# REGIONAL LAND USE AND ENERGY MODELING



BNL-21809

A.S. Kydes, J.B. Sanborn, T.O. Carroll
Department of Applied Science
Brookhaven National Laboratory
Upton, New York USA

CONF-761122--1

## Summary

The task of searching for and selecting strategies and measures which will bring about energy conservation vis-a-vis land use becomes that of understanding and defining the relationships between sets of possible land-use activities in a given region and the resultant energy end-use demand. The outcome of the search is the determination of the relative impact of such strategies and measures upon both the regional and national energy systems.

In this paper we present a brief review of our overall approach and results to date and discuss the land-use energy utilization model currently being used.

## I. Introduction

Virtually every current study of the energy problems of this country has concluded that energy conservation is not only the key to ameliorating our short-term energy supply problems but is also a necessary condition for a satisfactory medium and long-term energy supply and supply-demand situation.

There is no doubt that major reductions in future regional energy expenditures can be achieved through the propitious allocation and configuring of land-use activities. Studies of energy consumption in Sweden, for example, lend support to the concept that energy-conserving land-use patterns are intrinsically tied to higher density and to more intimate juxtaposition of residential, commercial and industrial activities.[1]

Among the most important driving forces for defining the final character of land-use activities are the basic development goals of the region. The function of the land-use model is to allocate land-use activities both spatially and among major land-use categories in a manner that is consistent with regional development goals and the constraints imposed by regional preferences.

Once a starting set of projected land-use activities is obtained, one can begin to estimate the projected total energy end-use demands for the region in question by utilizing the so-called energy intensity factors which are associated with each of the activities included in the projected set. The characterization and level of aggregation of these energy intensity factors, in addition to satisfying a number of practical criteria must, of course, take into account the limited domain of influence of planners and policy makers. The process of searching for and selecting strategies and measures designed to bring about energy conserving land-use practices reduces to that of assessing their effectiveness in intervening in the land-use energy-utilization system.

## II. Model Formulation

The land-use energy-simulation model with the integrated capability for generating energy demand is an extension of the classic Lowry model.[2] Such a model framework captures two essential features of the land-use energy-utilization interaction: (1) the spatial location of land-use activity is explicit, and (2) transportation energy demand is determined as an integral part of the spatial configuration. The model is divided both conceptually and computationally into three parts: the land-use model, a submodel for transportation which provides the work and shop trip distribution for spatial allocation of activities within the land-use submodel, and an energy submodel which determines energy demand resulting from the land-use configuration. Regional growth in the model is predicated upon a site-specific employment base called "basic" industry and a representation of the transportation infrastructure. The region is divided into tracts, and for basic industry, the employment and acreage are specified for each tract. Using a trip distribution function derived from the transportation network, which measures preference for travel in the region, a residential population is spatially allocated consistent with industrial employment opportunities. Retail and other commercial activity measured by employment opportunities is also spatially distributed through use of the characteristics of the transportation network for residential-commercial travel. Zoning and measures of agglomeration are expressed as constraints upon location of activities in specified tracts.

The model is adapted to the determination of energy demands in several important respects. The residential sector is disaggregated into types of housing within old and new housing stocks for which energy demands differ significantly. This facilitates examining the impact of the single/multi-family housing mix. A linear program is utilized to establish the housing mix in each tract, in which the objective function expresses preferences for each type of housing in the tract and the constraints reflect zoning restrictions and land availability. Commercial sector energy is similarly associated with different types of retail activity. Industrial sector energy is determined through basic industrial employment in the region.

Transportation energy is determined directly in the model. Since the actual spatial allocation is tempered by zoning and agglomeration factors, the resulting land-use configuration reflects the "constrained preferences" of residents with respect to travel. Modal split may be integrated into the model through specific grid assignments with altered trip distributions representative of accessibility to alternative modes of travel. Overall, the spatial land-use configuration both determines and is determined by the transportation network so that travel patterns and associated energy demand are explicit.

### Land Use Submodel

The development of a land-use configuration within the submodel is straightforward. To begin, the region of interest is subdivided into smaller parcels of land called "tracts" which, for good resolution and compatibility with the local shop trip distribution function, should be taken to be approximately one to two square miles in area.

Total employment in tract i, $E_i$, is the sum of basic employment, $E_j^B$, plus commercial employment, $E_j^{c_K}$. Three types of commercial employment are differentiated to reflect the different travel patterns and economies of scale required. Initially, there is no commercial activity in the tracts so that $E_j^{c_K} = 0$ for every

# DISCLAIMER

commercial type, and all employment in the tracts consists completely of basic industrial employees. In the general case, however, total employment is given by:

$$E_i = \left(\sum_{K=1}^{N} E_i^{c_K}\right) + E_i^B \tag{1}$$

Employment in tract i creates a need for residential units in tract i and surrounding tracts. The number of households generated in tract j as a result of employment in tract i is $g\ E_i T_{ij}^W$ where g is a normalization constant and $T_{ij}^W$ is the work "trip index" which measures the propensity for travel from residential sites in tract j to work sites in tract i. For the moment, we need only note that the trip indices $T_{ij}^W$'s are decreasing functions of the distance between tracts i and j which results in a decrease of residential units in tracts more remote from employment opportunities. The accessibility of tract j from all work sites gives households:

$$H_j = g \sum_{i=1}^{N} E_i \cdot T_{ij}^W \tag{2}$$

where N is the total number of tracts in the region and $H_j$ represents the number of households that would prefer to locate in tract j. However, zoning restrictions act to limit the maximum household density achievable in each tract to

$$H_j \le A_j^H Z_j^H \tag{3}$$

where $A_j^H$ is the area available for residential use in tract j and $Z_j^H$ is the maximum household density to be permitted for tract j. If this residential zoning constraint were to be violated by the number of households which would prefer location in a tract, then the number of households, $H_j$, is set to the maximum permitted by Eq. (3) and the excess households are redistributed subject to (a) work travel preferences ($T_{ij}^W$) and (b) the amount of residential land remaining vacant in other tracts.

Residential energy demand depends on the housing mix in each tract (single-family detached, single-family attached, multi-family, low rise, high rise). Since these are linked to zoning preferences ($Z_j^H$), a linear programming formulation was used to select the housing mix in each tract. If $H_j$ is the total number of households to be located in tract j and $H_j^m$ (m = 1, 2,3,4,5) is the number of households of structural type m in tract j, then the formal linear programming formulation is given by:

$$\text{Maximize } Z = \sum_{m=1}^{5} h_m H_j^m \tag{4}$$

subject to:

1. Consistent Total Households

$$H_j = \sum_{m=1}^{5} H_j^m \quad j = 1,2,\ \ldots,\ N \tag{5}$$

2. If $q^m$ is the area required for each residential unit of type m, then

$$\sum_{m=1}^{5} q^m H_j^m \le A_j^H \tag{6}$$

3. Zoning restrictions. If each $f_m \ge 0$, then

$$H_j^m \le f_m H_j \quad j = 1,2,\ \ldots,\ N \tag{7}$$

where, for feasibility, we require

$$\sum_{m=1}^{5} f_m \ge 1 \tag{8}$$

The coefficients in the objective function, $h_m$, may be designed to favor low density housing or to optimize any other linear utility function involving the number of households of each structural type. Once the proportions of different housing types are established, energy intensity factors may be applied to establish energy demand.

The market activity for commercial services of all types is generated by both home-based and work-based shopping trips. Work-based shopping trips are assumed to be walking trips which occur only within the tract of employment. Commercial employment to support households in tract i is again determined by a trip index $T_{ij}^{c_K}$, so that employment in tract j is

$$E_j^{c_K} = b^{c_K}\{d^K E_j + c^K \sum_{i=1}^{N} H_i \cdot T_{ij}^{c_K}\} \tag{9}$$

$$K = 1,2,3$$

where $b^K$ is a normalization constant. The parameters $c^K$, $d^K$, which indicate the relative importance of home-based shopping trips and work-based shopping trips, respectively, satisfy $c^K + d^K = 1$. The total employment in the region of retail type $c_K$ is assumed to be proportional to the total number of households in the region:

$$E^{c_K} = a^{c_K} H \tag{10}$$

The commercial employment of type $c_K$ in tract j as given by Eq. (9) is required to satisfy two additional conditions. First, a sufficiently high level of employment for retail type $c_K$ is required in a tract to make the existence of that retail type profitable. This agglomeration constraint takes the form

$$E_j^{c_K} \ge Z^{c_K} \quad \text{or set } E_j^{c_K} = 0\ . \tag{11}$$

If $e^{c_K}$ is the area required per employee of retail $c_K$, then the area required for commercial use in tract j is:

$$A_j^R = \sum_{K=1}^{m} e^{c_K} E_j^{c_K} \tag{12}$$

However, the area actually used for commercial purposes in tract j is further restricted by the area actually available for commercial use after unusable land $A_j^U$ and the land required by basic industry $A_j^B$ have been withdrawn, or

$$A_j^R \le r_j(A_j - A_j^U - A_j^B) \tag{13}$$

where $r_j$ is the fraction of available land which is zoned commercial. Values for $r_j$ determine the interspersion of commercial and residential activities. The acreage available for residential use is that which has not been utilized for other purposes:

$$A_j^H = A_j - A_j^U - A_j^B - A_j^R \tag{14}$$

Eqs. (12), (13) and (14) establish a priority on land use: basic industry has first priority, followed by commercial and finally residential activity.

Regional conditions on employment and total numbers of households are used to establish the normalization constants g and $b^{c_K}$ in Eqs. (2) and (9). The total number of households is the product of the inverse of the regional labor force participation rate f and the total employment,

$$H = \sum_{j=1}^{N} H_j = f \sum_{j=1}^{N} E_j \quad . \tag{15}$$

## Transportation Submodel

The transportation submodel serves two purposes. First, it provides the "trip indices" $T_{ij}^W$ and $T_{ij}^{c_K}$ to the land-use model [Eqs. (2) and (9)] for use in the spatial allocation of residential sites relative to employment centers, and of commercial activity relative to residential development. Second, it uses the spatial distribution of residences, employment, and commercial activity to compute vehicle mileage for work and shop purposes.

The trip indices $T_{ij}^W$ and $T_{ij}^{c_K}$ express the aggregate preference for travel between tracts i and j and depend upon the accessibility or difficulty of travel between these tracts. They are calculated on the basis of trip distribution function f reflecting the fact that fewer people will travel to tracts less accessible from their place of work or residence.

In the original version of the Lowry model, the trip indices $T_{ij}^W$ and $T_{ij}^{c_K}$ are functions only of the distance $d_{ij}$ between tracts i and j, that is

$$T_{ij}^W = f^W(d_{ij}) \tag{16}$$

$$T_{ij}^{c_K} = f^{c_K}(d_{ij}) \quad K = 1,2,3 \tag{17}$$

The functions $f^W$ and $f^{c_K}$ take the form of inverse polynomials, of the form

$$F^W(x) = \frac{1}{2\pi x} \left(C^W + B^W x + x^2\right) \tag{18}$$

where the constants $C^W$ and $B^W$ are calibrated using empirically derived trip-length data.

The computation of work-trip and shop-trip mileage is done within the context of the land-use model and is conceptually straightforward. Travel is assumed to occur over a uniform network of local roads, overlaid with a system of high-speed limited-access highways or mass transit. People are assumed to take the shortest time-path between any two points. Initial data to this portion of the submodel consists of the grid coordinates of the centroids of all tracts. Time-of-travel between pairs of tracts is initially defined as distance times the average local road speed. Highways are then introduced by reducing time-of-travel between pairs of tracts accessible to the highway or transit system. A modified Floyds algorithm is used to compute shortest-time paths between all pairs of tracts along with the associated distance.

Since the land-use model creates for each employment site a spatial distribution of residential housing around that employment site consistent with accessibility and zoning conditions (Eqs. 2 and 3), the home-to-work distances are known explicitly.

Eq. (2) implies that the number of employees working at i and living at j is

$$P_{ij} = (g/f)E_i T_{ij}^W \ . \tag{19}$$

The total daily, one-way work-trip passenger-miles from i to j is then

$$PM_{ij} = d_{ij}(g/f)E_i T_{ij}^W \tag{20}$$

where $d_{ij}$ is the distance (calculated as above) between tracts. The total work-trip mileage yearly is then

$$V^W = \frac{2m^W}{fp} \sum_i \sum_j d_{ij} E_i T_{ij}^W \tag{21}$$

where $m^W$ is the number of working days in a year, and p is the automobile occupancy rate for work-trip travel.

Shopping-trip mileage is computed in a slightly different manner from the final distribution of residential and commercial activity. Households are assumed to make a certain number of trips annually for each of the three types of shopping. The lengths of these trips were derived by examining the opportunities for shopping of each type relative to each residential site and dividing the households shopping trips among these opportunities according to their accessibility. If $m^K$ is the number of shopping trips per year per household for type K shopping, and $H_j$ the number of households in tract j, the total number of shopping trips for purpose K from i is $m^K H_i$.

These shopping trips are divided among neighboring tracts which have type K commercial activity (that is, for which $E_j^{c_K} \neq 0$) according to their accessibility. That is, the number of trips from i to j for purpose K is

$$t_{ijK} = \frac{(T_{ij}^{c_K})\ m^K H_i}{\sum_{\ell=1}^{N} T_{i\ell}^{c_K}} \tag{22}$$

The total yearly shopping trip mileage is therefore

$$V^S = \sum_i \sum_j \sum_K d_{ij} t_{ijK} \ . \tag{23}$$

## Energy Submodel

The energy submodel computes the energy requirements of the land-use configuration.

The residential energy consumption in tract j by structural type "m" homes and age group "a" is given by:

$$TR_{ja}^m = H_{ja}^m * G_a^m \tag{24}$$

where $G_a^m$ is the average annual energy required for structural type "m" and age group class "a". The total residential energy in the region due to type "m" homes in age class "a" is the sum over j of $TR_{ja}^m$.

The retail energy consumption is computed in a similarly straightforward manner on the basis of (1) the energy required per square foot of floor space for each retail type and age class and (2) the ratio of site space to floor space for each retail type.

Industrial (basic) energy requirements in each tract are computed using the energy required per "basic" employee of each category (light, manufacturing, synthetics, etc.) of employment.

Transportation energy for each mode and purpose is given by

$$TTE^{P,M} = \sum_{j=1}^{N} \sum_{j=1}^{N} VM_{ij}^{PM} \, t_e^{PM} \qquad (25)$$

where $VM_{ij}^{PM}$ = vehicle miles traversed by mode M purpose P between tracts i and j and $t_e^{PM}$ is the energy required per vehicle mile for purpose P and mode M.

## III. Applications

The computer model was developed as a tool for two specific types of applications. First, specific regions of the country can be analyzed to estimate the energy demands of the region under various growth scenarios. The object here would be to analyze the long term land use and energy implications of changes in residential zoning, commercial restrictions, and basic industrial sitings. In the second case, the computer model is intended to study the generic relationships between energy utilization and "urban form".

The model was calibrated and tested on the Nassau-Suffolk region to gain confidence in the model applicability. The results were heartening in that the model generated distributions which were quite similar to existing data. Figure III.1, comparing the model generated postulations versus the 1970 census, is one typical example. Table III.1 summarizes all land-use category results for the Long Island calibration. The smaller zone numbers indicate zones closer to New York City which, in this application of the model, was treated as a large "basic" work-site with no other useable land.

In this section we describe the preliminary findings of several computer runs of the model which are aimed at exploring the generic relationship between energy demand and "basic" industrial employment dispersion in an urban sprawl situation. The results are suggestive and indicate the need for further exploration with the model before definitive statements can be made concerning the magnitude and direction of the interactions.

The model has been applied to a prototypical region with 675 square miles. The total basic employment in the region was held fixed but the manner in which it was distributed radially around a preselected grid was allowed to vary according to the function

$$E_r^B = E(r_o) e^{-r/r_o} \qquad (26)$$

where r is the radial distance from the central grid and $r_o$ is a constant which determines the dispersion of basic employment in suburban regions. $E(r_o)$ is a constant with respect to r but is selected to obtain the proper total basic employment in the region. If $r_o$ is very large ($r_o \geq 100$ say), then the basic employment approaches the uniform distribution case whereas, as $r_o$ approaches zero the basic employment becomes more concentrated toward the "central business district".

The residential zoning restrictions were held fixed for all runs with a uniform maximum density constraint $Z_j^H$ roughly equivalent to suburban sprawl. Single-family detached, single-family attached and multifamily homes were permitted with a preference for single-family detached homes.

Figure III.2 summarizes the results of 12 computer runs. The dispersion factor ($r_o$) took on three values ($r_o$ = .3, 1.5, 7.5) for each of four populations (0.58 million, 1.15 million, 2.3 million and 5.0 million). Table III.3 summarizes the energy requirements for each case.

Figure III.2 illustrates the complex trade-off between work- and shopping-trip vehicle miles in each case. Centralized employment ($r_o$ = .3) implies that work trip lengths are relatively long whereas shopping trips tend to remain relatively short. For dispersed employment ($r_o$ = 7.5), i.e., where a central region of high basic employment is surrounded by significant levels of dispersed suburban employment, the graphs imply shorter work-trip lengths but longer shopping-trip lengths. The reason for these shifts appears to be a result of the agglomeration constraints. Lower population densities cannot support commercial development except at a limited number of sites. Overall, the greatest vehicle miles per household occurs for the case of some modest suburban employment.

It is useful to examine the total annual per capita consumption. Low, widely distributed populations (.58 million people with $r_o$ = 7.5) require $96.9 \times 10^6$ Btu/person whereas large centralized populations (5 million people with $r_o$ = .3) require $105.2 \times 10^6$ Btu/person. This points to the large potential savings which are achievable through careful choices of land-use patterns in a growing region.

Table III.2 indicates that growth in a region can be accomplished with either increasing or decreasing per capita energy consumption. This suggests that existing communities which are rapidly growing have options over the next 20 years leading to either increases or decreases in per capita energy consumption depending on the selected growth strategy.

## IV. Suffolk County - A Case Study for Year 2000

Since most future growth on Long Island, both in terms of land-use development and population, is expected to take place in the Island's eastern areas, the focus of this case study is to study land-use-energy-interactions under alternative conditions of growth in Suffolk County.

Three regional scenarios were constructed to explore the energy requirements of alternative growth patterns:

- Urban Sprawl (U.S.)
- Comprehensive Plan (C.P.)
- Growth Centers (G.C.).

Continued urban sprawl and the development of large population centers of concentrated land use and economic activity represent opposite extremes of projected future growth in the Nassau-Suffolk region. Their analysis outlines the extremes of energy consumption patterns associated with land use. On the other hand, the comprehensive plan prepared by the Bi-County Commission[4] provides practical guidelines for regional development consistent with environmental and other factors. In each case, overall population and employment projections remain the same, reflecting estimates for Suffolk County growth to the year 2000:

Suffolk Population and Employment (Thousands)

| | Year | |
|---|---|---|
| | 1975 | 2000 |
| Population | 1300 | 2350 |
| Households | 380 | 758 |
| Commercial Employment | 258 | 516 |
| Basic Employment | 178 | 355 |

These alternative land-use scenarios differ primarily in the spatial allocation of basic employment opportunities and zoning constraints imposed upon residential location. A summary of these allocations is given in Table III.3. With few exceptions, all other parameters were carried over to the Suffolk cases from the Nassau-Suffolk calibration runs.

In the urban sprawl case, industrial zoning and residential development is assumed to continue according to the pattern that has clearly developed in western Nassau and eastern Suffolk. Residential zoning constraints were established from 1975 land-use. A tract was considered "developed" if its residential density exceeded 2.5 dwelling units per acre. No further residential development of such tracts was permitted.

Industrial growth in the urban sprawl scenario will follow existing patterns so that the spatial distribution of Suffolk's basic employment force remained unchanged, i.e., internal "basic" employment of Suffolk County in 1975 was simply scaled up to the 355,400 basic jobs required to support a population of 2.35 million.

The second scenario is based on the land-use allocation of the comprehensive plan. Commuting to employment opportunities outside the region will not increase significantly over present levels so that the 1975 commuting patterns remain unchanged. (This implies a large increase in internal basic employment which was allocated mainly to middle and eastern Suffolk industrial zones and are described in the comprehensive plan. These industrial areas have good access to residential clusters and "centers".)

The residential density constraints are computed in a straightforward way to be consistent with zoning and residential densities in the 1985 comprehensive plan data. Land designated as vacant, farmland, or parks and recreation was designated as "unuseable".

The third case represents an extreme case of clustering in which all new basic employment after 1975 is allocated to four "centers". Commutation is assumed to remain the same as in the comprehensive plan above. Residential siting is constrained to 1975 levels except to within a radius of about six miles of these "centers". Tracts near these "centers" have very high residential-density constraints of 15 dwelling units per acre, allowing low- and high-rise construction. These conditions create four large population "centers", or cities, in the region.

The major energy-related results of these runs are summarized in Table III.4. Significant shifts in energy consumption patterns in the transportation sector result from the spatial patterns of basic employment sites in the different growth scenarios. In the urban sprawl case, a large fraction (13% of the work force) must commute from various locations in New York City, more than 20 miles away. The relocation of employment into Suffolk County in the other scenarios not only shortens the work-trip length for those employees whose place of employment has been changed but also for those who continue to commute because of the better availability of housing sites in the western part of the county. For example, the average trip-length for a Queens commuter in the urban sprawl scenario is 35 miles; for the comprehensive plan, it is 25.8 miles. The small reduction in work-trip mileage from the comprehensive plan to the "center's" scenario is significant but not as large as that from urban sprawl to comprehensive plan. Workers employed in the more compact "centers" have shorter trip-lengths than those employed in the industrial corridor of the comprehensive plan.

There is also a significant change in the residential energy consumption caused by the shift away from the single-family homes toward the higher-density types. The housing breakdown in the urban sprawl case is similar to the present breakdown in Suffolk and is clearly a result of the zoning imposed. The change in mix occurring in the comprehensive plan case is a result of clustering. Zoning encourages the emergence of clusters in the appropriate locations. Second, residential areas in the comprehensive plan are easily accessible from employment sites.

Commercial and basic energy utilization were intentionally held constant in these runs in order to effect a clear-cut comparison of other factors associated with land-use development patterns.

Two points are noteworthy regarding the overall savings in energy demonstrated under the comprehensive plan and the continued sprawl scenarios. The first is the large potential savings achievable in the transportation area as a result of the careful interspersion of "basic" employment and residential sites (and zoning). Secondly, the bulk of the savings in both the transportation and residential sectors was achieved within the guidelines of the comprehensive plan and under entirely reasonable assumptions. Finally, although the comprehensive plan was not initially designed to produce savings, it is clear that substantial energy benefits result from the creation of clustered and/or compact residential and commercial sectors if accessible from nearby employment sites.

Acknowledgment

The authors wish to thank the Office of Conservation and Environment of the Federal Energy Administration for their support and Robert Nathans and Philip Palmedo for their advice.

References

1. A. Doernberg, "Comparative Analysis of Energy Use in Sweden and the United States," BNL-20539 (September, 1975), Brookhaven National Laboratory, Upton, New York.

2. S. Lowry, "A Model of Metropolis," Rand Corporation: MR-4035ORC. Santa Monica, Calif., 1964.

3. T.O. Carroll, E. Beltrami, A.S. Kydes, R. Nathans and P.F. Palmedo, "Land Use and Energy Utilization-Interim Report," BNL-20577 (October 1975) Brook-
4. haven National Laboratory, Upton, New York.

4. Nassau-Suffolk Regional Planning Board, "Comprehensive Plan for 1985" (Hauppauge, Long Island, N.Y., 1970).

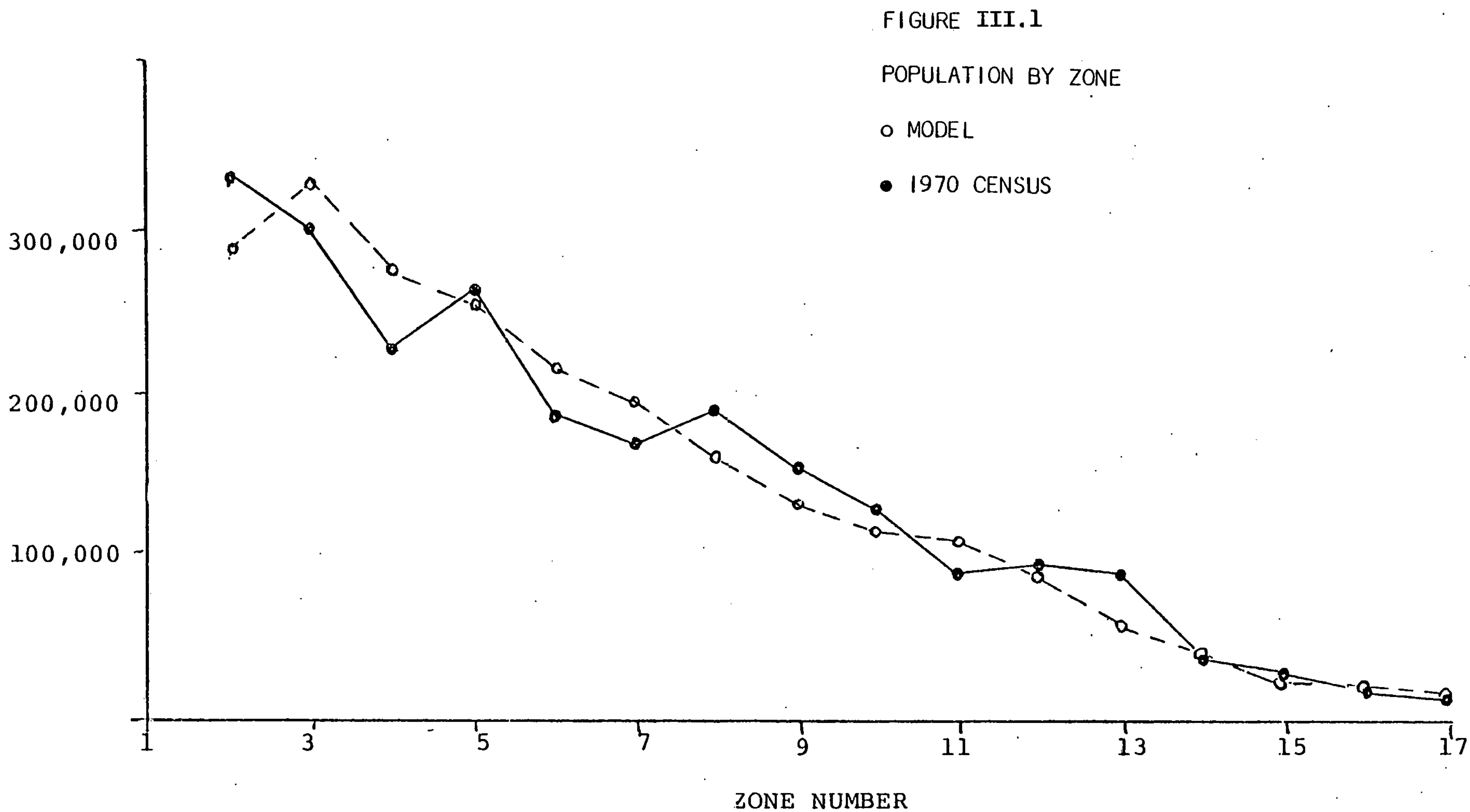
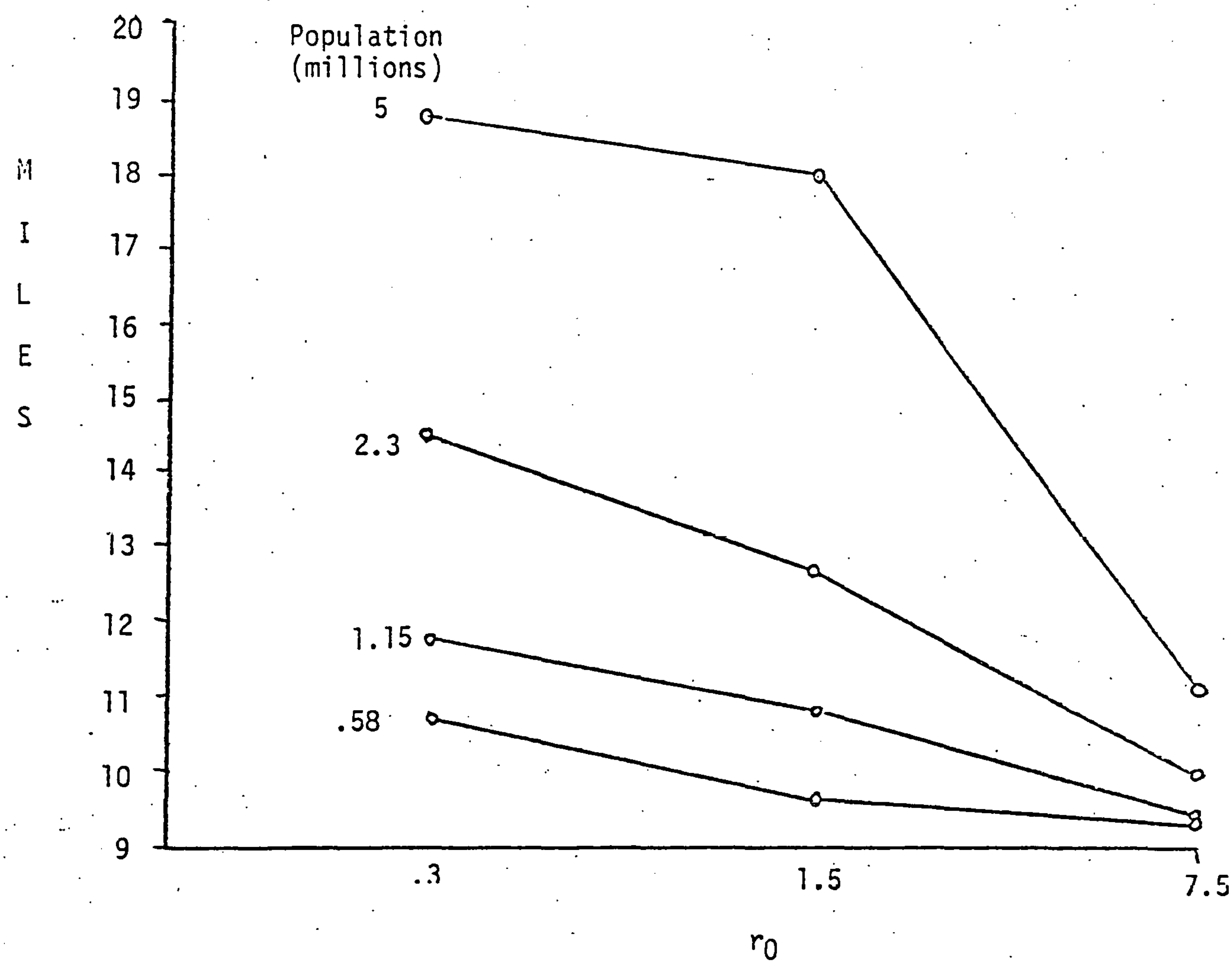


FIGURE III.1
POPULATION BY ZONE
o MODEL
● 1970 CENSUS
300,000
200,000
100,000
1
3
5
7
9
11
13
15
17
ZONE NUMBER

FIGURE III.2

TOTAL DAILY WORK TRIP MILEAGE PER HOUSEHOLD




TOTAL AVERAGE DAILY SHOP TRIP MILEAGE (TYPE 3) PER HOUSEHOLD

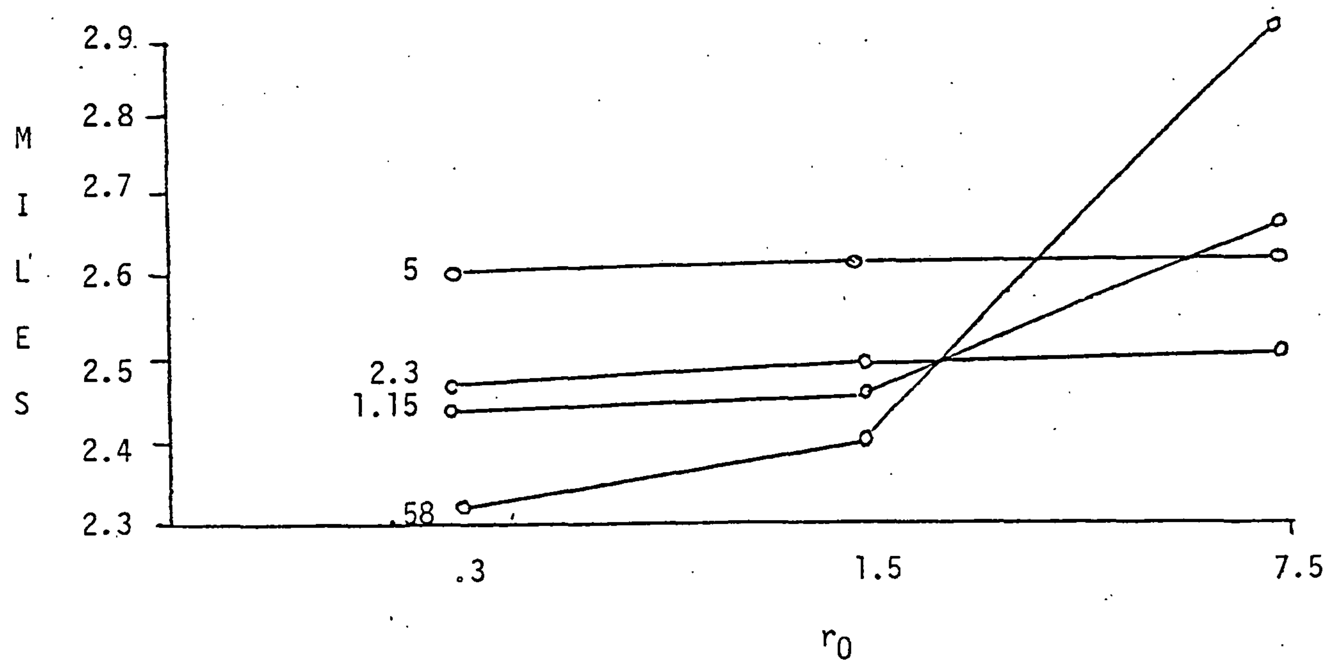


TABLE III.1

Energy Comparisons on Yearly Basis

| LAND USE SECTOR | ENERGY PREDICTED BY MODEL ($10^{12}$ BTU) | ENERGY DERIVED IN REPORT[ ]($10^{12}$ BTU) | % DIFFERENCE |
|---|---|---|---|
| Residential | 89. | 84.1 | +5.5 |
| Basic | 24.6 | 28.9 | -15% |
| Retail | 69.1 | 63.9 | 8% |
| Transportation | 44.1 | 47.1 | -6% |

TABLE III.2

ENERGY PER CAPITA PER YEAR

| POPULATION (millions) | $r_0$ | TRANSPORTATION | RESIDENTIAL | TOTAL |
|---|---|---|---|---|
| 5 | .3 | 32.7 | 32.5 | 105.2 |
| | 1.5 | 31.9 | 32.5 | 104.4 |
| | 7.5 | 23.8 | 32.5 | 96.3 |
| 2.3 | .3 | 25.6 | 32.9 | 98.5 |
| | 1.5 | 24.4 | 33.7 | 98.1 |
| | 7.5 | 20.6 | 33.7 | 94.3 |
| 1.15 | .3 | 23.8 | 34.4 | 97.7 |
| | 1.5 | 22.4 | 34.4 | 96.3 |
| | 7.5 | 20.6 | 35.5 | 96.9 |
| .58 | .3 | 22.8 | 34.9 | 97.7 |
| | 1.5 | 21.2 | 35.1 | 96.3 |
| | 7.5 | 20.6 | 36.0 | 96.9 |

TABLE III.3

Basic Employment Breakdown (Thousands)

| | Urban Sprawl | Comp. Plan | Growth Center |
|---|---|---|---|
| External | 190.0 | 112.1 | 112.1 |
| Internal (Industrial) | 165.4 | 243.3 | 243.3 |
| in 4 "centers" | 9.4 | 20.1 | 170.1 |

TABLE III.4

| | Case 1 (Sprawl) | Case 2 (C.Plan) | Case 3 (Centers) |
|---|---|---|---|
| ENERGY USAGE ($10^{12}$BTU/YR) | | | |
| BASIC | 42.6 | 42.6 | 42.6 |
| COMMERCIAL | 47.1 | 47.1 | 47.1 |
| RESIDENTIAL | 79.9 | 76.0 | 74.8 |
| TRANSPORTATION+ | 78.7 | 56.3 | 53.4 |
| TOTAL | 248.5 | 222.0 | 217.9 |
| PER PERSON ($10^6$BTU) | 105.6 | 94.5 | 92.7 |
| HOUSING BREAKDOWN (PERCENT) | | | |
| SINGLE FAMILY DETACHED | 89.2 | 69.3 | 65.5 |
| SINGLE FAMILY ATTACHED | 3.8 | 5.4 | 6.7 |
| LOW RISE | 6.7 | 19.4 | 20.5 |
| HIGH RISE | .3 | 5.7 | 2.3 |
| PERSONAL TRANSPORTATION | | | |
| DAILY WORK-TRIP DISTANCE* | 35.8 | 23.8 | 22.6 |
| DAILY SHOP TRIP DISTANCE** | 14.8 | 14.6 | 14.4 |
| PERCENT DECREASE FROM CASE 1 | | | |
| RESIDENTIAL | | 4.9 | 6.4 |
| TRANSPORTATION | | 28.6 | 32.3 |
| TOTAL | | 10.7 | 12.3 |

+ does not include social-recreational or truck; auto travel assumed.

* mileage travelled for work purposes on a weekday per household.

** total average shopping mileage daily per household.