URBAN POPULATION DENSITY GRADIENTS IN PORT OF SPAIN, TRINIDAD

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF ART

Department of Geography

1982

ABSTRACT

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This Thesis attempts to reveal the existence of a city which shows a transition between the non-western and western urban population density patterns. Using regression techniques, both the Clark and Newling Models will be tested as to their fit in Port of Spain. The data needed was population density by district, distance to the city center and distance squared. The analysis of this data using both of the models mentioned above, showed that it is possible to identify a transition density pattern. This is of particular significance since the trend in developing and developed nations is not dichotomous over time, but rather reflects the changing needs of the city as economic development proceeds. The work done in developed nations will prove to be a valuable source of information for planners and policy makers of the developing world in the planning, directing, ameliorating and anticipating the direction which urban growth will take.

DEDICATION

To my father and mother who

stood by me.

ACKNOWLEDGMENTS

This thesis would not be complete if I did not recognise the assistance given to me by many individuals. Among them are Kathy Frohnert who worked on the maps and figures used in this research and Jo Cornell who typed the finished product. Of special note are Dr. Joe Darden and Dr. Bruce Wm. Pigozzi under whose guidance this thesis was written. Special thanks must go to Dr. Pigozzi who patiently went through the numerous draft copies I produced -- your encouragement, comments and criticisms were deeply appreciated as it encouraged me to work that much harder. In addition to the assistance given to me by these individuals, I must also thank my sister Dawn, for her help in the laborious tasks of copying out the raw data I needed from those dusty volumes of statistics.

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CHAPTER I

CHANGING URBAN POPULATION DENSITY OVER TIME

In the recent years since the mid 1940's, geographers have begun to examine the processes of urbanization and urban growth. One aspect of these processes has been the changes in the spatial distribution of the urban population over time.

It has been suggested that differences exist in the urban population density patterns which are characteristic of "Industrial" and "Pre-Industrial"[1] or "Western" and "non-Western"[2] cities. These studies have tended to focus on the cities of the industrially advanced Western nations and their findings are of considerable value in the planning and promotion of the orderly growth of cities. However, the topic of the spatial distribution of the urban population in the developing nations has suffered from a lack of attention. In addition, quite often the findings of studies focused on the Western nations has been deemed inapplicable to the cities of the developing world.[3] Insight into the distribution of urban population densities in the developing nations is needed.

Works on the pattern of urban population densities seem to suggest that the trend observed in developed and developing nations is dicotomous. If nations move from an underdeveloped to a developed state, it is contended that the pattern of urban population densities should also approximate the pattern observed in Western nations, as the development process proceeds. As such there should be cities which incorporate features of the density patterns observed in both developed and developing nations -- an example of a transition from one stage to another. This Thesis attempts to reveal such a city which shows this transition.

The Problem

If the disparity in the pattern of urban population densities between developed and developing countries does exist, the findings of the studies concerned with urban density gradients in advanced nations will be of limited value for the developing nation. However, if it can be shown that the trend in developing and developed nations is not dicotomous over time but rather reflects the changing needs of the city as economic development proceeds, the work done in developed nations will prove to be a valuable source of information for planners and policy makers of the developing world in the planning, directing, ameliorating and anticipating the direction which urban growth will take. As such it is my purpose to identify the existence of a transition between the western and non-western urban population density patterns through an analysis of the changing form of the urban density pattern over time in the city of Port of Spain and its suburbs. The existence of a transition between the two patterns will be said to exist if features associated with both types of urban population density structures can be identified.

The Models

The differences in intra-urban population densities has been a subject of much attention especially since the work of Colin Clark in 1951.[4] The mathematical model developed by Clark describes the relationship between population density and distance from the center of the city or Central Business District. This model states that the spatial distribution of population densities within cities appear to conform to the following equation.

$$D_x = D_o e^{-bx} \qquad (1)$$

where

D_x = population density at distance x from the city center

D_o = population density at the city center

b = density gradient [indicating a negative exponential decline]

e = the base of natural logarithms.

The value of the density gradient slope (b) indicates the rate of change in population density with a unit change in distance (x), when the equation is log transformed. If the absolute slope value is large, this is indicative of a rapid decline in population density as distance from the Central Business District [CBD] increases. A city with a large slope value would be compact and relatively limited in spatial extent. [A small absolute slope value would indicate a dispersed and spatially extensive city.][5] A population density gradient is a line showing both the population density at varying distances from the center of the city and the rate at which population density decreases as distance from the city center increases.

Clark's model has undergone a series of applications, evaluations and revisions. These revisions have been aimed at making the model approximate reality move closely. However, the general linear's relationship specified by the equation

$$\ln D_x = \ln D_o - bx \qquad (2)$$

which is derived from (1) by performing a logarithmic transformation on the density data has been found to be representative of the distance decay function associated with population density in cities around the world.

The first revisions proposed independently by J. C. Tanner and G. G. Sherratt[6] suggested that urban population densities decline exponentially as the square of distance where

$$D_x = D_o e^{-bx^2} \qquad (3)$$

This modification is inadequate as a general rule as it assumes that

> "The instantaneous rate of change of density with distance at the center of the city is zero and does not recognize the possibility that the instantaneous rate of change of density at the center can be either positive [as when density first rises and then falls with increasing distance from the city center] or negative."[7]

Bruce E. Newling[8] extended the basic negative exponential model by the addition of distance squared [x^2] as an explanatory variable. This variable takes into account the likely fall in population density at the heart of the city when business and commercial activities preclude these same sites as locations of residence. Newling's model takes the following form:

$$D_x = D_o e^{bx-cx^2} \qquad (4)$$

$$\ln D_x = \ln D_o + bx - cx^2 \qquad (5)$$

where

$\ln D_x$ = the logarithm of the population density at distance x from the center of the city

$\ln D_o$ = the logarithm of the population density at the center of the city

b = a parameter which measures the change in density at the center of the city

c = a parameter which measures the change in density away from the center of the city.

It has not been decided whether Newling's model is superior to Clark's in terms of data conformance.[9] Hideaki Ishikawa undertook the formulation of a new model in an isolated, hypothetical city.[10] His model attempts to take into consideration the centrifugal and centripetal forces which influence population movements in urban areas. Ishikawa also attempts to present a model for the daytime [or working population] and residential population density distributions to derive the density crater seen in large metropolitan areas. However, Ishikawa's model was not applied to an actual city and as such, in this instance cannot be used as the Clark and Newling models have been to establish the existence of a transition between Western and Non-Western density patterns.

Bruno De Borger[11] used the basic Clark model in the study of surburbanization in Belgium. However, unlike the research discussed thus far, De Borger was concerned with the influence of income and transport costs on the changing values of the parameters of the urban population density functions.

The spatially systematic relationship between urban population densities and distance revealed by the Clark and Newling models have withstood time. However, it has not been determined whether the Newling or Clark model is superior in terms of data conformance - this depending on the city being examined and its development history.

Two major findings of Clark's model have been the subject of much discussion. First, where the model has been used to derive population density gradient parameters for a given city at different points in time, both the b values [slope term] and a values [central densities] have been found to differ. These differences have been taken to be indicative of an increase in the spatial extent of the city and changes in the concentration of population in the center of the city.[12]

In addition to this Harry W. Richardson noted that:

> "Apart from the observation that b becomes smaller over time [the suburbanization effect], there has been little systematic analysis of the behavior of D_0 and b in conditions of urban growth. Intuitively, population growth may be expected ceteris paribus to increase densities everywhere and to extend the boundaries of the city, but this might be associated with either a higher or lower b. Income growth [associated with economic development] will tend to flatten b, if the demand for space is income elastic and because higher incomes allow households to spend more on travel. When income and population change simultaneously, the consequences for urban spatial structure may be very complex."[13]

Second, when the density gradient of cities in the economically advanced and developing countries have been compared over time, the density gradient slopes for "Western cities" tend to decrease in value, indicating a suburbanization or "decompaction"[14] of the city along with an increase followed by a decrease in central densities suggesting a deconcentration trend. Slope values for developing countries on the other hand, have been found to remain relatively constant over time while central densities have continued to increase. The situation in developing countries is indicative of overcrowding [increasing central densities] and urban expansion without suburbanization in the Western sense. Figure 1 illustrates the differences between "Western" and "non-Western" cities in terms of density gradients and central densities over time.

Transition Density Patterns

I contend that the pattern theorised by Berry Simmons and Tennant for non-western cities will not be found in its pure form for Port of Spain as:

i) Trinidad is now among the ranks of the more developed of the less developed countries - implying that the country is progressing towards greater economic development. Ideally this process should continue until Trinidad is considered to be economically advanced.[15]

ii) In the process of growth, urban centers should undergo a transition from old morphological and functional patterns, derived from the Spanish and British colonial rule, to patterns commensurate with the goals and capabilities of the nation's economic plans.

iii) It would seem that to apply the term "non-western" to the city of Port of Spain is a mis-nomer, as, Port of Spain is, strictly speaking not a non-western city.

Figure 1: <u>Temporal Comparison of Western and Non-Western Cities</u>.

[Source: B.J.L. Berry, J.W. Simmons and R.J. Tennant, "Urban Population Densities: Structure and Change," <u>Geographical Review</u>, 53, 1963, pp. 403.

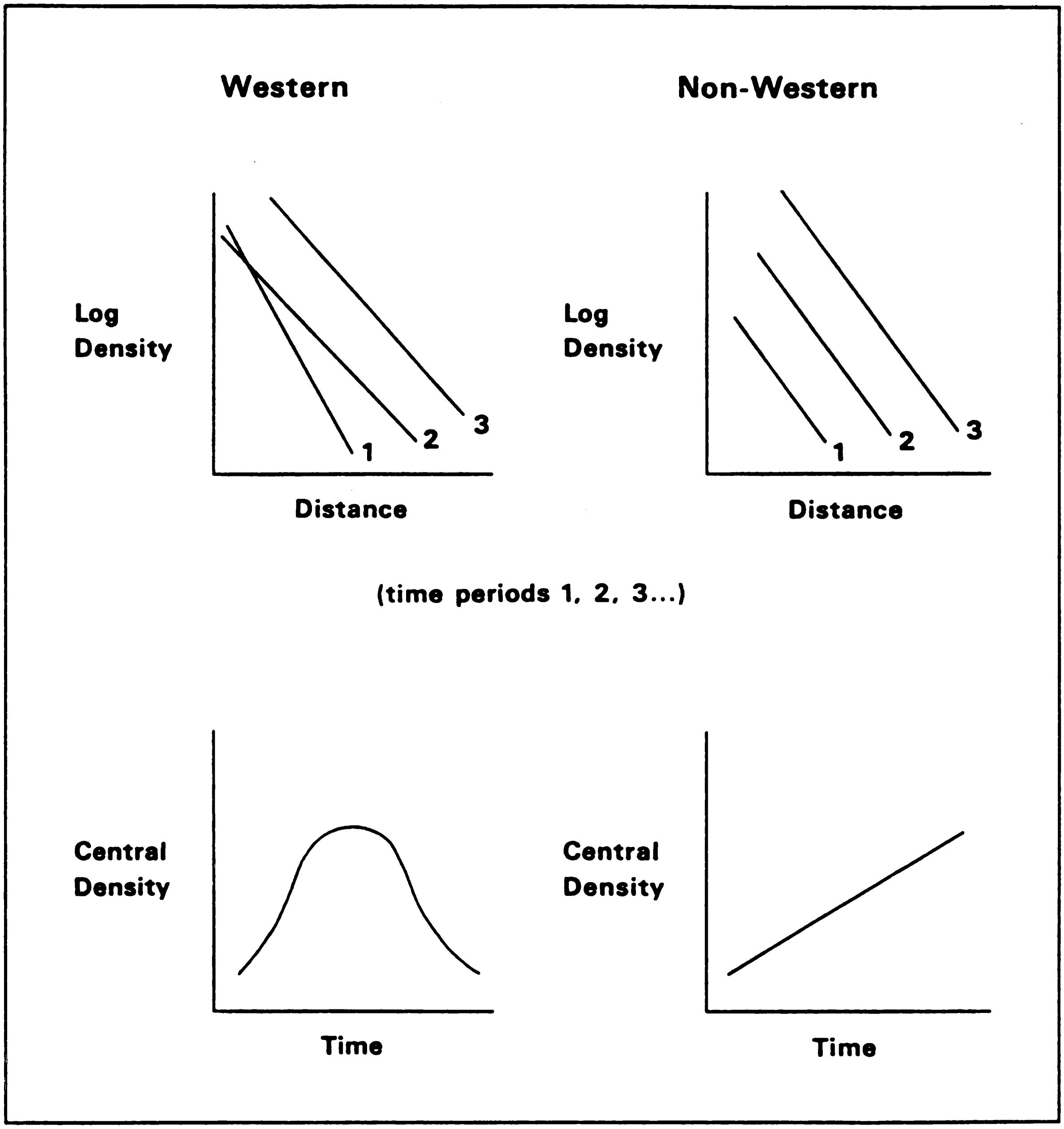


Figure 1. Temporal Comparison of Western and Non-Western Cities

iv) It is hypothesized by the researcher, that the pattern of urban population densities is not dicotimous; one pattern in less developed nations and another in advanced countries. Rather, there should be an intermediate pattern as the country moves towards the ranks of the economically advanced stage of economic development. Just as there is a continum of examples of countries at various stages of economic development, there should also be a continum of urban density patterns.

As such, Port of Spain should be an example of a transition from the non-western to the western urban density pattern. Through an examination of the urban density pattern in Port of Spain for 1960, 1970, and 1980, it is anticipated that features of both the western and non-western models will be found which would support the contension that the city represents an "intermediate pattern," a hybred which cannot be strictly classified as either a "western" or "non-western" pattern.

Hypotheses and Thesis Overview

This study is an attempt to identify a transition between the dicotimous western - non-western density patterns. To this end the following hypotheses will be tested.

H_1 - The rate of decrease of population density from the central city or "city proper" outwards has decreased over time between 1960 and 1980.

H_1 - The pattern of urban population density in Port of Spain is indicative of the city's transition from a "non-western" type of city to a "western" type, incorporating features of both.

H_1 - Those areas whose population density is either underestimated or over estimated by the density functions, can be regarded as indicative of the co-existence of old morphological urban structures with the new as the city develops.

The following chapters present a more detailed description of the study area - Port of Spain, the data needs and preparation, and statistical analysis involved in the testing of the hypotheses. Chapter II introduces the study area and deals with the factors influencing the form of density functions. Chapter III covers the data needs and manipulation necessary to carry out this study. The final chapter presents the results, conclusions and recommendations based on this study.

Footnotes

1. G. Sjoberg, "The Pre-Industrial City," American Journal of Sociology, 60:5, 1955, pp. 438-445.

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

3. Berry, Simmons and Tennants, op. cit.

4. Colin Clark, "Urban Population Densities," Journal of the Royal Statistical Society, 114:A, 1951, pp. 490-496.

5. Colin Clark, op. cit.

6. J.C. Tanner, "Factors Affecting the Amount of Travel" and G. G. Sherratt, "A Model for General Urban Growth," cited by Bruce E. Newling, "The Spatial Variation of Urban Population Densities," Geographical Review, 59:2, 1969, pp. 243.

7. Bruce E. Newling, ibid, pp. 243.

8. Bruce E. Newling, op. cit, pp. 242-252.

9. H. Morikawa, "The Spatial Distribution and Changing Pattern of Urban Population Density: A Case Study of Hiroshima City," Journal of Geography, 85, 1976, pp. 237-254.

10. Hideaki Ishikawa, "A New Model for the Population Density Distribution in an Isolated City," Geographical Analysis, 12:3, 1980, pp. 223-235.

11. Bruno De Borger, "Urban Population Density Functions: Some Belgian Evidence," Annals of Regional Science, 13:3, 1979, pp. 15-24.

12. Colin Clark, op. cit. A. Guest, "Population Suburbanization in American Metropolitan Areas 1940-1970," Geographical Analysis, 7:3, 1975, pp. 267-283. Ishikawa, op. cit.

13. Harry W. Richardson, "A Note on the Dynamics of Population Density Gradients," Annals of Regional Science, 10:3, 1976, pp. 15.

14. Berry, Simmons and Tennants, op. cit.

15. W.W. Rostow, Stages of Economic Growth: A Non-Communist Manifesto, Cambridge University Press, Cambridge, 1960.

CHAPTER II

STUDY AREA AND FACTORS AFFECTING DENSITY FUNCTIONS

The city of Port of Spain and its suburbs was chosen as being representative of a city in the developing world which would display a transition from the non western, underdeveloped density structure to a western type of urban population density form. The population in the city and its suburbs has increased from 134,105 in 1960 to 255,345 in 1970 and 287,075 in 1980[1] which represents a 47.48% increase between 1960-1970 and 11.05% between 1970-1980. The changing distribution of population density over time and space will be examined to reveal the existence of a "hybred" density form.

The models which have been discussed thus far, have considered three variables in describing the differences in the form of density gradients in different countries: - central population density, distance and distance squared. In considering Port of Spain as an example of a city displaying a transitional density form, it would be falacious not to take into consideration other factors which have been put forward to account for the differences in the form of density gradients.

While Clark believes that differences in Transportation systems are the reason for the disparity bewteen Western and Non-Western cities,[2] Berry, Simmons and Tennant disagree. They contend that sociocultural differences between "western" and "non-western" societies affect the demand for land, with non-western societies preference for central city residential location reducing the demand for land on the periphery.[3] These preferences restrict the horizontal growth of cities so necessitating increasing central population densities.

However, Berry, Simmons and Tennant did not take into consideration the fact that the Western pattern is not exclusively western nor non-western exclusively non-western. For example,[4] New York had a constant density gradient from 1910 to 1940; Brisbane, Australia and Christchurch, New Zealand had increasing central densities with almost constant gradients from 1933 to 1947 and 1936 to 1951 respectively; Poona, India had a non-western pattern between 1822 - 1881 followed by declining central density and density gradient and Okayama, Japan revealed a "western" pattern of urban density change from 1939 to 1953. Thus, the notion of dicotimous density patterns for developed and developing nations has been subject to serious question.

Using the city of Port of Spain as a case study, I hope to be able to show that features of both a western and non-western type city can and does co-exist over time and space. This would in effect take the argument for the non-exclusivity of the western - non western dicotomy a step further by identifying features of both types of cities in one city over time. Such a city would be an example of a hybred or "transitional density type."

Four major factors have been cited as affecting central density gradients over time and space: -

i) Age of city and mode of development

ii) The controlling influence of timing of development on subsequent form

iii) The density gradient

iv) Centrality preference and a preference for non-congested sites by the resident population.[5]

Using these four factors it is possible to structure the description of Port of Spain and its suburbs.

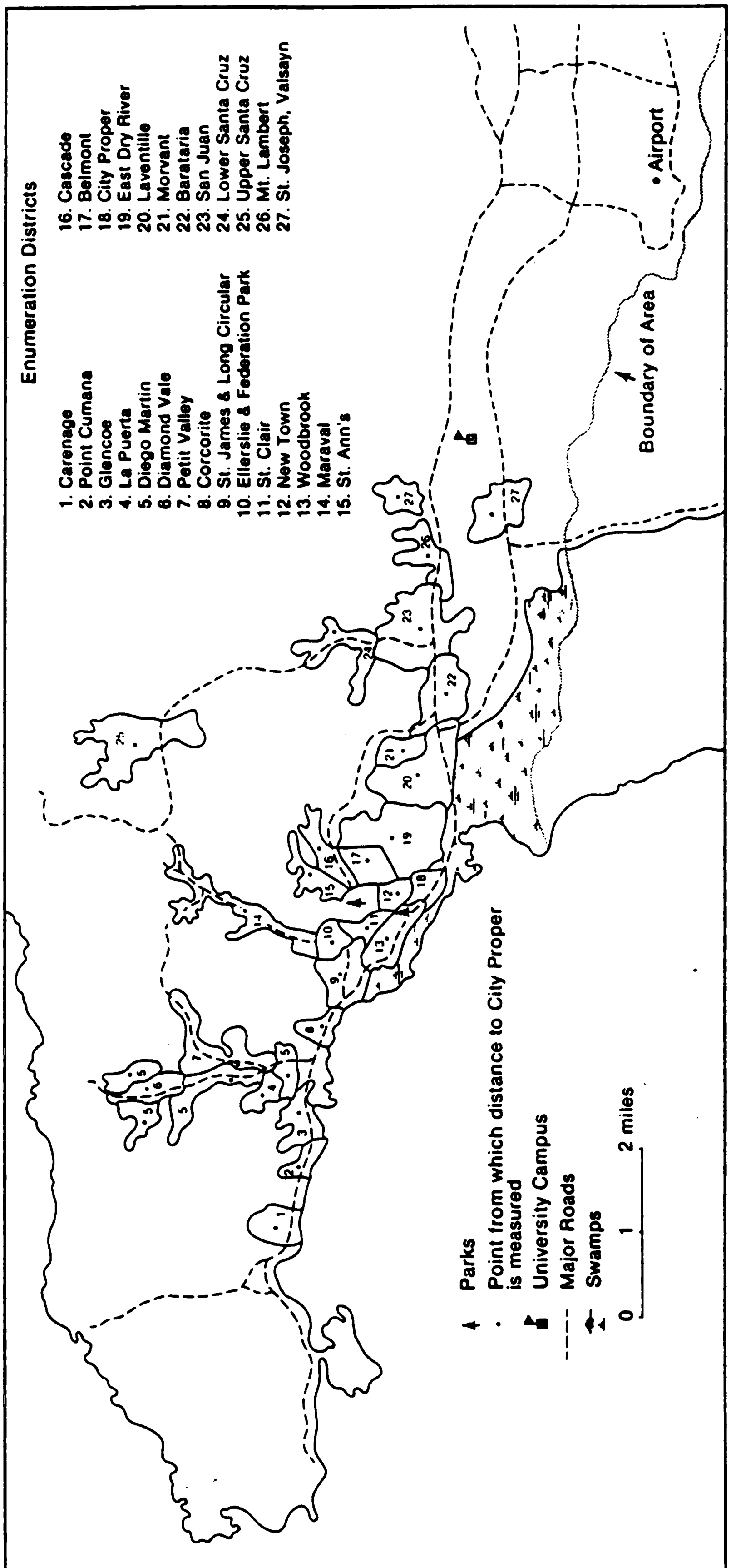
Age of City and Mode of Development

The original city of Port of Spain was established by the Spanish as a port and administrative center. In the Spanish tradition, as distance from the core of urban activity increased, the social and economic status of the residents decreased. This stemed from a desire by the more prominant citizens to be near to the seat of power, and the access to paved highways and services that such a location gave them. Such "relic" low density areas continue to exist today close to the CBD, where according to the Clark and Newling models, population density should be high.

In addition to this is the dying practice of entrepreneurs living on the premises of their business establishments in the CBD. As these entrepreneurs leave the central city, their movement out is reflected by declining central densities. The repelling influence of lower socio-economic groups on the location of elite residence is also reflected in the location of the elite St. Clair area and the poorer East Dry River on either side of the CBD as shown on the map of the study area [Map 1]. These patterns will influence the density gradients on either side of the central city area.

Timing of Development

The form of the city is the result of its "laws of growth up to that moment" [Growth creates form, but form limits growth].[6] Once a city has been established, the form it takes dictates its future development. In the case of Port of Spain, the importance of this is brought out by the co-existence of features of the original Spanish form and a more Anglo-American type of urban development today around the original city structure. In some instances the force of sentimental attachment and tradition are strong enough to perpetuate patterns which would otherwise not continue to exist. The physical form of the heart of the city was established in the past and continues to exist as it would appear to be the most expedient policy to follow at the present. To institute a radical change in the distribution of population could involve undesirable social dislocation.



Map 1. Study Area – Port of Spain and its suburbs

Density Gradient

Central Density is related to the density gradient which is in turn influenced by a variety of additional factors such as the size of the city, pattern of residential location displayed by the higher and lower socio-economic groups in the city. In Port of Spain, over time there has been a reversal of the situation where the most affluent favour a location close to the center of the city and the less well off being delegated to the periphery, to one similar to North America [i.e. wealthy suburbs and poorer classes close to the center]. However features of the older trend still exist along with the wealthy elite who move outwards to the periphery of the city, and poorer classes locate close to their place of work in the CBD.

Model assumptions of a circular city and the city center located at the center of the circle is somewhat idealistic. Few cities conform to these assumptions as asymmetry, lopsidedness, elongations and crenulations are common. Theoretically, density gradients should decrease as shape distortions increase, implying that areas which would normally be occupied by certain levels of densities are no longer available. Thus residents who prefer these densities must move outwards to the nearest available sites.

Port of Spain is not a circular city - rather it is linear in form. This is a reflection of the relationship between urban structure and intra-urban transportation,[7] and the influence of the Northern Range on the north and by the ocean and swampy land to the south, which is shown on Map 1. Population density in this urban area, decreases with increasing distance from the CBD having a directional bias or long axis.[8] Thus Port of Spain and its suburbs will have an elliptical rather than a circular pattern of urban densities - which is typical of oceanside [or lakeside] cities.[9] The movement outwards by residents to sites with prefered residential densities has the effect of also flattening the density curve over time.

Preference for Central Locations and Non-congested Sites

Emilio Casetti[10] has shown that a central preference and a preference for non-congested sites can account for the exponential decline of residential densities with distance from the city center. This would hold where individuals are free to maximize their locational utility; and when a collective maximal locational welfare is enforced provided that the places of work are sufficiently clustered around the city center.

However, in a real world situation, individuals are not free to maximize their locational utility as there are many factors to be considered which could force a suboptimal location. These factors include such things as economic and physical constraints.

Dennis Conway[11] has found that Port of Spain and its suburbs is atypical in that the high rent areas [such as St. Clair, Ellerslie Park and Federation Park] did not pull the growth of the entire city in the same direction. Rather, the city grew to the east by "leap frogging" low grade barriers such as East Dry River and Morvant to the available land beyond. [Valsayn is a product of this process.] In addition, the middle class areas of the north-west [Maraval] and north-east [St. Anns and Cascade] have maintained their middle class exclusivity. This growth by a leap frogging process has resulted in a discontinuous development of the suburbs as "hostile" areas are avoided. These areas are generally swampy or steeply sloping and show up on Map 1.

Dicotomy of Patterns

Bearing in mind the differences noted between Western and Non-Western cities with regard to the relationship between population density and distance from the city center, it is expected that the population density models will reveal the existance of deviant areas. These deviations result from the transitional stage that Trinidad is going through, local detail and the influence of the factors discussed above. This suggests that there should be a reflection of the economic growth and development in the pattern of urban population densities. For example, population density at the center of the city should decline as a result of the predominance of business and commercial activities at the center. [in keeping with an increasing specialization of land use as development proceeds.]

With the intension of confirming or refuting the views of Berry, Simmons and Tennant; John E. Brush[12] analyzed the patterns of Indian intra-urban population distribution in several cities. Berry et al. theorised that non-western and particularly Indian cities have a pattern of urban growth characterised by rising residential concentration in the city center concurrently with outward expansion and peripheral population increase. The pattern Brush observed differed depending on whether the city was an indigenous one or a "British" city. This points to the existence of non-western and western type patterns at the same time in one country. The distinction made here depends on a difference in culture and functions as accounting for the difference in population density patterns. In the case of the Indian cities, Brush found that a non-western pattern was characteristic of the indigenous cities while the western pattern typified the cities established by the British - so pointing to cultural factors as underlying the differences observed.

Like Brush, I am also concerned with the distinction drawn by Berry, Simmons and Tennant. Through an analysis of the changing form of the density gradients and the existence of "mis-fit" areas in one city - Port of Spain and its suburbs, I will show that there are not two separate patterns which can be expected for "western" and "non-western" areas (or cultures). Rather, there should be a movement from a non-western pattern to a western pattern as economic growth and development proceeds.

Footnotes

1. Based on data aggregated from the enumeration districts.

2. Colin Clark, "Transport - Maker and Breaker of Cities," Town Planning Review, 28, 1957-58, pp. 237-250.

3. A similar pattern existed in Spanish colonial cities - see for example Ernst Griffin and Larry Ford, "A Model of Latin American City Structure," Geographical Review, 70:4, 1980, pp. 397-422.

4. Bruce E. Newling, "Urban Population Densities and Intra-Urban Growth," Geographical Review, 54, 1964, pp. 440-442.

5. Berry, Simmons and Tennant, op cit., pp. 396-399 and Emilio Casetti, "Urban Population Density Patterns: An Alternative Explanation," Canadian Geographer, 11, 1967, pp. 96-100.

6. Berry, Simmons and Tennant, op. cit., pp. 394.

7. D.E. Boyce, "The Effect of Direction and Length of Person Trips on Urban Travel Patterns," Journal of Regional Science, 6, 1965, pp. 65-80.

8. Kingsley E. Haynes and Milton I. Rube, "Directional Bias in Urban Population Density," Annals of the Association of American Geographers, 63:1, 1973, pp. 40-47.

9. Haynes and Rube, op. cit.

10. Emilio Casetti, op. cit.

11. Dennis Conway, "The Use of Remote Sensing to Investigate Structural Change in Social Area Differentiation in Port of Spain, Trinidad," paper presented at the 4th General Session of the Conference of Latin Americanist Geographers, Calgary, Alberta, June 27-30, 1073.

12. John E. Brush, "Spatial Patterns of Population in Indian Cities," Geographical Review, 58:3, 1968, pp. 362-391.

CHAPTER III

DATA PREPARATION AND METHODOLOGY

In order to illustrate the existence of a city which shows a transitional density pattern over time, it is necessary to obtain population density figures over time for the various districts and their distance from the city centers. This data can then be analysed using regression techniques to illustrate the changing form of the density gradient over space and time. This chapter is concerned with the necessary data manipulations and methodology used in the analysis of population density in Port of Spain and its suburbs.

Data Preparation

To analyse the changing form of the urban population density functions over time for Port of Spain and its suburbs, it is necessary to obtain data for each enumeration district. The data needed to conduct this study consists of the population density by districts and the distance from each district to the city center. In addition the density at the city center was also needed. The raw data used in this study were obtained from the Central Statistical Office in Port of Spain, Trinidad. The population by enumeration districts, was obtained from the census reports of 1960 and 1980.

[The figures for 1970 were included in the 1980 report.][1] The boundaries of the sub areas in this study were defined on the maps of the census enumeration districts for 1960 and 1980.

Port of Spain was chosen as it represents a city which Berry, Simmons and Tennant would have classified as a "non-western" type of city. [Non-western being synonymous with underdevelopment.] However, over time, Port of Spain has also displayed some of the features associated with a western type city - such as the development of a suburban, professional elite, increasing specialization of land use particularly in the CBD and the movement to the periphery of the CBD [as opposed to the city as a whole] of the poorer classes. As such features of a western and non-western city should be found in Port of Spain and its suburbs.

This city was chosen because data was available for 1960, 1970 and 1980 - which incorporates a time period when the country was considered to be very underdeveloped. It also covers the period following the economic development and growth fostered by the oil crisis of the early 1970's. As such, not enough time has passed to completely obliterate the old "non-western" morphological structure, yet changes associated with economic development have had time to establish themselves. A second reason is my own familiarity with the study area which would aid in the explanation of the deviant cases and density pattern.

Areal Computation

Having obtained a map of the study area and the population for each district for 1960, 1970 and 1980, it was necessary to calculate the area of each of the districts. This was done using a Polar Planimeter with a fixed pole arm and adjustable tracer arm. The technique used was measuring with the pole outside the figure. This method is a common, simple and precise method of measuring areas.[2] The computed areas of each of the enumeration districts were used to derive the gross residential densities of each of the spatial units.

Distance Computation

To calculate the distance between each of the spatial units and the central city, it is necessary to determine a point in each district from which the distance to the central city could be determined. To this end, the "center" of each unit was derived by assuming the mid point of the longest radial across the areal unit would serve as the "center of gravity." As the study area as a whole is linear in form, a cursory examination of the main road network suggested that the road network did seem to have an effect on the shape of the composite units. Thus, by using the mid points of the longest radials as the reference points, the effects of transportation on the urbanization and suburbanization process is indirectly incorporated.

Generation of an Objective Surface

An inspection of each of the districts revealed that the area of each of the units varies considerably [from 52 acres to 620 acres[3]]. As such, if the density at only one point for each area were to be used, this would underestimate the effect of the larger units and over estimate the smaller units.

Robinson et al. and Latham and Yeates[4] noted that apart from the variation in the size and shapes of the spatial units, there is also a data mix [i.e. the density of an area is taken to be the density at a point within that area]. Thus, an objective surface was generated to serve the same purpose as Robinson et al. and Latham and Yeates' hexagonal grid. A hexagonal grid was not deemed to be appropriate in this instance because of the linearity of the area - a product of the relief of the area and reinforced by the transportation network.

An objective density surface was generated using density isolines interpolated from the initial reference points. It is possible to generate a density surface based on the supposition that density is not a discrete but rather a continuous phenomena over space.

The surface which was generated had to take account the discontiguous portion of the map. [These discontinuities also prevented the imposition of a hexagonal grid to achieve an objective surface.] The "empty" areas were treated as having zero population density on either side of the intervening area could be represented. The exclusion of the intervening areas from the enumeration districts also gives a more accurate representation of the population density pattern as the areas are not considered within the boundaries of the defined urban area.

New surfaces were generated for 1960, 1970 and 1980. Once this was accomplished, a stratified sample of points was taken at 0.25 inch intervals on the density surface. [1250 feet or 0.237 mile intervals on the ground.]. The density at each of the 138 points which were generated from this process, was interpolated from the imposed surface.

An examination of the original data in Appendix III revealed that the pattern of population density distribution around the central city is not symmetrical. This is particularly evident in the eastern portion of the study area. The areas concerned are St. Augustine, Tunapuna, Trincity and Arouca. These four areas were dropped from the study area as it was believed that the density patterns in these areas reflected the presence of a university campus in St. Augustine, the airport at Piarco and the third most important city in Trinidad; Arima.

The imposition of the unbiased density surface allowed me to objectively increase the number of observation units from 27 to 138. Had I considered only the original data points, it is believed that the small number of observations could have forced the acceptance of the null hypotheses in the statistical analysis. [A small number of observations would imply that the consequent F statistic would have to be correspondingly larger, if the relationship being examined is to be considered statistically significant.]

The distance of each of the 138 points [generated from the stratified sampling process], from the center of the central city was calculated as the straight line distance between the two points. Once this was done, this completed the basic data set needed to begin the regression analysis, using the Statistical Package for the Social Sciences.[5]

Limitations

It is expedient at this point to go through the limitations of this study - given the methodology used. First, the city of Port of Spain and its suburbs is smaller than the metropolitan areas to which population density models have been applied. This size factor may influence the amount of variance in the distribution of population density captured by the models. Typically, in a larger metropolitan area, the larger sample of density points allows the existence of deviant cases to be averaged out. The influence of the deviant areas in Port of Spain will lower the R^2 value because of their relative number and strength of their deviation given the actual number of sample points.

Second, the distance measurements are straight line distances, as opposed to the distance over the transportation network or travel time. Thus the distance measurements do not take into account the effects of congestion which would tend to increase the perceived distance from the city center as congestion increases. By increasing the perceived distance to the center of the city, this could affect the density gradient away from the center.

Third, this study does not take into account the effects of the possible emergence of secondary centers in the suburbs over time. Secondary centers could exert some influence on the population density around them, resulting in a layering of influence.[6] However it is not the purpose of this Thesis to identify such secondary centers, rather I am concerned with identifying a transitional density pattern using regression techniques.

Methodology

The SPSS package was used to determine the transformation of densities and distances for each of the "density points." The regression equations which were considered are as follows:

Clark Model

$$D_x = D_o e^{-bx}$$

log of Density = log of Central Density -b.distance

$$[\ln D_x = \ln D_o - bx]$$

Tanner and Sherratt Model

$$D_x = D_o e^{-bx^2}$$

log of Density = log of Central Density -b.distance^2

$$[\ln D_x = \ln D_o - bx^2]$$

Newling Model

$$D_x = D_o e^{bx-cx^2}$$

log of Density = log of Central Density + b.distance - c.distance^2

$$[\ln D_x = \ln D_o + bx - cx^2]$$

Robert F. Latham and Maurice H. Yeates[7] in their application of Newling's model, believe that it is the b parameter which is especially useful, since it can take a negative, zero or positive value, thus permitting the representation of all possible changes in the density gradient at the center of the city. They discovered that in time the model increasingly approximates Clark's linear model and it is the b parameter which is of greater importance, not the c. In addition to this, an examination of the Tanner and Sherratt model shows that to include this model as a separate model would be redundant, since the Newling model incorporates the exponent of their model. By setting b = o, the Newling model is in effect transformed to the Tanner and Sherrat Model. Similarly, by setting c = o, the Newling model is transformed into the Clark model, given the flexibility of the b parameter.

Regression Assumptions

Before the statistical analysis can be carried out certain assumptions as related to the transformation sof the equations must be met.[8] First, the model is an intrinsicly linear, non-linear one which allows the transformation to be done. Second, the independent variables are independent of each other, if not multicollinearity exists. Multicollinearty can be eliminated by the inclusion of other variables or the exclusion of variables. Third, the conditional distribution of the residuals from the regression has a mean of zero and is normally distributed. Fourth, the residuals are serially independent of each other and their covariance is zero. Fifth, it must be born in mind that when the original equation is log transformed, to return to the original form when interpreting the results, the error term will be a multiplicative not an additive one. As designed this thesis satisfies the critical assumptions laid out above. Having satisfied the assumptions of the methodology used, it is possible to proceed at this point to the formulation of the formal hypotheses of this research and interpretation of the coefficients of the equations used.

Interpretation of Coefficients and Formulation of Hypotheses

The SPSS regression package will be used to provide the coefficients of each of the equations for 1960, 1970 and

1980. [This programme also determines the significance of both the equations and individual parameters.] Based on the results produced using both the Clark and Newling models, because of an inability to establish the superiority of either one of the two models in terms of data conformance;[9] I will plot the density gradients which are significant at the 90% and/or 95% confidence level. These graphs together with a plot of the central density over time will be used in the confirmation, rejection or modification of Clark's conclusion concerning nations - that the rate of decrease in population density with increased distance from the city center while the central density has increased.

The formal hypotheses regarding the coefficients of the equations are:

<u>Clark Model</u>

It is expected that b will be significantly less than zero as this will be in keeping with a decline of density away from the center. That is H_1:b<o; H_o:b=o.

<u>Newling Model</u>

The hypotheses regarding the coefficients in this case will be more complex, as the coefficients should differ depending on whether they apply to western or non-western cities. Thus, the hypotheses regarding the statistics in this instance become a test of the western - non-western notion.

If the city is a non-western type of city the b parameter will be negative, while the c parameter will be either zero or positive depending on the degree of curvative of the density curve. Thus the resulting hypotheses are

H_1: $b<0$, H_0: $b=o$

H_1: $c>0$, H_0: $c=0$.

In the event that the city is a western type city the b and c parameters will differ from that expected in a non-western city. In this case the b parameter is expected to be positive, indicating the presence of a density crater around the city center. The c parameter should be negative indicating the increasing curvative of the density surface away from the density crater. Thus the hypotheses are:

H_1: $b>0$; H_0: $b=0$

H_1: $c<0$; H_0: $c=0$

Residuals

To complete the argument for a transitional density form, it is necessary to construct maps of the residuals or errors from the equations calculation of the population densities for the districts. An examination of the most deviant areas will confirm the co-existence of features of both a "western" and "non-western" type city, which in itself points to the existence of the hypothesised transitional stage.

Summary of Techniques and Hypotheses

The regression technique used in this thesis has been used to establish the existence of a transitional form of urban population density distribution. To this end the

following hypotheses will be tested:
The rate of decrease of population density from the central city outwards has decreased over time between 1960 and 1980. If Port of Spain is in effect an example of a 'transitional city,' there should exist areas whose density is extremely over or underestimated by the density functions. A discussion of these deviant areas will be conducted with the aid of maps of the residuals from the regressions. Based on the findings of this research, a case for the transition from a non-western to a western type density pattern will be put forward.

Footnotes

1. A list of the Sources of the data used in this study is given in Appendix I.

2. Areal computation explained in Appendix II.

3. See Appendix III.

4. A.H. Robinson, J.B. Lindberg and L.W. Brinkman, "A Correlation and Regression Analysis Applied to Rural Farm Population Densities in the Great Plains," Annals of the Association of American Geographers, 51: , 1961, pp. 211-221. Robert F. Latham and Maurice H. Yeates, "Population Density Growth in Metropolitan Toronto," Geographical Analysis, 2, 1970, pp. 177-185.

5. henceforth refered to as SPSS.

6. Daniel A. Griffith, "Evaluating the Transformation from a Monocentric to a Polycentric City," Professional Geographer, 33:2, 1981, pp. 189-196.

7. Robert F. Latham and Maurice H. Yeates, op. cit., pp. 179.

8. Michael A. Poole and Patrick N. O'Farrell, "The Assumptions of the Linear Regression Model," Transactions of the Institute of British Geographers, 52, 1971, pp. 145-158.

9. Hideaki Ishikawa, op. cit., pp. 224.

CHAPTER IV

RESULTS OF THE STATISTICAL TESTS

The statistical tests performed were done with the intension of assessing the performance of the two models - Clark's and Newling's in capturing the changing form of the urban density curves for Port of Spain and its suburbs. Systematic departure from the densities predicted by the models should indicate the reasons for the failure of the models to fit the study area. The existence of deviant areas may be attributed to factors relating to the transitional stage of city is going through. The existence and explanations for the deviant areas together with the form of the density curves predicted by the models will support the argument that there is a transition between the western and non-western type of city as demonstrated by Port of Spain.

Re-statement of Hypotheses

The hypotheses which will be tested are:

i) H_1 - The rate of decrease of population density from the central city or City Proper outwards has decreased over time between 1960 and 1980.

ii) H_1 - The pattern of urban population density in Port of Spain is indicative of the city's transition from a "non-western" type of city to a "western" type, incorporating features of both.

iii) H_1 - Those areas whose population density is either underestimated or overestimated by the density functions can be explained by factors other than the central density and distance from the center.

An explanation of the more relevant factors influencing the density levels in these areas will support the existence of a hypothesised transition density pattern.

Figure 2 shows the change in the central density over time for the central city. The decline in central density noted here is atypical of the "non-western" city as described by Berry, Simmons and Tennant. One can infer that the central density had increased to some critical level of crowding and that since 1960, the central density has been declining.

The rate of decrease of the population from the CBD outwards over time is best indicated by the slope parameter of the Clark and Newling model. Table 1 shows the changing value of b over time for both models. The comparison of b's from the Clark and Newling models is done based on the hypothesised similarity between these parameters in a

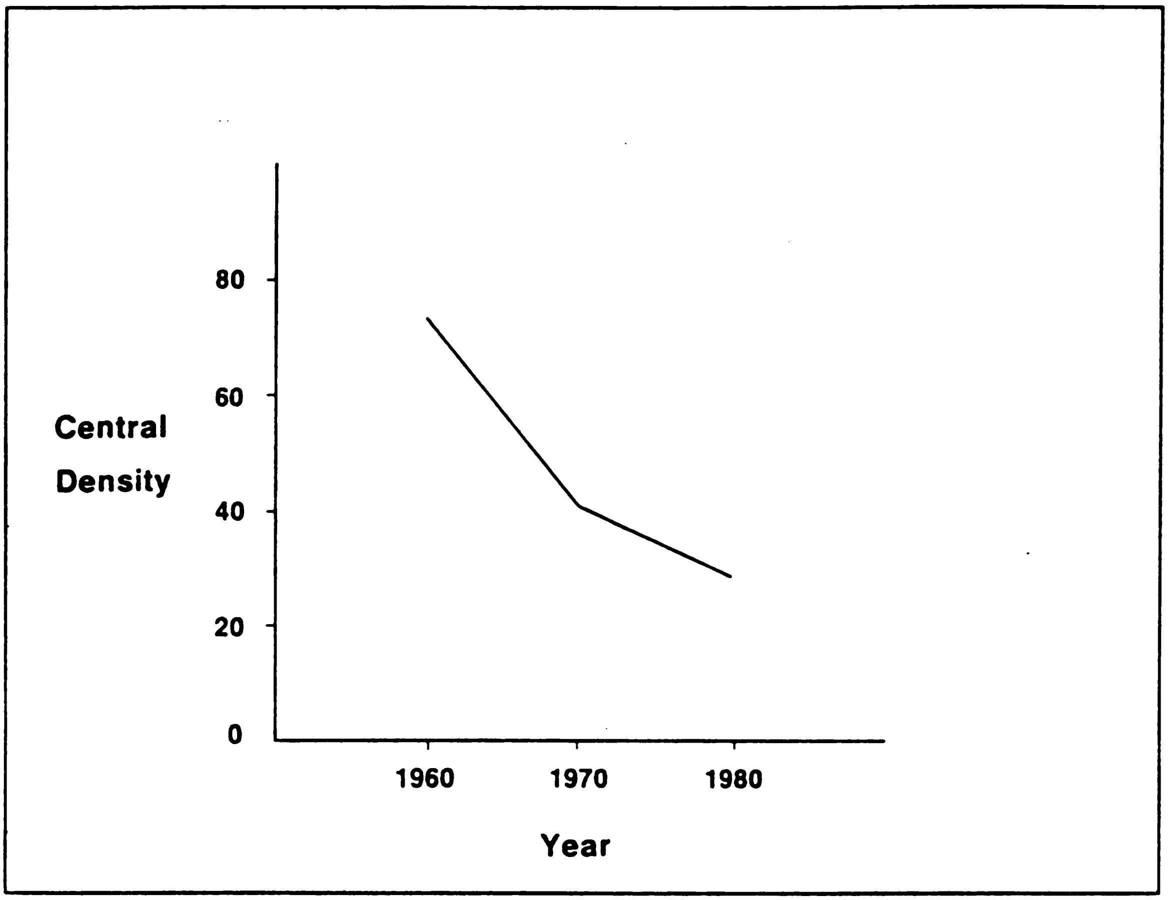


Figure 2. Central Density Over Time in Port of Spain

"non-western" type city.

Table 1 - Rate of Decrease of Population from the City Center Outwards 1960 - 1980

Years	Clark Model b value	Newling Model b value
1960	-0.330	-1.475
1970	-0.178	0.177*
1980	-0.096	0.241*

[* not significantly different from zero at the 90% or 95% confidence level]

As can be seen from the values shown above, the rate of decrease of the population has not remained constant over time which is similar to the western type of city discussed by Berry, Simmons and Tennant. The fact that b is positive in 1970 and 1980 using Newling's model is perhaps indicative of the replacement of the residential population by commercial activities. This together with the declining central density makes for the appearance of a "crater" in the density surface. This is inkeeping with the increasing specialization of land use within the "western" type city as economic development progresses. That is, competition for sites at the city center by commercial users drives up the economic rent of the sites beyond the means of the residential users - hence forcing them to move out. "Competition for sites at the city center ultimately causes a crater to form in the population density surface, and this stage of development involves a positive b parameter."[1]

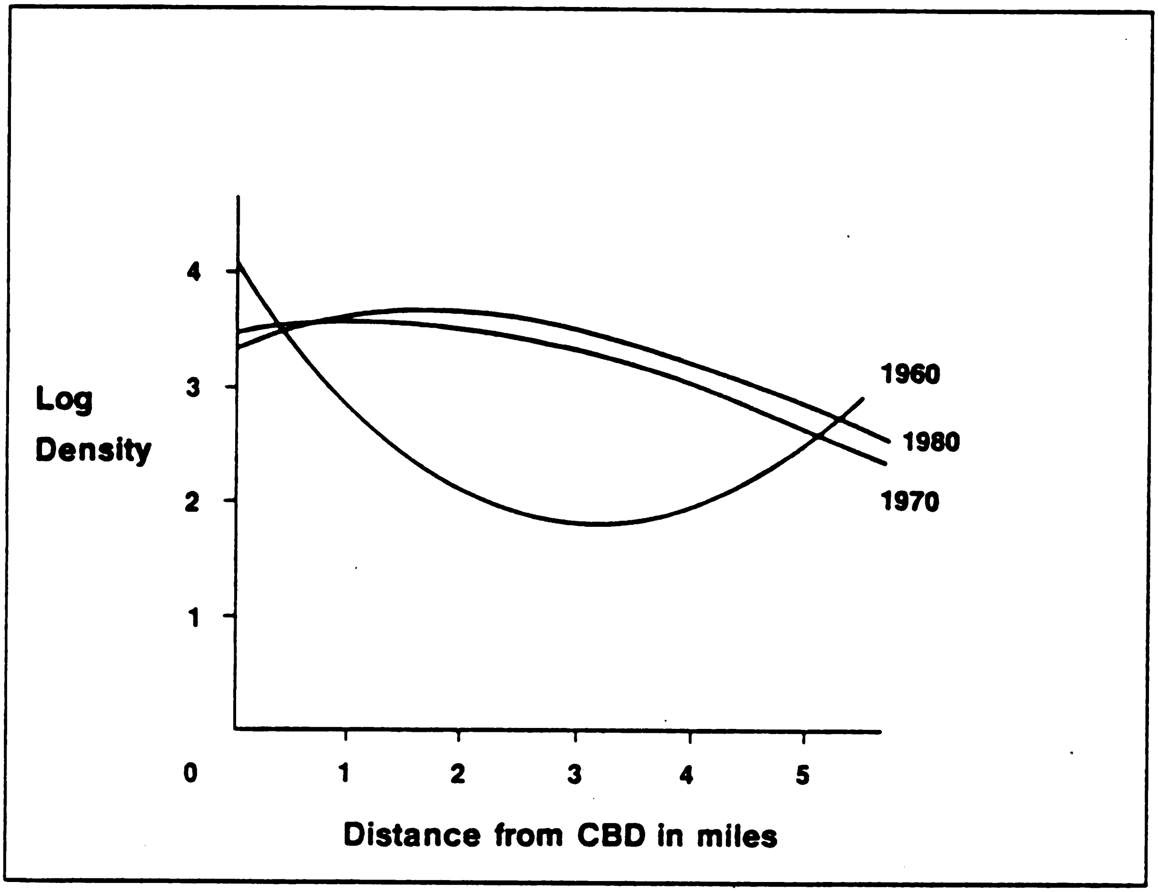


Figure 3. The 1960, 1970 and 1980 Residential Density Curves for Port of Spain and its Suburbs (Newling Model)

Using the Newling Model, the results for 1960 indicate a population density pattern typical of "non-western" cities. Figure 3 shows that the curve is concave to the origin with a hypothetical central density of 132 persons per acre. The central density is derived by taking the antilog of the intercept term. The slope of the curve is -1.475 which indicates a rapid decline in population density with distance. This rapid decline from the center indicates that business and commerical activities have not yet replaced the residential population.

The quadratic curve for 1970 indicates that the central density has now fallen to a hypothetical 31 persons per acre. At this time b = +0.12 and c = -0.06, indicating that a density crater has formed around the central city and the density curve is now convex to the origin. However, neither the b or c parameter is significantly different from zero at the 90% confidence level. The results of the quadratic equation for 1980 using Newling's model are not significantly different from zero at the 90% confidence level.

One of the problems with using Newling's model may be the intercorrelation of the two independent variables [x and x^2]. As such an accurate representation of the individual regression coefficients for each variable may not be possible. This problem can be overcome by the inclusion of additional data or variables may be excluded from the model. The omission of distance squared [x^2] from the Newling model transforms it to the Clark model.

Clark Model.

Table 2: <u>Parameters of Equations</u>

	Clark Model			Newling Model		
Variables	1960	1970	1980	1960	1970	1980
Intercept (a)	3.096	3.753	3.656	4.119	3.489	3.355
	(0.164)	(0.134)	(0.143)	(0.267)	(0.233)	(0.248)
Distance (b)	-0.330	-0.178	-0.096	-1.475	0.117*	0.241*
	(0.058)	(0.047)	(0.050)	(0.251)	(0.219)	(0.233)
$Distance^2$ (c)				0.233	-0.060*	-0.068*
				(0.050)	(0.043)	0.046

*not significantly different from zero at the 90% confidence level.
figures in parentheses are standard errors.

The regression using Clark's model produced a significant equation for 1960 [at the 99% confidence level], with a hypothetical central density of 124 persons per acre. A slope of -0.33 indicates, as the Newling model did, a rapid decline in population density with distance, as business and commercial activities have not pre-empted the residential population.

The density curve for 1970 exhibits a less steep decline in density away from the CBD as the slope term has increased to -0.178. This is inkeeping with a declining rate of decrease of population density with distance. This equation and the parameters are all significantly different from zero. However the 1970 figures have indicated an increase in the central density over the 1960 level which is not an accurate representation of reality.

The 1980 curve exhibits a decline in the central density to 45 persons per acre. As in advanced western nations the rate of decrease of density away from the central city has slowed. This is associated with the increasing commercial orientation of the city proper; along with increasing population density in the surrounding area which was captured by the Newling model.

As is typical of the results using Clark's model in "western" type cities, Figure 4 shows that there is a progressive flattening of the curve over time as the density gradient decreases over time. This is indicative of greater relative growth at the center, implying that the center is

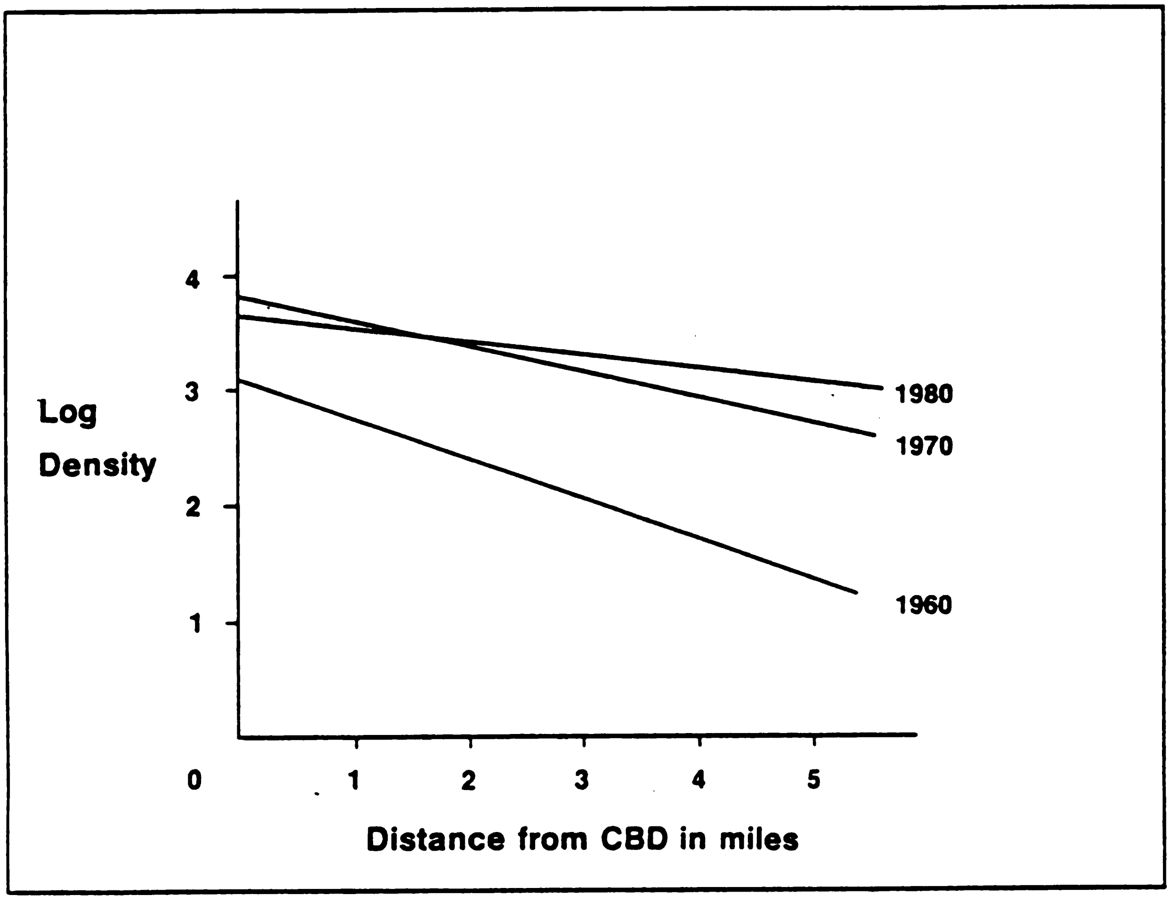


Figure 4. The 1960, 1970 and 1980 Gross Residential Density Curves for Port of Spain and its Suburbs

approaching or has approached saturation level as far as residential densities are concerned and the move to the suburbs is increasingly the dominant trend in residential development. This is inkeeping with the increased separation of place of work and residence [a common feature of economically advanced nations]. Income growth associated with economic development tend to flatten the density curve if the demand for residential space is income elastic. Higher income allows households to spend more on travel. When income and population change simultaneously [as in the real world], the consequences for the urban spatial structure may be very complex. This will be seen to be the case when the deviant areas are examined.

Explained Variance

Table 3 shows the F-test and R^2 for both the Clark and Newling models over time. The F-statistic is an indication of the statistical significance of the relationship described by the regression equation. The R^2 indicates the amount of variance of the dependent variable [ln D_x] explained by all of the independent variables.

Table 3: F-test and R^2 for the Two Models

	Clark Model		Newling Model	
Year	F-test	R^2	F-test	R^2
1960	32.65566	19.248	29.74605	30.432
1970	14.32080	9.464	8.16268	10.717
1980	3.62916	2.581	2.92507	4.124

While the relationship described by the regression equation is statistically significant, an examination of the R^2 over time, shows that the amount of variance in the residential densities explained by all the independent variables falls off very quickly. This is inkeeping with the existence of complexities in the pattern of population densities. Other researchers have usually found that the R^2 value is much higher, indicating a greater degree of explanation of the density pattern using distance raised to some exponent.[2]

The lower R^2 values found in this case is inkeeping with the existence of complexities in the population density patterns as a result of the transition nature of the city's density pattern. The low R^2 are also inpart, a function of the size of the city. Other researchers using large metropolitan cities have found that there is a density "generalization" which occurs because of the sample size. This "generalization" is not evident in Port of Spain.

The complexities refered to above stem from several factors - some of which have been mentioned previously: age of city and mode of development, the form of the city in the past and present. Traditional patterns continue to exist along with newer patterns of development. For example, in the city of Port of Spain, St. Clair and East Dry River are approximately the same distance from the city center, yet their socio-economic and density patterns are totally different - St. Clair being a traditional, elite residential area while East Dry River is a destination area for the poorer, rural-urban migrants.

The linear distortion of the city influences the shape of the density curve. Areas which would normally be occupied by certain levels of densities are not available. Thus, residents who prefer these densities must move outwards to the nearest available sites. This process is indicated by the "leap frog" process by which the middle class suburbs have developed.

The Government impacts on the pattern of residential densities in the planning and location of housing schemes [particularly low income housing schemes which are usually associated with higher density levels.] The existing form of the city limits the available areas for locating these projects, hence as transportation has improved over time, the need to locate these projects closer to the CBD has decreased.

Deviant Areas

It must not be forgotten that there are deviant areas which are not explained by the model. The existence of these deviant areas support the hypothesised co-existence of features of both the "western" and "non-western" type of cities. A comparison of the areas overestimated and underestimated by the models will strenghten the contension that the form of both the Clark and Newling models do not adequately define the population density in those areas.

Table 4 shows a great deal of similarity between both models. An examination of the maps of the residuals from the b regressions reveals that the models generally overestimate density to the west of the CBD and underestimates it to the east. This reveals one of the problems associated with the assumption of the Clark and Newling models - that the density curve is symmetrical about the CBD. The over and underestimation of density in this case indicates that the actual curve is not symmetrical about the CBD.

Table 4: Areas Overestimated and Underestimated by the Clark and Newling Models

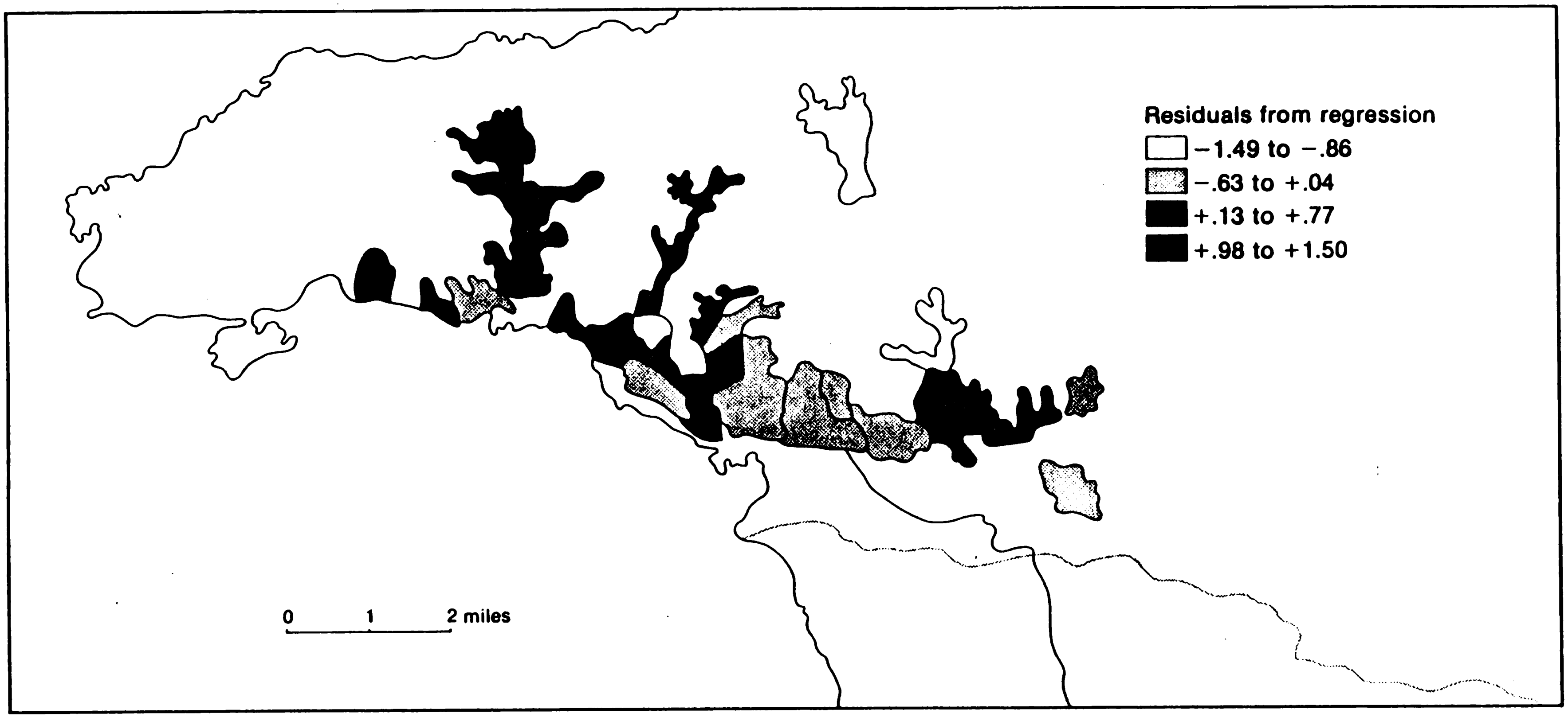
Overestimated Areas		Underestimated Areas	
Clark	Newling	Clark	Newling
1960		1960	
Ellerslie and Federation Park	Ellerslie and Federation Park	Carenage	Carenage
Upper Santa Cruz	Upper Santa Cruz	Point Cumana	Point Cumana
Lower Santa Cruz	Lower Santa Cruz	Belmont	Belmont
	Laventille	Mount Lambert	Mount Lambert
		City Proper	
		New Town	
1970		1970	
Ellerslie and Federation Park	Ellerslie and Federation Park	Mount Lambert	Mount Lambert
St. Clair	St. Clair		San Juan
Valsayn	Valsayn		Morvant
Diego Martin	Diego Martin		
St. Anns	St. Anns		
1980		1980	
Ellerslie and Federation Park	Ellerslie and Federation Park	Mount Lambert	Mount Lambert
St. Clair	St. Clair	San Juan	Morvant
St. Anns	St. Anns		Laventille
Valsayn	Valsayn		

Traditional elite residential areas such as St. Clair, persist today. This particular area is close to the edge of the old city and developed particularly during the cocoa boom of the late 19th century. Today it is the area in which the heads of the Anglican and Roman Catholic churches, government ministers and members of the diplomatic corps reside. This in itself allows the perpetuation of this elite residential area and acts as a magnet for similar development around it.

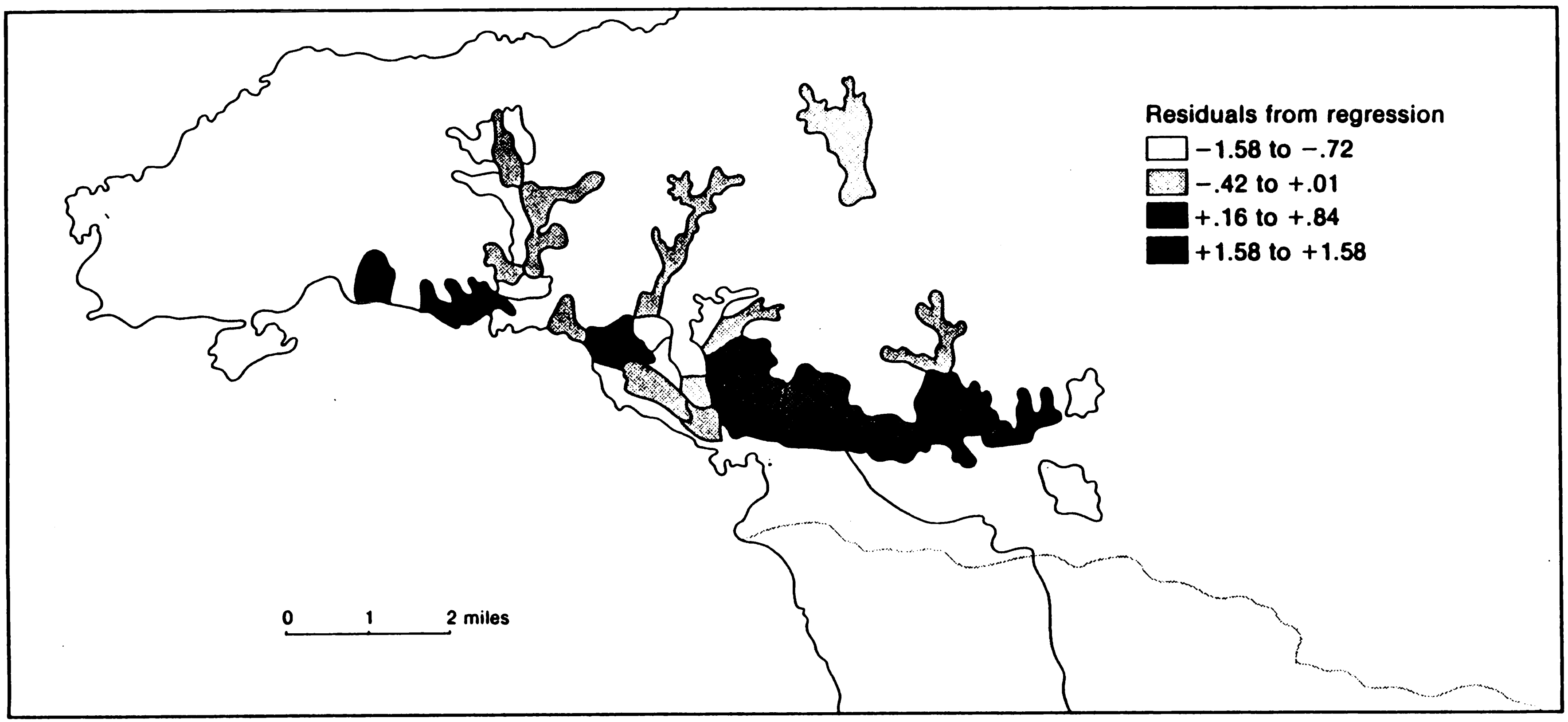
Ellerslie Park and Federation Park are also areas of elite residences, which exist in this case as a result of government policy. Many of the homes in this area are owned by the government and serve as residences for members of Parliament, the judiciary and defense force.

The existence of areas such as Ellerslie Park, Federation Park and St. Clair are an indication of an inherited Spanish tradition where the more affluent favour a residential location close to the center of the city but are also repelled by the poorer east side. Less well off individuals are delegated to the periphery of the city [at that point in time]. However, Port of Spain has grown to the east by leap frogging established low grade barriers [East Dry River and Morvant] to the available land beyond.

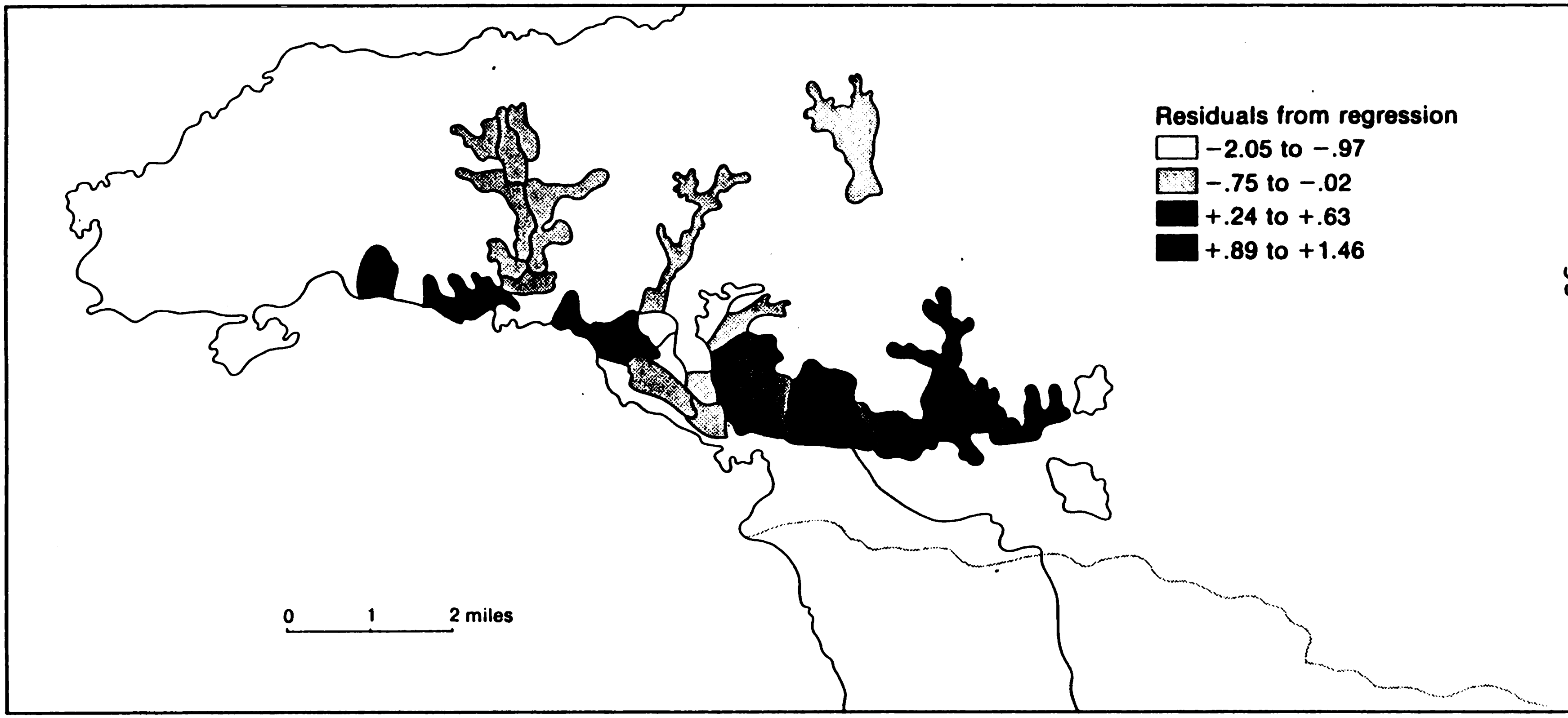
In the tradition of a colonial city the elite residents have also established themselves in the foothills of the Northern Range in areas such as St.Anns, Cascade and Dieyo Martin. The aesthetics of these areas [open spaces, fresh air, varied landscape] are appealing to those who can afford



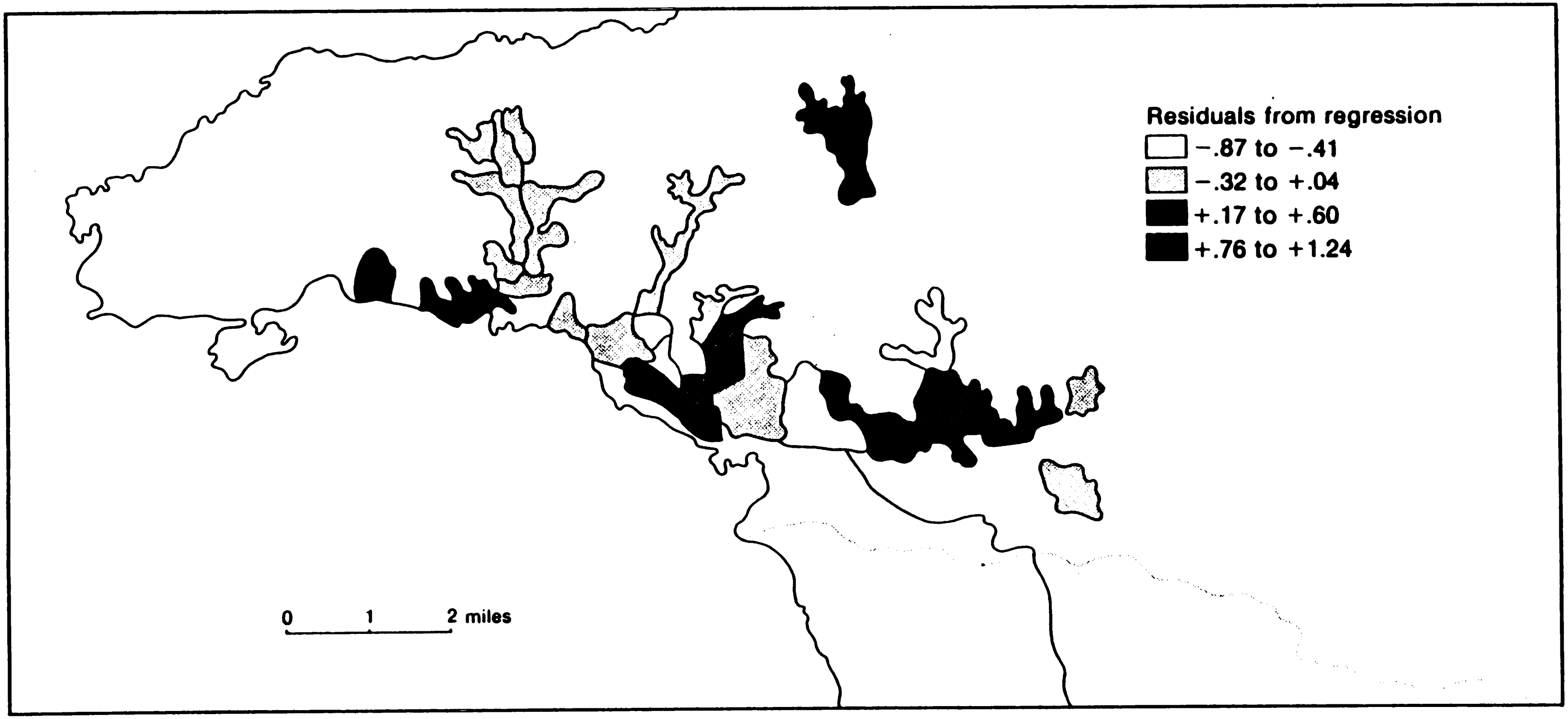
Map 2. Residuals from Regression of Log of Density with Distance from the CBD – 1960



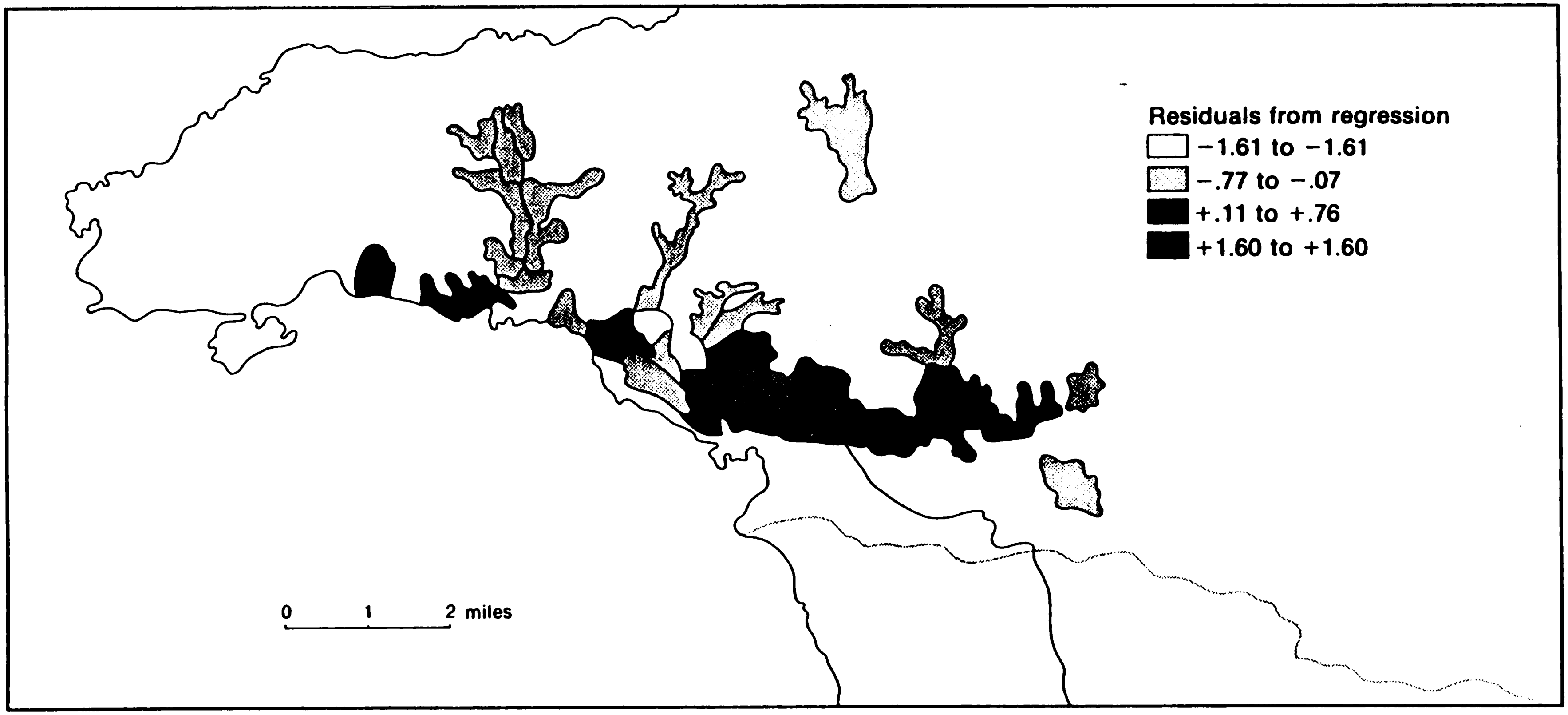
Map 3. Residuals from Regression of Log of Density with Distance from the CBD − 1970



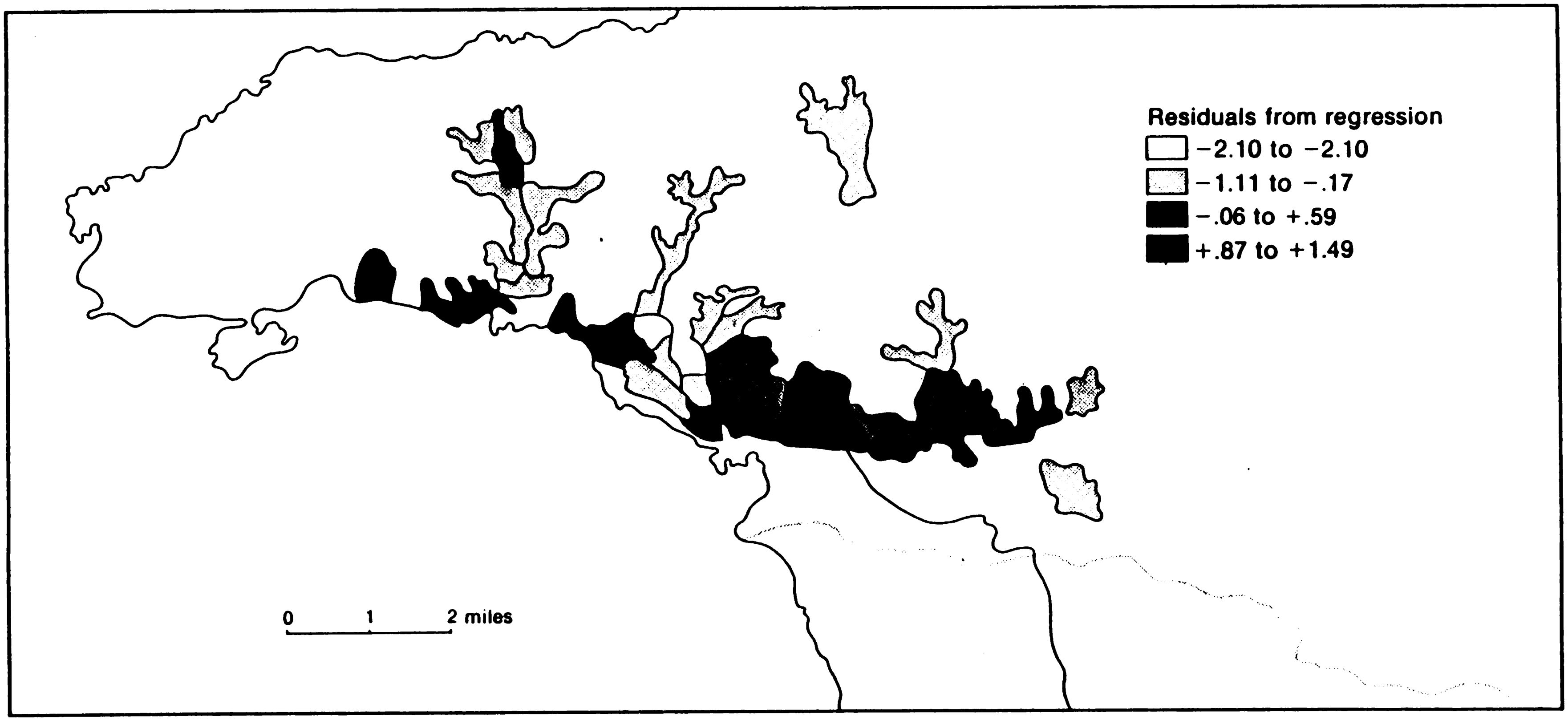
Map 4. Residuals from Regression of Log of Density with Distance from the CBD – 1980



Map 5. Residuals from Regression of Log of Density with Distance and Distance Squared – 1960



Map 6. Residuals from Regression of Log of Density with Distance and Distance Squared – 1970



Map 7. Residuals from Regression of Log of Density with Distance and Distance Squared – 1980

to develop the lands for residential use. Diego Martin and Valsayn have developed particularly since the 1960's and into the 1970's in the style of western type suburban development. This development was particularly enhanced by the improvements in the highway network in the 1970's.

The areas immediately to the east of the CBD which are underestimated co-incide with destination areas for rural-urban migrants. As a result of the limited availability of public transportation facilities, it is necessary for these individuals to live in relatively close proximity to the major employment center represented by the CBD. Mount Lambert represents an area of great overcrowding because of the prevalence of squatter settlements assocaited with the fringe of a minor commercial center - San Juan. In addition, Mount Lambert is an area in which there are several low income government housing estates. These housing estates are ultimately supposed to house the squatters. However, the squatter settlement is growing faster than the government can build adequate shelter for them.

Upper and lower Santa Cruz represents examples of local detail. These areas are discontiguous regions which constitute part of the suburbs of Port of Spain. Upper Santa Cruz is in fact part of the rural landscape. The area between Upper and lower Santa Cruz is devoted to market gardening to supply part of the food requirements of the city.

New Regressions

The Results thus far have confirmed the expected findings that Port of Spain and its suburbs are characterised by a declining rate of decrease of the density gradient over time. The central density has also fallen over time. However, the low R^2 values and lack of significance of the b and c parameters for 1970 and 1980 using the Newling model points to the existence of areas whose density levels cannot be explained in terms of the general expected pattern. In addition to this, the failure of both the Clark and Newling models to explain the density levels in the same areas point to the need to seek other reasons to explain the density patterns of the most deviant areas. This would suggest that by removing those areas whose estimated densities are beyond three standard deviations of the mean error term [the errors should be normally distributed], the level of explained variance in the density patterns should increase. Based on this, the following areas were removed from the data set: Mount Lambert, Upper Santa Cruz, Ellerslie Park, Federation Park, part of St. Clair, part of Maraval and part of Diego Martin. This reduced the data set from 139 to 123 observation points. The results using the Newling model are shown on Table 5.

Table 5: Changing Values of the Parameters, F-test and R^2.

Year	Log D_o	b	c	F-test	R^2
1960	4.19	-1.46	0.2232	37.90	38.71
	(0.25)	(0.23)	(0.0465)		
1970	3.65	0.13*	-0.0790	30.68	33.83
	(0.17)	(0.16)	(0.0314)		
1980	3.47	0.13	-0.1088	16.26	21.32
	(0.19)	(0.18)	(0.0367)		

*not significantly different from zero
figures in parentheses are standard errors

A comparison of the results of this regression with the findings shown on Table 3 show a marked improvement in the explanation of variance of the dependent varible by the independent variables, while preserving the trend previously described. The density curves are shown below.

The results for 1980 in this instance are of particular interest. Distance as an explanatory variable which was significant only at the 58% confidence level for 1970 is now significant at the 90% confidence level. These results are encouraging, as they suggest that over time, the Newling model may give a good indication of the urban population density patterns [with some special exceptions] in the Port of Spain area.

The fact that it is the Newling model which gives the best approximation of the density patterns in Port of Spain and its suburbs is particularly interesting as it is this

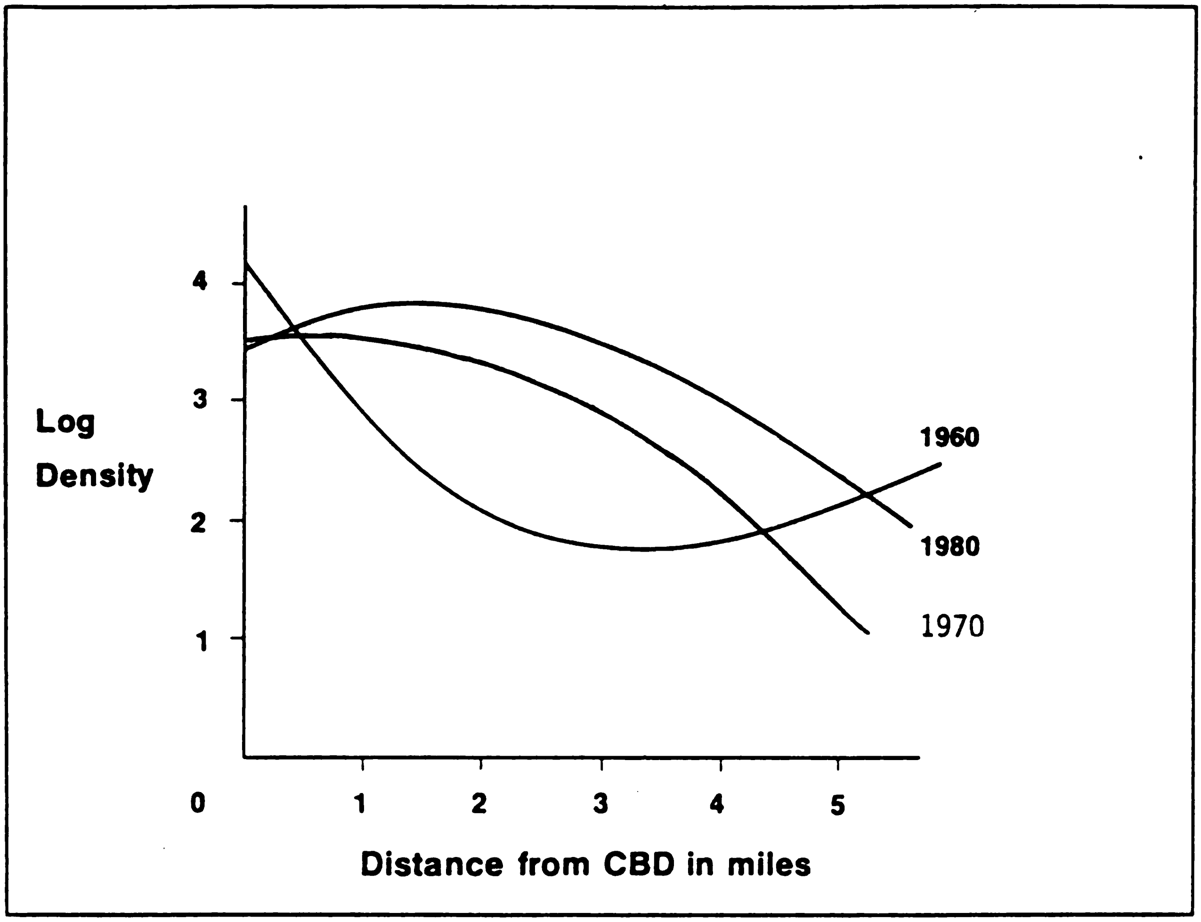


Figure 5. Gross Residential Density Curves for Port of Spain and its Suburbs: 1960, 1970, 1980 (123 Observations, Newling Model)

model which is able to capture the formation of a density crater at the city center associated with the land use specialization found in western type cities. In addition, it has been shown that the central density has declined over time as has the rate of decrease of the slope of the density curves - also associated with western type cities. However, there are some areas which did not conform with the predicted density patterns, as they more closely reflect features of a "non-western" type city. The following chapter will expand on these findings and attempt to anticipate the future trends in Port of Spain based on these results.

Footnotes

1. Latham and Yeates, op. cit., pp. 180.

2. see for example, Latham and Yeates, op. cit., pp. 184; De Borger, op. cit., pp. 20; Brush, op. cit., pp.

CHAPTER V

CONCLUSIONS

It was the objective of this research to identify a transitional density pattern between western and non-western type cities. Using Port of Spain as a case study the results presented in Chapter IV, does support the arguement for a transitional density form rather than dicotimous density patterns depending on whether the city was western or non-western. In general, population growth in cities may be expected to result in increased density levels over time, while the central density falls to make room for the increased specialization of commercial land use in the city center. This in turn causes a ridge of increased density to form around the density crater associated with the city center.

Income growth associated with economic development tends to flatten the density curve, if the demand for space is income elastic - a higher income allowing households to spend more on travel. Such a trend has been seen in Port of Spain as reflected in the changing distance decay parameters and the actual density curves for 1960 - 1980. Where both income and population have changed simultaneously, the consequences for urban spatial structure can be very complex.

Berry, Simmons and Tennant believe that western and non-western type cities differed in the way in which central density and the rate of change in density over distance changed through time. The contrast between western and non-western type cities was said to be the result of different patterns of residential location displayed by higher and lower level socio-economic groups in the city. However, in the case of Port of Spain, the preference patterns of the wealthy and poorer groups have not remained static. Rather, they have increasingly approximated the preference patterns seen in western cities; while at the same time retaining some of the features of a colonial city. For example, traditional wealthy residential areas close to the city center [St. Clair] co-exist with suburban elite residential areas such as Valsayn.

Port of Spain is characterised by high values of D_0, or high levels of overall congestion, while having relatively flat values of b [or a population which is widely distributed around the CBD.] The suburbanization process which has taken place in this city involves a great deal of deconcentration [outward movement away from the CBD as indicated by the density curves] and decongestion [decreases in the central density levels]. Along with this western type trend, in some areas such as St. Clair and East Dry River which are approximately the same distance from the CBD, very different density levels have persisted over time. St. Clair has continued to exist as a wealthy residential area partly because of the sentimental attachment of the families to this area, and also as a result of the government's desire to preserve the character of the area adjacent to the Queen's Park West as an area of historical and architectural interest.[1]

The contrasting high density levels in East Dry River is a reflection of the poverty of the area, haphazard system of land tenure, large numbers of squatters and the area's proximity to employment opportunities in keeping with their economically disadvantaged position. Areas such as East Dry River and Cocorite [both of which have similar socio-economic status] have continued to exist to a large extent because of the continued rural-urban migration process. The majority of these migrants to urban areas are young adults. As such the long term contribution of internal migration to urban population growth and density is actually much greater than just the number of in-migrants. The destination areas of these migrants have tended to remain the same because of family ties in these areas and employment opportunities in the informal economy which help the recent migrant to adjust to a foreign urban environment and life-style.[2]

Environmental stress generated by the encroachment of commercial land use on residential areas such as New Town and Woodbrook, over time has led to a net out migration of residents as they are no longer able to compete with commercial uses for sites in these areas. It is very probable that the displaced residents from these areas are part of the urban to suburban migration flow.

The co-existence of elite residential areas such as St. Clair, Ellerslie Park and Federation Park close to the CBD with western type suburban elite areas such as Valsayn on the periphery of the urban area is an indication of a dualistic urban structure which is different from both the Western and Non western types of structure suggested by Berry, Simmons and Tennant.

While examples have been found of western cities with non-western urban structures and non-western cities with western type urban structures,[3] Port of Spain constitutes an example of a city which displays features of both types of structures. This dualistic urban structure is a reflection of first, the development history of Port of Spain. Tradition dies slowly in Trinidad. This when considered with the influence of colonial powers up to 1964 when the country became independent has had a great impact on the urban structure of Port of Spain. The oil crisis of the early 1970's aided the development process in Trinidad as the country benefited from its oil resources. The economic development which has taken place has been accompanied by changes over time in the urban structure of the major city - Port of Spain.

Second, the growth of they city creates its form, but the form also limits the future growth of the city. Once a group has become entrenched in part of a city it is very difficult to change the area. However, over time these areas are subjected to increasing pressure from the surrounding areas, to conform to the general pattern. Thus areas such as St. Clair would be threatened in the future if steps are not taken to preserve the character of the area as it exists today. The forces pushing towards westernization and those maintaining traditional density forms will not remain in balance indefinitely. At present these forces interact to produce a transitional density structure. Ultimately, the modernization forces will dominate over the traditional forces in the interest of progress and development if the city is not to stagnate.

The areas of high population density associated with lower socio-economic groups may persist long into the future as the march of peasants continues into the city into traditional destination areas as much of the suitable land has already been settled. In addition to this, in the face of the inadequacy of public transportation, the area which is feasible as residential locations for these individuals remain restricted.

Recommendations

It would appear that if the development history of various countries along with the urban density patterns are considered, it is likely that as the structure of cities change to meet the demands of industrial development, there is also a need for residential patterns to change.

As such different density gradient patterns should be identified which correspond to stages of economic development rather than attribute differences to socio-cultural factors.

The constant rate of growth of urban population density over time suggested by previous researchers for "non-western" type cities does not seem to be practically feasible. The indefinite, continued increase in central density over time would eventually reach a point beyond which further increases would be impossible. At this point environmental stress would dictate that densities decline as individuals move to areas of less stress. Even without economic development, the weight of sheer numbers would generate a change in the pattern of urban population density.

Based on the findings of this study it would appear that a western - non-western dicotomy of density patterns is not valid. Rather, over time density gradient patterns indicate changes in economic development. Port of Spain has been put forward as an example of a transition between western and non western urban density patterns which displays a dualistic pattern of urban structure.

If urban population density is viewed as a series of stages of patterns, population density models could be used by developing nations for analytical and predictive purposes to their own benefit. This would be of particular value in the planning process for underdeveloped countries.

Second, this study has focused only on one relatively small city in a developing country. To confirm the generality of the findings of this study, it would be necessary to examine the changes which have occured over time, in a wide cross section of cities, in several countries at different stages of economic development. In this way the validity of the western - non-western dicotomy could be tested with greater confidence in the universality of a link between economic development and urban density patterns.

Third, using several indices of economic development over time, it would be possible to prove empirically, that there is a link between changing urban density patterns and economic development. The unavailability of sufficient economic data for Port of Spain over time, has precluded such an empirical examination. However, based on the improvements which have taken place in Trinidad and the views of the government which support the fact that economic development has taken place since 1960, I can argue that there is a link between the development process and changes in the urban structure of Port of Spain.

Footnotes

1. Planning for Development: The Capital Region, Development Planning Series NoTi/2/3, Town and Country Planning Division, Port of Spain, 1975, pp. 123.

2. S. Angel and Stan Benjamin, "Seventeen Reasons why Squatter Problems can't be Solved," Ekistics, 41:242, 1976, pp. 20-28.

3. Bruce E. Newling, 1964, op. cit., pp. 440-442.

APPENDICES

APPENDIX I

Data Sources

1. The Population Census for Trinidad and Tobago 1960; Vol ii, Pt A, Central Statistical Office, Port of Spain, Trinidad, 1963.

2. 1980 Population and Housing Census, Bulletin No 1, Central Statistical Office, Port of Spain, Trinidad, 1981.

3. Annual Statistical Digest, 1978,; No 25; Central Statistical Office, Port of Spain, Trinidad, 1980.

APPENDIX II

Areal Computation using a Polar Planimeter

A starting point was selected on the boundary of each enumeration district, such that the measuring wheel showed the least amount of movement. Thus the effect of small errors at the start or finish of the tracing could be minimized. Once the first measurement was taken, the instrument was not reset to zero. This was done to minimize subsequent measuring errors. As such the final reading after completing the tracing of each area was subtracted from the previous reading.

To compensate for human error in the tracing and small instrument errors, the area of each district was measured using the compensating feature of the planimeter. Two tracings of each district were made and their readings taken. The mean value of both readings was then used for the area computation.

$$\text{i.e.} \quad N = \frac{N_1 + N_2}{2}$$

where

N = final result

N_1 = initial reading

N_2 = second reading.

The compensating feature was applied in the following manner: - the area of each district was measured first with the tracer arm extended to the right of the pole arm. Then, with the pole in the same position as before, the process was repeated with the tracer arm extended to the left of the pole arm.

Following this the actual planimeter operation was completed. The reading N is known to be the value of one vernier unit [the units in which the length of the tracer arm is given]. The value of one vernier unit was specified to be 0.010 square inches, with the length of the tracer arm set to 13. The area of each district could then be computed using the formula

$$A_s = N \times V$$

where

A_s = Area

N = final reading

V = given scale value

V in this case is a product of the scale ratio and vernier value

i.e. $V = Sc^2 \times v$

Sc = the scale ratio

v = vernier value [0.010]

Given that the scale of the map used was 1:60,000 [ie.e one inch represents five thousand feet]

$$V = 5000^2 \times 0.010$$

$$V = 250,000 \text{ ft.}^2$$

The tracer arm length of 13 was chosen as the shorter tracer arm setting guarantees the highest degree of accuracy since it has the smallest individual vernier scale. The accuracy of the computed areas of each enumeration district were checked at a later point with the areas computed by the Town and Country Planning Division of the Ministry of Finance, Port of Spain, Trinidad.

APPENDIX III

Data Base

Areal Unit	Area [Acres]	Distance to City Center [mls]	Density 1960	Density 1970	Density 1980
Carenage	215	4.17	14	29	39
Point Cumana	52	3.73	24	45	50
Glencoe	92	3.31	10	25	44
La Puerta	161	3.20	4	22	31
Diego Martin	620				
Diamond Vale	295	4.15	5	20	28
Petit Valley	482	3.29	2	18	18
Cocorite	156	1.72	4	22	32
St. James/ Long Circular	317	1.48	3	27	90
Ellerslie Pk/ Federation Pk	237	1.84	5	13	4
St. Clair	137	0.89	9	6	5
New Town	55	0.36	73	39	28
Woodbrook	286	0.77	36	26	21
Maraval	422	2.13	5	27	34
St. Anns	222	1.30	12	19	11
Cascade	201	1.84	18	17	19
Belmont	318	0.83	36	43	40
City Proper	241	--	73	41	27
East Dry River	336	0.71	28	68	72
Laventille	430	1.18	2	53	75
Morvant	232	1.07	17	64	110
Barataria	424	2.07	26	35	35

(Appendix III (cont'd.).

Areal Unit	Area [Acres]	Distance to City Center [mls]	Density 1960	Density 1970	Density 1980
San Juan	789	2.84	5	53	54
Lower Santa Cruz	404	2.96	3	16	19
Upper Santa Cruz	607	3.73	2	15	19
Mount Lambert	72	3.73	29	104	125
Valsayn	588	4.44	7	7	7

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