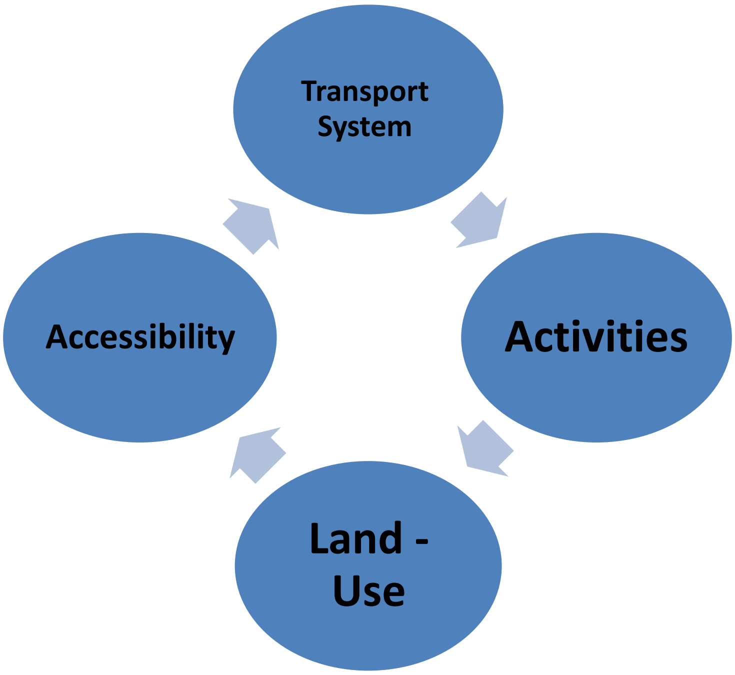
Transport Related Land-Use Models

Land –Use Transport Interaction

- Land development generates travel, and travel generates the need for new facilities, which in turn increases accessibility and attracts further development.
- The question of whether transportation influences land –use (development) or whether land use dictates transportation has been a matter of ongoing concern among transportation professionals.
- Thus, the connection between transportation and land use is a fundamental concept, which needs to be understood clearly, in transportation planning as transportation and land use are inexorably connected.
- Everything that happens to land use has transportation implications and every transportation action affects land use.
- Transportation's most significant impact on land use development and more development generates additional travel.
- Increased access to land raises its potential for development and more development generates additional travel.
- One access has been provided land patterns begin to change over a period of time. The results of these changes are, for the most part, irreversible.

Land –Use transport feedback cycle



Selection of land use Transport Model

A variety of land – use transport models have been developed in the past 15 years. A few of them are research models having excellent capabilities for sensitive forecasting, while some are operational models. The former group of models require extensive data collected through special surveys, whereas the latter need data which are collected routinely by planning departments. The Lowery derivative models fall into the latter group and are very popular.

While selecting the model a number of consideration become important. These are:

1. **Simplicity**: the model should have a simple causal structure, which should be easy to comprehend. A simple model will generally consume less of time and resources.
2. **Modest data requirements**: data requirements must be modest; in fact, some of the good models make use of data routinely available with the planning department.
3. **Adaptability**: the model should be adaptable to any given location.
4. **Comprehensiveness**: the model should be comprehensive and should synthesis the relationship between activities, housing and transportation adequately well.
5. **Operationally and rapidity**: the model should be operational, capable of easy interpretation and should be able to test rapidly a wide range of policy options.
6. **Computer cost**: the model should be operational at relatively cheap computer cost.

1. Lowery Derivative Model

The Lowery derivative models have many of the above attributes. They are simple to use, require modest data, are comprehensive and economical, have good response to change in input variables and have simple causal structure.

They have therefore been used extensively and successfully in a number of studies.

The fundamental structure of the model is illustrated in Figure (1):

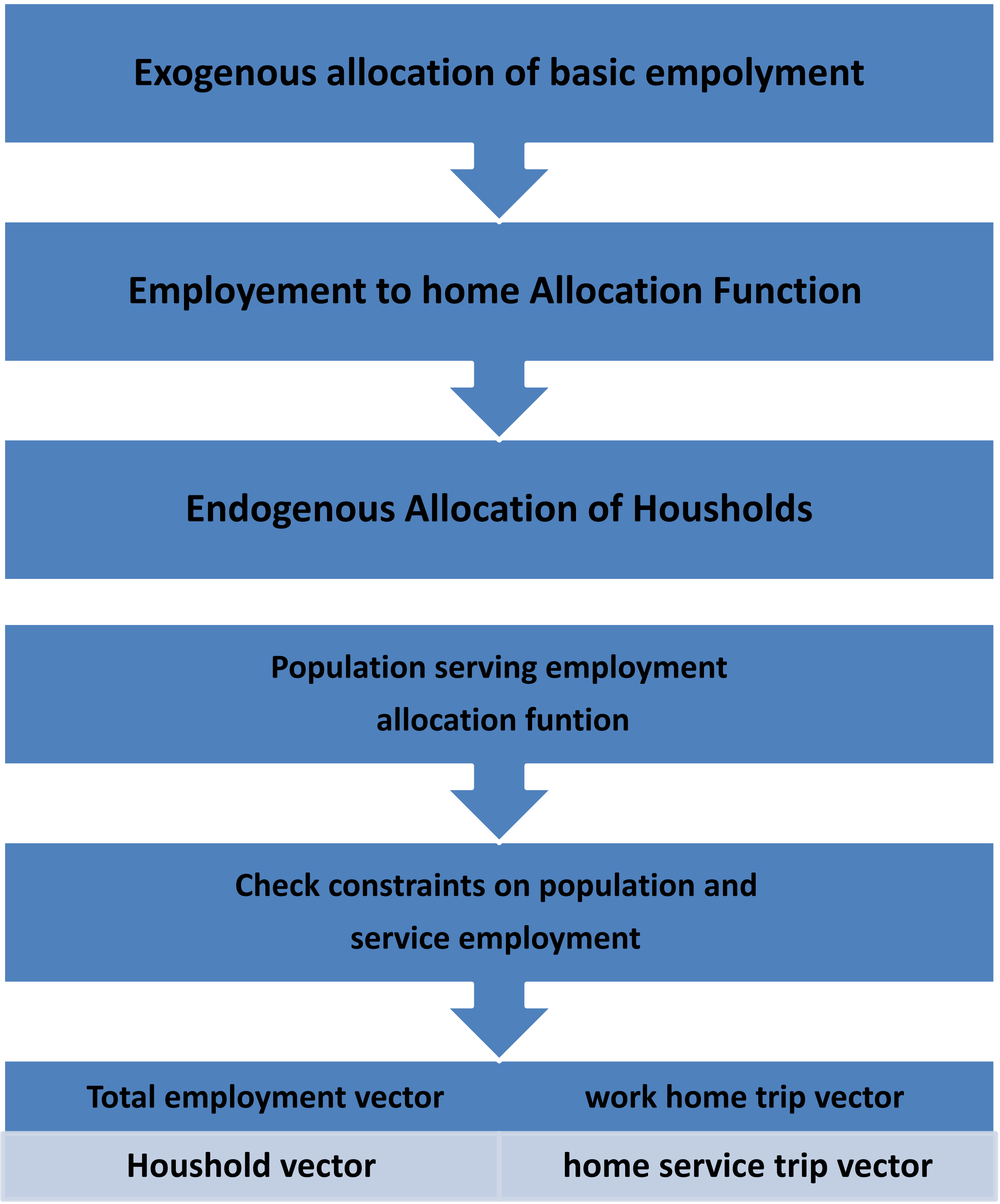


Figure (1): Structure of Lowery Model.

The Lowery model relates the three principle components of the urban area:

1. Population.
2. Employment.
3. Communication between population and employment.

Model Equation System

The Lowery model can be represented in terms of nine simultaneous equations and three inequalities; the following notation will be used:

A= Area of land.

E= Employment (number of persons).

N= Population (number of households).

T= Index of trip distribution.

Z= Constraints.

The following superscripts are used in conjunction with the above notation:

U= Unusable land.

B= Basic sector.

R= Retail sector.

H= Household sector.

k= Class of establishments within the retail sector (groceries, clinics, primary schools, cloth shop etc.).

m= Number of classes of retail establishment.

k=1, m

n= Number of zones(i=1,2,….n

j=1, 2,….n)

<u>Land Use</u> : the total land available in each zone and the land therein not useable by any of the three activities are given. Thus:

$$\boldsymbol{A_j = A_j^U + A_j^B + A_j^R + A_j^H}$$

Basic sector: for each zone, the land by basic establishments A_j^B and the employment opportunities provided by these establishments E_j^B are exogenously specified.

Retail sector: retail sectors are divided into groups, each having its own characteristics production function. The employment in each of the retail sector can be considered roughly to be a function of the households in the region.

$$E^k = a^k . N$$

The distribution of this retail employment among the zones depend upon the market at each location. Assuming that the shopping trips originate either from home to from work places, the market potential of any given location can be defined as weighted index of the number of households in the surrounding areas and the number of persons employed nearby. Thus:

$$E_j^k = b^k \left[\sum_{i=1}^{n} \frac{c^k N_i}{T_{ij}^k} + d^k E_j \right]$$

c^k, d^k are measures of the relative importance of homes and work places as origins for a particular type of shopping.

b^k is a scale factor which adjust retail employment.

$$E^k = \sum_{j=1}^{n} E_j^k$$

Total employment: the above procedure determines the amount of employment in any zone for each category of retail trade. The sum of these employment figures, plus the quantity of basic employment allocated to the zone is the total employment for the zone. Thus:

$$E_j = E_j^B \sum_{k=1}^{m} E_j^k$$

Household Sector: the region's population of household is a function of total employment. Thus:

$N = f \sum_{i=1}^{n} E_j$

the population living in any zone j is also a function of the employment opportunities in the different zones and the measure of accessibility from zone j to each of these zones. Thus:

$$N = f \sum_{i=1}^{n} \frac{E_i}{T_{ij}}$$

The coefficient factor f is a scale factor.

The sum of zone population must equal to the total population of the region :

$$N = \sum_{i=1}^{n} N_j$$

Constraints:in order to limit the dispersion of retail employment, a minimum size constraint Z^k is imposed , expressed in terms of employment. If the market potential of particular location does not justify an establishment above this minimum size, the customers are sent elsewhere. Thus:

$E_j^k \leq Z^k \; or \; else, E_j^k = 0$

In order to prevent the system from generating excessive population densities in locations with high accessibility indices, a maximum density constraints is imposed. The value of this constraint (number of households per unit area of residential space) may vary from zone to zone, as would be the case under zoning ordinances.

$N_j \leq Z_j^H . A_j^H$

And lastly , the amount of land set aside of retail establishments must not exceed the amount available.

$A_j^R < A_j - A_j^U - A_j^B$

This constraint also prevents the assignment of negative value to the residential land.

2. Hansen's Accessibility Model

It is designed to predict the location of population based on the premise that employment is the predominant factor in determining location. He suggested the use of an accessibility index, A_{ij}, where

$$A_{ij} = Ej / (d_{ij})^b$$

Where

A_{ij} = accessibility index of zone *i* with respect to zone *j*

Ej= total employments

d_{ij}= distance between *i* and *j*

b= an exponent

The overall accessibility index for zone *i* is therefore:

$$\underset{j}{A_{ij}} = \sum Ej / (d_{ij})^b$$

The amount of vacant land that is suitable and available for residential use is also an additional factor in attracting future population to the zone in question. This is referred to as holding capacity (H_i). The development potential of a zone D_i is, therefore,

$$D_i = A_i H_i$$

And population is distributed to zones on the basis of the relative development potential

$$A_i H_i / \sum A_i H_i$$

If the total growth factor in population in a future year is G_t, the population allocated to zone *i* will be

$$G_i = G_t (A_i H_i / \sum A_i H_i) = G_t (D_i / \sum D_i)$$

3. Density-Saturation Gradient Method

This Density-Saturation Gradient (DSG) Method was first used in Chicago Area Transportation Study (CATS), since then, many researchers have elaborated on this basic work.

Three empirical rules are used in this method:

1- The intensity of land use declines as the distance or travel time to the CBD increases.
2- The ratio of the amount of land in use to the amount of available land decreases as distance from the CBD increases.
3- The proportion of land devoted to each type of land use in an area remains stable.

Clark derived the basic equation for expressing this density-distance relationship. The basic equation:

$$d_x = d_0 e^{-bx}$$

Where:

d_x = population density at distance x from the city center

d_0 = central density as extrapolated into the CBD of the city

b = density gradient or slop factor

e= base of natural logarithms

Clark made another assumption that is not dealt with by the density equation. He assumed that the higher downtown densities and the lower suburban densities will tend to equalize over time in most urban areas. This is supported by the findings of the most recent census, which indicate strong trends of population decline in the CBD and increased population movement toward peripheral and suburban areas. This observation implies that the density-saturation gradient is a function of age or regional location of the city and can be determined experimentally.

Holding capacity is given by the following expression:

$$HC_i = P_i + V_i d$$

<u>Where:</u>

HC_i = holding capacity of zone i

P_i= existing residential population of zone

V_i = vacant, available, and suitable land in zone i

d= anticipated average density at which all future residential development will occur

Also, Percentage population saturation of zone$i$ in a certain year =

(Population of zone i in a certain year / holding capacity of zone i) × 100

<u>The general procedure can be described as follows:</u>

1- Establish the relationship between residential density and the distance from the CBD.
2- Determine the percent population saturation for each zone and aggregate this percentage by ring and sector

3- Determine the percentage area of useful available land in each zone that has been earmarked for residential use. This percentage, known as the percentage residential saturation, is plotted against distance from the CBD.

4- Obtain the total population for the forecast year for the city. This figure is determined exogenously.

5- Plot a curve representing the residential density, similar to the one plotted under step 2, such that the area under the curve is proportional to the total population obtained in step 4. This is the most critical and subjective step.

6- Forecast population totals by analysis rings. These totals are determined by scaling off appropriate ordinate values from the horizon-year curve.

7- Distribute ring totals to individual zones by subjectively weighting each individual zone's attractiveness according to such factors as distance to shopping centers, distance to major street systems or bus lines, residential capacity, nearness to school, and so on.