MODE OF TRANSPORTATION AND THE INCOME-DISTANCE TO WORK RELATIONSHIP IN PIRACICABA, SÃO PAULO, BRAZIL

By

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To Marshlea and Cyrus B. Dawsey, Jr.

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Empirical evidence suggests that a positive relationship exists between income and distance to work within cities of Anglo-America. The relationship appears to be negative in Latin American cities. A normative bid-price model which applies Von-Thünen's framework to residential land use can be transformed into a model of interaction between the residence and place of work. In this form the model describes the income-distance relationship characteristic of Anglo-America when distance overcoming costs are measured in monetary units. The model describes the relationship characteristic of Latin America when the costs are measured in units of time.

Hypotheses of a positive relationship between income and distance to work for automobile using commuters and of a negative relationship between income and distance to work for commuters who use other modes of transportation were tested in Piracicaba, São Paulo, Brazil. Linear regression analyses of data collected from interviews of a 4 percent

sample of the city residents showed that the hypothesized relationship could be inferred only for the group who walked to work. When length (in years) of residence was added as a measure of utility maximization, the significant relationship became not significant at the .05 level. The research hypotheses were rejected. A negative relationship between income and distance to the city center was significant at the .05 level for all groups differentiated according to the mode of transportation used.

Relative location with respect to the city center was concluded to be more important than to the place of work. The negative income-distance to the city center relationship for automobile users was concluded possibly to be the result of a low marginal utility of residential land. The results imply that the characteristic negative income-distance to the city center relationship will not be changed by increasing dependence on the automobile in Brazil.

CHAPTER I

RESEARCH SCOPE AND OBJECTIVE

Introduction

A dominant characteristic of man has been his tendency to seek out his own kind. Since the beginning of their presence on earth, people have protected and enriched themselves by clustering in groups, and ultimately towns evolved. From the small early villages in China, Egypt, Babylonia and India, settlements have developed into the giant metropolitan areas of today.

For primitive man, gathering into groups was probably natural. He, just as the primates, compensated for physical weakness by hunting and fighting along side others of his own species, and through a process of natural selection, this efficient behavior survived. Those who opted for societal life more often lived on to transmit their culture to offspring.

Although the exact definition of a city varies (Mayer, 1971), the growth of early settlements involved many complex factors. Improvements in agricultural techniques created food surpluses, and groups of people not directly involved in subsistence production could be supported. At physically favorable locations, people gathered to exchange goods, so that a professional merchant elite eventually emerged. The increasing knowledge was dealt with by an educational elite; rites and

cultural functions were conducted by a religious elite; and the whole agglomeration was ruled by a governmental elite. The growth of cities, therefore, was related to technological innovation and increased productivity as well as to professional diversification and specialization.

History since the industrial revolution has been marked by an ever increasing shift of people from rural to urban areas. In 1800, only 3 percent of the world's population lived in places of 5,000 people or more, and 1.7 percent lived in places of 100,000 or more. By 1950, over 30 percent lived in places of 5,000 or more while 13 percent resided in cities containing 100,000 or more inhabitants (Hauser, 1967, p. 7). Although most of the people of the world still live in rural areas, the trend toward urbanization is evident.

The growing importance of the urban area as a home for man has led to increased interest in cities. Curiosity has been aroused by apparent regularities and differences encountered among and within cities. What, for example, causes the sprawl of Los Angeles or the high density of Calcutta? Why is Paris the fashion capital, or why does Detroit produce automobiles? What causes financial executives to seek downtown offices while supermarket operators locate in suburbs?

Curiosity has not been the only reason for focusing attention on cities. While a growing number of people are choosing an urban area for a home, cities are less than ideal environments. Much investigation, therefore, has been aimed at the solution of particular problems. To try

to improve the quality of urban life, researchers look for answers to questions like: why is social pathology associated with certain racial and economic groups; what causes squalid squatter settlements around large Latin American cities; or how can visual and aural blight as well as water and air pollution be controlled?

The study of cities can be divided into two categories: inter-urban and intra-urban. The first concerns the external relationships of a city. These would be the city's association with other cities, ties to a rural hinterland, or how the town fits into a larger regional or national pattern. Intra-urban study, on the other hand, involves internal characteristics of an urban place. Interest is concentrated on the component parts of a city and how they interact with each other.

Although inter-urban studies are an important field of investigation (witness the attention devoted by geographers to Central Place Theory), the scope of the research presented in this paper is intra-urban. It concerns events and characteristics found within cities.

Intra-urban studies are conducted by researchers from various fields. History and geography are different from most social sciences in that they focus on a dimension rather than a particular subject or activity. While sociologists study group behavior and economists study economic behavior, historians and geographers look at any or all activity through time and over space. This spatial aspect is one of the characterizing features of the field of geography.

The orientation of this research is geographic. Although some of the concepts and models are developed using economic theory, the basic dimension of interest is spatial. How certain factors vary over physical space and distance is of primary concern.

One of the factors which varies over space is residential land use, and much attention has been devoted to the study of where people live within cities. Some researchers are content to map or describe residential patterns (Jones, 1931; Applebaum, 1952; Niedercorn and Hearle, 1964; Loewenstein, 1963), but others are concerned with discovering regularities from one city to another. These regularities can be stated in terms of descriptive models. The concentric zone (Burgess, 1925), sector (Hoyt, 1939), and multiple nuclei (Harris and Ulman, 1945) models are the ones most often cited, and recent studies show how the patterns described by each of these is related to different factorial dimensions found within cities (Anderson and Egeland, 1961; Berry, 1965; Simmons, 1965; Murdie, 1969).

Regularities in residential location, therefore, appear to exist in urban areas. What causes these patterns? Why do people live where they do? The residential location decision is a very complex psychological process that involves a variety of known and unknown factors. Basically, however, it concerns the evaluation of information about the perceived environment. Each individual considers desirable and undesirable residential characteristics, compares them to the perceived locational possibilities, and makes the decision of where to live.

This decision need not be a logical one. What is or is not desirable to a given person depends on what his physical and psychological needs are. These needs may be different from those of other people. Furthermore, the decision is based on a perception of reality rather than the real world itself. This perception also varies from one individual to another (Wolpert, 1966; Pred, 1967 and 1969; Wood, 1970).

Many features of the site itself might weigh heavily in the process. Characteristics of the land and the house are obviously important factors. Another group of considerations involves relative location. The proximity to a polluting factory or a busy street, for example, might be negative features of a particular location, while nearness to a shopping center, the children's school, or a parent's job could be positive aspects. Proximity to a large number of urban features, therefore, is an important component of the locational decision.

The aggregate location of residences within cities, is the sum of a large number of individual decisions, each of which is based on a variety of considerations. Site considerations are important, but so too are those pertaining to the relative location with respect to other features found within the city. Proximity to certain items is avoided while accessibility to others is sought.

Research Objective

The objective of this study is the investigation of the relationship between residential sites and one of the items to which accessibility

is desired: the place of work. Empirical evidence indicates that accessibility to the place of work may be more desirable for some income groups than for others. A relationship, therefore, appears to exist between income and the distance people are willing to travel to work.

The income-distance to work relationship, however, is not the same for people living in industrialized countries and developing areas. Research conducted in Anglo-American cities shows that distance usually increases with income; poor workers live nearer their jobs than rich individuals do. Descriptive accounts of Latin American cities, however, indicate that the pattern in these towns may be the opposite with poor people travelling farther to work than wealthier individuals. The relationship between income and distance to work, therefore, appears to be positive in industrialized societies and negative in developing ones.

The study presented here considers a possible explanation for the difference between the income-distance to work relationship characteristic of cities in Anglo-America and Latin America: the type of transportation used for the journey to work. The following specific question is asked: is the type of transportation used for the trip to work important in determining the nature of the relationship between income and distance to work? If transportation mode is indicated to be an important variable, then it must be included with income in an explanation of the distance people choose to live from their jobs.

Partial causality is implied. Income and transportation type influence distance to work which is in turn related to where people live. If a change in the income-distance relationship occurs when a change takes place in the type of transportation used, then the inclusion of the new variable, mode of transportation, adds some information to a general understanding of why people live where they do. Transportation mode can thus take part in the explanation of residential location.

CHAPTER II

INCOME AND DISTANCE TO WORK: ANGLO-AMERICA

The Journey to Work

As stated in Chapter I, relative location is a factor in the locational decision. While proximity to various features within a city might be desirable, accessibility to the place of work is one of the most important considerations.

The ebb and flow of the working force is the single most important component of movement within cities. In Chicago the number of trips originating from home going to work is almost twice as large as the next highest destination category (Chicago, 1959), and in Toronto roughly half of all trips involve job commuting (Toronto, 1966). Other studies place the figure for various cities at 40 percent and higher (Wingo, 1961a).

Many aspects of the journey to work are being widely investigated (Wheeler, 1969a) since commuter flow is related to many urban problems. The concentration, for example, of travel at peak hours leads to inefficiencies in the use of transportation networks. Social (Wolforth, 1965) and marginally increasing economic (Walters, 1961) costs associated with traffic congestion have led to the advocacy of variable pricing schemes. These would discourage the use of highways at peak

hours (Vickrey, 1963). On the other hand, the financial viability of various public transit alternatives to the automobile have been compared, and the present bus system is seen as being the most efficient in the short run for most cities (Meyer, Kain, and Wohl, 1965).

Evolution of the Journey to Work

The journey to work is the result of the separation between residence and job, and it is a recent phenomenon. In earlier times production was small scale, and people worked at home or next door in small shops. In many instances gainful employment was not distinguishable from household activity (Sjoberg, 1960).

The industrial revolution brought increased capitalization and plant size as producers took advantage of economies of scale. As industry became larger and more complex, a greater and more diverse labor force was needed at each plant (Liepman, 1944). Domestic functions gradually became different from income producing work, and, with improved means of transportation, the activities became physically separated.

Small, pre-industrial domestic or shop industry gave way to larger factories which were ringed by worker's houses. These mills in turn were gradually replaced by complex plants which were spatially removed from the residences of the labor force. The process was shown in a study of Chorley, England (Warnes, 1970) for the period 1780-1850, where distance to work is compared to two characteristics

of industry: size (positive relationship) and age (negative relationship). Workers tended to cluster around older and smaller mills but not newer, larger ones.

Improvement in transportation technology was the main factor involved in the separation of workers and their jobs. Streetcars, railroads, buses, and the automobile made it possible for people to commute to work. They could cover large distances in a short period of time, and there was, therefore, no longer the necessity to live next door to the factory. Technological change brought about a reduction in the costs associated with overcoming distance, and spatial interaction over a much larger area was made possible (Janelle, 1971).

Not only did workers move away, but industry as well decentralized. The use of trucks and electricity allowed plants to break away from sites favored by railroads or rivers. Physical proximity to such features was no longer necessary.

The separation of the home from the place of work, occasioned by reductions in the costs of transportation, has led some authors to contend that the relationship between the residence and the job is becoming weaker (Wolforth, 1965; Boyce, 1969; Forrest and Tan, 1970). The argument can be made, however, that what has changed is the "form" of the journey to work, and not the "process."

Theoretically, form refers to the static characteristics or morphology of events, while process refers to changes in these events

through time. Ultimately, everything can be defined as form--where the change in time is 0--and process--where the change in time is infinite. The static or form feature of residential location, for example, is concerned with where people live and it can be mapped or described by using the concentric zone, sector, or multiple nuclei models. On the other hand, residential location process refers to where people move (i.e., change residence) (Rossi, 1955; Moses, 1962; Boyce, 1969).

The journey to work is by and large a process. It occurs twice daily for most individuals, and the aggregate volume of flow varies greatly from hour to hour. Spatially, it is the process of interaction which occurs between the two locations; home and work.

The form of the journey to work, or the physical distance between home and employment, has indeed grown longer. At the aggregate level, commuting occurs over a much broader area than it did in the past. The increase in distance does not mean, however, that the travel to work process has changed. Perhaps some modification has taken place because of a shorter work week or owing to increased lunch box use but not as a result of changes in the cost of transportation.

If a century ago a causal link existed between residential location and accessibility to work, the influence of one upon the other is equally present today. Patterns are simply blown up to a larger dimension involving greater physical distances. A decrease in the cost of transportation does not mean that the basic shape or the strength of these

patterns has changed, and proximity to work should still be important in determining residential location. Accessibility is why people live in cities, and it follows, therefore, that nearness to work is a major factor. Most urban travel is, after all, made up of commuters.

The Gravity Model

A series of models is often used to describe the relationship between the residence and the place of work. These are various forms of the "gravity" or "potential" model originally conceived by Zipf (1947). The main function of the models is the prediction of the volume of interaction which takes place between two or more locations. The models are allegorical in that they apply physical science relationships between mass and distance to human events. The general form of the gravity model is as follows:

$$I_{ij} = \frac{M_i + M_j}{d_{ij}^b}$$

where:

I_{ij} = interaction between locations i and j.

M_i = measure of mass (population, for example) at i.

M_j = measure of mass at j.

d_{ij} = distance between i and j.

b = empirically derived exponent.

With basically the same format, the gravity model is expanded to include the actual or possible interaction between an area i and all

other areas j. In this form it is referred to as a "potential" model.

The use of such a framework in a number of studies indicates that as distance increases the volume of interaction does decrease. Even though the model has been applied to interaction between home and other possible destinations (Huff, 1963; Wheeler and Stutz, 1971; Hale, 1973), most interest has centered on the link between the residence and the place of work.

Empirical research shows that the number of employees at a given place of work decreases as distance from that place increases. The number, for example, of people working in factories in Massachusetts declines significantly with distance from the plant after the first two or three miles (Carroll, 1949). Much later, Getis (1969), using a probabilistic approach, wrote that within a certain radius of the place of work a "frictionless" area exists within which workers are indifferent about their place of residence. Outside this area the decay of distance occurs as predicted by the gravity model.

Distance is also minimized by commuters in Montreal who tend to select the shortest possible route to work (Scarlett, 1970). Although people of Athens travel farther to work than they do for other reasons, the number of trips decreases significantly with distance (Pappas, 1970). Hecht (1973) discovered that individual stress increases when the length of the journey to work increases.

Distance to work is frequently used as a variable in the prediction of future growth. A potential model can describe present accessibility

of urban sectors with respect to the working force, and future growth in each sector can be evaluated when a parameter of total regional growth is included. Development would depend on the number of employees who commute from a sector and how far they must travel to their jobs. The farther they go, the less likely it is that their home sector will grow (Hansen, 1959).

Gravity models are often used for planning purposes. Predictions of future growth are based on a series of input factors including present accessibility between employment and employees. Lowry (1968) has summarized the characteristics of the most important of these models and discussed drawbacks and promises involved in their use.

In order to increase its predictive value, the gravity model is continually being modified. The inclusion of items such as residential attractiveness (Wilson, 1969), and intervening opportunity (Schneider, 1959), as well as the mating of the model to probability and game theory (Malm, Olsson and Warneryd, 1966) are all attempts to better relate the framework to reality.

Problems of the gravity model have been widely recognized (Lowry, 1964, p. 22; Colenutt, 1970, p. 116; Berry and Horton, 1970, p. 493). The major criticism has been that the model is basically descriptive. It is used as a tool for making predictions of the future based on present empirically determined relationships. This use is limited because predictions are dependent on current or past conditions and not on general explanatory concepts.

The theoretical underpinning of the model consists of laws borrowed from physics and of an informal knowledge concerning the costs of overcoming distance. This knowledge leads to the conclusion that the statement of the model--that interaction decreases as distance increases--is obviously true. The nature, however, of the various costs is not dealt with, and the model says nothing about how distance is related to human behavior in general.

Methods of Minimizing Distance

Studies of interaction using gravity type models do prove that a relationship exists between the residence and the place of work. While the commuting distance has increased over the years, the journey to work is still a strong link which shapes the character of cities. The model indicates that the distance between home and job tends to be minimized but it does not state how this is accomplished. The possible means of shortening the distance are: a change in the residential site, a change in the employment location, and a change in the journey itself.

Barring changes in transportation technology, the journey itself should already be optimal. The worker already uses the shortest route or the quickest and cheapest means of getting to work (Scarlett, 1970).

Changes in the location of employment are very possible. Harris (1954), and Vance (1966) have argued that the labor component is an important factor which is often overlooked in industrial location theory.

The historical spreading of job sites, discussed above, is a contemporary process. Taaffe, Garner, and Yeates (1963) showed that in Chicago many firms have moved to locations in peripheral residential areas. Although many workers still go downtown, a large proportion of them commute to these non-central jobs. The trend has been confirmed in Sydney (Logan, 1968) and London (Daniels, 1973).

A change in the place of work, therefore, is recognized as a possible distance minimizing response. Workers can change jobs and employers can change the site of their plant or office. If employers locate according to where people live, the distance to work does not explain residential patterns. It explains the location of jobs. Investigating changes in employment opportunities and labor migration in Los Angeles, Burns (1964) found a strong correlation between the two but no time lag. This would have possibly indicated which causes the other by showing which occurs first.

Most researchers seem to agree that the residential location is more flexible than that of the place of work, and they have used the commuting distance to explain residential land use patterns (Carroll, 1952; Duncan, 1956; Kain, 1962; Taaffe, Garner and Yeates, 1963; Goldstein and Mayer, 1964; Loewenstein, 1965; Wheeler, 1967, 1968b; Halvorson, 1973). Lowry (1968), in formulating his planning model, allowed the residential site to be a free variable; one that responds to the location of industry and commerce.

The study presented here considers the mode of transportation variable as being a factor which modifies the relationship between income and the distance to work. Other research indicates that the commuting distance is most often, although not always, modified by changing the place of residence. If this is true, and if transportation mode does influence the income-distance relationship, the results of this investigation should add more to an understanding of the location of residences than work places.

The Bid-Price Model

The major function of the gravity model, as applied to the journey to work, is the description of empirically observed relationships which exist between the volume of movement and distance. The model, however, states nothing of how the various costs associated with distance are related to human behavior. Why, for example, do people tend to minimize the amount of time devoted to commuting?

A group of regional economists and urban geographers are increasingly investigating the journey to work from a different perspective. They use the normative approach. Rather than seek aggregate patterns or relationships in nature, these researchers are concerned with developing a deductive model of what man does under certain conditions.

The advantage of the normative methodology is that general theory is built into the model, and "why" or "how" questions are answerable.

The problem is that if the general theory is incorrect, the model must likewise be incorrect. The test of validity is whether or not the explicit or implicit assumptions of the model apply to real situations.

Development of the Bid-Price Model

One normative residential land use model is an urban application of Von Thünen's ideas (Hall, 1966) about the rural landscape. The value of property in the city, as in the country, is said to be tied to benefits which accrue to the owner in terms of savings in expenses of transportation to a central location. Land users with large transportation costs value accessibility more highly and will, consequently, pay more for property than other potential owners. The land goes to the highest bidder.

The basic idea was presented in an early work by Hurd (1903) who related accessibility to the amount of money individuals or firms are willing to bid for property. Land value was said to depend on proximity, which is equal to convenience.

Later, Haig (1926) added the concept of transportation costs, stating that they are the reflection of the "friction of distance." The value of a given piece of land depends on the savings in transportation expenses which the location provides, as well as on characteristics of the site itself. Haig was the first to consider residential land. Space for a home was said to be evaluated like any other personal purchase with the costs and benefits weighing in the consideration. In 1949 Ratcliff (1949) added the idea that maximum aggregate utility is reached

when total transportation costs in a city are minimized. This point was later attacked (Alonso, 1964) and defended (Goldberg, 1970).

Despite some criticism (Wendt, 1957), the general model was continued and expanded in the early 1960's. Kain (1962) developed a utility function which includes as a negative component the cost of transportation in the journey to work. Wingo (1961b) treated transportation in depth and added the opportunity costs of, or the loss of income due to, time spent commuting.

During the past decade, two landmarks have emerged in the development of the normative model. William Alonso's Location and Land Use, published in 1964, served two important purposes. It incorporated the variability of the size of the residential site, and the book formally developed the normative ideas in precise mathematical language.

Finally, Richard Muth (1969) broadened the model and included the quantity of housing as a variable. He stated that the site which is bid on possesses two characteristics: land and building; the demand for each is variable with income. Muth also included more than one place of work but did not completely develop the potential ramifications.

Use of the model has continued with work by geographers and economists. The individual demand for land and transportation has been variously related to population densities (Cassetti, 1969; Cassetti

and Papageorgiou, 1971), the aggregate cost of distance (Goldberg, 1970), the third spatial dimension of high rise apartments (Wright, 1971), and open versus closed urban systems (Wheaton, 1974). Goldstein and Moses (1973) have summarized the more recent developments in the field.

The normative residential land use model is based on rational behavior by economically oriented individuals. All extraneous variables are controlled with general assumptions while the few items of interest are manipulated mathematically. A simple version of the model is presented and discussed in Appendix A.

Income and the Slope of the Bid-Price Function

The normative land-use model shows that transportation costs cause an individual's bid-price, or the amount he is willing to pay per unit of residential land to achieve a given level of satisfaction, to decline as distance from the place of work increases. The bid-price function over distance, therefore, is negative. Moreover, when transportation costs are monetary and directly variable with distance, the slope, or rate of change, of the bid-price curve varies with income.

The bid-price functions of two individuals are presented in Figure 1. Both workers commute to a central location (t_0) and they are identical in every way except for income. When distance is plotted horizontally, the high income or "rich" person has a gentle sloped bid-price function, and the low income or "poor" worker has a steeper one.

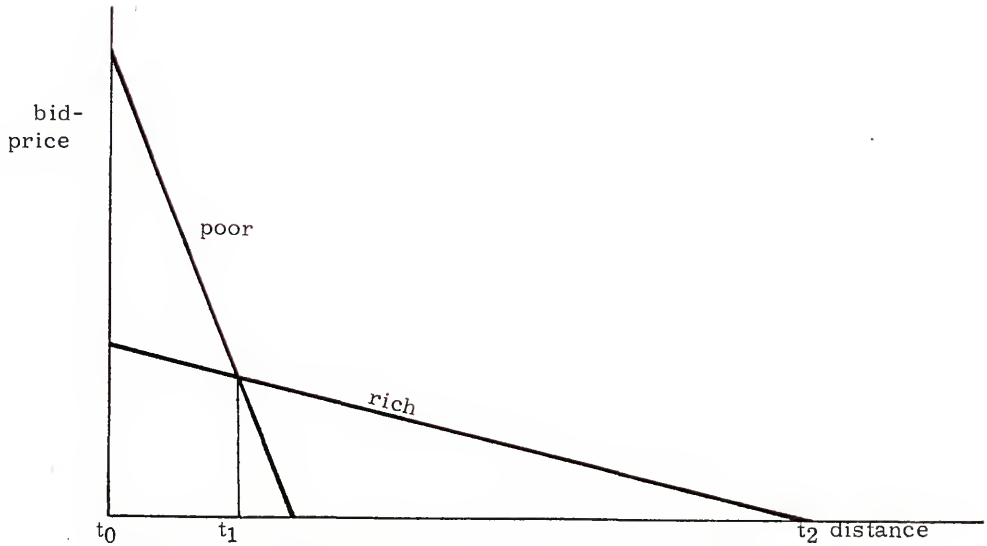

Figure 1. Bid-Price Curves for Rich and Poor Individuals; commuting costs are monetary.

Because property goes to the highest bidder, land in the t_0-t_1 interval is purchased by the poor commuter, and the distance between t_1 and t_2 goes to the rich bidder.

Many different income (y) levels could be added to the model. Each person in the city would be identical to the others except for the amount of money each earned. The effect is shown in Figure 2 where $y_1<y_2<y_3<y_4<y_5$. The greater the income (the larger the subscript), the more gentle is the slope of the bid-price curve. Each higher level of income acquires land farther away from the place of work. The result of the addition of many people earning different amounts of money is to "round" or "smooth" the linear individual functions into an exponential aggregate price of land curve.

Generalizing for many bidders, therefore, changes in the slope component of the bid-price function with changes in income lead to a direct relationship between individuals' income and the distance they live from the central work location. This occurs under the condition that the people are identical in every way except in the amount of money they earn.

The presence of low income groups on high-priced land at the center of large American cities is thus explained by the bid-price model. The cost of transportation (k) is not variable with income, and the expense constitutes an ever greater proportion of the budget as income gets smaller. The quantity of land can be modified, though. Poor people can live on ever smaller pieces of land (or more crowded in apartment

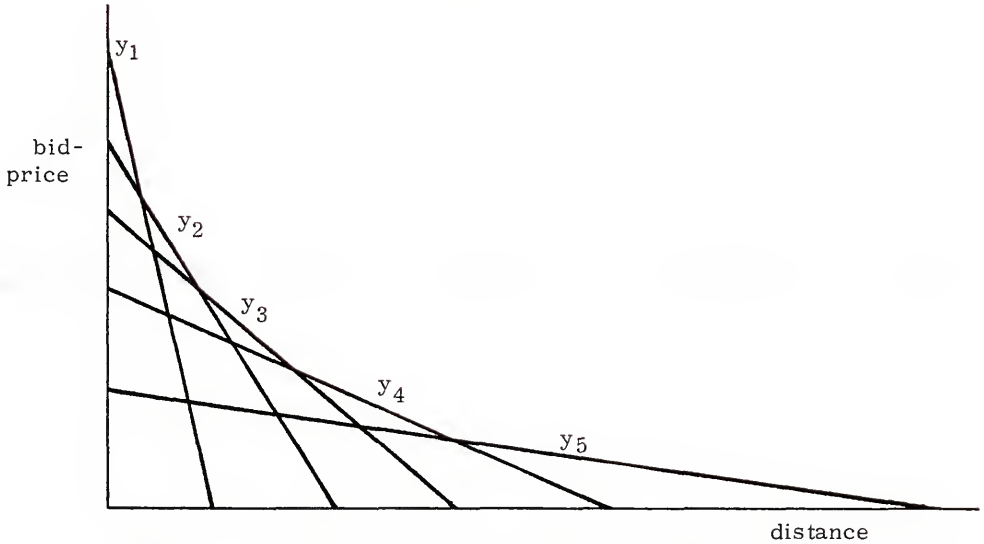

Figure 2. Bid-Price Curves of People at 5 Different Income Levels.

buildings) as their earnings decrease. The value of accessibility becomes a more important commodity in comparison to the quantity of land.

Multiple Work Locations

The normative urban land use model, as developed by Alonso, Wingo, and others, is generally tied to one central place of work. Rationale for using accessibility to the place of work and not to just any trip destination is that income itself is made dependent on paying the commuting costs. The worker does not have the option to go or not to go. For economic man total utility = 0 if y = 0.

The model need not be restricted to one place of work (Muth, 1969, p. 87). At any residential site, the individual who submits the highest bid, regardless of his place of employment acquires the use of the land. The incorporation of many job locations can be shown more clearly with schematic diagrams than with mathematical equations.

Assume a linear city with several employment sites. Workers in the city are homogeneous in every way except the location of their work place. Their bid-price functions are likewise identical except that k is measured from each individual's place of employment rather than from one central location. The bid-prices "peak," or reach their highest value (where k = 0), at the work site of the person who is bidding. A city with three places of work (E_1, E_2 and E_3) and the bid-price curves of their workers are shown in Figure 3. Employees of E_1 acquire the

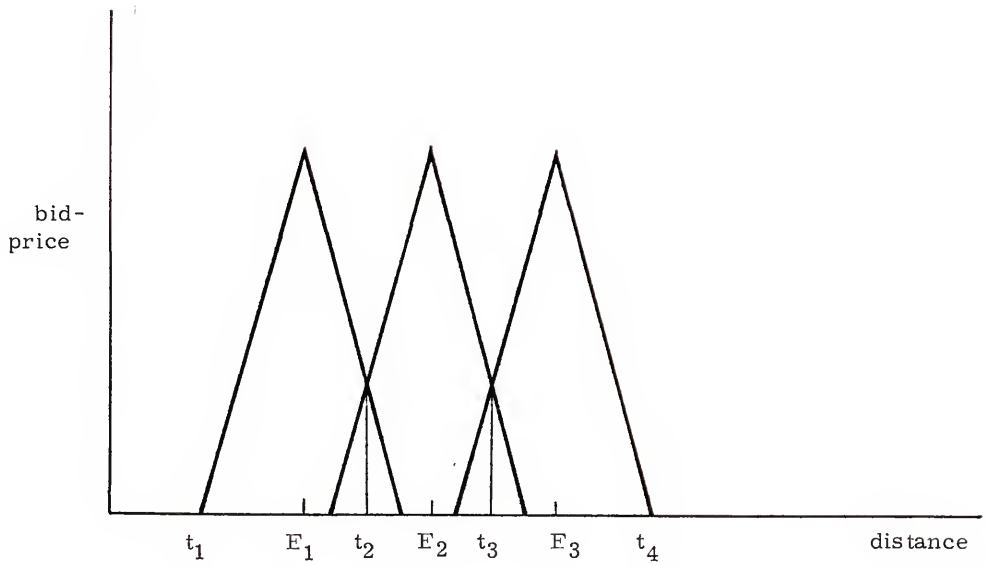

Figure 3. Bid-Price Curves of Workers at 3 Different Employment Sites.

the land between t_1 and t_2, those of E_2 live between t_2 and t_3, and the workers at E_3 occupy the t_3-t_4 interval.

Assume that another group of workers is added. These are identical to all others in the city except that they work at E_1 and receive a higher income. Let the whole population, therefore, be divided into poor (all previous workers) and rich (new, higher income group). The bid-price function of the rich is not as steep as that of the poor (see Figure 1). The effect of the addition of this new rich group is shown in Figure 4.

Land in this linear city is acquired in the following manner:

Interval	Purchasing Group
t_0-t_1	rich--E_1
t_1-t_2	poor--E_1
t_2-t_3	rich--E_1
t_3-t_4	poor--E_2
t_4-t_5	rich--E_1
t_5-t_6	poor--E_3
t_6-t_7	rich--E_1

Land is purchased by the rich--E_1 group of workers only in those intervals where their more gently sloped bid-price curve is higher than the one of the other groups. Land close to intermediate job sites is not rented because of high competition from the employees of those places of work.

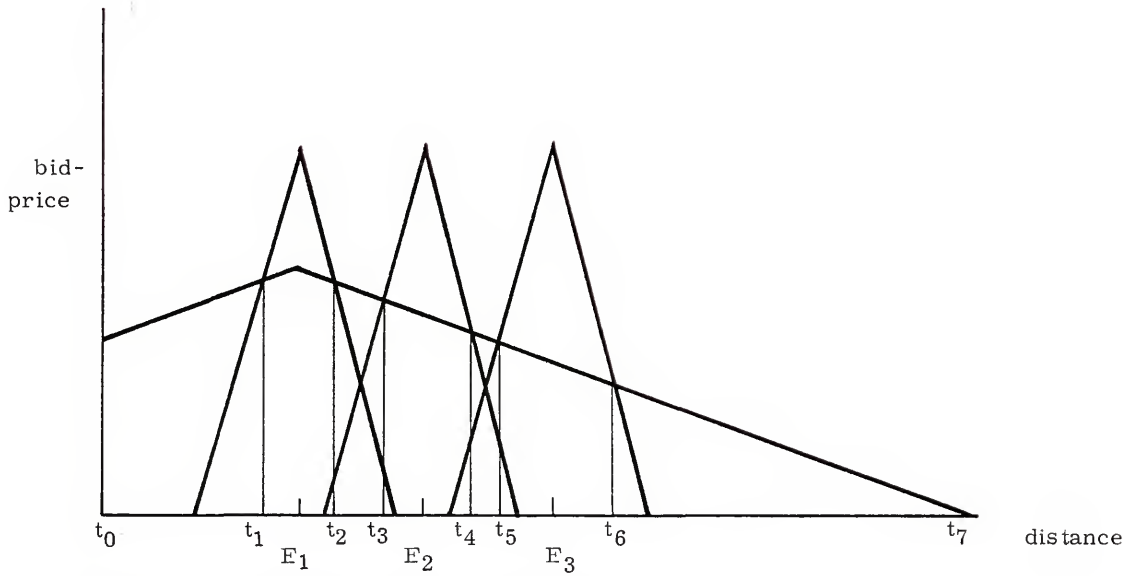

Figure 4. Bid-Price Curves of Rich Workers at E_1 and Poor Workers at E_1, E_2 and E_3.

Many different income levels could be added for each employment site. The effect would be to "round" the curves as in Figure 2, but with the intermediate peaks of Figure 4. Generalizing further, many places of work with differing numbers of employees who earn different incomes could be considered in a city of two spatial dimensions.

Graphically, the result of these modifications would be an aggregate land value cone which is centered on the general area where the most people are employed. At different locations the generalized cone surface would be altered with subsidiary peaks rising around intermediate places of work. The model concerns only residential land use, but the shape of this conic surface closely resembles the often reproduced (Chorley and Haggett, 1967, p. 337; Yeates and Garner, 1971, p. 252) allegorical "circus tent" diagram which is used by Berry (1963) to describe urban land values. Empirical land value studies (Knos, 1962; Yeates, 1965; Mills, 1969) confirm the general shape.

For the argument to be true, an important requirement is that there be competition among the different groups of land users. Various income levels must be represented at each of the employment sites. Otherwise, there would be no distance differentiation; the rich would live near their place of work on one side of town, and the poor would live close to their job site in another part of the city.

In the hypothetical, two dimensional city, on which the model is based, residential patterns of different income groups could be very

complex. There would be accessibility oriented lower income people clustered around the various employment sites with the intervening space going to higher income bidders of more distant places of work. Differentiating residential land use according to income could be difficult, if not impossible, and a general pattern might not be evident on a residential land use map.

If competition is present, the basic relationships between income, the value of land, and accessibility would still hold true, however. The bid-price functions continue to be shaped by the same variables of the linear city. Distance to work is still the item which determines how much money an individual is willing to pay for land to achieve a certain level of utility.

As discussed, the bid-price model becomes one of interaction rather than land use. Different income groups may be mixed or segregated, concentrated or dispersed because jobs are unevenly distributed across the city. Where people live can be normatively explained, however, when the distance to work variable is included.

The statement of the model is unambiguous. Despite the residential land use picture, the positive relationship between distance to work and the level of income holds true. The rich live farther from their jobs than the poor do.

As stated previously, the test of a normative model lies in the validity of the assumptions which are made. Obviously cities are not homogeneous plains, human behavior is not rational, not all land is

exchangeable, information is imperfect, nothing remains fixed through time, and commuting costs are not measured only in money. Furthermore, there is no guarantee that residential location is the dependent variable.

A wide gap exists, therefore, between the hypothetical world of the model and the real world of "everyday." While the deductive logic of the normative framework may be perfect, many of the factors which the model leaves out bear strongly, if not decisively, on the final location decision. It would be hopeless to expect real city patterns to conform completely to those which are predicted by the normative model.

On the other hand, the normative approach is a valid one (Chisholm, 1971). The assumptions which are made need not be flawlessly true. If there are elements of truth in them, then there is some validity to the conclusions of the model. If statements such as "man is basically rational," or "information is by and large available," can be made, the normative model does provide some understanding.

The important question concerns those variables which are made constant by the assumptions. For example, is distance to work and the cost of commuting really the main consideration of the decision maker, or are items such as the availability of housing, social segregation, and historical preference more important.

Empirical Research

The validity of the bid-price model must be determined through

empirical investigation. When commuting costs are money expenditures, the model predicts a positive relationship between income and the distance to work, and this relationship is generally confirmed in Anglo-America. The early concentric zone model described an increase in the social status of neighborhoods as distance from the city center grew larger. Duncan (1956) confirmed a direct relationship between distance to work and occupational status in Chicago, and other investigators have obtained similar results in different American cities (Kain, 1962; Lowry, 1963; Goldstein and Mayer, 1964; Loewenstein, 1965; Wheeler, 1969b; Catanese, 1970; Bederman and Adams, 1974).

Variations, however, are present in the general pattern. Wheeler (1968a) discovered that the relationship holds true for white workers in Pittsburgh, but not for blacks. Furthermore, black people tend to work in certain areas of the city, regardless of distance from home or access to public transit (Whiting, 1952; Wheeler, 1966; Biel, 1972).

Soot (1974) found that a negative relationship existed between distance to work and income in Milwaukee for the 1949 and 1959 periods but that this relationship is disappearing at the present. Also examining general trends, Wheeler (1974, p. 46) stated that for the richest and poorest people the distance to work should be greater than it is for middle income groups. In Charleston, West Virginia, Halvorson (1973) discovered exactly the opposite. The middle income groups live the fartherest from the place of work, and the highest and

lowest income groups live the closest.

Differences among types of commuting are also evident. Although the positive relationship between income and distance is present for those who travel to work in the central business district, no such pattern is discernable for those who go to suburban jobs (Taaffe, Garner, and Yeates, 1963; Logan, 1968; Wheeler, 1970a). This tends to discredit the normative model and to suggest that access to the city center is more important than proximity to work.

The verdict is not yet in on the normative residential location model. The empirical findings, to some extent, support the predicted relationship between income and distance to work, but many questions remain. The wide difference between reality and the idealized world of the model have led many to reject it (Wolforth, 1965; Boyce, 1969; Johnston, 1970).

To explain the distribution of rich and poor, those who reject the normative model often rely on a general theory about the nature of housing. As people earn more money, they seek better quality residences, and since these are built by developers on the periphery, the higher income group moves farther away from downtown. In the center of the city the old homes are left behind to "filter" down to lower and lower income groups (Vernon, 1964; Johnston, 1971, Edel, 1972). Racial and status discrimination encourage the process. Poor, predominantly black people, therefore, are said to be trapped downtown because of racial segregation and characteristics of the housing market.

The filtering theory also presents some problems, however. It depends on urban expansion, and, as Alonso (1964, p. 109) pointed out, cities which are not growing, present the same positive relationship between income and distance to work. Furthermore, the theory assumes that housing is not controlled by demand but by developers. Are people really forced to build new homes on virgin peripheral land instead of using present or buying new property in their current neighborhood? Growing cities in non-industrial countries do not present the direct relationship between income and distance, even though houses are continuously being built.

In conclusion, neither the normative model nor the filtering theory are completely adequate in explaining the positive relationship between income and distance to work. A cross-cultural comparison of this relationship might shed light on what causes it.

CHAPTER III

INCOME AND DISTANCE TO WORK: LATIN AMERICA

Non-Western Residential Pattern

Little research has been done concerning the interaction between residence and place of work in non-industrial countries. The distance relationship between home and job in these areas, therefore, must be largely inferred from descriptive studies of residential land use. The majority of these studies indicate that the distribution of families by income is different from that found in industrialized societies. The people of greater wealth tend to choose homes at the city center, and poorer groups live on the urban periphery.

The income distribution pattern, commonly termed "non-western," is most prevalent in Latin America. Seven empirical land use studies stand out (Schnore, 1967; Amato, 1968) as landmarks in the description of urban structure. These investigations show that in Merida (Hansen, 1934), Oaxaca (Hayner, 1944), Mexico City (Hayner, 1945), and Guadalajara (Dotson and Dotson, 1954), Mexico; La Paz (Leonard, 1948), and Sucre (Hawthorn and Hawthorn, 1948), Bolivia; and Guatemala City (Caplow, 1949) the residential areas of the upper classes have traditionally been nearer the city center than those of the middle and lower status groups. The findings are confirmed in various other cities of Spanish

America (DeLaubenfels, 1957; Whiteford, 1960; Chaves, 1965; Amato, 1970) and Brazil (Araujo, 1951; Bernardes, 1954; Prandini, 1954; Pyle, 1970, Nakagawara, 1973).

The location of residential areas within Latin American cities is indicative of the relationship between workers' home and job locations. Land use patterns indicate the distance relationships between residences and work sites because most employment tends to be concentrated at the city center. Professionals and bureaucrats as well as vendors, clerks, and laborers are most often employed in the downtown area. In the larger cities, factories are, or have been until recently, centrally located (Hoyt, 1963; Harris, 1971); and industrial workers often, if not always, commute to the city center.

Possible Causes of the Non-Western Pattern

Why is the spatial distribution of rich and poor classes opposite that found in the developed world? Several arguments are advanced. One is that the cultural history of Latin America is basically different from that of other areas. The rich are said to prefer to live downtown because the center of the city has traditionally been the most attractive location. The importance of the central square as a focus for professional and social activity, the characteristic house types, and the checkerboard street patterns are all deeply rooted in the Spanish and Portuguese heritage. Gabenheimer (n. d.) and Reis (1968) have presented interesting accounts of the importance of culture in shaping the morphology of early Latin American cities.

Although culture is undeniably important, the argument that it is the primary cause of the non-western residential pattern can be questioned. A variety of non-Iberian societies, including pre-industrial Anglo-America, exhibit, or have exhibited, the same distribution of rich and poor. Furthermore, recent evidence (see below) indicates that the pattern in Latin America may be changing. This means either that the cultural attachment of the rich to the center is weakening or that other events are shaping urban morphology.

Rural-urban migration is also often considered to be a factor in the distribution of the rich and poor within cities. The migrants are largely low-income and unskilled people who settle at the urban fringe in squatter communities. A popular myth is that they are generally unemployed and live, therefore, marginal to, or outside of the urban economic system. Although generalization is impossible, 90 percent of the residents of the Lima barriadas do have jobs (Andrews and Phillips, 1971). In a survey of the rural-urban migrants of Rio de Janeiro, São Paulo, and five other major Brazilian cities, Hutchinson (1963) found that 85 percent of the household heads secured a job during the first month after arrival.

Another misconception is that the inhabitants of the poor sections always come from agricultural backgrounds. Portes (1971) summarized recent studies dealing with slums in seven Spanish American cities and found that the majority of the dwellers were born at their present residence or came to the city at an early age. Of the remainder, most

had had urban experience elsewhere. Morse (1971) stated that two-thirds of those who are rural migrants are urbanized in their education and skill.

These findings show that the peripheral poor of Latin America are an integral part of the urban population. They have lived in cities most of their lives and are interacting with the economic system. Although the pay is meager, they go to work daily as does the rest of the population. Slum sections, therefore, are integrated components of the urban system. Recent studies confirm that the low income sections are not squalid, parasitic growths as once was thought but are communities with high levels of social organization (Eyre, 1972; Souza and Porter, 1974).

Changes in the Non-Western Pattern

Various studies show that the spatial distribution of income groups in Latin America is changing. Cities may be evolving toward a "western" pattern where the rich live farther from the center than do the poor. The process is altering the traditional spatial arrangement of Merida (Hansen, 1934), Mexico City (Hayner, 1945), Guadalajara (Dotson and Dotson, 1954), Bogota (Amato, 1968; McCallum, 1974), Rio de Janeiro (Bernardes, 1967), Caracas, and Lima (Harris, 1971, p. 249) where the elite groups are leaving their central location.

Other cities, however, are not following the trend (Hayner, 1944; Leonard, 1948; Hawthorn and Hawthorn, 1948; Araujo, 1951; Bernardes, 1954; DeLaubenfels, 1957). Throughout the continent the non-western

residential pattern characterizes small and medium size towns. In these communities, the wealthy families remain firmly attached to the downtown area.

Some researchers have incorporated the current changes into a general evolutionary explanation of the non-western residential location pattern. Schnore (1967) and Hoyt (1963) have believed that all cities may pass through different evolutionary stages as economic development occurs. The recent abandonment of the city center by the rich could evidence the beginning of the process of filtering (Johnston, 1972) which is said to be characteristic of industrial society.

Others (McGee, 1971; Herrera, 1971; Alonso, 1973), however, have maintained that the evolution of cities in industrial areas cannot be used to explain present conditions in the developing countries. The urbanization process, population of the cities, and socio-economic infrastructure of these areas are basically different from that of the United States and Europe during the last century.

Transportation as an Explanation of the Non-Western Pattern

Transportation has also been cited in order to explain residential distributions found in Latin American cities. Schnore (1967) and Berry, Simmons, and Tennant (1963) referred to transportation technology as being the important factor which differentiates the western and non-western patterns. Amato (1968) stated that improved transportation made it possible for the rich to move away from the center of Bogota, and in a study of Buenos Aires, Sargent (1972) developed a

dynamic model which has speculation and settlement occurring within a transportation framework.

Transportation modifies residential location by affecting intra-urban spatial interaction. A change in transportation technology does not change residential location directly, but alters the mobility of people. Transportation, therefore, has a direct impact on the journey to work and a secondary influence on residential location. If transportation is the important modifying variable, the non-western pattern is really a result of interaction between residences and work sites. What appears to be an urban spatial income distribution is in fact a relationship between income and distance to work.

Wheeler and Thomas (1973), in a pioneer study, investigated journey to work interaction in Tegucigalpa. The results showed that the population of the city is highly immobile, with most of the people working in the same section of town in which they live. Those who use motorized transportation generally travel farther than the workers who walk. Factor analyses of an origin-destination matrix, after a technique used previously by Wheeler (1970b), however, showed little spatial patterning.

The changes which are occurring in the residential pattern are often explained by stating that the increased availability of motorized vehicles makes it possible for the wealthy to leave the center of town. They can afford cars or train rides and are thus able to live where they want. The lower income groups, meanwhile,

are restricted to an area which is within walking distance from the city center. The rich have a greater mobility because they use a different type of transportation.

Although such a framework explains current trends, questions concerning the causes of the western and non-western residential patterns remain unanswered. If Latin America is evolving into a motorized society where few people walk, the mobility of the rich and poor will again be the same. What happens then to the spatial distribution of the different income groups? Clearly, transportation used as an explanatory variable in this form cannot show how the non-western residential distribution is evolving into the pattern of the motorized societies of today. A comparison of the distance to work of the immobile poor and the mobile rich explains neither the western nor the non-western patterns. In primitive societies everyone walks while in developed cultures the vast majority uses motor vehicles.

In present-day Latin America primitive means of travel are rapidly being substituted by buses, automobiles, or motorbikes, and the current transitional period is unique in that two distinct systems are present side by side. Are residential distributions evolving from a non-western to a western pattern? If so, is changing transportation technology truly an important variable influencing the process? To understand the effect of changes in the transportation system, care must be taken not to compare the distance to work of two groups with different

mobility levels. Regardless of income, someone who walks should always live closer to his place of work than someone who uses an automobile. Income and transportation, therefore, must be considered separately if the distance to work is to be explained.

Time Costs and the Bid-Price Model

The normative bid-price model, as discussed in Chapter II, can be used to explain the relationship between income and distance to work in industrialized areas. It is also applicable to residential patterns in Latin America. As presented by Alonso, the model is, in many ways, unrealistic, and the assumption made concerning the nature of transportation costs is one of the least valid. The cost of commuting, even in a motorized society, involves more than monetary expenses. The price of gasoline, for example, might be of minor concern when compared to the nervous stress produced by travelling on congested urban streets.

An important non-monetary cost is that of time. The hours spent commuting to work are hours which are not available for other uses. Eating, sleeping, playing, and money making are limited by the amount of time used for the journey to work.

For many years social scientists have recognized time as a component of the aggregate cost of commuting (Haig, 1926, Liepman, 1944; Lillibridge, 1952). The change in transportation which made the separation between home and place of work possible was a reduction, not in money, but in the amount of time which was necessary to travel a given distance (Vance, 1966).

Developers of the bid-price model have also been aware of time costs, and leisure has generally been included in the personal utility function. The estimation of the value of leisure time is not new in economics, but it was first applied to commuting by Wingo (1961b).

People were said to attach a certain utility to money and to time spent off the job. The point at which time and money are optimally combined can be obtained when the time utility function and wage rate are known. Wingo (p. 55-62) showed that when commuting is introduced, employers are forced to pay a higher wage for a given period of work because the amount of leisure available to the worker is reduced. This extra wage is the monetary price of commuting.

As developed by Wingo, the cost of time can be included in generalized mathematical formulations of the normative model. Operationalizing and testing such a model, however, is difficult because money and time utility values are unknown. Utility is a conceptual tool and not an observable and measurable quantity. A model that shows a change in the slope of the bid-price curve with a change in income (as developed in Chapter II) and that also includes time as a commuting distance cost requires that the utility relationship between time and money be estimated. When this is done, the rate of change of the bid-price curve is unpredictable. As shown in Appendix B, the component which involves the monetary cost of distance tends to lessen the slope with an increase in income, while the component related to the time cost of distance increases the slope.

Some of the problems encountered in the attempts to test the normative model in industrial countries may be the result of the counteracting effects of time and money costs on the slope of the bid-price function. Halvorson (1973) for example, obtained inconclusive results in his investigation of the relationship between income and distance to work in Charleston, West Virginia (see above p. 31). When time is used as a surrogate for distance, however, he found that the higher income groups opt for shorter work trips and outbid the poorer people for homesites which are accessible to the place of work.

In a motorized society, time and money costs are interwoven in a complex manner. The automobile commuter, for example, uses amounts of both money and time for the trip to work, and items such as traffic congestion and parking influence the ratio of the two costs. Isolating the time factor in such a society is difficult.

When monetary expenses are excluded, the statement of the model is clear. As shown in Appendix B, the value of time spent commuting increases directly with income, and the bid-price function of a rich individual, therefore, is steeper than that of a poor person (see Figure 5).

The generalizations of many different income levels (see Figure 2), multiple work locations (see Figure 4), and two spatial dimensions (See discussion on p. 28) can be made with the only difference being the reversal of the bid-price curves of the rich and the poor. In all instances where the groups compete for land there is a negative relationship between income and distance to work; the rich live

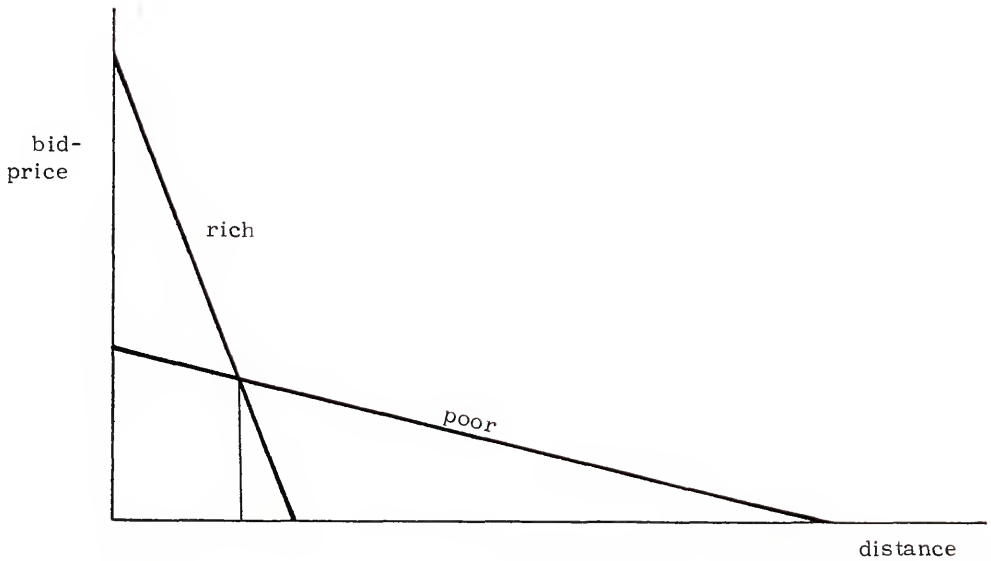

Figure 5. Bid-Price Curves for Rich and Poor Individuals; commuting costs are temporal.

nearer their jobs than do the poor.

The normative bid-price model, therefore, predicts two different relationships between income and distance to work. Where motorized transportation is used, a positive relationship between income and distance to work prevails, but where non-motorized transportation is used, the function becomes negative.

These conclusions were also graphically derived by Lave (1970) and Harvey (1972). The bid-price curve of the high income walking group was said to be steeper because time is "more valuable" to the rich. The authors, however, did not formally deal with the relationship between opportunity costs and money income.

A society in which time commuting costs are predominant is one where transportation is primitive; one where bicycle riding or horse cart use, for example, are important means of travel. Walking is the ultimate commuting time cost. Money outlay, except for shoe expense, is non-existent, but time expenditure is greater than for any other transportation mode.

At the present, motorized and non-motorized societies coexist in Latin America. The normative bid-price model, if confirmed, can not only explain the non-western residential pattern of the pre-automobile era, but it can also predict what the spatial structure will become as fewer and fewer people walk to work.

Research Hypotheses

The bid-price model predicts two different spatial relationships between income and distance to work. The variable which differentiates the relationships is the means of transportation which is used for commuting. The purpose of this research is that of searching for these predicted relationships in a Latin American city. The hypotheses to be tested are:

1. For workers who use a means of transportation for which the cost of overcoming distance involves primarily money expenditures, a positive relationship exists between income and the distance between residence and place of work.

2. For workers who use a means of transportation for which the cost of overcoming distance involves primarily time expenditures, a negative relationship exists between income and the distance between residence and place of work.

CHAPTER IV

DATA COLLECTION IN THE STUDY AREA

Piracicaba

The research hypotheses presented in the previous chapter describe certain relationships which exist between variables of the bid-price model. To test the hypotheses, these variables must be translated into items of information which can be collected and measured in a real environment. For this study, Piracicaba in the state of São Paulo, Brazil was selected as the study area. One hundred miles northwest of São Paulo city, Piracicaba is a regional center with a population of 123,806 people (1970).

History and General Characteristics

Although officially founded in 1776, the settlement dates back to the 17th century. During this period, the interior of the state of São Paulo was penetrated by groups of people (bandeiras) who searched for gold and Indians to be enslaved (Morse, 1965). Common practice was for the group to settle down periodically and grow food crops to replenish supplies. The favorable soil, navigational barrier, and fish supply made the site near the rapids on the Piracicaba river a favorite for these temporary stops. In time, the settlement became permanent.

Little changed, however, until the early 18th century when work on a projected road link between São Paulo and the gold mines of Cuiabá brought a boom to the area. This growth culminated in the incorporation of the city in 1776.

The 19th and 20th centuries have been marked by continued economic progress. Coffee was important until the 1920's, but recent development has been a result of the shift of sugar cane production from northeast Brazil to the interior of the state of São Paulo. This move was caused by the decline of Brazilian export markets, the increase in consumption in the populous southeast, and the modern cultivation and refinery techniques which are used in São Paulo.

In the southeast, the physical setting has been most favorable around Piracicaba. Paleozoic sedimentary bedrock of the area has led to the formation of a clay-rich podzol soil series (Queiroz, 1968, p. 500) which, coupled with a favorable subtropical climate, makes conditions ideal for sugar cane cultivation. Piracicaba, therefore, became the focus of the crop's production in southeastern Brazil. Today, practically all agricultural activity near the city involves sugar cane. For the 1972-73 growing season, 79 percent of the county's cultivated acreage was devoted to the crop.

Piracicaba has developed into a commercial distribution and supply center for all goods related to the cultivation, refinery, and distillation of cane. The industrial sector of the city's economy has greatly expanded since the first plant was built during the 1800's.

Substantial activity within the city is related to sugar refining and distillation, but most production involves the fabrication of heavy machinery components for sugar mills. The "Grupo Dedini" consortium supplies 80 percent of all refinery and distillery equipment used in Latin America and accounts for over half of Piracicaba's total productive output. Many other goods are also produced with furniture and textiles representing important segments of the industrial economy.

The growth of the urban population has been most dramatic in recent years (See Table 1). The racial and ethnic composition is not significantly different from that of other São Paulo cities. Portuguese, Spanish, and Italian backgrounds are well represented, but Piracicaba does not contain a large Japanese colony as do some of the other interior towns.

Table 1

Urban Population of the City of Piracicaba

1920	19,169
1940	31,923
1950	46,611
1960	80,672
1970	123,806

The sugar boom, industrial development, and population increase are related to the overall prosperity which the state of São Paulo has experienced in recent years. Piracicaba is forecast to continue

to grow if the international price and demand for sugar products remain high. At the present, an incentive program aimed at reducing the concentration of factories around greater São Paulo is leading to a diversification of production in Piracicaba. A large industrial park is being developed in which the Caterpillar Tractor Company, for example, is building a plant second only to its home installation in Peoria, Illinois.

Piracicaba as the Study Area

A number of factors contribute to make Piracicaba a good city in which to test the research hypotheses of this study. In the first place the size of the town is such that almost all of the urban area is accessible to people who walk. On the other hand, distances are great enough, for those who walk, for there to be a true "friction" due to the distance.

Secondly, motorized and non-motorized transport systems do exist side by side. The number of inhabitants per motor vehicle (8.7) is less in Piracicaba than for any other city in Brazil, but most of the people still walk to work.

Thirdly, secondary and tertiary activities are equally well represented. Of the males over ten years old, 15,584 are industrial workers, and 15,870 have commercial, administrative, or other service jobs.

Finally, the city approaches, in many ways, the closed system assumed by the bid-price model. Piracicaba is a regional center (Muller, 1966) and although goods flow in and out of the city, most of the people live and work within the urban area. Few people either

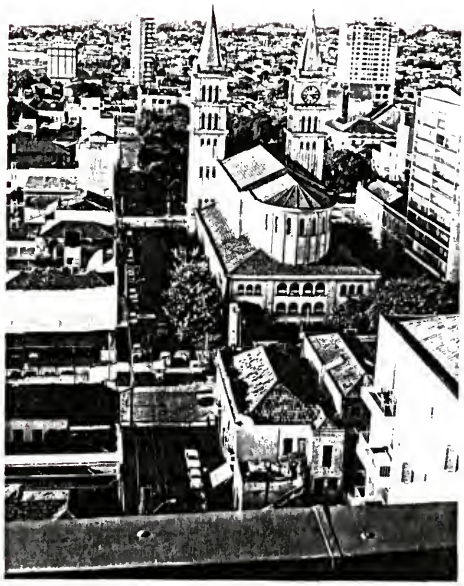

Figure 6. City Center. View of the central area with the traditional square and Catholic church.

Figure 7. Southwest Panorama. Residences and privately owned vacant property are in the fore and middle ground. Cuestas in the distance are evidence of differential erosion between Jurassic basalt and more ancient shale and sandstone.

Figure 8. Water Falls. Partial view of Piracicaba river rapids and the public sightseeing park.

Figure 9. Pumping Station. Old building houses water intake controls of the Boyes textile mill.

commute from residences or travel to jobs which are outside the study area.

Data Collection

Variables to be Measured

Before data could be collected in Piracicaba, a decision was necessary as to what measurable information most closely corresponded to the variables of the bid-price model. For this study, distance was assumed to be airplane, or straight line distance. Because of the natural barrier of the Piracicaba river (See Figure 10), distance for those who commuted across the river was measured from the work place to the most convenient bridge, and from there to the residence.

Walking and bicycle riding were assumed to be the obvious transportation modes for which overcoming distance involves time costs and automobile use the mode which involves money expenses. The price of a bus ticket is not variable with distance in Piracicaba. Although a ticket costs money, the expense which is directly variable with distance for bus users is time. Bus travel, therefore, was also assumed to be a mode for which overcoming distance involves time costs. Other means of transportation are not important in Piracicaba.

Income was assumed to be the per-month earnings derived by the household head from his principal job. While other members of the household might hold jobs, the locational decision, and hence the distance to work, was thought to be primarily based on the family head's income

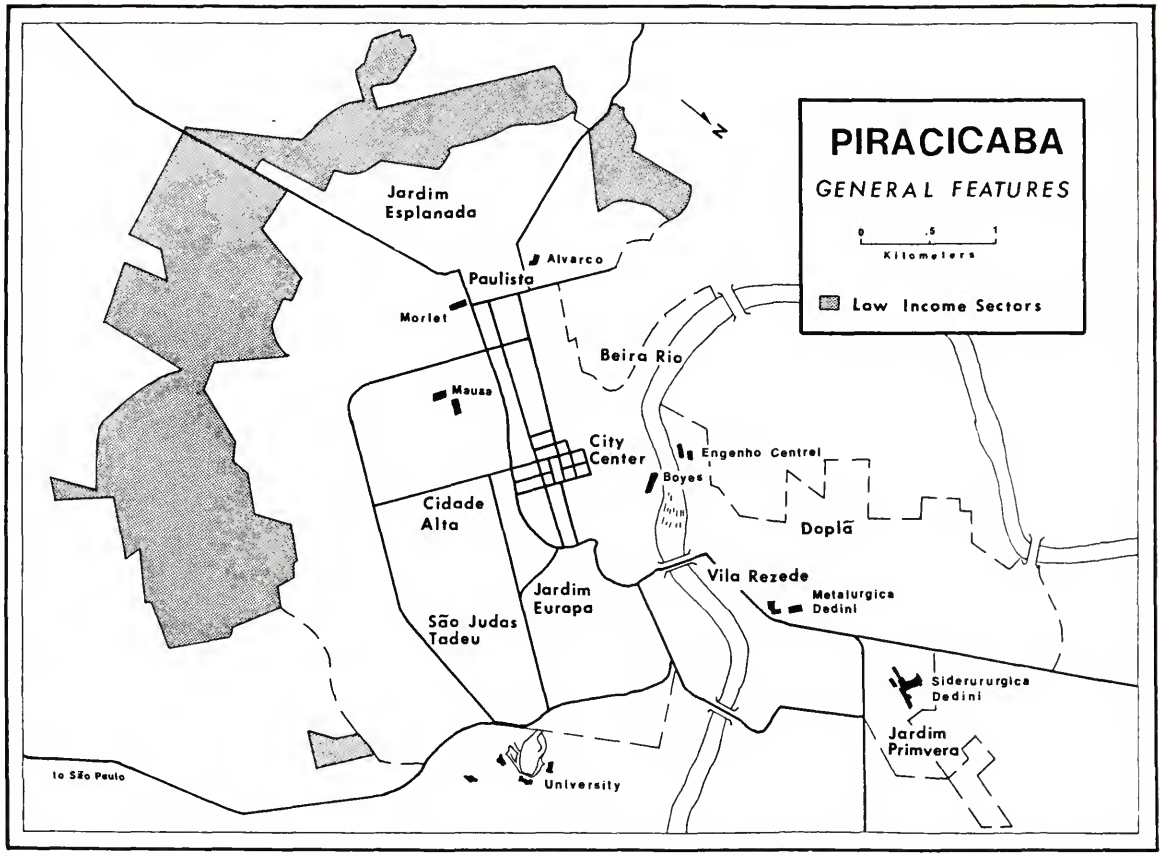

Figure 10. General Map of Piracicaba.

from his principal job. Rationale was as follows: Each household probably has a variety of income sources, including, for example, money from the father's work, the mother's washing and ironing, the son's shoeshine job, pensions, retirements, and rent paid to the family. Any number of non-monetary items such as vegetables from a garden or gifts from a friend might also be received.

Determining all sources of income for each household would be impossible, and the principal job income was adopted for this reason as a standardized surrogate for total income. Furthermore, the valuation of time and the opportunity cost of commuting are developed (See Appendix B) by considering income to be the amount of money earned on the job (during the time period J). Other surrogates for total income might be various items related to wealth or affluence, and so data were collected on certain of these variables which were available.

Interviews

The major sources of data were personal interviews conducted in Piracicaba during the June, 1973-May, 1974 period. A questionnaire was prepared in which the household head, or the family member earning the most money, was asked his place of work, the type of transportation which he used to go to work, and his principal job income. Information concerning the length (number of years) of residence and work at the present location, as well as the length (number of years) of transportation use was also requested.

Of the total households in Piracicaba, interviews were conducted in a sample of 4 percent (1 of 25). An adequate frame from which to draw the sample was unavailable, and steps had to be taken, therefore, to ensure an adequate representation of the city's entire population.

An areal sampling technique was used, and, for this, a household density map of the city had to be constructed. Household was defined as being the family group permanently inhabiting one housing unit, and census criteria (direct access to outside, independent kitchen facilities, and separate living quarters in general) were used to define housing units. Hotels, boarding houses, and other such establishments were not considered to be permanent places of residence.

In order to draw an areal sample based on a density map, an assumption had necessarily to be made. The population of interest in Piracicaba was that of workers with a fixed residence and job location. This group, therefore, was assumed to be randomly distributed in the general population with no particular spatial pattern distinguishing the residences of the commuting workers from those of the rest of the city inhabitants. Evidence subsequently gathered during the interviews indicated that the assumption was valid.

Two sources were used in the construction of the density map. The first was a series of air photographs (taken in 1969 at a scale of 1: 12,000) which were available at the local university (University of São Paulo agricultural extension "Luiz de Queiroz"). Based on information derived from these photographs, the city was spatially divided into

different sectors with the sole criteria for differentiating the sectors being the number of residential units per square area. For each sector a housing density measure was recorded.

The second source used in the construction of the density map was information gathered from ground observation. Each of the sectors was visited, and densities of randomly chosen blocks were checked against the density figure derived from the photographs. Particular attention was given to areas where closely grouped buildings made difficult the distinction of separate residential units from the photographs. Care was also taken in the commercial sectors where stores and residences were mixed, and in parts of town which had developed rapidly between 1969 and 1973.

The number of sectors and the density values of each were modified when the airphoto information did not agree with observed conditions. The final map contained sixty-three sectors with densities ranging from 1 to 65 housing units per block (1 hectare or 10,000 square meters). An added 64th sector included Piracicaba's seventeen multi-storied apartment buildings.

The final map provided a density figure for each sector. The total area of each sector was also determined, and the combination of both measurements yielded the number of housing units per sector. The total number of residences in Piracicaba estimated from the density map (25,252) was slightly greater than that arrived at during the 1970 census (22,125). The difference between these figures can be

attributed to growth from 1970 to 1973, difference in the criteria used, and human error. Where the borders of the sectors of the density map approximated those of historical sections of town for which census information was available, the census and density map values were also not substantially different.

The collection of data was sectorially stratified, and a randomized cluster sampling technique was used within each sector. The procedure was to select a location in a sector by using a grid, map, and table of random numbers. The residences on the street block nearest to this randomly chosen point constituted the sampling unit, and a maximum of eight interviews were then conducted at the location. If there were less than eight houses with people at home on the block, the number of interviews equalled this lesser number.

The procedure was then repeated with the selection of another random point and in turn repeated until the full 4 percent of all residences in the sector had been visited. All sectors were treated identically until the required 1,010 interviews were made in the city.

Blank questionnaires soliciting the desired information were distributed during the morning or early afternoon hours, and the completed forms were gathered the following day. Accompanying each questionnaire was a standard instructional paragraph and a copy of a letter of introduction from the city mayor.

Every effort was made to leave a copy at each house in the sample area (until the maximum of eight had been distributed). Skeptics

were assured that the interviews were of scientific value and that complete confidentiality would be maintained. If no one was present, the house was necessarily skipped and not included in the sample. If for some reason the questionnaire had not been completed by the following day, additional calls were made on subsequent days.

Some problems were posed by the fact that the head of the household was usually at work during the time of the interview. Special care had to be taken to ensure that the instructions were well grasped by the person who was spoken to (usually the wife) and that she could communicate them to the head of the family.

Another problem was that an unavoidable bias against unmarried workers was built into the study. Their homes were generally empty at the time of the interviewing. In special instances when the members of the visited family could neither read nor write, the instructions and questions were read orally by the interviewer who also recorded the answers.

Property Survey Data

Data were also gathered from confidential files at city government offices. Most of the results of a recent city-wide property survey were made available, and from this source the surrogates for economic status were collected. The availability of this second information source made it possible to compare land value, house quality and house size where interviews had been made with the value, quality, and size of the property and residences where the residents had not responded

(Property value was obtained from a confidential map which is revised yearly by city officials; house size referred to general floor space; house quality was a tabulated point score compiled from individual ratings on fourteen different criteria.).

Thus, in a general manner, differences in economic status could be detected between those who had responded to the questionnaire and those living on the same block who had rejected, not received, or failed to return the form. In this manner, the built-in bias against groups such as unmarried workers and unresponsive people could be, albeit crudely, tested for.

Student's "t" tests were performed to check this bias. The property value, house size, and house quality of the individuals who responded to the questionnaire were compared to the same measures pertaining to people who were not at home at the time of the interview. Similar comparisons were made between respondents and persons who received but failed to return the questionnaire as well as between respondents and the individuals who had refused to accept the blank forms.

For all tests, null hypotheses of no difference between respondent and non-respondent statistical populations were accepted at the .05 level of significance. The economic status of the people who answered the questionnaire was not appreciably different from that of their neighbors who did not.

A comparison was also made between the principal job income

data obtained from the interviews and the surrogate measures of economic status (property value, house size, and house quality) obtained from the municipal government. Student's "t" tests indicated a greater than zero value for coefficients in a correlation matrix (See Table 2) of the four variables. Null hypotheses of no correlation between income and each of the economic status variables were rejected at the .05 level of significance. Principal job income and the surrogates, therefore, were inferred to be different measures of the same general quality; total wealth. Income information, as obtained from the interviews, is a valid measure of total wealth.

Table 2

Correlation Matrix of Income and Surrogate Measures of Economic Status

	Income	House size	House quality	Land value
Income	1.00	0.69	0.73	0.40
House size		1.00	0.78	0.48
House quality			1.00	0.42
Land value				1.00

Definition of the Effective Statistical Sample

Of the 1,010 questionnaires distributed, 759 were completed. Of these positive responses, some could not be included in the sample because the situation of the family head did not meet certain necessary conditions. The first requirement was that the household head have

a permanent place of work within the city to which he commuted on a daily basis. As shown by the breakdown of the positive responses with respect to the place of work in Table 3, 63.1 percent met this condition.

Table 3

Work Situation of Respondent Household Heads

	Number	Percent of Total
Fixed place of work	479	63.1
Work location not fixed	59	7.8
Out of town work location	81	10.7
Retired	80	10.5
Unemployed	31	4.1
Work at home	27	3.6
Student	2	0.2
Total positive responses	759	100.0

A second requirement concerned income. Some individuals received highly variable incomes from month to month, and others refused completely to answer questions concerning earnings. Responses of this nature were not included in the sample. Of the 479 responses with a fixed place of work, 464 contained valid income data.

Finally, information concerning the means of transportation was necessary. All of the 464 responses met this requirement. Table 4 shows the transportation used for the journey to work by the

respondents who had a fixed, non-home place of work and a steady income rate.

Table 4

Transportation Used for the Journey to Work by the Respondents Who Had a Fixed Place of Work and a Steady Rate of Income

	Number	Percent of Total
Walk	199	42.9
Private car	126	27.2
Bus	95	20.5
Bicycle	36	7.7
Other	8	1.7
Total	464	100.0

The responses which included one of the "other" (motorcycle, horsecart, and company vehicle) transportation types were excluded from consideration. For each of these transportation groups, the sample size was too small for effective statistical analyses.

Of the 759 total positive responses, therefore, 456 were of such a nature as to make them usable in the testing of the research hypotheses. This group of responses became the effective sample, and all statistical inferrences are based on the data contained in this sample.

CHAPTER V

RESULTS

General Description

Residential Areas

The residential areas of Piracicaba are made up of many different sectors which feature widely varying characteristics. Some sections are inhabited exclusively by upper income groups, while within others only the poorest people live.

The highest status area is the Jardim Europa section northeast of the city center. In this exclusive neighborhood all of the measures of socio-economic status are higher than for anywhere else in the city; the mean income per month is over $1,000 whereas the city average is $225. Houses in this area are architecturally elaborate, and they occupy relatively large areas. Yard space is minimal, however, and the empty land that is available is used for decorative rather than functional purposes. Workers are most often merchants, doctors, lawyers, corporate executives, or professors at the university, and a commuter generally drives to work in one of the family cars.

The São Judas Tadeu section is also composed of high income families, but the wealth of Jardim Europa is not matched. Although also expensive, the residences are generally smaller and feature less luxury than those of the richer neighborhood. Most families own cars,

Figure 11. Doctor's Home. Jardim Europa residence featuring decorative yard and expensive Brazilian-made car.

Figure 12. Business Executive's Home. Large and luxurious Jardim Europa residence.

and household heads work in various professional positions.

The poorest sections of town are the peripheral areas of the south. These form a semi-circle originating in the southeast along the São Paulo highway and extending to the western areas where the urban limit intersects the Piracicaba river. The residents of these sections lead difficult lives. Although unemployment is not proportionally greater than elsewhere, the majority of those who work are severely underemployed. Many earn only the $48 minimum wage at a variety of industrial jobs. Others receive even less as house painters, bricklayer's assistants, maids, and street vendors. Amenities such as running water, sewage, indoor plumbing, and paved streets are scarce. Although most houses are made of brick, many families inhabit no more than a 15 or 20 square meter wooden structure which offers no protection against a climate where temperatures are comparable to those of north Florida.

Although some migrants have come from surrounding rural areas, many of the low income residents have spent their life in Piracicaba. Walking and the city bus system are the most often used methods of travel to work or to the city center.

Most of the residential sections of Piracicaba are not economically segregated. The majority of the people in these mixed neighborhoods earn moderate incomes (as compared with other groups and not by United States standards), and the family heads work in a wide range of blue and white collar jobs.

Figure 13. Resident of São Judas Tadeu Section. Husband of the pictured woman is a traveling salesman who earns approximately $500.00 U.S. per month.

Figure 14. São Judas Tadeu Residential Block. Typical housing of the sector. All residents of the pictured houses own automobiles.

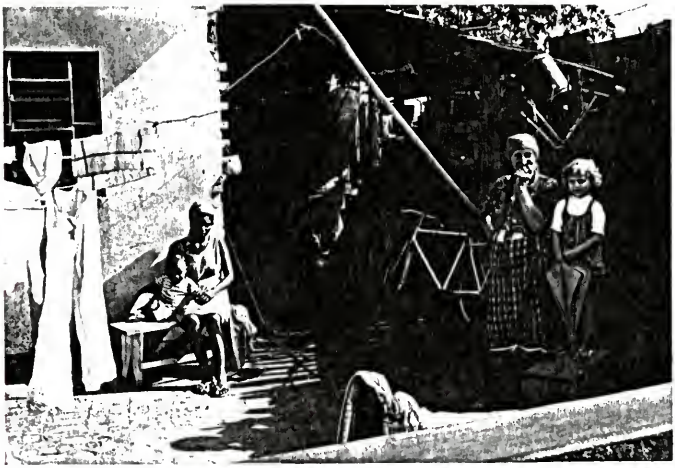

Figure 15. Backyard. Typical morning activity of the family and neighbor of a low income blue-collar worker.

Figure 16. Peripheral Poor. Wood and brick building is inhabited by three families.

Figure 17. Rented Rooms. Property owner in a southern peripheral area rents five small units in his backyard at about $10.00 U.S. apiece per month. Tennant with the maximum total family income earns $48.00 U.S.

Figure 18. Communal Water. The public water source is a social gathering spot for poor women, many of whom earn money from washing clothes.

Although generalizations for the large middle income group are difficult, certain characteristics are evident. Houses are modest but do feature running water, bathrooms, kitchens, and separate bedroom areas. Sometimes the family owns a car, but more often, commuting is performed on foot or by bus.

Some basic attitude differences seem to exist between the middle and lower income groups. The poor people appear to be resigned to their fate. They complain about the lot which has been dealt them, but they feel, and often are, powerless to improve their situation.

The middle class, however, has adopted a work ethic. Many families set economic goals and strive to achieve them. A positive outlook toward future earning potential is common, and many goods are purchased on credit. Consequently, this group probably spends more time at work than any other group.

Although the middle class inhabits a large proportion of the mixed residential areas, the poor and rich make up a substantial share of the neighborhoods. Residences comparable to those of Jardim Europa are scattered throughout these sections, but they are most prevalent near the central commercial district and along the major avenues. Many low quality houses are also evident, but they are not very often located near the city center.

The intermixture of the different status groups does not necessarily indicate a social integration of the various classes. On the blocks which register a wide economic variation, there appears

to be very little personal contact among the neighbors. Non-mixed blocks show evidence of more social interaction.

Some anomalies exist in the general residential patterns of Piracicaba. The Beira Rio section is the oldest and most colorful part of town. The poor residents of the left bank of the river possess a culture and tradition that differentiates them from the rest of the urban community. Most activity in this neighborhood is directly tied to the river. The waterfalls attract sightseers as well as fishermen, and some of the Beira Rio residents do a brisk business of selling bait and renting boats.

Others make a living by fishing, and the fish festival is a traditional event. The practice of wading into the dangerous turbulent water at the falls and barehandedly catching small fish is in itself a tourist attraction, but recent deaths and stricter enforcement of city ordinances have led to a decline in the practice. Twenty years ago fish of 200 pounds or more were often caught by the serious fishermen, but the Jaú, Dourado, and Pintado have abandoned the now polluted river. Piracicaba, which in the Tupí language means "The Place Where the Fish Come," no longer lives up to its name.

Another group of neighborhoods which stand out from the general residential pattern are the subsidized low and middle income housing developments. Since 1965, the federal government has made a conscious effort to improve the quality of housing in Brazil. The National Housing Bank (B. N. H.) was created to provide low interest mortgage loans to

Figure 19. Poor Family in a Mixed Neighborhood. Most sections of Piracicaba contain high as well as low income families mixed in the predominantly middle income areas. Small yard space forces children to play on the sidewalk.

Figure 20. Homogeneous Architecture. Housing in a middle income neighborhood. Some units are rented but most are owned privately by the residents.

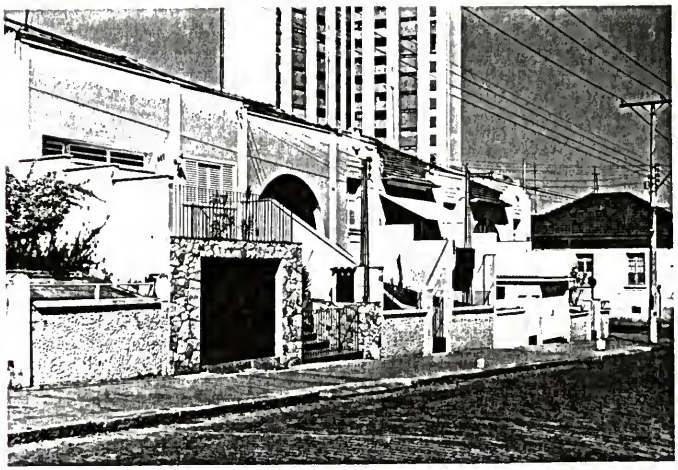

Figure 21. Heterogeneous Architecture. Homes near the city center, remodeled at different times, reflect taste changes in style and in the choice of material used for finishing.

Figure 22. Beira Rio. Section of the colorful residential area which is the oldest part of Piracicaba.

Figure 23. Swimming Area. Woman washing clothes and fisherman in boat are Beira Rio residents.

people of low income, and a total of 772,000 units had been financed in the country by 1972 (Costa, 1972). Rios (1974) and Trindade (1974) present opposite positions concerning the success of the program.

Jardim Esplanada, Jardim Primavera, and a general section known as Doplã are the principal areas of subsidized housing in Piracicaba. The residents are generally of a low economic status. Most workers are blue collar employees, and those who live on the north side of the river are almost invariably employed at the nearby Dedini foundary or the metal plants of Vila Rezende.

Houses are of uniform size, quality, and general aspect. The inhabitants are highly sociable and consider themselves fortunate to have been chosen for the low interest loans necessary to finance the purchase of their new homes.

Places of Work

Unlike many Latin American cities, the place of work in Piracicaba does not invariably coincide with the city center. While a substantial number of people are employed in downtown shops and offices, an equally large group commutes to non-central locations.

The Vila Rezende section north of the Piracicaba river is the primary industrial area of town. Machinery plants and distilleries combine to form a center of blue collar employment, but the largest plant is the Siderurgica Dedini located farther north on the urban periphery. Heavy industry is not confined to this section, however. The Morlet and Mausa machinery plants, Boyes textile mill, Engenho

Figure 24. Dopla. New construction in the Dopla subsidized housing section.

Figure 25. Jardim Primavera. Subsidized housing finished in 1971 for low income families.

Central sugar refinary, and Alvarco autoparts factory also draw large numbers of commuters.

White collar workers are most often employed in the downtown area. Secondary commercial centers, although small, also exist in the Paulista, Vila Rezende, and Cidade Alta sections. White collar workers do not necessarily earn higher incomes than blue collar employees. Many menial bureaucratic tasks are performed for low wages. All utility bills and bank statements, for example, are delivered from door to door by messengers because the postal system is not reliable.

The standard work day is eight hours with a two-hour lunch break. Saturday mornings are also spent on the job. The relatively long lunch period is used by many to return home for the noon meal which is the most important for Brazilians. Automobile users invariably eat lunch at home, while walkers and bus riders stay at work if the distance is too great.

Some commuters, therefore, travel to work twice as often and incur greater distance costs during a given time period than others do. Information about whether or not the family head eats lunch at work was also solicited in the interview. Personal conversation and an examination of the data showed that "lunch at home" is more likely to be a result and not a cause of the distance to work. The factor could not, therefore, be used as an independent variable, and it was excluded from the statistical analyses.

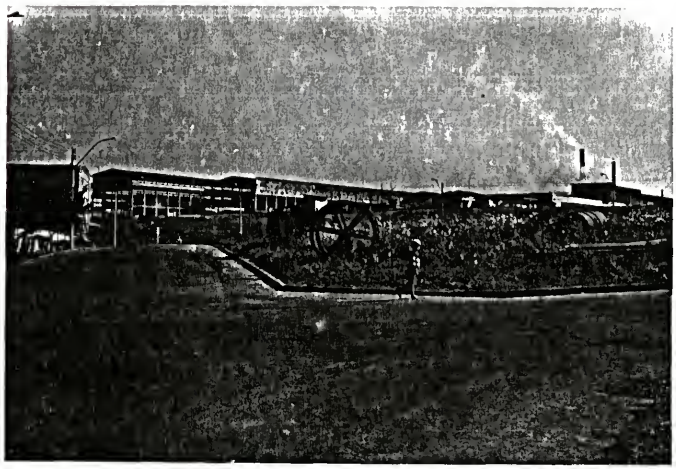

Figure 26. Siderurgica Dedini. Foundary where steel is made from scrap metal. The plant employs more workers than any other in Piracicaba.

Figure 27. Metalurgica Dedini. Interior view of a portion of metal plant where machinery for sugar refineries is produced.

Figure 28. Plant Expansion. Construction of an addition to a metal plant of Vila Rezende.

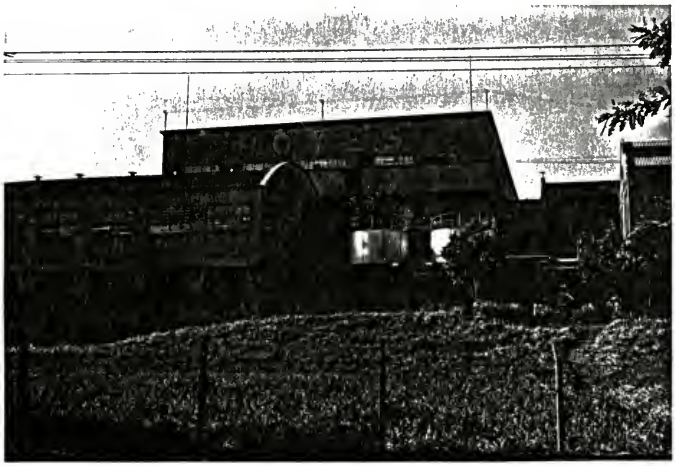

Figure 29. Boyes. River facing portion of textile mill which is the second largest employer in Piracicaba.

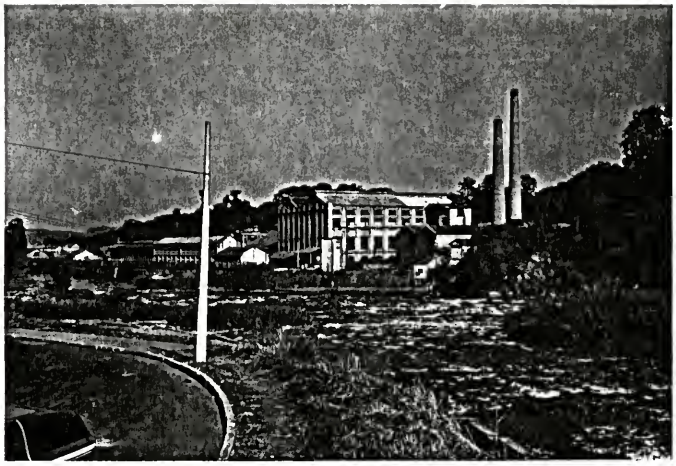

Figure 30. Engenho Central. Plant is the only sugar refinery located within the Piracicaba urban area. The city, however, is a supply center for many other such mills located throughout the region.

Figure 31. Chair Factory. Small scale operation in the Paulista section where cheap chairs and tables are produced.

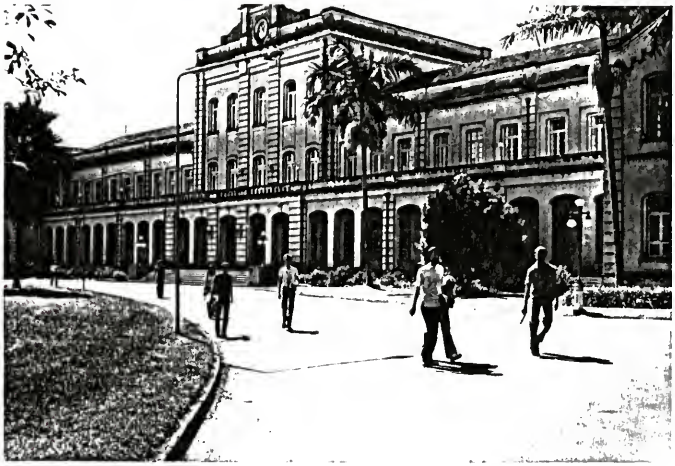

Figure 32. Luiz de Queiroz University. Administration building of the agricultural extension of the University of São Paulo. The school employs many low income custodial workers as well as the high salaried professors. Students live in campus dormitories or in local boarding houses.

Transportation

As shown in Table 4, 20.5 percent of the work force uses the city bus service. Two transit companies operate in Piracicaba, and their networks cover the complete metropolitan area. A total of forty-eight different routes serve the public, and bus stops are within easy walking distance from anywhere in town. A trip between any two urban locations costs less than 7¢ for an adult.

The total number of riders averages 1,400,000 per month, and figures indicate a slight increase over the past three years. The number of trips per day is greater on working days, but weekend evenings are also busy time periods.

The number of people who ride buses has remained constant over the past few years, but the number of automobile users has not. Table 5 indicates the growth in the number of passenger cars licensed during this period. Streets and parking areas are rapidly becoming overcrowded, and, amid political controversy in 1973, Piracicaba became the first city in Brazil to install parking meters.

Table 5

Passenger Cars Licensed in Piracicaba

1968	7,704
1970	9,820
1972	14,303

Figure 33. Bus Terminal. Main transfer point for users of the city bus system.

Figure 34. Taxi Point. The increasing number of automobiles is causing congestion in the downtown area. Strapped on signs differentiate taxis from other vehicles.

Figure 35. Parking Meters. Cobblestone street and parking area are separated by recently installed parking meters.

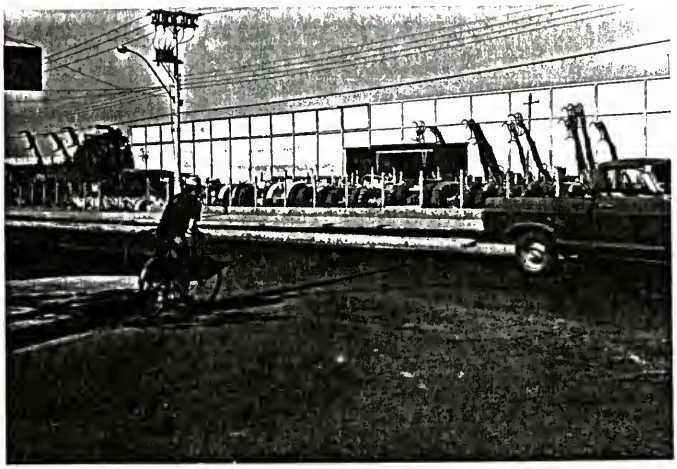

Figure 36. Bicycle Commuter. Man going home from work in front of the Motocana tractor distributorship of Vila Rezende.

Figure 37. Repair Shop. Local bicycle service shop in Vila Rezende.

Figure 38. Charrete Stop. Horsecarts (charretes) are widely used for hauling small amounts of freight but seldomly used for commuting.

Statistical Analyses

Distance to the City Center

As described above, the general residential distribution by income of the Piracicaba population appears to conform to the general non-western pattern. The rich live near the city center and the poor inhabit the urban periphery.

A simple regression model was used to investigate the relationship between the place of residence and the city center. A general linear relationship is proposed:

$$Y_c = B_o + B_1 x_1 + e$$

where:

Y_c = distance to the city center

x_1 = income

e = error

B_o and B_1 = parameters

The model applies to a general statistical population. Because complete information is not available, the parameters of interest must be estimated from the sample data. The model which was tested, therefore, is:

$$y_c = b_o + b_1 x_1$$

where:

y_c = estimate of Y_c (y is here used differently from appendices A and B where it represents income)

b_o = estimate of B_o

b_1 = estimate of B_1

If the relationship between the variables of the sample is to make a valid estimate of the populational relationship, certain inferential requirements must be met. The deviations from the linear relationship must be random. The error term e, therefore, must be normally distributed about the relationship with an unknown variance and a mean of zero. A skewness test showed that the sample data were evenly distributed about the respective variable means. This indicated that e is random.

Another requirement is that x_1 be the independent variable and y_c the dependent one. An unconditional statement of causality is impossible, and income is assumed, therefore, to influence residential location.

A standard computer program (B. M. D. 02R) was used to estimate the linear relationship. The estimated parameters are:

$$y_c = 2,028 - 0.16\ x_1$$

where:

y_c = measured in meters

x_1 = measured in cruzeiros (6.5 cruzeiros = $1.00 U.S.)

The relationship is significant at the .05 level, and a null hypothesis of no relationship between x_1 and y_c must be rejected. Of the total variance in y_c, 13.14 percent is explained by x_1.

Parameters of the model were then estimated separately for each mode of transportation used for travel to the city center (Bicycles were often ridden to work but not to town). Table 6 presents the

sample means and the estimated parameters, and Figure 39 shows the linear relationships.

Table 6

Sample Means and Estimated Parameters for Income-Distance to the City Center Relationships

Transportation	Mean x_1	Mean y_c	b_o	b_1	Standard Error	Significant at .05 level	Explained Variance
Walk	1,023	1,852	2,105	-0.24	0.05	yes	10.62%
Car	2,961	1,432	1,666	-0.07	0.01	yes	11.61
Bus	786	1,932	2,460	-0.67	0.17	yes	14.04

For each of the transportation types, the negative relationship between x_1 and y_c is confirmed at the .05 level of significance. Although the parameters are different, the total explained variance does not change by more than 3.42 percent from one mode to another.

Statistical analyses of the income-distance to the city center relationship tends to confirm the presence of the characteristic non-western residential pattern in Piracicaba. A negative relationship can be inferred between income and distance to the city center for the total working population as well as for each of the transportation differentiated groups.

Distance to Work

The research hypotheses of this study predict a positive relationship between income and distance to work for the commuters who use automobiles and a negative relationship between income and distance

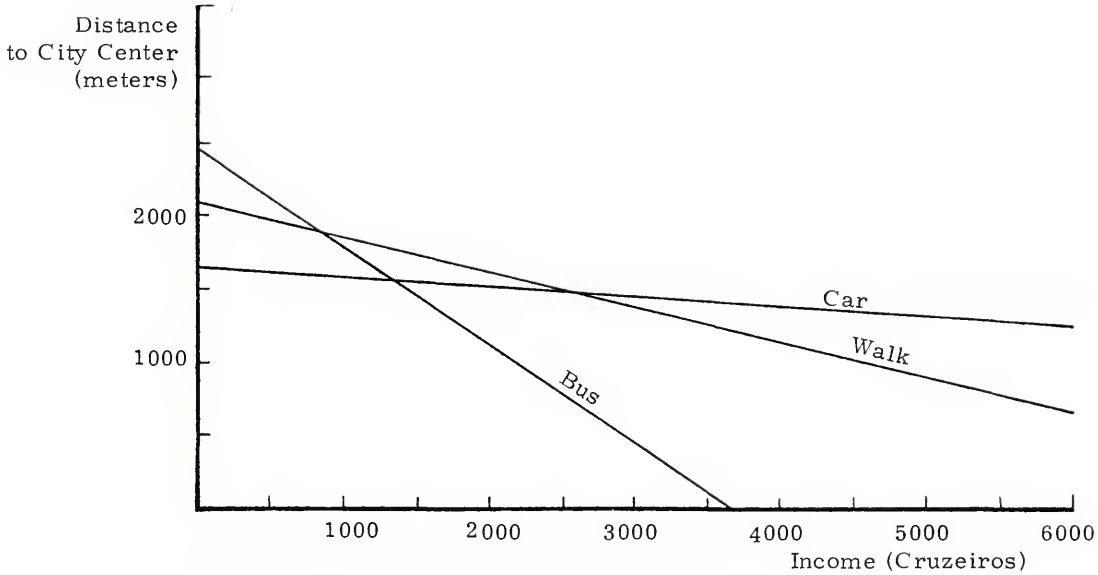

Figure 39. Income-Distance to City Center.

to work for those who ride buses, bicycles, or who walk.

These hypotheses were tested with a linear model similar to the one used to relate income to the distance to the city center. Again a general model of the form:

$$Y_w = B_o + B_1 x_1 + e$$

where:

Y_w = distance to the place of work

was estimated by:

$$y_w = b_o + b_1 x_1$$

where:

y_w = estimate of Y_w

A skewness test indicated the sample data were evenly distributed about the variable means, and a random e was thus assumed. While an irrevocable statement of causality is again impossible, the normative bid-price model from which the research hypotheses are derived assumes that income influences the distance to work and not vice-versa.

A standard computer program (B. M. D. 02R) was used to estimate the relationship between x_1 and y_w. Data were not initially differentiated according to transportation. The estimated parameters are:

$$y_w = 1,630 - 0.06\ x_1$$

where:

y_w = measured in meters

The relationship is significant at the .05 level. The portion of the variance which is explained is 1.14 percent.

Parameters of the model were then estimated separately for each mode of transportation used for the journey to work. The sample means and estimated parameters are shown in Table 7.

Table 7

Sample Means and Estimated Parameters for Income-Distance to Work Relationships

Transportation	Mean x_1	Mean y_w	b_o	b_1	Standard Error	Significant at .05 Level	Explained Variance
Walk	1,023	1,014	1,122	-0.10	0.05	yes	2.21%
Car	2,961	1,453				no	
Bus	786	2,607				no	
Bicycle	620	1,816				no	

Only the walking group evidenced a significant relationship between income and distance to work. No relationship between the independent and dependent variable was present for the other modes of transportation.

From the regression analyses of the sample data, therefore, a negative relationship between income and distance to work can be inferred for the walking commuter population of Piracicaba. For the people who use cars, buses, or bicycles, however, no relationship is evident.

A cursory evaluation of the results might lead to a rejection of the money-cost research hypothesis and an acceptance of the one pertaining to time-costs. The negative relationship exists for walkers because the value of time increases directly with income. The time spent commuting is more valuable to the rich than to the poor, and the wealthy, therefore, are more strongly motivated to minimize the distance to work.

The size of the research area might be a possible explanation for the non-confirmation of the money-cost research hypothesis. Physical distances in Piracicaba may simply not be great enough for any relationship to exist for the non-walking commuters. Transit riders spend more time waiting at bus stops than overcoming distance, and most points in town can be reached from any other location in less than half an hour on a bicycle.

The city may approach a frictionless plain for the automobile commuter. Although the price of gasoline is high, the few kilometers traversed in a city of the size of Piracicaba involve little expense of any kind.

A preliminary conclusion, therefore, might be that the bid-price model is correct in its assumptions, but Piracicaba is simply not large enough for the costs of overcoming distance to be important to any of the non-walking commuters.

Expanded Model

To further investigate the relationship between income and

distance to work, the linear model was expanded. Variables pertaining to the length (number of years) of residence, length (number of years) of employment at the place of work, and length (number of years) of transportation use were added.

Rationale for inclusion of the new permanence variables was as follows. The bid-price model assumes that society is in equilibrium and that all individuals are maximizing their total utility within the economic system. The optimum distance to work has been achieved by each worker. A real city, however, presents a constant flux. People move, change jobs, earn different incomes, and grow old. The city itself expands, new jobs are created, companies go bankrupt, and technology changes.

A general assumption was made: permanence and stability indicate individual equilibrium. A person does not move, change jobs, or alter his transportation because he is satisfied with his present situation. He is maximizing total utility. The greater the number of years spent at the present residence or place of work, for example, the greater the probability that total utility is being maximized.

A supportive hypothesis, therefore, was formulated. The relationships of the research hypotheses would become more evident with increases in the measures of permanence: length of residence at the present site, length of work at the present location, and length of transportation use.

A stepwise multiple regression analysis (using computer program

B. M. D. 02R) was performed in which parameters were estimated for a model of the form:

$$y_w = b_o + b_1x_1 + b_2x_2 + b_3x_1x_2$$

where

x_2 = one of the measures of permanence (length of residence, length of work, or length of transportation use)

x_1x_2 = statistical interaction between x_1 and x_2

b_2 and b_3 = parameters

As before, the parameters of the regression model estimate those of a more general statistical population model. A skewness test indicated that the deviations of each variable were evenly distributed about the means. Student's "t" tests of the income-length of residence and the income-length of work correlation coefficients indicated that income and each of the permanence measures were independent. Null hypotheses of zero correlation were accepted at the .05 significance level. A similar null hypothesis of zero correlation between income and the length of transportation use was rejected, and this variable was excluded from further consideration.

A total of eight additional regression analyses were performed: one for each combination of the transportation type and the length of work and length of residence measures of permanence. The item of interest was the behavior of the income (x_1)-distance to work (y_w) relationship when the length of residence or length of work (x_2) and the statistical interaction (x_1x_2) terms were included. Significant values for the statistical interaction term would indicate that the

measure of permanence did influence the income-distance to work relationship.

The addition of the permanence measures to the linear model did not alter the basic parameters pertaining to car, bus, or bicycle riders. For each of these transportation modes the relationship between income and distance to work remained not significant when the additional variables were included.

The relationship for the walking commuters, however, did change when length of residence and length of work were added to the model. The parameters are presented in Tables 8 and 9. The modifications in the basic linear relationship resulting from the addition of the permanence variables are shown in Figure 40.

Table 8

Estimated Parameters for Income-Distance to Work Relationship for Walkers Before and After the Inclusion of the Length of Work Variable

	b_o	b_1	Standard Error	F Ratio	Significant at .05 Level	Interaction
Before	1,122	-0.10	0.05	4.44	yes	
After	1,268	-0.21	0.09	4.99	yes	no

Table 8 and Figure 40 show that when length of work is included as a variable the rate of change in distance with income (the b_1 parameter) increases. Graphically, the slope of the regression line becomes steeper, or less horizontal to the income axis. This change is as predicted.

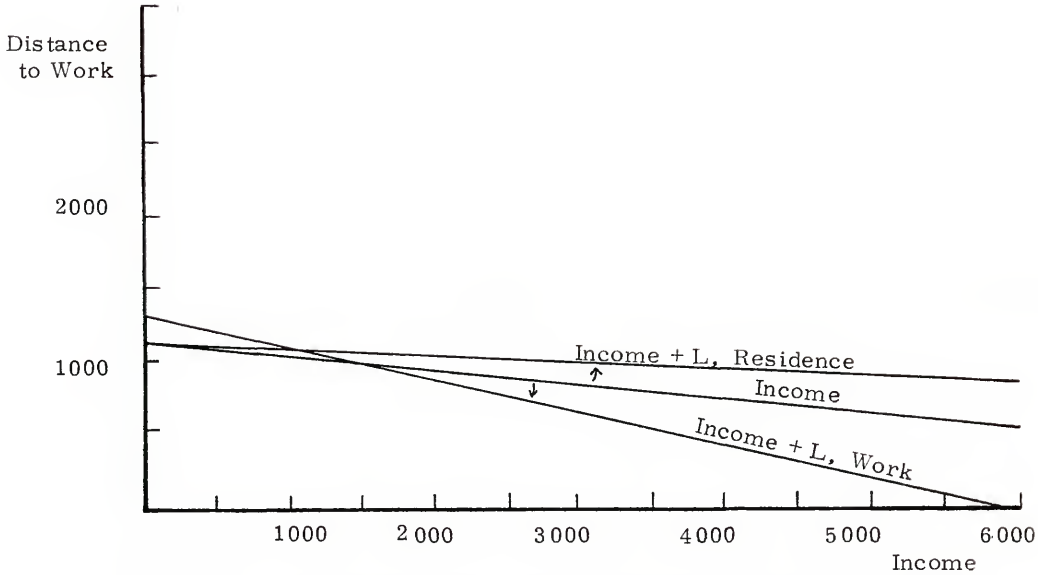

Figure 40. Changes in the Income-Distance to Work Relationship for Walkers After the Inclusion of Length of Work or Length of Residence Variables.

As the length of work variable increases, the relationship tilts or shifts to a steeper function.

Table 9

Estimated Parameters for Income-Distance to Work Relationship for Walkers Before and After the Inclusion of the Length of Residence Variable

	b_o	b_1	Standard Error	F Ratio	Significant at .05 Level	Interaction
Before	1,122	-0.10	0.05	4.44	yes	
After	1,126	-0.05	0.06	0.75	no	yes

The shift, however, is accompanied by an increase in the variance about the regression line. Although the relationships before and after the inclusion of the length of work variables are both significant at the .05 level, the increased variance prevents the statistical interaction term from also being significant. A hypothesis, therefore, of no difference between the before and after functions must be accepted.

The length of residence variable has the opposite effect upon the income-distance to work relationship. As length of residence increases, the slope becomes less steep, or more horizontal to the income axis. Furthermore, since the variance does not appreciably change, what was a significant relationship becomes not significant. Statistical interaction is present, therefore. A null hypothesis of no change in the income-distance relationship with a change in the length

of residence must be rejected.

In summary, length of work does not change the relationship between income and distance to work for any of the modes of transportation. Length of residence alters only the relationship of the walking group; as length of residence increases, the relationship becomes less significant.

The research hypotheses cannot, therefore, be accepted if length of residence is an indicator of equilibrium and utility maximization. Regardless of the transportation used, no relationship between income and distance to work can be inferred for any of the families who have lived in their present location for a considerable length of time.

Conclusions

The regression analyses of the sample data indicate that several conclusions might be drawn concerning the Piracicaba family heads who commute to a fixed place of work. The results of the statistical analyses can be summarized in the following inferential statements:

1. For all commuters, a negative relationship exists between income and distance to the city center.
2. For commuters who walk, a negative relationship exists between income and distance to work when these variables are the only ones considered or when length of work is included in the model.
3. For all commuters, no relationship exists between income

and distance to work when length of residence is included in the model.

As shown in statement 1, the non-western residential pattern is confirmed for the interviewed inhabitants of Piracicaba. The rich live nearer the city center than do the poor. Moreover, the strength of the relationship changes only slightly from one transportation group to another.

The city of Piracicaba has a large (for Latin America) proportion of commuters who drive to work, and these people have owned cars for almost as long as they have been living in their present residences. For the car users interviewed, the mean length of transportation use was 4.3 years, and the average length of residence was 5.2 years. Automobile owners, as shown by the mean distance in Table 6, tend to live nearer the center of town than do the people who walk.

These facts indicate that the current trend registered in some Latin American cities of the rich leaving the downtown area is not occurring in Piracicaba. The importance of transportation as an explanation of these trends, therefore, can be seriously questioned. Piracicaba has a highly motorized population, but, despite their great mobility, the members of the upper income groups still prefer to live near the city center.

The mode of transportation as a variable in the interaction between the residence and place of work does not seem to add any knowledge to an understanding of urban structure. Rationale for the application of

the normative bid-price model in an interaction framework was perhaps to discover some order where no order was evident. A relationship between income and distance to work was thought possibly to exist where no spatial distribution patterns were present.

In Piracicaba, the opposite appears to be true. For families who have spent many years at the same location--thus indicating utility maximization--no relationship between income and distance to work can be inferred. When the length of residence variable is not included, a relationship does exist for the walking commuters of the sample. The relationship is much weaker (2.21 percent of the variance is explained), however, then the one between income and distance to the city center for the same group (10.62 percent of the variance is explained).

Although a 5 percent probability of a type I statistical error exists, the null hypothesis of no relationship between income and distance to work must be accepted. The research hypotheses are rejected, and the study contributes no evidence to the support of the bid-price model, as developed, when distance overcoming costs are either time or money.

Must the model itself be rejected? Just as a confirmation of the hypotheses of this project would not have been sufficient grounds for an unqualified acceptance of the bid-price model, so too the non-confirmation of the hypotheses cannot be used to reject the model unequivocally. The mathematical deduction of what would occur under certain conditions remains intact. This study, however, shows that these same conditions were not present in Piracicaba at the time of the collection of information.

Many specific local conditions can account for the absence of an income-distance to work relationship. Physical characteristics, particularly the river barrier, make the city far different from the homogeneous plain of the model, and the dimension of the study area has already been mentioned.

Another possibility is that the different income groups are not competing for the same space. The section north of town, for example, is a center for blue collar workers, and the university on the eastern periphery is a focus of high income professionals.

The presence of recently constructed government subsidized low income housing indicates that the residential location of many people was determined by an outside agent. There is no guarantee that the site selection for these projects occurred in response to individual preferences.

The many restrictive assumptions of the model concerning human behavior and the operation of the economic system may not be applicable. Evidence indicates that in Piracicaba information may not flow as freely or property be as exchangeable as in other areas. The assumption of an economically motivated person may also be violated. Whether Latin Americans--and people from the state of São Paulo in particular--are any less economically motivated than other people, however, may be seriously questioned.

Local conditions, therefore, can be used to explain the lack of success in the testing of the research hypotheses. To resort to this

type of an explanation, however, is to deny the value of model building in the first place. All locations possess individual characteristics. The purpose of the construction of an urban model is that of picking out and examining factors which are common to most, if not all, cities. Likewise, a model of human behavior attempts to specify activity which is common to most, if not all, individuals.

The results of this study, therefore, bring into question the universality of the bid-price model as applied to spatial interaction between the places of residence and work. While the relationships postulated in the research hypotheses might exist elsewhere, they are not evident in Piracicaba.

When distance to the city center is made the dependent variable, a significant relationship between income and distance can be inferred from the data. Moreover, if interaction occurs between the residence and the downtown area, the bid-price model can be applied to explain the relationship.

A disadvantage of this application is that income, and total utility in the bid-price model, is not made contingent upon overcoming the distance. Evidence, however, does indicate that trips to the downtown area are more necessary in Piracicaba, and in other Latin American cities, than they might be in an Anglo-American one. Practically all household ware, clothing, and other durable goods must be purchased in the central area. The traditional market as well as the more modern supermarkets, with a few exceptions, are also at the city center. Banks,

public offices (where utility payments must be made in person), the health center, dental clinics, doctor offices, and many other commercial and service establishments are almost exclusively located in the central section.

Social activity on weekends invariably involves a trip to town where clubs, movies, and other entertainment facilities are located. The Saturday and Sunday evening custom of "footing," where lines of interested young men and women move around the main square in opposite directions, is disappearing, but the city center is still the place where old and new friends meet.

An advantage of the application of the bid-price model in a framework specifying interaction with the downtown area instead of the place of work is that competition for land is ensured. All people desire accessibility to one location. The possibility of a low income group, for example, minimizing distance to an employment center where only the poor work while a rich group resides near a place where they are the only workers is avoided.

When distance to the city center is substituted for distance to work, the hypothesized relationship between income and distance is confirmed for people who walk and ride buses. As expected, a negative function appears to exist between income and distance to the city center.

A relationship opposite that expected can be inferred for the individuals who drive to town. This would indicate that, for them, time is more important than money. For the number of cars, parking problems

Figure 41. Main Street. General view of the major commercial area where most stores are located.

Figure 42. Market. Centrally located traditional market is still where most food is bought despite growing competition from American-style supermarkets.

Figure 43. General Store. Merchant of the Cidade Alta area stocks a wide range of perishable and durable goods. Credit from 3 to 12 months.

Figure 44. Shoppers. Downtown shoppers waiting for the bus to go home. Streetcars were removed from the city over ten years ago, but in many places the tracks remain.

Figure 45. Vendors. Children from a low income neighborhood after a day of selling home-made candy.

and congestion are in fact worse in Piracicaba than they would be in a comparable United States city.

Another possible indication is that land has a relatively small marginal utility. Increases in income are not accompanied by more purchases of land, and the denominator (Q) in the slope of the bid-price function (See Equations 17 and 39 in Appendices A and B) remains relatively constant. People spend their money for other goods.

The few and small yards, fairly constant lot size, and increasing number of apartment buildings indicate that land in Piracicaba may indeed have a small marginal utility. If this is true, the rich behave as expected by purchasing accessibility to the city center instead of land on which to live.

Implications

The findings of this study show that Piracicaba, in its present state of development, exhibits some features which are not characteristic of many other cities of the world. In industrialized countries a positive relationship seems to exist between income and the distance to work. Based on a number of descriptive studies, the relationship can be inferred to be negative in many Latin American cities. Neither of these patterns seems to exist in Piracicaba. The distance to work does not appear to be influenced by income. A person's earnings cannot be used to predict the distance he will choose to live from work relative to others who use the same type of transportation for commuting.

Knowledge of the results presented here could be useful to policy makers. Clearly, public and private planning decisions are made within a political and financial realm, and the advocacy here of a given course of action would be improper. Of interest, however, might be the probable result of changes in certain variables considered in this study.

Increases in income or shifts from one transportation use to another should not cause a relationship to develop between income and distance to work. If, for some reason, a relationship is desirable, variables other than the ones considered here should be manipulated. For employees at a particular site who use a given transportation mode, no separating according to distance can be forecast for the future.

If a Pareto style utility maximization is desirable, the residential location of different income groups should not be limited to a given distance from an employment center. People have unpredictably varying preferences for accessibility to work, and restrictive zoning would probably limit the total satisfaction of the labor force.

Increased usage of buses or automobiles would probably not be accompanied by a separating of income groups. For the modes of travel considered in this study, no relationship between income and distance to work could be inferred.

The findings of this research show that different income groups do appear to desire different amounts of accessibility to the center of the city. Again, however, no differentiation according to transportation mode is evident, and car users actually live nearer the center of town

than the people who walk.

If a rearranging of the distribution of the different economic classes relative to the city center is a desired objective, a change in transportation is probably not the means of achieving the goal. Bus lines could be added, street patterns changed, and subways constructed (as in Rio de Janeiro and São Paulo), and the different income groups would remain in the same location relative to each other.

These conclusions are pertinent to future growth in Brazil. Car ownership in the country is rapidly increasing. The automobile industry continues to expand despite current world economic problems, and product demand shows little sign of slackening. For some models a six-month waiting period for new car delivery is not unusual.

An implication of this study is that the increasing mobility is not likely to affect the relative location of the different income groups. If a change in the present distribution is to occur it will probably be the result of a more general modification of psychological and societal variables.

One possible change is that the marginal utility of residential property may increase. Higher income people might, as the bid-price model predicts, be willing to reduce accessibility as greater quantities of land are purchased. Amato (1968, p. 127) related the movement of the elite in Bogota to a preference for new architectural home styles. The wealthy are said to be leaving the old colonial homes at the city center and moving into new, peripherally located, "California" style

Figure 46. The Coming of the Automobile I. Two cars in the garage is not uncommon even for families of a moderate income level.

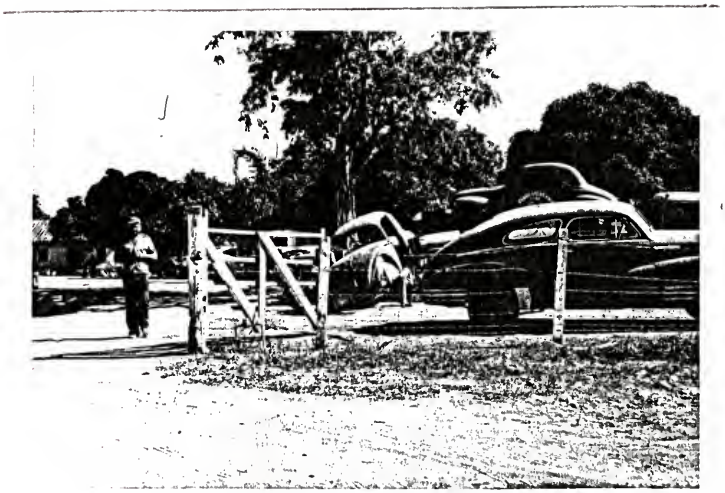

Figure 47. The Coming of the Automobile II. Junkyards are becoming a common sight within the Piracicaba urban area.

ranch houses which are surrounded by open space.

Residential patterns might also change, or be changed, if the attractiveness of the downtown area is reduced. At present, the concentration of commercial, service, and social activity at the city center is overwhelming. Until some of these functions are decentralized, accessibility to the area should remain an important consideration to the residents. Conscious encouragement of a peripheral shopping center, for example, could possibly be a lead factor. Increasing pollution and congestion from the automobile might also eventually reduce the attractiveness of the downtown area.

General evidence suggests that public policy in Brazil is likely to be aimed at preserving the city center as a strong focus of interaction. There is also no sign that the marginal utility of land is increasing. The distribution of different income groups relative to the downtown area, therefore, should not change in the immediate future.

Despite rapidly increasing automobile use in Piracicaba, the results of this research present little evidence of a future change in the relative location of the different economic groups. Distance to work does not appear to be related to income regardless of what type of transportation is used. Distance to the city center is related, but there is no indication that the characteristic non-western pattern will be altered by the ongoing changes in transportation.

The residential location of people with respect to their jobs and to the city center appears to be tied to more general cultural

factors. The desire for land or social activity on Saturday night may be variables more important than the ones considered here. Government officials and private planners, therefore, cannot forecast the future by simply examining present patterns in economically more advanced societies. Effective prediction and control of what is to come in Piracicaba and Brazil must be based on knowledge of the values which pertain to the local way of life.

APPENDICES

APPENDIX A

NORMATIVE BID-PRICE MODEL; TRANSPORTATION COST = MONEY

A simplified version of the bid-price model set forth by Alonso (1964) is as follows:

Assumptions:

1. A single city is located on a homogeneous plain with a single, central place of employment.
2. Human behavior is economically rational; man attempts to maximize total utility.
3. Information is perfect.
4. All land is of equal natural quality and immediately exchangeable.
5. The variables are static and unchanging with time.
6. The society is motorized. Transportation costs vary only with distance and are measured solely in terms of money expenditures.

Let: $y = P_z Z + P_t Q + k$ (1)

where:

y = income for a fixed time period

t = distance to the place of work

Q = quantity of land

P_t = price of land at distance t

k = total cost (in money) of transportation used for commuting

Z = quantity of a composite good (everything else)

P_z = price of the composite good

This is the income function, and it shows that a person's earnings must be used for three goods: land, transportation, and by definition, everything else. While more formal treatments include additional variables (housing, for example), the model is restricted for the sake of simplicity.

Let: Total U = U (Z, Q, t) (2)

where:

Total U = total utility

U (Z, Q, t) = the utility value of Z, Q, and t.

This is the personal utility or satisfaction function. Each individual maximizes total utility by combining Z, Q, and t within the constraints of his income. While utility cannot be measured, it is a useful concept for relating goods, services and money to actual satisfaction. (Some authors add a Lagrangian scaler λ [lambda] to indicate the declining marginal utility of money itself. To a poor person, for example, $1.00 is more useful than it is to a rich person.)

The normative model is based on the concept of a bid-price function. At any location, the bid-price is the amount an individual is willing to pay for the use of a fixed quantity of land to achieve a given level of satisfaction. The bid amount is determined by the cost of transportation, the personal utility structure, and income. For a given distance interval, bids for an infinite number of locations can be evaluated, and, when these are combined over linear distance, a bid-price curve can be calculated.

Although parameters are unavailable, the form of the bid-price function can be determined. At a given location i the bid-price is:

$$y = P_z Z + P_{ti} Q + k_i \tag{3}$$

and:

$$P_{ti} = \frac{y}{Q} - \frac{P_z Z}{Q} - \frac{k_i}{Q} \tag{4}$$

At i, y, Q, P_z, and k_i are by definition fixed amounts. P_{ti} is whatever part of y is left after Z is purchased. If Z is assumed to be constant over distance, P_t is a linear negative function of the cost of transportation k. As k increases, P_t decreases by the same amount. Where Q and Z are held constant over distance, the bid-price function is:

$$P_t = \frac{y}{Q} - \frac{P_z Z}{Q} - \frac{k}{Q} \tag{5}$$

The principle determinant of the shape of the curve is k. In the model this variable changes directly with distance. In an automobile using society, it refers to the cost of gas, tires, oil, or any other item which is used up over a certain mileage. The car itself depreciates as a function of distance.

Expenses associated with other forms of motor transportation also vary directly with distance. Subway or bus ticket costs are a reflection of how far the user travels. All costs are measured in money, and costs in time or effort are not considered. Obviously, final conclusions of this normative model might be questioned because the assumptions may not exactly conform to reality.

When Q and Z are allowed to vary with distance, the model becomes more complicated. As y is reduced because of k, less money is available for allocation to Z and Q, as well as P_t. How much each variable changes depends on their relationship to each other in the individual's utility function. Total utility changes with each change in Z, Q, and t. Differentiating for each of these three variables:

$$\text{Total } U = U(Z, Q, t) \tag{2}$$

$$d \text{ Total } U = U_z dZ + U_q dQ + U_t dt \tag{6}$$

where: U_z, U_q, and U_t are marginal utility values of Z, Q, and t. Let Total U be maximized and the change in Total U = 0.

$$0 = U_z dZ + U_q dQ + U_t dt \tag{7}$$

The income function (Equation 1) shows that money is used to buy three goods: land, commuting, and the composite good. Of the variables, some remain constant and others change over distance. P_z and y remain constant. The cost of transportation k increases with distance which means that less and less money is left over to spend on Z or P_tQ. Whatever money is used to purchase land (spent on P_tQ) can either be used to buy a greater amount (allocated to Q) or to buy accessibility (allocated to the bid-price P_t). In the income function, therefore, y and P_z remain constant while Z, P_t, Q, and k change with distance.

At any specific location i, the price which is bid for land depends on: 1) how much of y remains after k is paid and 2) of what value

accessibility is to the bidder in comparison to Q and Z.

To simplify the analysis, Q and Z in turn are held constant over distance. First let Q = constant over distance. In Equation 7 the term $U_q dQ = 0$ since $\frac{dQ}{dt} = 0$

$$0 = U_z dZ + U_q dQ + U_t dt \tag{7}$$

$$0 = U_z dZ + 0 + U_t dt \tag{8}$$

rewriting:

$$\frac{dZ}{dt} = \frac{-U_t}{U_z} \tag{9}$$

The marginal rate of substitution between good Z and accessibility (negative of t) is a reflection of their relationship in the utility function. Income (y) is a constant over distance. Therefore, $\frac{dy}{dt} = 0$. Three items in Equation 1 change over distance: Z, P_t, and k. Differentiating the income function over distance, therefore:

$$y = P_z Z + P_t Q + k \tag{1}$$

$$0 = P_z \frac{dZ}{dt} + Q \frac{dP_t}{dt} + \frac{dk}{dt} \tag{10}$$

$$\frac{dP_t}{dt} = -\frac{P_z}{Q} \frac{dZ}{dt} - \frac{1}{Q} \frac{dk}{dt} \tag{11}$$

substituting Equations 9 and 11:

$$\frac{dP_t}{dt} = \frac{P_z}{Q} \frac{U_t}{U_z} - \frac{1}{Q} \frac{dk}{dt} \tag{12}$$

Now, let Z = constant over distance.

$$0 = U_z dZ + U_q dQ + U_t dt \tag{7}$$

$$0 = 0 + U_q dQ + U_t dt \tag{13}$$

rewriting:

$$\frac{dQ}{dt} = -\frac{U_t}{U_q} \tag{14}$$

Again, the marginal rate of substitution between the quantity of land Q and accessibility (negative of t) is a reflection of their relationship in the utility function. Income (y) is a constant over distance. Therefore, $\frac{dy}{dt} = 0$. Three items in Equation 1 change over distance: Q, P_t, and k. As before, differentiating the income function over distance:

$$y = P_z Z + P_t Q + k \tag{1}$$

$$0 = 0 + \frac{dP_t Q}{dt} + \frac{dk}{dt} \tag{15}$$

$$\frac{dP_t}{dt} = \frac{-P_t}{Q}\frac{dQ}{dt} - \frac{1}{Q}\frac{dk}{dt} \tag{16}$$

substituting Equations 14 and 16:

$$\frac{dP_t}{dt} = \frac{P_t}{Q}\frac{U_t}{U_q} - \frac{1}{Q}\frac{dk}{dt} \tag{17}$$

Equations 12 and 17 indicate the change of the bid-price with a change in distance when either Q or Z are made constant. To examine what occurs when income (y) varies, only Equation 17 will be considered. The analysis is similar, however, if Z is made variable and Q is held constant over distance as in Equation 12.

Equation 17 is the derivative of the bid-price function when Z is held constant. It shows how the individual's bid-price changes with distance. The amount of money he is willing to pay per unit of land depends on how his income is reduced by the cost of transportation

(the $-\frac{1}{Q}\frac{dk}{dt}$ term) and how he partitions the remaining income (y) between accessibility and quantity of land (the $\frac{P_t}{Q}\frac{U_t}{U_q}$ term).

Both terms in the equation are negative. Total utility is actually reduced as t increases, and U_t, therefore, must be negative. The value $\frac{P_t}{Q}\frac{U_t}{U_Q}$ shows a decline in the bid-price over distance $(\frac{dP_t}{dt})$. The negative value of the equation indicates that for a bidder to maintain a constant level of satisfaction, he is willing to pay less and less for land as distance increases.

Graphically, Equation 17 is the "slope" or the rate of change of the bid-price function. If P_t is plotted vertically and t horizontally, a high value of $\frac{dP_t}{dt}$ indicates a "steep" or "near vertical" function. A low value shows a "gentle" or "near horizontal" curve. If $\frac{U_t}{U_Q}$ is constant the function is linear.

A change in income affects the bid-price slope as follows. Q has positive utility, and an increase in y should increase the amount of land which is bought. The denominator in $\frac{1}{Q}\frac{dk}{dt}$ must increase ($\frac{dk}{dt}$ is constant) and the value of the term, therefore, decreases. What happens to $\frac{P_t}{Q}\frac{U_t}{U_q}$ is not readily evident. Either P_t, or Q, or both could change depending on what the $\frac{U_t}{U_q}$ relationship is.

On balance, therefore, the rate of change probably, but not necessarily, decreases as income grows larger. A decrease in

income leads to a greater rate of change over distance. As income gets larger, the slope of the graphed bid-price function becomes gentler (small $\frac{dP_t}{dt}$ value) or closer to horizontal, and as income decreases, the slope becomes steeper (large $\frac{dP_t}{dt}$ value) or more vertical.

APPENDIX B

NORMATIVE BID-PRICE MODEL: TRANSPORTATION COST = TIME

The value of the time spent for commuting can be estimated as follows:

Let economic man possess a given allotment of time which can be used for income producing work or for leisure activity.

Let: $T = J + L$ (18)

where:

T = a given quantity of time available for allocation to J and L.

J = quantity of time spent for income generating activity (on the job)

L = quantity of time devoted to leisure

(variables are measured in equal units)

This is an allocation possibilities function which specifies that all time of a given period T must be used for J or L. If T is a given constant, the rate of exchange between J and L is:

$$dT = dJ + dL \tag{19}$$

$$0 = dJ + dL \tag{20}$$

$$dL = -dJ \tag{21}$$

$$\frac{dL}{dJ} = -1 \tag{22}$$

A change, therefore, in L or J must be accompanied by an equal opposite change in the other term.

A utility function can also be written:

$$\text{Total } U = U(J, L) \tag{23}$$

where:

Total U = total utility

U (J, L) = utility obtained from J and L

The individual obtains positive satisfaction from both J and L and he allocates the total allotment of time according to their relative utility values. For this to be true, a general assumption must be made: J and L are perfectly exchangeable. People can freely substitute work and leisure for each other.

In reality this may not be possible. Institutional rigidities exist as to the amount of labor which can be done during a given time period. Employees must often work eight hours per day, or not at all; must work five days per week, and not seven or three.

While perfect exchangeability is impossible, many modifying mechanisms are available in present-day society. People do go to jobs on weekends and work hours other than straight shifts. Varying amounts of part-time labor can be performed, and self employment is common.

Assuming, therefore, exchangeability between J and L, total utility can be maximized. At the optimum combination of J and L the change in total utility = 0. Differentiating Equation 23, therefore:

$$d\,\text{Total } U = U_j dJ + U_l dL \tag{24}$$

where:

U_j = marginal utility of J

U_l = marginal utility of L

$$0 = U_j dJ + U_l dL \tag{25}$$

rewriting:

$$\frac{U_j}{U_l} = \frac{-dL}{dj} \tag{26}$$

U_j and U_l are the utility amounts added to total utility by the respective change in J and L.

Equation 26 is the marginal rate of substitution between L and J. If U_j decreases, for example, a greater amount of J is necessary to maintain a constant level of total utility. If the units of measurement are the same, Equations 22 and 26 can be combined. At the point of maximum total utility:

$$\frac{U_j}{U_l} = 1 \tag{27}$$

or:

$$U_j = U_l \tag{28}$$

At the point of maximum possible total utility, the marginal utilities of J and L are equal. The addition to total utility caused by an increase in J, for example, is matched by an exactly equal loss in total utility resulting from the decrease in L.

At the point where J and L are optimally combined:

$$\text{Tot } U_T = \text{Tot } U_j + \text{Tot } U_l \tag{29}$$

where:

Tot U_T = total utility derived from T

Tot U_j = total utility derived from J

Tot U_l = total utility derived from L

At the optimum point the rate of exchange between time units of J and L and between utility units of J and L is the same: one for one. Just as Tot U_T is related to T, therefore, Tot U_j is related to J and Tot U_l is related to L:

$$\frac{\text{Tot } U_T}{T} = \frac{\text{Tot } U_j}{J} = \frac{\text{Tot } U_l}{L} \tag{30}$$

and:

$$\frac{\text{Tot } U_j}{\text{Tot } U_l} = \frac{J}{L} \tag{31}$$

Even though total and marginal utility is unmeasurable, J and L can be used as estimates of Tot U_j and Tot U_l. If a worker is maximizing total utility, the proportion of his total time which is devoted to J and to L reflects the composition of his utility function. If he devotes, for example, six hours during the day to work and eighteen to leisure, the total utility derived from work is 1/3 as great as that obtained from leisure. An average hour at home is three times more important than one at work, and he allots his time accordingly.

To consider the value of the time spent for commuting, the following assumptions must be made.

1. As stated above, let J and L be exchangeable.
2. Let $\frac{\text{Tot } U_j}{\text{Tot } U_l}$ be a constant and unvarying with the length of the total time period (If the ratio is 1/3, for example, six hours

per day, 7.5 days per month, and 3 months per year are spent at work).

3. Let the time spent commuting have no utility value other than its limiting effect on J and L.

Total time can be allocated as follows:

$$D = T + G \tag{32}$$

where:

D = total time period (one day, for example)

G = time spent for commuting

If an individual devotes part of his time to commuting (G), the total amount T available for allocation to J and to L is reduced. J and L possess positive utility and commuting, therefore, must be a cost. If the individual maximizes total utility, he divides all time between J and L; and if period G were not used for commuting, it would also be distributed according to the constant ratio: $\frac{\text{Tot } U_j}{\text{Tot } U_l}$. Since G is not available for allocation, G is a reduction of total utility by the same ratio. The value of $\frac{J}{L}$ can also be used to estimate how G would be allotted were commuting not necessary.

Let:

$$G = G_j + G_l \tag{33}$$

and:

$$\frac{G_j}{G_l} = \frac{J}{L} \tag{34}$$

where:

G_j = portion of G which would have been used for J if commuting were unnecessary

G_1 = portion of G which would have been used for L if commuting were unnecessary

substituting in Equation 30

$$\frac{\text{Tot } U_j}{\text{Tot } U_T} = \frac{J}{T} = \frac{G_j}{G} \tag{35}$$

G_j is the amount of time by which J is reduced due to commuting, and it can be estimated when J, T, and G are known. The commuting opportunity cost, or the amount by which income (y) is reduced depends on the value of G_j. If all income is earned during J at a fixed rate per unit of time:

$$K = \frac{y}{J} G_j \tag{36}$$

where:

K = time, or opportunity, cost of commuting

$\frac{y}{J}$ = is the wage rate (y per hour, for example)

K is the amount by which income is reduced because of the time spent commuting. If someone, for example, spends his time as follows:

D = 24 hours

J = 5 hours

L = 15 hours

G = 4 hours

The portion of G which would have been used for J were commuting not necessary (G_j) is 1 hour (from Equation 35). If y = \$20.00, for

example, per day, solution of Equation 36 yields a value of $4.00 for the time spent traveling to work.

If J and L are optimally combined in the United States, and if an average of 2 hours per day are used for commuting:

$$\frac{J}{T} = \frac{40}{158} = .253 \text{ per week}$$

Of the 10 hours spent for commuting, 2.53 hours (the value of G_j) would have been used for money producing work. The opportunity cost of each commuting hour is about 25 percent of the normal wage rate.

The value of .25 is slightly less than empirically obtained measurements. Becker (1965) used commuter behavior in Seattle to estimate the cost of time at .40 of the wage rate, and Beesley (1965) set the figure between .30 and .50 for public transit users in London. Other studies list values anywhere between .20 and .80 (Waldo, 1974), but the .40 figure seems to be preferred (Ingram, Kain, and Ginn, 1972; Stucker, 1973).

Equation 36 predicts and empirical studies confirm an opportunity cost of less than the wage rate for the time spent on the journey to work. While parameters arrived at by different researchers may vary, the time which is spent commuting does involve a money cost. Income is restricted because the time devoted to work is reduced by some factor.

This commuting time cost cannot be directly substituted for k in the normative model as developed by Alonso (See Appendix A). The variable y in the income function (Equation 1) refers to actual money earnings, and an opportunity cost cannot be subtracted from

a worker's take-home paycheck. The problem has led to the use of sophisticated models where total utility is optimized subject to time as well as budgetary constraints (Muth, 1969; Cassetti and Papageourgiou, 1971; Stull, 1973; Rothenberg, 1973; Stucker, 1973).

The individual's income is dependent upon the magnitude of K. If the time spent commuting (G) is directly variable with distance, income (y) also changes with distance. The amount of money which is available to be spent on the various goods of Equation 1 is reduced by K as distance t (and the time spent for G) increases. In the differential of the income function over distance, y cannot be eliminated as in Equations 10 and 15; $\frac{dy}{dt}$ can be substituted, however, by $-\frac{dK}{dt}$, the amount by which y changes.

Therefore:

$$y = P_z Z + P_t Q + k \tag{1}$$

$$\frac{dy}{dt} = \frac{P_z\, dZ}{dt} + \frac{dP_t\, Q}{dt} + \frac{dk}{dt} \qquad \text{(Equation 10 with y variable over t)}$$

$$-\frac{dK}{dt} = \frac{P_z\, dZ}{dt} + \frac{dP_t\, Q}{dt} + \frac{dk}{dt} \tag{37}$$

Holding $\frac{dZ}{dt}$ constant over t as in Equation 15, substituting $\frac{dQ}{dt}$ as in Equation 17 and rewriting:

$$\frac{dP_t}{dt} = \frac{P_t}{Q}\,\frac{U_t}{U_q} - \frac{1}{Q}\,\frac{dk}{dt} - \frac{1}{Q}\,\frac{dK}{dt} \tag{38}$$

This is the slope of the bid-price function when the opportunity cost of commuting is considered. The transportation cost variables k and K both increase directly with distance and the slope, therefore,

is negative. Both variables involve a limiting or a restricting of the money which is available to be spent on other, more satisfying goods. The opportunity cost K occurs before y is earned while k takes place afterward. Both costs must be paid by the individual before any money can be spent on Z or Q.

When k alone is used to measure transportation costs, a change in income produces a change in the slope of the bid-price curve (See Appendix A). A greater value of y decreases the negative value of the function, and makes it more gentle or near horizontal to the t axis.

A change in the income level yields ambiguous results when time costs are included. An increase in y may cause the $\frac{P_t}{Q}\frac{U_t}{U_q}$ term in Equation 38 to increase or decrease (See p.138). The value $\frac{1}{Q}\frac{dk}{dt}$ grows smaller because Q has positive marginal utility and k is constant (See p.138). The time cost factor $\frac{1}{Q}\frac{dK}{dt}$, however, increases with income. K is, by definition, linearly related to y (Assumption 2 on P.143); the cost of the time spent commuting is always a fixed proportion of a person's income. The denominator Q also increases with income, but it does so at an ever lesser rate. Q has a decreasing marginal utility. The satisfaction gained from the 1,000th acre, for example, is less than that gained from the first one.

In conclusion, when both measures of commuting costs are included in the model, the behavior of the bid-price function with a

change in income is not predictable. An increase in income may change the slope of the function in either a positive or negative direction. A knowledge of actual parameters would be necessary to identify the nature of this change.

If the monetary commuting cost = 0, the model becomes:

$$\frac{dP_t}{dt} = \frac{P_t}{Q}\frac{U_t}{U_q} - \frac{1}{Q}\frac{dK}{dt} \tag{39}$$

The effect of a change in income for such a model is clear. As income increases, so too does the slope of the bid-price function. K increases linearly with y but Q does so at a marginally decreasing rate.

APPENDIX C

QUESTIONNAIRE

The following questionnaire was distributed to the sampled households:

1. Where is your place of work?
2. How long have you worked at the present location?
3. What type of transportation do you own?
4. How long have you owned it?
5. What type of transportation is used for the journey to work?
6. How long have you used it?
7. How many days per week do you go to work?
8. How many days per week do you go to the city center?
9. How long have you lived at the present location?
10. Is the house you live in your own or rented from someone else?
11. How much rent per month do you pay?
12. How many other families live in the same house?
13. Why did you choose this place to live?
14. How much money do you earn per month from your principal job?

The nature and objectives of the research project were briefly explained to the person who received the questionnaire. Instructions describing how the form should be completed stressed the facts that the questions were directed at the family member who financially supported the rest of the household, and that the inquiries referred

only to the household head's principal job. When the completed questionnaire was collected, additional questions were asked verbally. Information was also requested concerning the nature of the work performed by the household head, the number of people in the family, the number of family members who were employed, additional sources of income, how often per day the family head made the trip to work, and what mode of transportation was used for the trip to the city center.

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BIOGRAPHICAL SKETCH

Cyrus Bassett Dawsey III was born in the north Florida town of Madison in August, 1945. His early childhood years were spent in several communities of North and South Carolina where Cyrus' parents, Marshlea and Cyrus B. Dawsey, Jr., served various appointments as ministers of the United Methodist Church. In 1952 the family moved to Brazil as missionaries where Cyrus' father had been born the son of a previous generation of missionaries. Like their father, Cyrus and the three other Dawsey children grew up in Brazil. Ten years were spent in the cities of Sorocaba and São José do Rio Prêto in the state of São Paulo where Cyrus attended local elementary and secondary schools.

In 1963 Cyrus returned to the United States and attended Florida State University in Tallahassee where, after four years, he received the B.S. degree with a major in psychology and a minor in economics. He completed a masters program in international affairs at the same university and followed it with an Army tour of duty lasting two years, one of which was spent in Viet Nam. In 1969 he married Barbara Saucer of Oviedo, Florida, and their first child, Marc, was born in 1970.

In 1971 Cyrus initiated course work at the University of Florida and was admitted to candidacy for the PhD degree in 1973. During this year a second child, Amanda, was born. Field research for this paper was conducted in Brazil from June, 1973 through May, 1974 after which Cyrus and his family returned to Gainesville to analyze the collected data and write the final report.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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