on the basis of the 448 tracts having center points within six kilometers of the railway station. Independent variables included the demographic, transportation, economic and employment variables discussed and illustrated in the preceding sections of this chapter.⁹²

One of two possible outcomes from the correlation analyses was expected, given the nature of changes that occurred in the independent variables during the 1952-1972 period. The general tendency toward steady change through time in the values for the independent variables led to an expectation of strong linear relationships with density

⁹²Data for the independent variables may be found in Appendix B.

Figure 15

The Employed Labor Force of Taiwan,
By Sector, In 1952 and 1972

Data Source: Council for International Economic Cooperation
and Development, Taiwan Statistical Data Book,
1973 (Taipei: Executive Yuan, 1973), pp. 8-9.

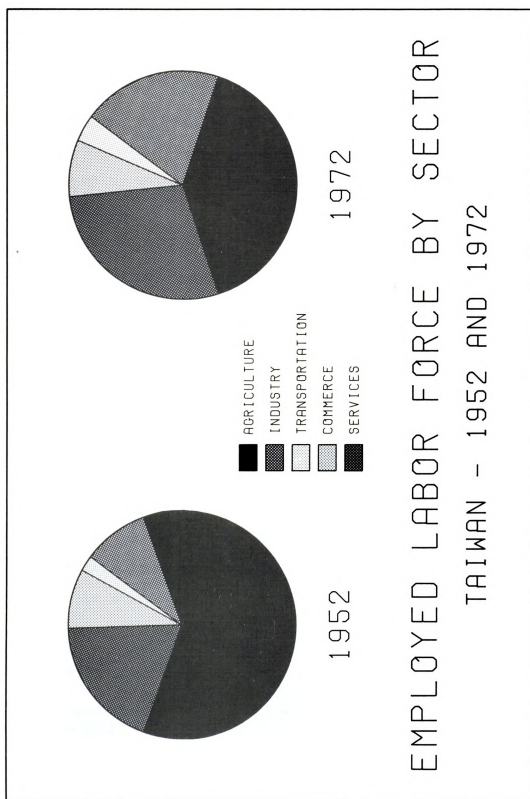


Figure 15.

gradient slopes (b values) and weak or non-existent relationships with central densities (a values). This type of outcome was anticipated in light of the Western pattern of steady decline in gradient slope, and central density values that first increased and then decreased.⁹³ The results to be expected from correlation of density gradient parameters for a non-Western city with the independent variables, however, would be opposite of the first type of outcome. The constant density gradient slope values would result in coefficients of zero when correlated with the independent variables. At the same time, relationships between the independent variables and continually increasing central density values would be strong and represented by high correlation coefficients.

Two sets of correlation coefficients were computed using first density gradient slope (b) and then central density (a) as the dependent variables (Table 14). The results clearly indicate that change in density gradient slopes was strongly associated with changes in economic development indicators. Relationships between central

⁹³While the steepness of the density gradient slopes declined over time, the numerical slope values increased from $-.710$ to $-.379$. Thus development measures that increased in value should be positively correlated with the slope variable, while those that declined should be negatively correlated with the slope variable.



Table 14

Simple Linear Correlation Coefficients Reflecting Relationships Between Density Gradient Parameters and Selected Independent Variables

Independent Variables	Dependent Variables and Significance Levels			
	Slope (b)	Significance Level	Intercept (a)	Significance Level
Demographic Measures				
Birth Rates	-.99	.001	.08	----
Death Rates	-.94	.001	-.15	----
Dependency Ratio	-.47	.05	.89	.001
Modes of Transportation				
Bicycles	.57	.05	.70	.001
Motorcycles	.90	.001	-.53	.05
Automobiles	.93	.001	-.49	.05
Buses	.99	.001	-.27	----
Trucks	.92	.001	-.53	.05

Economic Indicators

Agricultural Production	.99	.001	-.11	----
Industrial Production	.94	.001	-.46	.05
Agricultural % of N.D.P.	-.97	.001	.25	----
Industrial % of N.D.P.	.98	.001	-.09	----
Agricultural Exports	-.98	.001	.09	----
Industrial Exports	.98	.001	-.09	----
Raw Per Capita Income	.99	.001	-.29	----
Real Per Capita Income	.98	.001	-.30	----
Employment In:				
Agriculture	-.98	.001	.30	----
Industry	.96	.001	-.35	----
Services	.95	.001	-.36	----
Transportation	.96	.001	.03	----
Commerce	-.15	----	.86	.001

density and the independent variables were generally weak and not significant. These findings correspond with those expected when density gradient parameters for a Western type of city are correlated with measures indicating economic development. Results to be anticipated when non-Western city density gradient parameters are used as dependent variables failed to appear.

Three apparent departures from the general trend of the correlation analysis results require explanation. Low correlation coefficients characterize the relationships between density gradient slope and the dependency ratio, bicycles and employment in commerce variables. The low coefficient values are accounted for by the three independent variables having curvilinear relationships with time, while slope had a linear relationship with time. Values for each of the three independent variables first increased and then decreased, with peak values occurring in 1962, 1966 and 1965 respectively. The result of using time based observations in correlating a time-linear dependent variable with independent variables that are curvilinear over time was a set of low correlation coefficients.

The second apparent anomaly in the results also involves the dependency ratio, bicycles and employment in commerce variables. Each of these variables has a strong relationship with central density. Once again, the



explanation involves curvilinear relationships with time. In this case, however, the dependent variable, central density, also has a curvilinear time relationship, and values for all four variables tend to rise and fall together. The result is a set of high linear correlation coefficients.

The last of the departures from the general trend in correlation analysis results involves relationships between central density and the motorcycles, automobiles, trucks and industrial production variables. In each case the correlation coefficient is not particularly high, but nonetheless significant. The explanation here lies in the pace at which the independent variable values increased with the passage of time. During the 1950's and early 1960's the values rose at a slow rate, while from the mid-1960's onward the rate of increase became more rapid.⁹⁴ This period coincided with the decline in central density values. In effect, time based curvilinear relationships existed and became particularly strong during the later portion of the study period. As central densities decreased, the independent variable values increased, yielding moderately strong negative linear correlation coefficients.

⁹⁴The relationships between central density and the transportation variables over time may be seen by comparing Figure 14 with the graph showing central densities based on data for all quadrants in Figure 10.



The overall results of the correlation analyses indicate strong relationships between density gradient slope and measures related to economic development. At the same time, relationships between central density and economic development measures, with the few exceptions noted, were found to be weak or non-existent. These findings are consistent with expectations based upon density gradient parameters for a Western type of city and indicators showing a definite trend toward development. The exceptions themselves do not detract from the nature of the findings, but instead serve to strengthen the connection between appearance of a Western population density gradient pattern and economic development. The strong relationship between central density and the dependency ratio indicates that the demographic transition, historically associated with economic development, is linked to the appearance of the Western pattern in a significant manner. Similarly, the relationships between density gradient parameters and the transportation variables show a connection between modernization of transportation and the spreading out of the city indicated by continually declining density gradient slopes and, late in the study period, decreasing central densities. Finally, the gradient parameters-industrial production relationships may be interpreted as indicating a connection between deconcentration of urban population and expansion of the industrial sector of the economy. This particular

connection is readily apparent in the recent growth of secondary settlement nodes that ring Taipei. Population growth has generally accompanied or followed establishment of new industrial plants at these locations, and they are presently the sites of the most intense residential construction activity.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The purpose of this study was to examine the proposition that a difference exists in the population density gradient patterns characterizing Western and non-Western cities, and to demonstrate that the appearance of a Western pattern is associated with economic development. The analyses and findings presented clearly validate the hypothesis that the gradient pattern for Taipei exhibits the same kind of changes in slopes and central densities that have been said to characterize Western cities. The density gradient slopes declined continually throughout the study period and central densities first increased and then decreased. In addition, trends in population growth, changes in weighted mean center locations, and corollary relationships all substantiate the conclusion that Taipei's gradient pattern is of the Western type. The patterns illustrated in Figure 16 clearly show that Taipei is more like the Western cities of London and Chicago in terms of density gradient patterns than non-Western cities such as Calcutta and Poona. The primary difference is that the

Figure 16

Population Density Gradient Patterns:
Taipei, Poona, London, Calcutta and Chicago

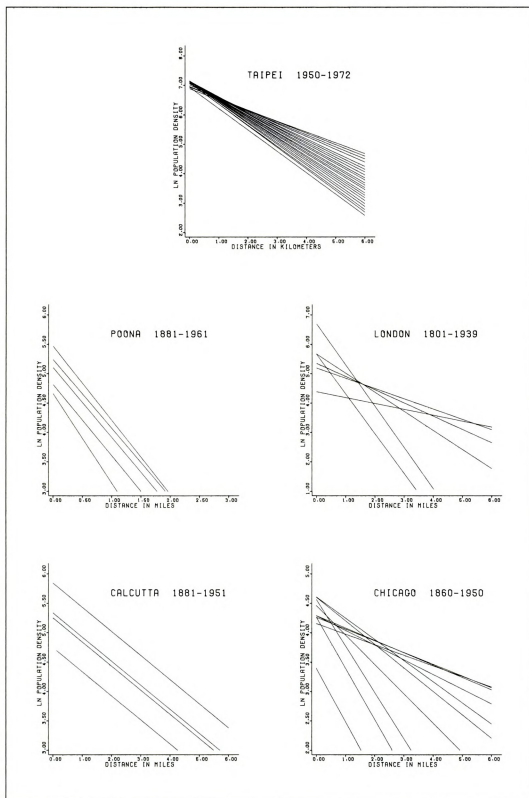


Figure 16.

Western pattern has appeared in Taipei over a relatively short period of time when compared to Chicago or London. This is especially true of the changes in gradient slopes. It took fifty years for a decline in slopes to occur in London and thirty years in the case of Chicago, while a similar decline in Taipei required only twenty-three years. The differences in time spans required for similar changes to occur points to the importance of the opportunity to adopt new technology instead of having to invent and develop it before its effect can be seen.

The evaluation of relationships between density gradient parameters and indicators of economic development served to demonstrate a link between Taiwan's economic development and parameters shown to be characteristic of a Western density gradient pattern. Rapid changes in transportation facilities and large increases in industrial production beginning in the 1960's were shown to be significantly related to declines in central densities. General trends in economic development as measured by the demographic, transportation, economic and employment variables were also shown to be related to the decline in density gradient slopes during the study period. The conclusion that may be drawn from these findings is that Taiwan's economic development was significantly related to the appearance of a Western population density gradient pattern in Taipei.



Given the nature of the results obtained and conclusions drawn in this study, a question that remains to be answered is why the notion of a Western - non-Western dichotomy in population density gradient patterns persisted over the past decade. Answers to this question may be found by considering the shortcomings and problems involved in previous research. The most prominent shortcoming of earlier research has been the failure to fully appreciate the implications of Clark's model in terms of the population growth rate characteristics to be expected in a Western city. As was shown earlier, the non-Western pattern can appear only when population growth rates are identical throughout an entire urban area. Temporary existence of such a situation is possible and was approximated in Taipei during the early 1950's. Interminable continuation of that situation, however, would appear to be unrealistic. Central densities would eventually rise to a point beyond which further increases would become impossible. At that point local growth rates would have to change, and with them, the parameters describing the density gradient. Even without economic development, therefore, the sheer weight of numbers would eventually force a change in the density gradient pattern. With the notable exception of Newling's work in 1966, the physical limitations upon mathematically possible continuation of the non-Western density gradient



pattern have not been recognized or appreciated.⁹⁵ Thus, one explanation for the continued acceptance of the Western - non-Western dichotomy can be found in the failure to critically evaluate the implications of the supposed non-Western pattern in terms of Clark's model.

A second shortcoming of previous research has been the failure to evaluate density gradient patterns in conjunction with the history of industrial development in the Western world. Density gradient patterns for London and Chicago clearly contain elements of both the Western and the non-Western patterns (Figure 16).⁹⁶ London gradients for the two earliest points in time (1801 and 1841) bear a strong resemblance to those for Calcutta and Poona. A similar series of almost parallel gradients characterized Chicago in the 1860-1880 period. In both cases the periods marked by parallel density gradients preceded modernization of transportation facilities available to the population and the heavy industrialization of national economies. With the advent of steam power for both transportation and industry, and the later development of electrically-driven mass urban transportation, both cities experienced changes

⁹⁵Newling, "Urban Growth and Spatial Structure: Mathematical Models and Empirical Evidence," op. cit.

⁹⁶Density gradient parameters for London, Chicago, Poona and Calcutta are listed in Table 1. Those for Taipei appear in Table 9.



in population distribution as reflected by changes in the density gradients. In short, the role of economic development in the appearance of Western gradient patterns in Western cities has been overlooked.⁹⁷

Failure to examine development trends in Western nations has encouraged the proposition that socio-cultural differences between Western and non-Western nations can account for differences found in density gradient patterns.⁹⁸ The evidence strongly indicates, however, that the differences are actually associated with stages in the process of economic development. Prior to industrialization and economic development, density gradient patterns of the non-Western type characterized both Western and non-Western cities. General economic development, on the other hand, has been associated with shifts to the Western type of gradient pattern. This conclusion is substantiated to the extent that the appearance of Western density gradient patterns in London, Chicago and Taipei all coincided with periods of economic development characterized by industrialization and modernization of transportation facilities.

⁹⁷Clark noted the importance of changing transportation technology in his original work, but did not point out the association of general economic development with the density gradient patterns. Clark, "Urban Population Densities," op. cit., pp. 491, 495; idem., "Transport--Maker and Breaker of Cities," op. cit.

⁹⁸Berry, Simmons and Tennant, op. cit., pp. 402-407.

In the case of Taipei, the availability of data on an annual basis made possible a clear illustration of the relationship.

From a practical standpoint, the most serious problem encountered in research into population density distribution questions has been the difficulty involved in obtaining adequate data for analysis. Generally, detailed and extensive longitudinal data are available for only the most economically advanced nations. As a result, attention has been focused on cities in Western nations while those in developing countries have received little consideration. Another data-connected problem is related to the relatively recent appearance of firm development trends in the non-Western world. In the absence of movement toward economic development it is doubtful that definite shifts in density gradient patterns would be evident even if adequate data were available. To a large extent, this fact probably explains why Berry, Simmons and Tennant were led to conclude that socio-cultural differences between Western and non-Western nations accounted for dissimilar density gradient patterns. The 1881-1951 data for Calcutta with which they worked did not include a period of economic development, industrialization or modernization of transportation facilities. Had data for Taipei during the same period been examined it is highly probable that trends similar to those for Calcutta would have been found. The shortcomings

of available data do not, however, lessen the impact of the failure to analyze historical trends in Western cities, nor do they excuse neglecting a careful consideration of the implications of Clark's model in terms of the supposed non-Western density gradient pattern. Indeed, the idea of a Western - non-Western dichotomy would not have been accepted for such a long period of time had a full and careful evaluation of previous research findings and their implications been carried out.

Recommendations

Two recommendations based upon the findings of this study and field observation are here offered for consideration. The first is related to the idea of a Western - non-Western dichotomy. In light of the shortcomings in previous research and the findings and conclusions of the present study, a new paradigm is proposed as a replacement for the dichotomous Western - non-Western model. In place of an approach emphasizing the existence of a dichotomy, let us view density gradient patterns as indicators of progress in economic development. Instead of focusing attention on social and cultural differences between nations, differences in stage or level of economic development should be considered for an explanation of variation in density gradient patterns. Then, rather than consigning cities in the non-Western world to an unchanging pattern

of constant gradient slopes and ever increasing central densities, the evolutionary role of development could be recognized and changes in population distribution characteristics anticipated.

By making a change in outlook and approach, the population density gradient model may be converted from a descriptive tool to a dynamic means for analysis and prediction. For example, evaluation of Taipei's density gradient parameters for the 1950-1972 period shows that the appearance of a developed economy gradient pattern took place quite rapidly when compared to Britain and the United States. The speed with which the pattern appeared indicates a general quickening in the rate at which economic development has occurred over the last century. In turn, this implies a potential for rapid development in other places and points to a need for careful planning that includes provision for expanding urban systems. In terms of anticipating changes, Newling has already shown how density gradient slopes may be entered into projections of urban population.⁹⁹ Latham and Yeates have also demonstrated a density predicting technique involving parameters from a

⁹⁹Newling, "Urban Growth and Spatial Structure: Mathematical Models and Empirical Evidence," op. cit., pp. 216-220.



quadratic expansion of Clark's basic equation.¹⁰⁰ Clearly, the time has come when use of a simplistic dichotomy that effectively relegates many of the world's growing urban centers to a kind of second-class status can no longer be continued. Adoption of a new dynamic conception of the population density gradient model promises not only to yield a more realistic and useful view of urban growth, but also to open new doors to exploration, examination and evaluation of change in urban systems.

The second recommendation offered here concerns the topic of future research. The findings of this study strongly indicate that the Western - non-Western dichotomy is actually an indication of economic development. There is a chance, however, that Taipei is an atypical case and unrepresentative of other cities in developed and developing nations. Any number of features might contribute to its uniqueness among the world's metropolitan centers. Taipei, for example, has a somewhat more compact settlement pattern than most other cities that have been studied. The city's growth is also constrained due to its location in a basin ringed by steep hills and mountains. In addition, Taipei has grown most rapidly in a period marked by

¹⁰⁰R. F. Latham and M. H. Yeates, "Population Density Growth in Metropolitan Toronto," Geographical Analysis, Vol. 2 (1970), pp. 177-185.

political tensions and military confrontation.¹⁰¹ Any one, or all, of these and a host of other considerations might have contributed to conditions influencing the results of this study.

To answer the implied question of whether or not Taipei is a unique case, it is recommended that studies similar to the one reported here be conducted. Should results like those for Taipei be obtained for other locationally and culturally non-Western cities, the idea of a Western - non-Western dichotomy could be confidently replaced by one that stresses the role of economic development in the appearance of "Western" density gradient patterns. It is further recommended that cities in a variety of nations characterized by different levels of economic development be selected for study. In the East Asian portion of the world Japanese cities such as Tokyo, Nagoya and Sapporo might be selected as representatives of the most developed non-Western nation. Results of the study of Taipei could be considered along with those derived from research on the Korean city of Seoul as representing cities in rapidly developing nations. Finally, density gradient patterns for cities like Bangkok, Manila and

¹⁰¹Taiwan is still governed under the rules of martial law due to the unresolved civil war between Nationalist forces on Taiwan and Communist forces on the mainland of China.

Djakarta could be used to represent newly developing nations. The results from such a broad based study would not only yield gradient patterns depicting population distribution changes in the subject cities, but would also provide a more definitive picture of the highly probable link between economic development and the appearance of the "Western" type of density gradient pattern. Given favorable results from this kind of research undertaking, the idea of a Western - non-Western dichotomy could be laid to rest and the nagging question about Taipei's possible uniqueness dismissed. Until a broad based research project aimed at investigating the connection between development and "Western" density gradient patterns can be completed, however, the results obtained for Taipei may be viewed as a strong indication that such a link probably exists. A start has been made with the present study of Taipei, but work remains to be done before final conclusions may be reached concerning the apparent strong relationships hidden by the Western - non-Western dichotomy.

APPENDICES

APPENDIX A

CHANGES IN POPULATION WEIGHTED MEAN CENTERS



Appendix A

Changes in Population Weighted Mean Centers

To investigate changes in the distribution of population within an urban area, one may examine changes or shifts in weighted mean centers of subdivisions of the area. Shifts in weighted mean centers associated with changes in the distribution and size of the population can be illustrated by means of a series of examples. An analogy will be used that equates concentric zones about the central business district (CBD) to stacks of bricks, and individual bricks to population. The effects of increasing the population and changing its distribution on mean centers and density gradients will be examined in four situations.

As a starting point assume that 180 bricks are arranged in fifteen stacks, each stack containing twelve bricks. Assume also that the stacks are arranged in a line at one meter intervals and that each stack is numbered according to its distance from the leftmost stack. The number of bricks in each stack is indicated at the top of the stack, and the distance separating each stack from the leftmost position (analogous to the CBD) is indicated at

the foot. The stack numbers not only identify the stacks, but also serve as distance measures (Figure 17, A).

Dividing the fifteen stacks into three groups, each containing five stacks, provides gross groups for which detailed data are available. The weighted mean center of each group of stacks may be determined using the number of bricks in the stacks as the weights. The location of the weighted mean center of each group is obtained by multiplying the number of bricks in each stack within a group by its associated distance value, summing the products, and dividing the sum by the total number of bricks within the group.¹ The weighted mean centers for the three groups are located at two, seven and twelve meters for the left, middle and right groups respectively (Figure 17, A). These locations are indicated by the dots immediately below the line of stack numbers. In this special case of an even distribution of bricks (population) among the stacks (concentric zones) the weighted mean centers coincide with the physical centers of the groups of stacks.

The distribution of bricks among the stacks bears little resemblance to the general distribution of population within an urban area (Figure 17, A). There is no change

¹Maurice Yeates, An Introduction to Quantitative Analysis in Human Geography (New York: McGraw-Hill, Inc., 1974), pp. 30-33.

Figure 17

Mean Center Locations Under Different Distribution Schemes

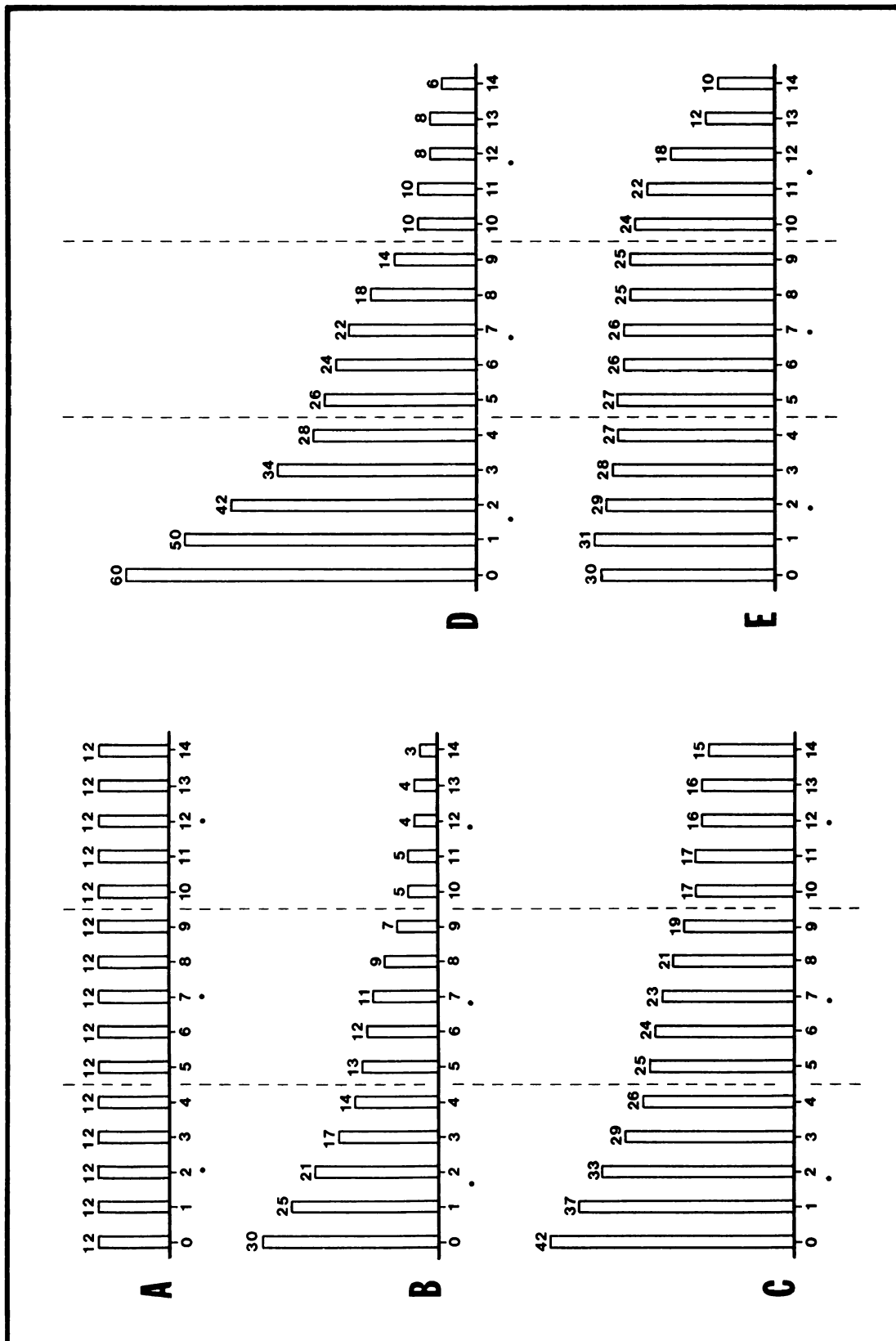


Figure 17.



in the number of bricks per stack (persons per unit area) as one moves from stack 0 (the CBD) to stack 14 (the urban fringe), i.e., the slope of the density gradient is zero. An approximation of decreasing population density (bricks per stack) with the increasing distance from the CBD may be obtained by rearranging the 180 bricks among the stacks (Figure 17, B). The weighted mean centers for the left, middle and right groups of stacks are located at 1.63, 6.71 and 11.76 meters respectively. The leftward shift of the weighted mean centers is due to the relative concentration of bricks on the left side of each group. This situation is analogous to the relative concentration of population on the inward (CBD) sides of concentric zones, yielding a difference between the weighted mean centers and the physical centers of the groups. The slope of the density gradient is -1.71 , indicating a decrease of 1.71 bricks per stack for each additional meter away from the leftmost position.

Increasing the number of bricks distributed among the stacks, analogous to increasing the population within an urban area, will usually affect the locations of the group weighted mean centers. For example, if the number of bricks is doubled by the addition of 180 bricks, but all are placed on stack number eight, the weighted mean center of the middle group of stacks would shift to the



right and be located at 7.71 meters. The centers of the other groups would not be affected.

It is rather unlikely that an increase in population would be concentrated entirely in a single zone. A more realistic scheme for the distribution of additional population is to spread the increased numbers evenly throughout the urban area. In terms of the stacks of bricks, this would involve adding twelve of the additional 180 bricks to each of the fifteen stacks (Figure 17, C). The effect of such a change on the group weighted mean centers would be considerable. All three would shift to the right and toward the physical centers of the groups. The center of the left group would shift from 1.63 to 1.76 meters, that of the middle group from 6.71 to 6.87 meters, and from 11.76 to 11.94 meters in the right group.² The shifts in the mean centers are due to the greater proportional increases in the rightmost stacks within each group. The addition of twelve bricks to stack fourteen for example increases its proportional share of the total from .0167 to .0417, giving stack fourteen greater weight in the

²It is interesting to note that with a scheme of even distribution of additional numbers the weighted mean center of a group will never quite equal the physical center of the group regardless of the numbers added. For example, adding one million bricks to each stack in the right group yields a weighted mean center 11.9999 meters from the zero point, slightly less than the physical center located at twelve meters.



determination of the weighted mean center. The change in stack ten occasioned by the addition of twelve bricks is from .0278 to .0472, a smaller increase in proportional value than occurred in stack fourteen.

Under the even distribution scheme, involving addition of the same value to all stacks, the slope of the gradient, describing the rate of change in the height of the stacks with increasing distance, will be unchanged. The intercept of the gradient, however, will be increased by the number of bricks added to each stack. This change is similar to that which occurs in the roof of a house under which the foundation is raised. The slope of the roof remains unchanged but the height of the roof above the ground is increased by the amount added to the foundation. This rather singular effect of an additive, even distribution procedure on the slope of the density gradient, proves to be quite important in distinguishing between Western and non-Western cities by means of weighted mean center shifts.

A third possibility for the distribution of additional population is proportional allocation. Under this scheme each zone within the urban area receives the same proportion of the additional population. Thus, a doubling of the total population will result in a doubling of the population within each zone. Because population changes within the zones are proportional, there is no effect on



the locations of the weighted mean centers. Instead of moving toward the physical centers, the weighted mean centers will remain at the locations they occupied prior to the increase (Figure 17, D).

The proportional mode of distribution of additional population contains a mathematical feature of salient interest in the evaluation of population density gradient patterns. A direct tie between weighted mean center shifts, and population density gradient patterns can be established making it possible to anticipate the type of weighted mean center shifts to be found in non-Western cities. The connection lies in the computational rules involved in the use of logarithms.

The proportional distribution of additional population is basically a multiplicative process. The population of each concentric zone is multiplied by the proportional increase (growth rate) for the total population. For example, if the total population doubles, the population of each zone will be multiplied by two (compare Figures 17, B and D). Under the rules of computation using logarithms, a multiplicative procedure becomes an additive procedure where the logarithm of the product is the sum of the logarithms of the multiplicand and the multiplier.³ Since a

³Federal Electric Corporation, Logarithms (New York: John Wiley and Sons, Inc., 1972).

logarithmic conversion is used to transform the population density-distance relationship described by the density gradient to a linear form, the multiplicative process on the raw data becomes an additive process on the transformed data. The logarithm of the multiplicative factor (two in the case of a doubling of the population) is added to the logarithms of the original raw values. As previously demonstrated, adding a constant to all values increases the value of the intercept without affecting the slope of the density gradient. A series of proportionally distributed population increases will, therefore, yield a series of parallel population density gradients--the pattern postulated for non-Western cities and exemplified by the case of Calcutta (Figure 1). Since it has already been shown that proportional distribution of additional population results in no change in the locations of weighted mean centers, the mathematical connection between proportional distributions and parallel density gradients implies an absence of weighted mean center shifts in non-Western cities as their populations grow.

Let us now turn to the type of weighted mean center shifts that may be anticipated in a Western city. The growth experience of Western cities has shown elements of both the proportional and additive patterns. The density gradients for London indicate that the proportional pattern of distribution of additional population existed between

1801 and 1841 (Figure 1). The same may be said for Chicago on the basis of population density gradients for 1860 and 1870. Since the mid-nineteenth century, however, the proportional patterns have disappeared. Central city populations have stabilized and, in more recent times, declined. Suburban areas have filled in and cities have expanded into the less populated fringe areas.

Returning once again to the examples involving the stacks of bricks, the type of distribution of additional population experienced by Western cities can be seen in Figure 17, E. Even though there are twice as many bricks as in Figure 17, B, the distribution has a much more even nature. A density crater in the CBD, filling in of the middle (suburban) area, and expansion into the fringe areas are all represented.

The effect of the distribution of additional bricks on the weighted mean centers is quite different from that occasioned by a proportional distribution. Instead of remaining static, the centers have shifted, but not in the manner described for an even distribution of additional numbers (Figure 17, C). Decreases in the proportion of the population living in the CBD and inner city along with filling in of the nearby suburban areas (middle group of stacks) has led to an outward shift in weighted mean centers. The shift is illustrated by the movement of the

left group weighted mean center from 1.63 to 1.90 meters, and from 6.71 to 6.96 meters in the middle group.

The right group of stacks, representing the urban-rural fringe, has increases concentrated in stacks 10, 11 and 12. This corresponds to urban expansion into previously lightly settled fringe areas, a phenomena particularly pronounced in the metropolitan centers of the United States. Such a growth pattern shifts the weighted mean center to the left, away from the physical center of the group and toward the CBD, as represented by stack zero. In the case of the brick stacks illustrated in Figure 17, E, the shift was from a weighted mean center located at 11.76 meters to one located at 11.55 meters in the right group of stacks. Also, the slope of the density gradient associated with the distribution in Figure 17, E is about one third less than that associated with Figure 17, B, -1.24 in the former case and -1.71 in the latter.

While a number of possible configurations might be used to illustrate the distribution of additional population in Western cities, they will bring about shifts in weighted mean centers. In fact, any departure from a strictly proportional distribution of additional population will result in weighted mean center shifts in one or more groups of concentric zones. Similarly, any departure from a proportional distribution in a series of additions to population will result in a series of non-parallel density



gradients. Western and non-Western cities may be distinguished, therefore, on the basis of the presence or absence of weighted mean center shifts.



APPENDIX B

DATA FOR INDEPENDENT VARIABLES

Appendix B

Data for Independent Variables

Variable Definitions

<u>Variable</u>	<u>Definition</u>
1	Births per thousand population
2	Deaths per thousand population
3	Dependency Ratio: number of persons aged zero through fourteen years plus number of persons aged sixty years and over per 100 persons aged fifteen through fifty-nine years of age
4	Bicycles per thousand population
5	Motorcycles per thousand population
6	Automobiles per thousand population
7	Buses per thousand population
8	Trucks per thousand population
9	Index of agricultural production (1952 = 100)
10	Index of industrial production (1952 = 100)
11	Agriculture's percent share of Net Domestic Product
12	Industry's percent share of Net Domestic Product
13	Agriculture's percent share of exports by value
14	Industry's percent share of exports by value
15	Raw per capita income (N.T. \$)
16	Real per capita income (N.T. \$), at 1966 prices

- 17 Percent of employed labor force in agriculture
- 18 Percent of employed labor force in industry
- 19 Percent of employed labor force in services
- 20 Percent of employed labor force in transportation
- 21 Percent of employed labor force in commerce

Variables

<u>Year</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>
1952	46.62	9.88	86.8	63.2	.24	.32	.200
1953	45.22	9.43	87.8	72.3	.52	.39	.229
1954	44.63	8.17	89.0	85.8	.78	.44	.247
1955	45.29	8.59	90.2	94.0	.37	.53	.273
1956	44.84	8.02	91.9	100.0	.31	.60	.277
1957	41.39	8.46	93.3	104.6	.40	.61	.287
1958	41.65	7.58	94.7	112.0	.68	.67	.300
1959	41.18	7.23	95.7	129.0	1.52	.68	.298
1960	39.53	6.95	98.4	136.4	2.45	.75	.319
1961	38.31	6.73	100.2	145.1	2.94	.80	.323
1962	37.37	6.44	100.9	159.0	3.11	.87	.329
1963	36.27	6.13	100.5	162.1	3.38	.92	.339
1964	34.54	5.74	99.4	166.1	4.04	1.01	.366
1965	32.68	5.46	97.5	171.2	5.40	1.20	.392
1966	32.40	5.45	94.4	172.7	7.28	1.48	.426
1967	28.47	5.47	92.2	171.2	29.29	1.89	.433
1968	29.26	5.47	89.5	165.0	35.41	2.25	.454
1969	27.92	5.04	82.9	139.9	43.90	2.76	.510
1970	27.16	4.90	80.6	132.8	47.94	3.38	.542
1971	25.64	4.78	78.1	123.3	55.13	3.67	.594
1972	24.15	4.72	76.4	115.0	62.62	4.71	.617

Variables

<u>Year</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>	<u>13</u>	<u>14</u>
1952	.49	100.0	100.0	35.7	17.9	95.2	4.8
1953	.51	109.8	124.3	38.0	17.6	92.7	7.3
1954	.51	112.2	132.8	31.5	22.0	92.1	7.9
1955	.51	112.6	148.0	32.5	20.9	92.3	7.7
1956	.50	121.4	155.4	31.2	22.2	86.8	13.2
1957	.51	130.0	176.3	31.3	23.6	91.3	8.7
1958	.56	139.8	189.8	31.0	23.8	86.3	13.7
1959	.65	141.3	214.7	30.3	25.5	76.1	23.9
1960	.69	143.2	244.6	32.5	24.7	66.1	33.9
1961	.71	155.4	281.9	31.3	24.9	57.2	42.8
1962	.73	158.7	313.6	29.0	25.7	49.2	50.8
1963	.77	157.9	342.4	26.6	28.0	56.9	43.1
1964	.84	178.0	409.6	27.7	28.2	56.0	44.0
1965	.99	191.2	487.0	27.0	28.2	54.1	45.9
1966	1.21	201.1	565.0	25.7	28.6	45.1	54.9
1967	1.41	213.0	660.5	24.5	29.4	41.1	58.9
1968	1.99	226.0	803.4	23.8	30.3	33.6	66.4
1969	2.47	223.7	948.6	20.3	31.6	27.5	72.5
1970	2.79	237.1	1115.3	19.1	32.5	21.8	78.2
1971	3.17	242.1	1349.7	17.1	34.5	19.6	80.4
1972	3.69	246.7	1700.6	15.7	36.6	17.1	82.9

Variables

<u>Year</u>	<u>15</u>	<u>16</u>	<u>17</u>	<u>18</u>	<u>19</u>	<u>20</u>	<u>21</u>
1952	1716	4277	61.0	9.3	19.0	2.2	8.5
1953	2215	4420	61.3	9.2	18.7	2.3	8.5
1954	2273	4481	60.4	9.6	19.0	2.6	8.4
1955	2604	4712	59.9	9.8	19.3	2.6	8.4
1956	2858	4759	59.9	9.9	19.2	2.6	8.4
1957	3198	4942	58.2	10.4	20.2	2.8	8.4
1958	3434	5017	57.1	10.9	20.5	2.8	8.7
1959	3849	5224	56.6	11.1	20.6	2.9	8.8
1960	4557	5360	56.1	11.3	20.7	3.0	8.9
1961	4953	5596	55.8	11.3	21.0	2.9	9.0
1962	5189	5752	55.3	11.5	21.3	3.0	8.9
1963	5782	6333	54.5	11.7	21.7	3.2	8.9
1964	6728	7105	54.2	11.8	21.9	3.2	8.9
1965	7032	7354	53.7	12.0	22.1	3.2	9.0
1966	7677	7677	53.0	12.3	22.4	3.3	9.0
1967	8461	8256	49.4	14.6	23.4	3.7	8.9
1968	9554	8689	49.4	16.4	21.7	3.7	8.8
1969	10499	9142	45.0	15.9	27.2	3.5	8.4
1970	11727	9956	44.5	15.9	27.5	3.6	8.5
1971	13168	10836	42.3	18.0	28.0	3.7	8.0
1972	15001	11644	39.9	19.8	28.4	3.8	8.1

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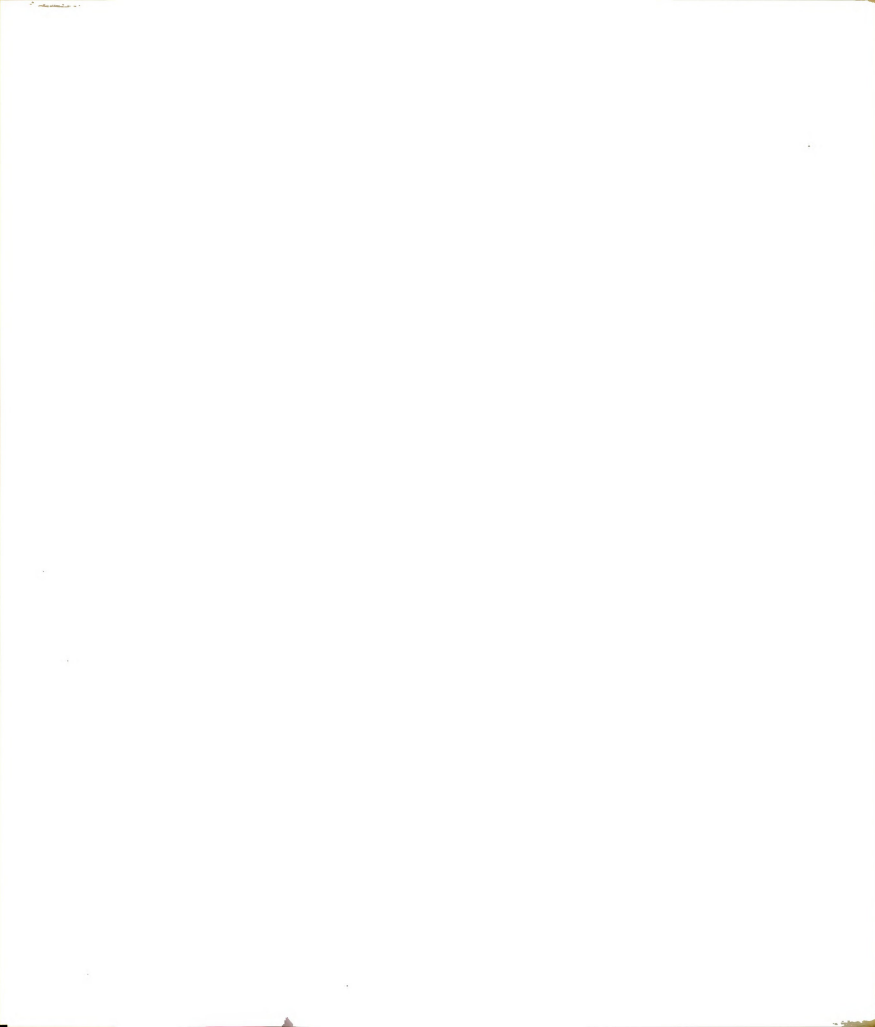


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