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16. Abstract

The age of a population is observed to be influential in how land is used. Various land uses attract different volumes of traffic. With population pyramids, the population of the age groups can be predicted, and it follows that future land requirements by type of use can be estimated. These land use estimates can, in turn, be used to predict the amount of transportation facilities needed to meet the traffic volumes attracted.

Two demand models are formulated to study the land use and the transportation need. The demand model for land in different uses consists of two parts. First, two equations one for single-unit housing and the other for multiple-unit housing, are used to relate residential land use to the three identified age groups: the young (15-19), the middle-aged (20-64) and the old (65 years and over) groups. Elasticities resulting enable officials to estimate the total percentage change in residential use. Second, the model assumes that the percentage distribution of land uses to total developed area remains unchanged over the study period. Therefore, the percentage change in residential use estimated can be assigned to other land equations, relating automobile vehicle-miles and transit vehicle-miles separately to residential and commercial uses.

The estimation results indicate that the middle-aged group is significantly responsive to single-unit housing, with an elasticity of 0.8802 while the young and the old groups to multiple-unit housing with elasticities of 0.9909 and 0.7138, respectively. Commercial land use is found to be significantly responsive to housing units without automobiles to be responsive to transit vehicle-miles.

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ESTIMATING DEMAND FOR LAND USES AND TRANSPORTATION FACILITIES WITH POPULATION PYRAMIDS

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Research Report 225-25
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Economics of Highway Design Alternatives

Sponsored by the State Department of Highways
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PREFACE

The authors wish to express their appreciation to those who have assisted or facilitated this study. Special acknowledgement is given to Mr. James R. Farrar, Jr., of the Texas State Department of Highways and Public Transportation for his valuable comments, and Mr. Jeffery L. Memmott of Texas Transportation Institute, for his assistance in data collection and for his many suggestions. Also, special acknowledgement is extended to Mrs. Susan Freedman, Mrs. Deanne Anderson and Ms. Patti McClurg for their efforts in typing the manuscript.

ABSTRACT

The age of a population is observed to be influential in how land is used. Various land uses attract different volumes of traffic. With population pyramids, the population of the age groups can be predicted, and it follows that future land requirements by type of use (including streets and roads) can be estimated. In turn, these land use estimates can be used to predict the amount of transportation facilities needed to meet the traffic volumes attracted.

Two demand models are formulated to study the land use and the transportation need. The demand model for land in different uses consists of two parts. First, two equations one for single-unit housing and the other for multiple-unit housing, are used to relate residential land use to the three identified age groups: the young (15-19), the middle-aged (20-64) and the old (65 years and over) groups. The model's resulting elasticity coefficients can be used to estimate the total percentage change in residential use. Second, the model assumes that the percentage distribution of land uses to total developed area remains unchanged over the study period. Therefore, the percentage change in residential use estimated can be assigned to other land uses. The demand model for transportation facilities by land uses consists of two equations, relating automobile vehicle-miles and transit vehicle-miles separately to residential and commercial uses.

The estimation results indicate that the middle-aged group is significantly responsive to single-unit housing, with an elasticity of 0.8802 while the young and the old groups to multiple-unit housing with elasticities of 0.9909 and 0.7138, respectively. Commercial land use is found to be significantly responsive to automobile vehicle-miles while residential land use as represented by the number of housing units without automobiles to be responsive to transit vehicle-miles.

SUMMARY OF FINDINGS

The growth of a city depends much on the growth of its population, and population of the various age groups is observed to be influential in how land is used. It is also known that various land uses attract different traffic volumes. It appears that population pyramids are useful to predict population of age groups in future years, and to serve as a good data base for estimating future land requirements by type of use. In turn, future land requirements by type of use can predict the appropriate amount of transportation facilities needed to meet the growth. For city planners and officials, information derived from these predictions is essential in city planning. The closer the predictions are to reality, the better a city is prepared to provide adequate services for its inhabitants.

Existing prediction models of land uses and transportation needs are complex and costly to use. Most of them require a lengthy survey conducting process. Simpler models are needed when transportation officials have neither the time nor funding to implement the complex models in their initial planning. It is for this need that the present study attempts to fulfill. The simpler models are especially needed in transportation planning for smaller cities.

Among all the land uses, residential use seems to be most age-related. The proposed model of demand for land uses consists of two parts. First, the model attempts to relate residential use by housing type to three age groups: the young, middle-aged and the old with age ranges of 15-19, 20-64, and 65 years and over, respectively. Single-unit housing is hypothesized as a function of the three age groups, real median house price and real family income, while multiple-unit housing is expressed as a function of the same three age groups, real median house price, real rent and real per capita income. The

resulting elasticity coefficients enable officials to estimate the total percentage change in residential use. Second, the model assumes that the percentage distribution of land uses to total developed area does not change. Hence, the percentage change in residential use can be assigned to other land uses.

Censuses of Population and Housing for 1960 and 1970 provide data for estimating the coefficients for the housing demand equations. The ordinary least squares (OLS) regression technique is applied to the log-log functions which serve as the housing demand equations. The estimation results reveal that the middle-aged group is significantly responsive to single-unit housing, with an elasticity of .8802 as compared to an elasticity of 0.0719 for the old group. Meanwhile, the young and the old are found to be positively and significantly influential in multiple-unit housing with elasticities of 0.9909 and 0.7138, respectively.

To estimate the demand for transportation facilities by land uses, two equations are formulated. One equation expresses the demand for automobile vehicle-miles as a function of family income, number of housing units with one or more cars, and sales of all retail trades and receipts of all selected services. The other equation expresses the demand for transit vehicle-miles to be related to family income, number of housing units without a car and all retail trade and service trade receipts. The housing unit variables represent residential land use and the last variable, all retail sales and service receipts, stands as proxy for commercial land use.

Using the OSL regression technique, to predict auto vehicle miles, it is found that the results of commercial land use has a significant effect, with an elasticity coefficient of 0.9155 while residential has an insignificant effect. As for transit vehicle-miles, residential use has a significant effect, with an elasticity of 1.0545 while commercial use has an insignificant effect.

The resulting models require a minimum of easily obtained input data and give reasonably accurate estimates of the demand for different land uses and in turn the demand for transportation facilities. These models are ideal for use by cities that do not maintain large enough data bases to use more complex prediction models, also, the State Department of Highways and Public Transportation can use these models to quickly identify cities in the state which will be experiencing major changes in transportation demand in the next decade.

IMPLEMENTATION STATEMENT

The report proposes two demand models, one for land in different uses and the other for transportation facilities, utilizing the readily accessible census data as the data source. The findings of the report can be of immediate use to officials in city planning and in public transportation. If implemeted, these findings can provide these officials with a fast and rough estimation on future land uses and transportation needs. These models are most applicable in cases where transportation officials do not have enough time or funds to maintain the large data bases and implement complex models in their transportation planning process. Such may be the case for the smaller cities. Even the State Department of Highway and Public Transportation can make use of these models to quickly identify major changes in transportation demand in all the cities in the state.

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INTRODUCTION

The growth of a city is a direct result of growth in population which is due either to natural accrual or to migration from other cities or rural areas. With the increase in population, new living and working spaces will be demanded. City planners and officals have to estimate the total growth of their cities, based on population projections, and map out areas needed for the various land uses to meet the demand.

It is believed that population age differences play some part in the demand for land in various uses, and, in turn, the demand for different land uses will affect the demand for various types of transportation facilities. If the demand for land in various uses is age-related, then the knowledge of the current population of the various age groups can indicate the characteristics of the future population of these age groups and the acreages of future land uses can be estimated. Once the number of acres of each type of land uses is estimated, the amount and type of transportation facilities can be projected to meet the attractions of these land uses.

Over the years, models of land use projection and traffic assignments have been developed and used extensively by city, state, and federal planners. However, these officials have found that most of the operational models require extensive data collection, which is often costly and time consuming. As a result, the present study was authorized for the development of simpler and less time consuming estimation models of demand for land in different uses and transportation needs. Such models are needed by smaller cities that do not have large data bases. The State Department of Highway and Public Transportation (SDHPT) can also make use of these models and encourage their use by city officials.

Objective and Scope of Study

The objective of this study is to develop simplified models which offer quick but rough estimates of the quantity of land and transportation facilities demanded 10 or so years in the future. The scope of the study is limited to areas defined by the objective. Transportation facilities are restricted to auto-related and transit-related. Further breakdown of these two types of facilities are not considered in this report.

Contents of Report

This report presents the development of a demand model for land uses, utilizing census data which are readily accessible. Another model of demand for transportation needs as attracted by the various projected land uses is also presented.

The major divisions of the body of the report are as follows: (1) demand for land in different uses (2) demand for transportation facilities and (3) conclusions and recommendations.

DEMAND FOR LAND IN DIFFERENT USES

If demand for land in different uses is influenced by age differences, then among all the land uses, housing seems to be the most aged-related. Both observations of the housing market and reports from literature reveal that multiple-unit housing is more likely to be occupied by the young and the old-aged groups and single-unit housing by the more affluent middle-aged group [1].

After leaving their parental household, young people, often forced by their budget constraint, tend to establish their first home in multiple-unit housing. By the time they reach their twenties, they are fairly well established in their careers. With higher and steadier income, many of them can afford to buy a single-unit house and many of them do so. As this middle-aged group reaches retirement, many find the responsibility of keeping a house too much to bear physically and/or financially. As a result, they may move back into multiple-unit housing such as apartments, townhouses or condominiums.

Therefore, knowledge of the most current population pyramid of a city should prove to be helpful in predicting the demand for the different types of residential land use in that city. The notorious baby boom in the 1950's should result in a big increase in population of the middle-aged group in the 1980's. For reasons discussed above, single-unit housing is preferred by this group and consequently, in the 1980's, there should be a big increase in the demand for this type of housing. Although the high interest rates which are prevailing in the housing market currently may discourage many people from purchasing now, once interest rates decline, these people would likely jump into the market and purchase their long dreamed single-unit house. Information not only of the demand for the types of housing but also of the magnitude of demand should be helpful to city planners and the people in housing industry.

Therefore, the present study attempts to construct a model relating land uses to the population of age groups by utilizing census data of housing and of population pyramids and housing data from the United States Bureau of Census reports. The assumptions needed for the model and the structure of the proposed model are presented separately in this section.

Basic Assumption

In order to study the relationship for land use and age groups, one basic assumption has to be made. It is assumed that the percentage distribution of land uses over the total developed land area in a city remains fairly constant over the years. In other words, in a particular city, the percentage of each land use to total developed area in any past year will be about the same as in any future year. Such assmption is believed to be within reason, because an increase in the amount of residential acreage means a need for a corresponding increase in commercial acreage to provide services and shopping facilities for the additional residents who move there. More streets and roads have to be built for the accessibility of the new residents. Schools and churches have to be expanded or added to accommodate the educational and religious needs of the newcomers. Also, additional park and recreational areas are needed for the aesthetic and recreational aspects of a community. City planners of a city tend to keep the same corresponding relationship among land uses when they make their projections on future land uses.

An investigation of historical land use distributions for several cities over the state indicates that the above assumption is valid (Table 1). Except for those of the cities of Bryan and College Station, the older land use distributions are not very different from the newer distributions, even though at

Table 1. Historical Percentage Distributions of Land Use of Total Developed Areas for Several Cities in Texas

City	Year	Residential (%)	Commercial (%)	Industrial (%)	Railroad & Utilities (%)	Streets & Alleys (%)	Parks & Recreation (%)	Public & Semi-Public (%)	Total Developed (%)
Arlington	1964	45.0	7.9	4.6	2.3	24.8	4.2	11.2	100.0
Arlington	1970	43.0	11.5	4.5	4.0	23.4	7.2	6.4	100.0
Arlington	1975	43.9	10.8	4.9	3.4	24.5	6.6	5.9	100.0
Arlington	1978	46.9	10.4	4.5	3.2	23.2	6.2	5.7	100.0
Bryan-C.S.	1958	47.2	3.5	3.5	2.7	30.8	5.2	7.1	100.0
Bryan-C.S.	1970	43.5	6.8	3.7	2.7	29.7	5.1	8.5	100.0
Bryan-C.S.	1982	43.3	8.3	5.6	1.6	28.6	4.2	8.4	100.0
Dallas	1964	45.8	7.1	5.0	4.6	24.8	6.7	6.1	100.0
Dallas	1970	45.0	8.0	4.3	3.8	23.3	6.7	8.9	100.0
Dallas	1978	45.3	8.5	4.4	3.5	23.5	6.4	8.6	100.0
Tyler	1964	45.5	4.5	5.6	6.2	27.8	1.9	8.5	100.0
Tyler	1970	42.2	4.9	7.7	7.1	28.0	2.4	7.7	100.0
Tyler	1980	44.2	7.0	7.5	2.8	27.8	2.6	8.2	100.0
Waco	1964	33.1	3.3	5.6	3.8	25.7	3.8	23.9	100.0
Waco	1977	35.6	4.8	9.4	a	24.3	b	25.9	100.0

a Included with Industrial
b Included with Public & Semi-Public

Sources: State Department of Highways and Public Transportation planning documents and/or planning departments of the above cities [2,3].

least 13 years separate them. Also, the average percentage distributions of land uses for three groups of cities in Texas and the United States have very similar distributions even though the distribution for the group of 53 cities [4], is over 20 years older than the distribution for the group of four cities (Table 2).

As for projections of each type of land use in terms of percentage of total developed area, most of the cities studied retain nearly the same land use distributions even for predicting land usage 20 years into the future (Table 3). Houston and Tyler have predicted land use distributions that are highly similar to their historical distributions of over 20 years earlier. Figures 1 and 2 illustrate the similarity of the historical and projected land use distributions for Bryan-College Station and Tyler.

Structure of Land Use Demand Model

The structure of the model of demand for various land uses is composed of two major parts. The first part attempts to estimate the demand for residential land use by the formulation of two estimating equations, one for each type of housing. The second part attempts to assign the demand for other land uses based on results obtained from the housing demand models. These two parts of the model will be discussed separately below.

Estimation of the Demand for Residential Use

For the first part of the model, residential land use is divided into land use for single-unit housing and land use for multiple-unit housing. By definition, single-unit housing represents one-unit structures while multiple-unit

Table 2. Average Percentage Distribution of Land Uses of Total Developed Land for Various Groups of Cities in the United States

Land Use	Average Distribution (%)		
	53 Cities[a] (1955)	77 Cities[b] (1964)	4 Cities[c] (1987-82)
Single Family	36.6	42.0	39.5
Multiple Family	3.0	2.7	5.5
Commercial	3.3	5.8	8.6
Industrial	6.4	4.5	5.5
Railroad	4.9	4.4	2.1
Streets & Alleys	28.1	27.0	25.6
Parks & Recreation	6.7	5.7	5.5
Public & Semi-Public	10.9	7.9	7.7
Total Developed Land	100.0	100.0	100.0

[a] For cities with populations of 250,000 or less, scattered over the mid-western part of the United States [4].

[b] For cities in the Dallas-Fort Worth Metroplex [5].

[c] For the cities of Dallas, Arlington, Tyler and Bryan/College Station, obtained from the State Department of Highways and Public Transportation.

Table 3. Comparison of Percentage Distributions of Land Use of Total Developed Areas for Previous and Projected Years for Several Cities in Texas

City	Year	Residential (%)	Commercial (%)	Industrial (%)	Railroad & Utilities (%)	Streets & Alleys (%)	Parks & Recreation (%)	Public & Semi-Public (%)	Total Developed (%)
Abilene	1965	23.8	2.8	6.4	1.1	34.2	0.0	31.7	100.0
Abilene	1985[a]	25.8	4.6	8.0	0.8	28.1	0.0	32.7	100.0
Baytown	1965	36.6	2.5	24.2	2.3	26.4	0.5	7.5	100.0
Baytown	1980[a]	43.5	4.5	17.9	1.1	22.7	4.5	5.8	100.0
Bryan-C.S.	1958	47.2	3.5	3.5	2.7	30.8	5.2	7.1	100.0
Bryan-C.S.	1980[a]	42.8	2.4	5.7	1.7	29.8	6.8	10.8	100.0
El Paso	1965	34.3	17.9	12.5	0.0	22.6	2.9	9.8	100.0
El Paso	1985[a]	40.4	13.3	15.6	0.0	20.3	2.6	7.8	100.0
Houston	1965	43.9	4.1	7.4	3.7	31.2	3.4	6.4	100.0
Houston	1980[a]	46.3	4.2	8.4	3.4	28.1	3.5	6.1	100.0
La Porte	1965	26.9	4.3	32.9	3.8	22.2	5.8	4.1	100.0
La Porte	1980[a]	30.0	3.7	36.8	1.3	22.1	2.9	3.3	100.0
Tyler	1964	45.5	4.5	5.6	0.0	27.8	1.9	8.5	100.0
Tyler	1985[a]	45.5	4.5	5.6	5.6	27.8	2.6	8.4	100.0
Waco	1964	33.1	3.3	5.6	3.8	25.7	3.8	23.9	100.0
Waco	1985[a]	33.1	3.1	6.9	2.3	25.1	6.3	23.2	100.0

a Projected

Sources: State Department of Highways and Public Transportation planning documents and/or planning departments of the above cities [2, 3, 6, 7, 8].

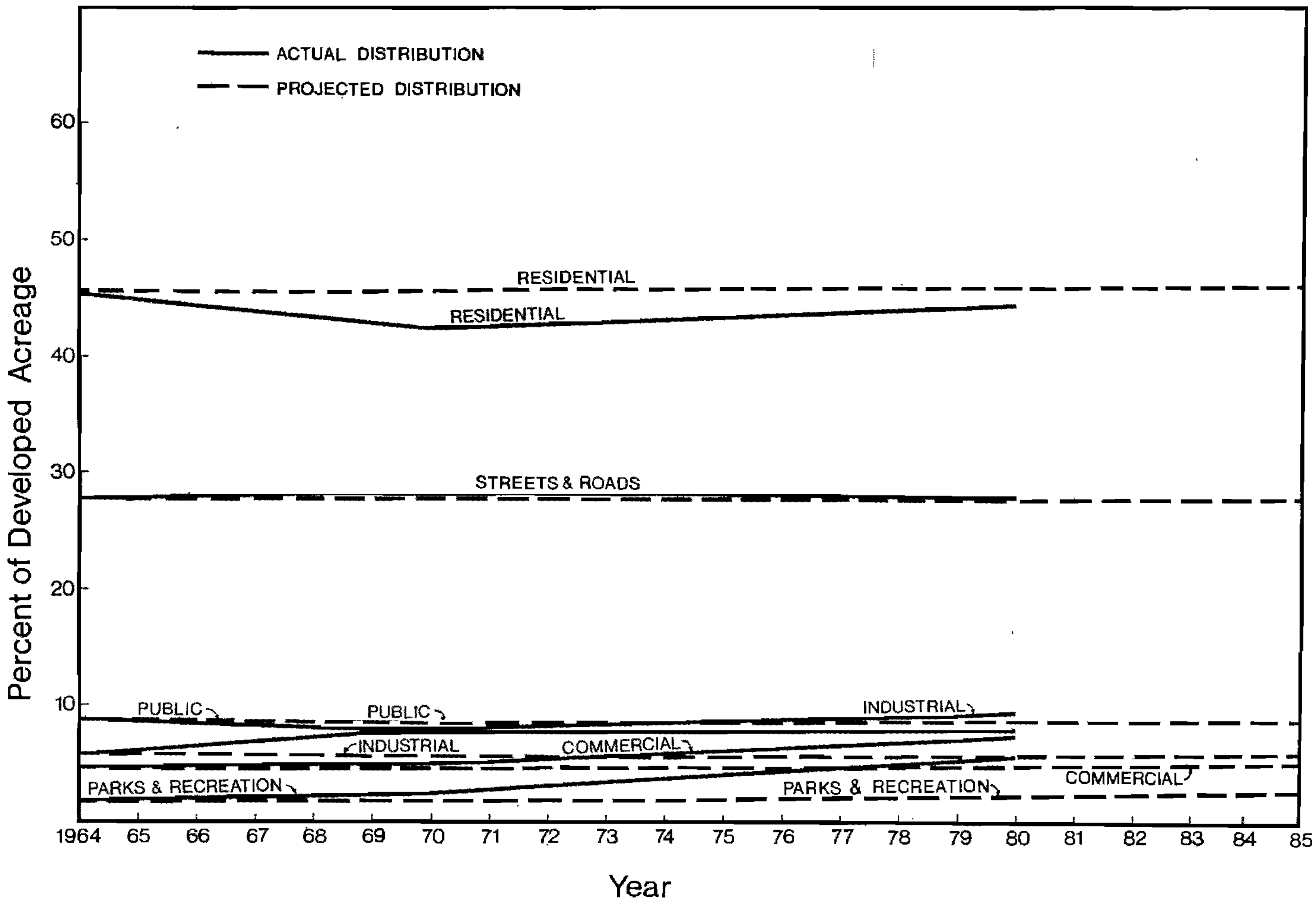

Figure 1. Land Use Distributions For Tyler

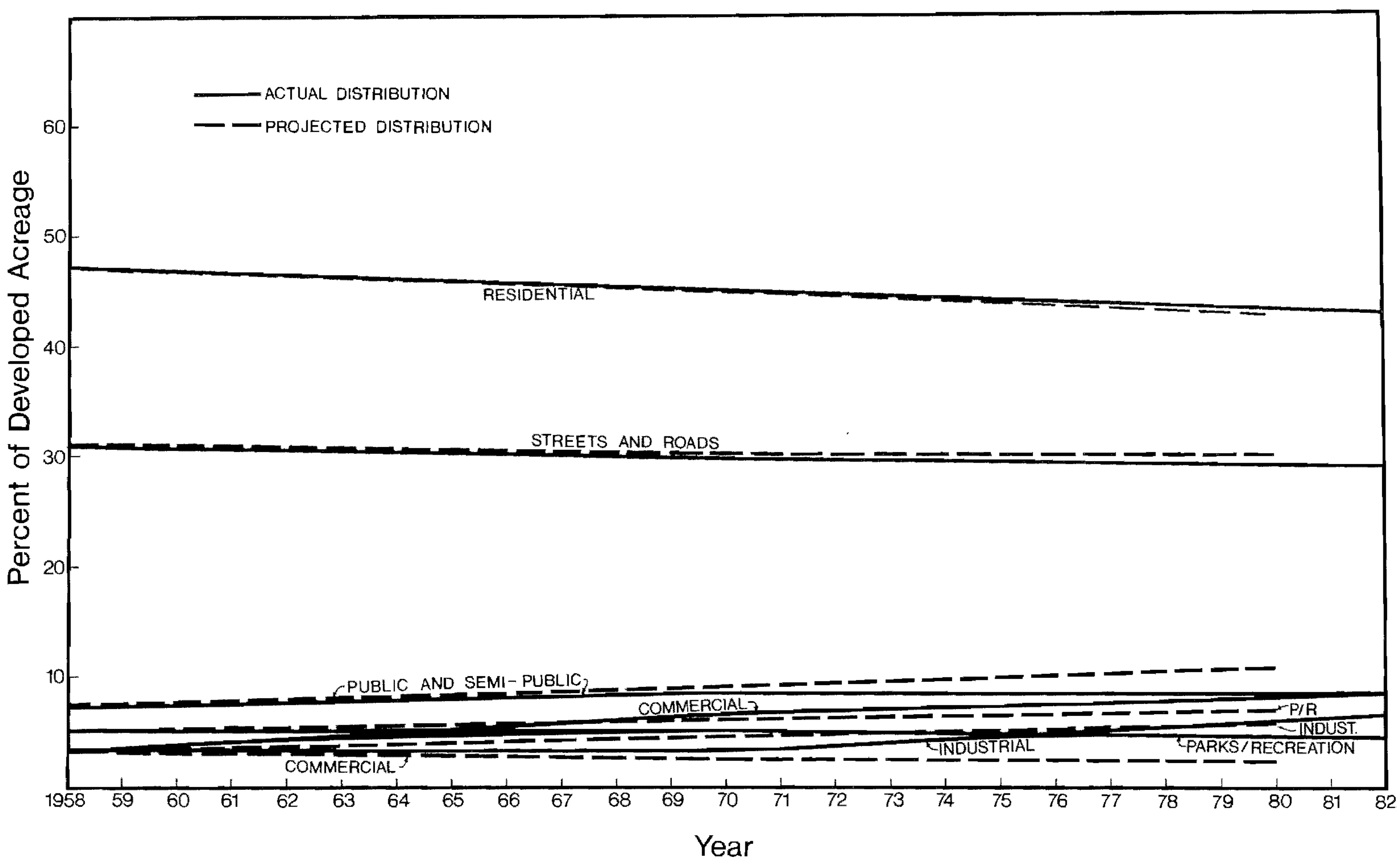

Figure 2. Land Use Distributions For Bryan-College Station

housing refers to housing with more than one-unit structures. Both of them are expressed in numbers of units. For a land use study, the total number of housing units in each type can be converted into acres by adopting the appropriate unit factor of units per acre which is representative of the housing characteristics of a city.

The description of the residential land use demand equations and the determination of their coefficients are presented below.

Description of Equations - Two equations are constructed to relate each type of housing to different age groups. Equation 1 estimates the demand for single-unit housing. The demand for single-unit housing is hypothesized to be a function of age group, real median house price and real median family income. Equation 2 estimates the demand for multiple-unit housings. The demand for multiple housing is hypothesized to be a function of age group, real median house price, real rent and real per capita income. Period and city size differences are also tested in both models. These two equations can be expressed in functional form as follows:

Equation 1:

$$SH = f(Y, M, O, RHP, RFI, PD, CS1, CS2) \text{ and}$$

Equation 2:

$$MH = f(Y, M, O, RHP, RNT, RPI, PD, CS1, CS2)$$

where SH = number of single-unit housing units,

MH = number of multiple-unit housing units,

Y = population of the young group,

M = population of the middle-aged group,

O = population of the old group,

RHP = real median house price,

RNT = real rent,

RFI = real family income,

RPI = real per capita income,

PD = 0, 1 dummy variables for period differences,

CS1 = 0, 1 dummy variables for city size differences between big and medium-sized cities with population of over 300,000 and between 100,000 and 300,000, respectively, and

CS2 = 0,1 dummy variables for city size differences between big and small cities with population of over 300,000 and under 100,000, respectively.

The variables used in the above equations are defined as follows:

1. Age Groups - Three age groups are identified as young, middle-aged and old with age breakdowns of 15-19 years, 20-64 years and 65 years and over, respectively.

2. Median House Price - The median house price represents the price variable in Equation 1. It also serves as the price of a substitute in Equation 2. Consequently, a negative sign for this variable is expected in Equation 1 and a positive sign in Equation 2. In order to remove the factor of inflation over the years, the median house price is deflated by the consumer price index to give a constant dollar value.

3. Rent - The variable rent represents median gross rent charged to tenants. Again, median rent is also deflated by the consumer price index to yield real rent tenants pay. If single-unit housing is the hypothesized type of housing for the middle-aged group, most of whom can afford this type of housing

and are not willing to accept multiple-unit housing as a substitute, to this group then, multiple-unit housing is not a substitute. Therefore, real rent is not included in Equation 1.

4. Family Income and Per Capital Income - Most single-unit housing are occupied by families with more than one wage earner, whereas most multiple-unit housing are, in general, occupied by single persons, widows or widowers. Therefore, it is appropriate to use family income in Equation 1 and per capita income in Equation 2. Both variables are deflated by the consumer price index to give the real family income and real per capita income.

5. Dummy variables for period differences and city size differences - All dummy variables are the 0,1 type and are used to determine the existence of differences between period of time and among city sizes in the demand relationships of single-unit and multiple-unit housings.

Determination of Coefficients - The data for determination of the coefficients of the two residential demand equations are from the United States Bureau of Census' 1960 and 1970 series of Census of Population and of Housing for the twenty-eight most populated cities in Texas.

Both of the estimating equations are expressed in log-log functional form so that the estimated coefficients will yield elasticities which are of greater interest to officials. The ordinary least squares (OLS) regression technique is used for the estimation. The coefficients obtained for the variables together with their signs and statistical significancies are discussed below and shown in Tables 4 and 5.

Age Groups. The age groups (young, 15-19 years; middle-aged, 20-64 years; and old, 65 and over) used in the model are more significantly related to the

Table 4. Estimation Results of Equation 1

Variable	Definition	Coefficients	t-Ratio
Y	Young group (15-19)	-.033	0.34
M	Middle-aged (20-64)	.880*	7.66
O	Old group (65 & over)	.072*	2.00
RHP	Real median house price	-.488*	-5.50
RFI	Real family annual income	.393*	3.64
PD	Period dummy	-.134*	-2.67
CS1	City size dummy (medium-sized deviated from large-sized)	-.009	-.15
CS2	City size dummy (small deviated from large-sized)	-.082	-1.09
Intercept		1.489	
R^2		.993	

*Significant at 5 percent level

Table 5. Estimation Results of Equation 2

Variable	Definition	Coefficients	t-Ratio
Y	Young group (15-19)	.940*	1.83
M	Middle-aged (20-64)	-.297	-.51
O	Old group (65 & over)	.867*	3.36
RHP	Real median house price	1.065*	2.07
RNT	Real gross rent	.494	.83
RPI	Real per capita income	-.015	-.03
PD	Period dummy	-.045	-.18
CS1	City size dummy (medium-sized deviated from large-sized)	.263	.85
CS2	City size dummy (small deviated from large-sized)	.676**	1.65
Intercept		-16.736	
R^2		.929	

* Significant at 5 percent level
** Significant at 10 percent level

number of single and multiple housing units in the sample of 28 cities used to develop the model than the following age groups:

Young	Middle	Old
15-24	25-64	65+
15-24	25-59	60+
15-24	25-69	70+
15-19	20-59	60+
15-29	30-64	65+
15-29	30-69	70+
20-29	30-64	65+

Also, the census breakdown limits the selection of more ideal age groups. The census gives the population for separate years for ages 17, 18 and 19. Then for ages 20-69, the population is given in five-year increments. Last, for ages 70 and older, the population is given for an open-ended group.

Both the middle-aged (20-64 years) and the old (65 years and over) groups are found to be positively and statistically significantly related to the number of single-unit housing units, with the middle-aged group unquestionably dominating in both magnitude and level of significance. As expected, the young group is found to be noninfluential in the demand for single-unit housing (Equation 1), but they and the old group are significantly influential in the demand for multiple-unit housing (Equation 2). Apparently, the old group tends to be indifferent to either type of housing.

The estimated coefficients of these age groups reveal that for a ten percent increase in population of the middle-aged group and a similar increase of the old group, demand for single-unit housing will increase by 8.80 percent and 7.2 percent, respectively. For the same percent increase in population of each of the young and old groups, the demand for multiple-unit housing will increase by 9.4 percent and 8.7 percent, respectively.

Real Median House Price and Real Rent. Real median house price is found to be negative and statistically significant in the demand for single-unit housing, as expected. The higher the price, the fewer units will be demanded. However, in the demand for multiple-unit housing, median house price is found to be positive and significant, indicating that single-unit housing represents substitute housing for the multiple-unit housing. As the price of single-unit housing decreases, some people from the young and the old groups who live in multiple-unit housing may increase their demand for single-unit housing as an alternative, whereas before, they cound not afford to have this alternative; consequently, fewer multiple-unit housing will be demanded.

Real rent is found to be positive but insignificant in the demand for multiple-unit housing. Within the range of real rents which have been used for the analysis, the young and the old groups may be price-takers. No matter what the rent is, they have to live in apartments or townhouses.

Real Family Income and Real Per Capita Income. In the demand for single-unit housing, real family income is found to be positive and significant, indicating that as real family income rises, more people can afford single-unit housing, and as a result, more single-unit housing units will be demanded. Real per capita income is shown to be negative but insignificant in the multiple-unit housing demand relationship. For the affected groups, the young and the old groups, perhaps the income constraint is not a significant factor in influencing their decision in choosing multiple-unit housing as their mode of housing.

Other Variables. The estimated coefficients of the period difference dummy variable, is found to be statistically significant in Equation 1 and insignificant in Equation 2. City sizes are found to be insignificant in both equations.

Estimation of Demand for Other Land Uses

Based on the assumption made at the beginning of the section that a city's percentage distribution of land uses does not change significantly over the years, demand for other land uses, besides residential use, can be estimated. Each type of land use should experience the same percentage change as the total residential land use obtained in the first part of the model structure. If residential land use is estimated to increase by ten percent by the target year, commercial, industrial, streets and alleys, railroads, parks and recreation areas, and public and semi-public uses, will each increase by ten percent as well. With the availability of current land use data, city officials and planners can, therefore, estimate the magnitudes of the different land uses for the target year.

Accuracy of Demand Model Estimates

Two cities, Dallas and Tyler, are used to test the accuracy of the demand model's estimates. These cities are two of the 28 cities used to develop the estimating coefficients for the model.

Using each city's 1970 population pyramid, projected increase in total population between 1970 and 1980 (used actual increase), 1970 single and multiple housing unit counts, appropriate housing units per acre density factors for each type of housing, a recent land use distribution, and the model's coefficients, the estimated numbers of acres of land in each use in 1980 is calculated for each city. Actual and projected acres of land in each use in 1980 are obtained from SDHPT documents. The SDHPT documents [8,9] do not describe a specific procedure that is used to make the land use predictions.

The estimating errors resulting from using the TTI and SDHPT procedures for the two cities are calculated and shown in Table 6. The TTI procedure yields overall errors of 20.2 percent for Dallas and 16.8 percent for Tyler; whereas, the SDHPT procedure yields overall errors of 39.5 percent for Dallas and 1.8 percent for Tyler. Hence, the TTI procedures yields errors of similar magnitudes for the two cities (one large and one small), but SDHPT procedure yields errors of very different magnitudes. The average total error for the two cities is 18.5 percent for the TTI procedure and 20.7 percent for the SDHPT.

The TTI procedure yields only one error above 30 percent for a specific land use, but the SDHPT procedure yields six errors above that level. So, in conclusion the TTI procedure yields errors that are smaller and more nearly the same magnitude than does the SDHPT procedure.

Application of Demand Model Estimates

From the outputs of the the demand model, officials of a city should be able to estimate demand for land in various uses in a future year. Elasticities of the various age groups, which turn out to be statistically significant in the above model estimation process, for each type of housing tell the percentage change in the number of a particular housing type for a one percent change in population of the significant group (or groups). Based on a current population pyramid, together with a population projection, officials should be able to estimate percentage changes in the population of various age groups.

Table 6. Percentage Errors of Estimation for TTI and SDHPT Procedures by Type of Land Use

Land Use	Estimation Errors (%) Dallas TTI Procedure[a]	Dallas SDHPT Procedure[b]	Tyler TTI Procedure[c]	Tyler SDHPT Procedure[d]
Residential	+18.7	+45.0	+19.8	+6.8
Commercial	+10.4	+11.8	-12.6	-72.6
Industrial	+17.5	+56.3	+28.7	-43.6
Streets & Roads	+20.3	e	+27.6	+1.5
Parks and Recreation	+28.9	e	-43.1	-191.6
Public and Semi-Public	+27.2	+33.2	+17.2	-10.6
Total Developed	+20.2	+39.5	+16.8	+1.8

[a] 1980 land use estimated for Dallas with 1970 population pyramid and compared with 1980 (extrapolated from 1970, 1975 and 1978 data) historical data for Dallas.

[b] 1980 land use estimated for Dallas county using 1964 historical data and 1985 projections compared to 1980 (extrapolated from 1970, 1975 and 1978 data) historical data for city of Dallas.

[c] 1980 land use estimated for Tyler with 1970 population pyramid and compared with 1980 historical data.

[d] 1980 land use estimated for Tyler using 1964 historical data and 1985 projections compared with 1980 historical data.

[e] Added to public and semi-public.

The total percentage change in the number of each type of housing is obtained by multiplying the respective elasticities by the percentage change in population of the affected age group(s). If more than one age group are significantly influential in a particular housing type, the percentage change in the number of a specific housing type needed by each age group is first estimated. The summation of the percent age changes in the number of this type of housing needed by all the groups should yield the total percentage change in the number of a specific housing.

With the current city data of housing available, the total number of units for each type of housing needed for the target year can be calculated. By adopting an appropriate unit factor that is representative of the future housing density for each type of housing, the number of housing units can be converted into acres. The sum of the acres for both single and multiple-unit housing will yield the total acres of land needed for residential use in target year. The same percentage change in acres of residential use can be applied to other land uses, enabling officials to estimate how land will be used to meet all different needs in a future year.

To illustrate the technique described above for estimating the demand for land in various uses, an example is given below. In 1970, a city with a total population of 253,539 and with a population pyramid as shown in Figure 3, is faced with the problem of estimating the demand for various land uses in 1980. The projected population growth rate is about 36.3 percent during that period. The period of ten years shifts the population pyramid by two age groups as indicated in Figure 3. The 5-9 years old group in 1970 with a population of 22,609 would become the 15-19 years old group in 1980. In addition the 36.3 percent growth rate is assumed to be experienced uniformly by each age group. Therefore, the projected population of the 15-19 years old group in 1980 should actually be 30,816 [22,609 x (1 + 36.3%)].

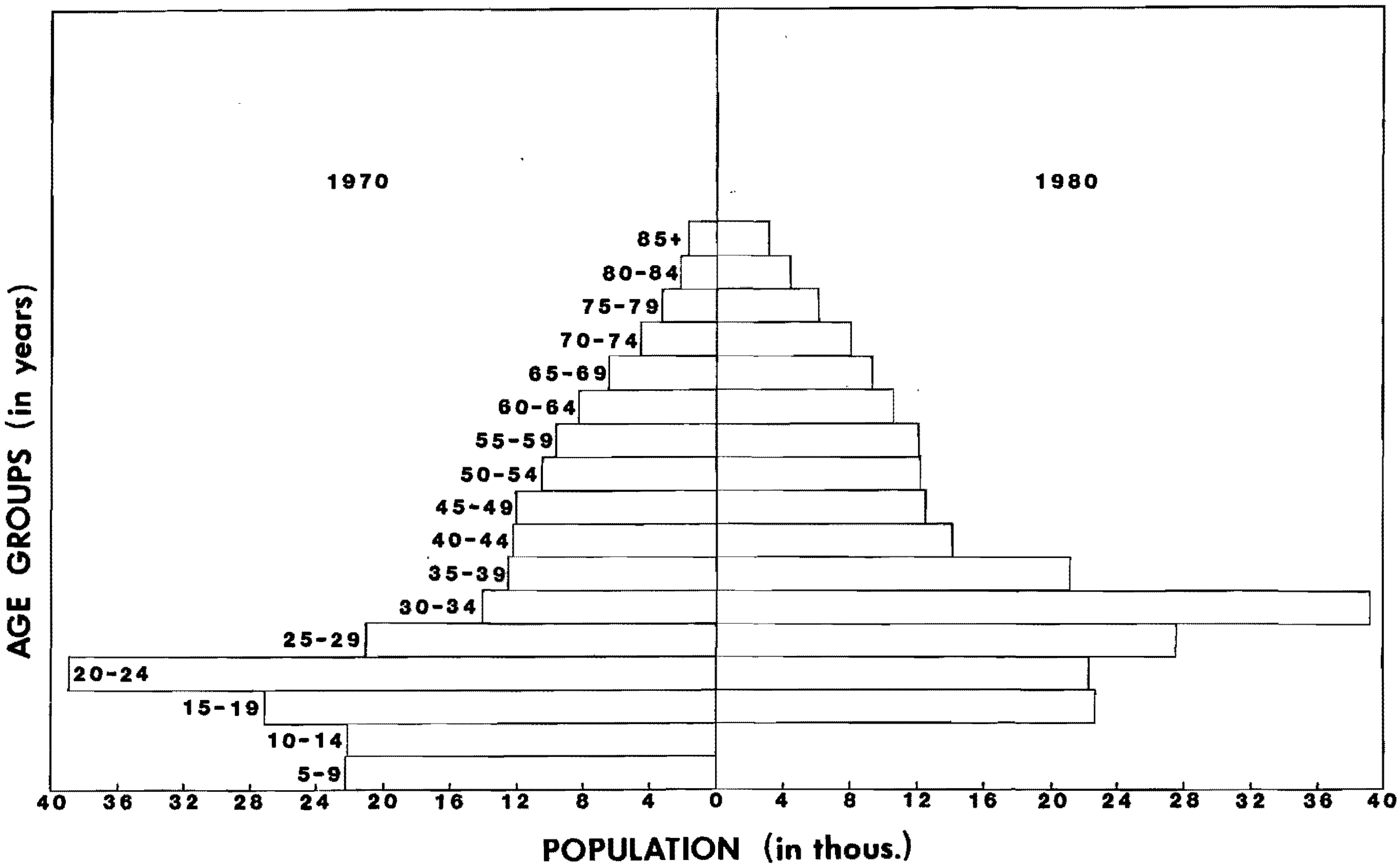

Figure 3. Population Pyramid of Example City for 1970 and 1980

According to the three age groups defined in the study, the young, middle-aged and old groups had populations of 27,715, 139,868 and 17,663 in 1970, respectively, and by 1980, the population for the corresponding groups should be 30,816, 247,924 and 43,131 reflecting both the shifts in the population pyramid and the projection of the growth rate. In other words, the young, middle-aged and the old groups would experience population changes of 11.19 percent, 77.26 percent, and 144.19 percent, respectively.

The elasticity coeefficients obtained from the model that estimates single-unit housing and shown in Table 4, are 0.88 and 0.072 for the middle-aged and old groups, respectively, giving rise to changes in demand for single-unit housing in 1980 of 67.99 percent (0.88 x 77.26%) and 10.38 percent (.072 x 144.19%) by the corresponding groups with population changes calculated above. In response to the population changes by the two groups, a total change in the demand for single-unit housing is represented by the sum of the changes in the demand by the two groups for this housing type, which would amount to 78.37 percent (67.99% + 10.38%).

By following a similar manipulation and by adopting the set of estimated coefficients for Equation 2 (Table 5), changes in the demand for multiple-unit housing by the young and the old groups would be 10.52 percent (0.94 x 11.19%) and 125.01 percent (0.867 x 144.19%), respectively. The total change in the demand for multiple-unit housing would be 135.53 percent.

Therefore, with the 1970 acreages for single-unit and multiple-unit housing reported to be 9,520 and 1,986 acres, separately, the 1980 acreages for the two housing types estimated would be 16,946 (9,520 x (1 + 78.37%)) and 4,667 (1,986 x (1 + 135.53%)) acres, correspondingly. In turn, they represent a total increase in demand for residential acreage of 10,107 acres or 87.8 percent.

By the basic assumption of unchanged percentage distributions among land uses over the years, the other land uses would have the same percentage increase by 1980. Therefore, commercial acreage would increase from 1,320 acres in 1970 to 2,482 acres in 1980 and industrial use from 2,250 acres to 4,230 acres, each representing an increase of 87.8 percent. The same percentage change is applied to all the other land use categories in the land use distribution. Table 7 shows the distribution of land uses in the example city in 1970 and the estimated demand for land in various uses in 1980, as indicated by the model.

Table 7. Land Uses in Example City Reported for 1970 and Estimated for 1980

Land Use	1970	1980
	- - - - Acre	- - - -
Residential		
Single-Unit	9,520	16,945
Multiple-Unit	1,986	4,667
Total Residential	11,506	21,612
Commercial	1,320	2,481
Industrial	2,250	4,230
Railroads and Utilities	500	939
Streets and Alleys	10,430	19,579
Parks and Recreation	2,050	3,849
Public and Semi-Public	1,570	2,948
Total Developed	29,626	55,638

DEMAND FOR TRANSPORTATION FACILITIES

Future development of a city depends mainly on its population growth. As demonstrated in the above demand model for land uses, population growth of the various age groups dictates to some extent land uses of the city. Meanwhile it is believed that transportation facilities are also influenced by how land is used in an area. A densely populated neighborhood with mostly apartments and townhouses has transportation needs different from those of a neighborhood which is sparsely inhabited. A high traffic volume generator such as a shopping mall or an office building, may require transportation facilities different from those by an industrial park. Therefore, various land uses pose different effects on travel, and findings of these effects are essential in transportation planning.

Traffic assignment models have been used extensively by city planners and officials to estimate and assign traffic volumes to existing and planned transportation facilities in areas which may face the largest growth. Most of these models include specific variables such as traffic generators, trip purposes, trip length, speed and delay which invariably require field surveys to provide the necessary data. In this study, attempts are made to provide these officials with a simpler model of demand for transportation facilities which are defined here as auto-related or transit-related, by utilizing the more readily accessible census data. Transportation demand can be measured in vehicle-miles. By sacrificing the comprehensiveness that other models offer, the proposed model promises a rough but quick estimate of the demand for transportation facilities by the relevant land uses. It is hoped that this model can be used by officials during the initial transportation facilities planning stages.

Basic Assumption

One basic assumption is necessary in order to relate transportation facilities to land uses. It is assumed that the housing characteristics of a city in relation to possession of automobiles remains unchanged over the study period. In other words, the ratio of the number of households with automobiles to the number of households without automobiles is constant over the years. If there is any foreknowledge of a change in these characteristics, adjustments should be made to take into account the expected change.

Structure of Transportation Demand Model

The demand for transportation facilities by land uses is separated into demand for automobile vehicle-miles made by automobile users and demand for transit vehcile-miles made by transit users. Whether the automobile users are carpoolers or not is not considered in this simple transportation demand model. Similarly, the present study does not distinguish among the transit vehicle-miles made by the different transit modes. Because of limitation of data available, it is concluded that separating the demand for transportation facilities by land uses into the demand for the two major modes--auto and transit--represents the best possible solution if a simple model is to be desired.

Also, the model concerns itself only with vehicle-miles attracted by residential and commercial land uses. The major reason lies with the fact that data on other land uses are not readily available. Also, these two types of land uses constitute the majority of trips made. A recent survey taken in Houston, Texas [7] indicates that residential land use attracted 52.9 percent of all internal person trips while commercial land use attracted 22.5 percent. Together these two land uses attracted over three-forths of all person trips made in the zones surveyed.

Estimation of the Relationship Between Automobile Vehicle-Miles and Land Uses

The majority of person trips are made by automobiles. In the above mention survey, over 90 percent of the person trips were made by persons either as drivers or as passengers of automobiles. Reports by other Texas cities reveal similar dominant uses of automobiles [5, 10]. If the total vehicle-miles by automobiles can be estimated for a target year, city officials can then make plans to provide facilities to accommodate these vehicle-miles, either by widening, extending the existing roads or by building new roads. An adequate transportation system can avoid congestion which indirectly increases user costs.

An attempt is made to relate automobile vehicle-miles needed to family income, residential land use and commercial land use. An equation in log-log functional form can be used to express these relationships as follows:

Equation 3:

$$\log(\text{Auto Vehicle-Miles}) = f[\log(\text{Family Income}), \log(\text{Residential Land Use}), \log(\text{Commercial Land Use})].$$

Each of the variables included in the above equation is discussed separately below.

1. Automobile Vehicle-Miles - Total annual vehicle-miles traveled by automobiles on all types of roads, arterials, collectors and local, represent the variable of automobile vehicle-miles.

2. Residential Land Use - For residential land use, the number of dwelling units with one or more automobiles is used. If this number increases, more person trips from home or to home will be made; consequently more automobile vehicle-miles will be made. Therefore, a positive sign for this variable is expected.

3. Commercial Land Use - Since actual commercial land use data are difficult to obtain, a proxy consisting of two items which are believed to best represent commercial land use; is used. One is the total sales of retail trade of all establishments which include businesses such as food stores, automobile dealers, general merchandise stores, eating and drinking places, gasoline service stations, furniture, home furnishings and equipment stores, building materials, hardware, farm equipment dealers, apparel and accessory stores and drug stores and property stores. The other item that constitutes commercial land use is total receipts for selected services of all establishments which include hotels, motels, and camps, automobile repair and services, and amusement and recreation including motion pictures. Both items are expressed in 1,000 dollars.

It is believed that, in general, larger sales or receipts mean more purchases of goods and services which, in turn, require increased movements of goods and services, either by the customers themselves, or by delivery people. Automobile vehicle-miles should, therefore, be positively related to the commercial land use.

4. Family Income - Family income is found to correlate with the number of automobiles a family owns [3]. Families with higher income tend to own more automobiles. The more automobiles households own, the more vehicle-miles they will make. Family income, as a result, is an important variable in determining the demand for automobile vehicle-miles. Median family income is used for this variable.

Estimation of the Relationship Between Transit Vehicle-Miles and Land Use

What prompts people to use transit is a complex question. The results of several studies [11, 12, 13] have concluded that fares do not affect users' decision to take transit as much as the combination of fares and the quality of service does. Complications arise when the elements indicating the quality of service are multiple and complex. One of the most important elements seems to be time. The quality of a particular transit service often is determined by punctuality, transfer time, overall travel time, and so on. However, the value of time to a person varies from person to person, for example, an extra five minutes' delay of the bus may not be that important to a retired person but may prove to be most unacceptable to a businessperson. All in all, it is difficult to define uniformly good transit service.

For the above reasons together with the limitation on data available, the present model is limited to looking at transit demand of the transit-captive households who do not have their own automobiles. For these households, transit is the only means of transportation available to them, and quality of transit service becomes irrelevant to them. Consequently, by focusing on such households, variables derived from defining the quality of service can be avoided; instead, the only motive for using transit is assumed to be financially related.

The model attempts to relate transit vehicle-miles to land uses by expressing transit vehicle-miles as a function of family income, residential land use and commercial land use. A log-log function is chosen for use which can be expressed as follows:

Equation 4:

$$\text{Log(Transit Vehicle-Miles)} = f[\text{log(Family Income), log(Residential Land Use), log(Commercial Land Use)}].$$

Variables included in the model are discussed separately below.

1. Transit Vehicle-Miles - Transit vehicel-miles represent the total annual vehicle-miles traveled by all types of transit modes, expressed in 1,000 vehicle-miles.

2. Family Income - In the earlier discussion, it is indicated that the number of automobiles owned by a household is generally dependent on the family income of that household. For families with one or more automobiles, alternatives for transportation are available to them, and they are less dependent on transit, whereas families without any car depend heavily on transit for their traveling needs. In other words, the higher the family income, the less transit vehicle-miles are needed. Therefore, a negative sign for this variable is expected. Again, median family income is used to represent this variable.

3. Residential Land Use - To represent residential land use, the number of dwelling units without any automobile is used. Arguments for using this variable are given above and hence are not repeated here.

4. Commercial Land Use - Commercial land use attracts not only automobile traffic but also traffic generated by transit. Sales of all establishments of retail trade and receipts from all establishments of selected services described previously, are used to represent commercial land use.

Determination of Coefficients

In order to estimate the coefficients of the two equations in the transportation demand model, appropriate data on all the independent variables are obtained from the United States Bureau of Census' 1972 County and City Data Book. Data on vehicle-miles are taken from the 1974 National Transportation Report, an Urban Data Supplement published by the United States Department of Transportation. The above data are obtained from eighteen Texas cities varying in sizes such as Houston, Dallas, Abilene, Laredo and Tyler.

Use of the log-log equations yield coefficients that are also elasticities. The OLS estimation procedure is used on the data to estimate these elasticities and determine their statistical significance.

The results of the estimation of Equation 3 and 4 are presented below for each variable used in the two equations. The estimated coefficients with their t-ratios and the R^2's for each equation are summarized in Tables 8 and 9, respectively.

Family Income - As expected, family income is found to be positively related to automobile vehicle-miles but negatively related to transit vehicle-miles, although in both cases, the statistical test of significance fails to pass at confidence level of 90%.

Residential Land Use - The number of housing units with one or more automobiles is shown to have a positive but insignificant effect on the demand for automobile vehicle-miles while the effect of the number of housing units without a car on transit vehicle-miles is positive and significant. The positive sign of the estimated coefficients of the residential variable indicates that as the number of housing units (with or without a car) increases more vehicle-miles of the corresponding type of transportation are needed.

Table 8. Estimation Results of Equation 3

Variable	Coefficients	t-Ratio
Family Income	.1211	.60
Residential - Number of housing units with one or more autos	.2521	.65
Commercial - Sales and Receipts	.9155*	2.32
Intercept	-1.7822	-.93
R^2	.9797	

* Significant at 5 percent level.

Table 9. Estimation Results of Equation 4

Variable	Coefficients	t-Ratio
Family Income	-.9053**	-1.56
Residential - Number of housing units without autos	1.0545*	2.71
Commercial - Sales and Receipts	.4731	1.16
Intercept	-.3773	-.08
R^2	.9165	

* Significant at 5 percent level
** Significant at 10 percent level

The significant estimated coefficient of the residential land use variable in the equation estimating transit vehicle-miles can be interpreted that for a one percent increase in the number of housing units without a car, the demand for transit vehicle-miles will increase by 1.0545 percent. Because of the insignificant coefficient obtained in the estimating Equation 3, exact percentage changes between housing units with one or more cars and automobile vehicle-miles cannot be verified. This insignificant relationship may be due to use of imperfect data. However, economies of scale could play some part in the results. As an area gets more dense, people do not have to go as far to fulfil their travel needs, and as a result, less vehicle-miles per household are needed, even though total vehicle-miles for all households are more.

Commercial Land Use - Commercial land use as expressed by the total sales of all retail trades and receipts of all selected services is found to be positively and significantly influential in the demand for automobile vehicle-miles. An elasticity coefficient of 0.9155 is obtained which indicates that a one percent rise in commercial land use will generate 0.9155 percent more automobile vehicle-miles. The estimated coefficient of this variable turns out to be positive but insignificant in the demand model for transit vehicle-miles, indicating that commercial land use perhaps does not draw a significant amount of transit vehicle-miles. These findings are consistent with those estimated by Kern and Lerman [14] who formulated a model equating retail sales as a function of transit access, auto access, income level, number of white collar workers and a lag sales variable. They found the effect of transit access on retail sales as a function of transit access, auto access, income level, number of white collar workers and a lag sales variable. They found the effect of transit access on sale to be negative and insignificant while the elasticity of sales with respect to auto access is 0.653.

Application of Transportation Model Outputs

From the results of the land use demand model presented in the previous section, the percentage changes in residential and commercial land uses over any study period are obtained. These percentages multiplied by the appropriate elasticities estimated above, will enable city officials to estimate the amounts of automobile and transit vehicle-miles generated by the increases in demand for these land uses.

For example, the same city described in the example in the previous section is used again. The percentage change in automobile vehicle-miles between 1970 and 1980 is estimated by multiplying the elasticity coefficient of 0.9155 for the commercial variable in Equation 3 by the predicted increase of 87.8 percent in commercial land use between 1970 and 1980. The result of this calculation (.9155 x 87.8%) yields a predicted 80.38 percent increase in automobile vehicle-miles.

The percentage change in transit vehicle-miles between 1970 and 1980 is estimated by multiplying the elasticity coefficient of 1.0545 for the residential variable in Equation 4 by the predicted increase of 87.8 percent in residential use between 1970 and 1980 and then multiplying that total by 1/19, which is the ratio of the total number of housing units to the total housing units without automobiles in 1970. The result of this calculation [1/19(1.0545 x 87.8%) yields a predicted 4.63 percent increase in transit vehicle-miles. In using this procedure, one must assume that the ratio of total housing units to total housing units without automobiles (1/19) remains constant between 1970 and 1980.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

As expected, housing demand is found to be age related. From the estimation results of the demand equations for single housing and for multiple housing, it is revealed that the middle-aged group is significantly responsive to the single housing, with elasticity of 0.8802, as compared to a significant elasticity of 0.0719 for the old group. Meanwhile, the young and the old groups are found to be positively and significantly related to multiple housing with elasticities of 0.9909 and 0.7138, respecitvely. Although period differences are found to play a significant role in the demand for single housing, city size is found to have no effect on either type of housing.

Percentage changes in both types of residential land uses from a study year to a target year represent the total percentage change in demand for housing as estimated by adopting the appropriate elasticities and the expected population of the influential groups. Percentage changes in other land uses are assumed to be the same as that in residential use.

As to relating land uses to transportation needs, only residential and commercial uses are studied since these two land uses attract a major portion of all person trips. Two equations are formulated for this model. The first one expresses automobile vehicle-miles as a function of family income, number of housing units with one or more cars and sales of all retail trades and receipts for all selected services. The second one expresses transit vehicle-miles as a function of family income, number of housing units without a car and sales of all retail trades and receipts for all selected services. In both equations, the second independent variable represents residential land use while the last variable serves as proxy for commercial land use.

Results indicate that commercial land use is significantly related to automobile vehicle-miles with an elasticity of .9155. However, residential land use has an insignificant effect on automobile vehicle-miles. For transit vehicle-miles, the reverse is true. Residential use is significantly related to transit vehicle-miles, with an elasticity of 1.0545 while commercial shows no significant effect on transit vehicle-miles.

Although the results obtained are not as complete as some other models offer, the proposed models do provide a fast and rough estimation on future land uses and transportation needs. It is hoped that they can serve city officials (especially those of small cities) in their initial planning without having to spend considerable amounts of time and funds.

Recommendations

The proposed age breakdown for the young age group (15-19 years old) seems to be rather narrow. The meaningful results obtained may reflect the trend of the 1960's and the 1970's when young people after leaving their parental home established their own households in multiple housing. It would be interesting to see if the age of this group has changed by the 1980's. For economic or social reasons, perhaps, those in the lower range of the middle-aged group may be forced into choosing their housing needs as the young group does. Therefore, they might have to be removed from the middle-aged group and included in the young age group.

Also, it is believed that with the inclusion of the 1980 census and a larger sample of data on vehicle-miles by city, the results of the transportation demand model could be improved.

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