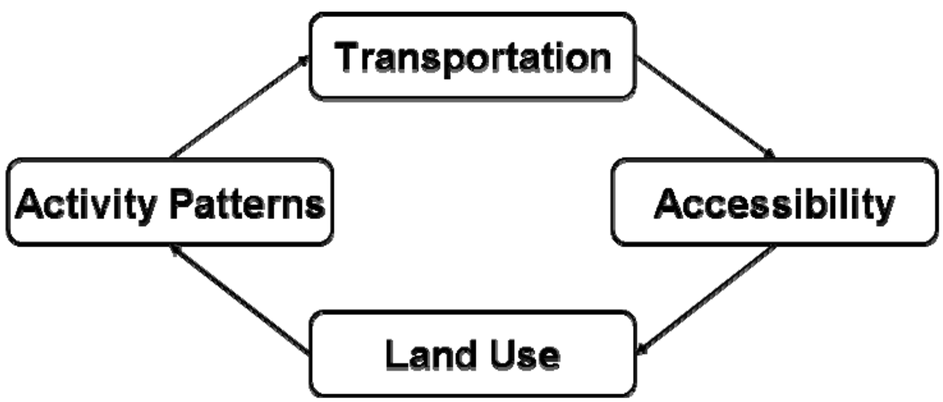
Module 4

Land use

INTRODUCTION

Land use characteristics and transportation are mutually interrelated. The use of the term land use is based on the fact that through development, urban space put up a variety of human activities. Land is a convenient measure of space and land use provides a spatial framework for urban development and activities. The location of activities and their need for interaction creates the demand for transportation, while the provision of transport facilities influences the location itself. Land uses, by virtue of their occupancy, are supposed to generate interaction needs and these needs are directed to specific targets by specific transportation facilities. The following diagram explains the transportation land use interaction



Land use means spatial distribution or geographical pattern of the city, residential area, industry, commercial areas and the space set for governmental, institution or recreational purposes. Most human activities, economic, social or cultural involve a multitude of functions, such as production, consumption and distribution. These functions are occurring within an activity system where their locations and spatial accumulation form the land uses. So, the behavioral patterns of individuals, institutions and firms will have an impression on the land use.

Land use system

The essential components of the land use system in terms of land use transport modeling are location and development. The urban land use is largely modeled by simulating the mechanisms that effect the spatial allocation of urban activities in the city. A number of other important economic concepts underpin land use transport models, serving as proxies for the complex interactions and motivations driving urban location. Among these are the ideas of bid rent, travel costs, inertia (stability of occupation of land), topography, climate, planning, and size.

Transport system

The second major component of a land use transport model, simulated along side land use is the transport system the traditional way of characterizing the transportation system in urban simulation models is a four stage process. The process begins with modeling travel demand and generating an estimate of the amount of trips expected in the urban system .the second phase trip distribution allocates the trips generated in origin zones to destinations in the urban area. The third phase is modal split. Here trips are apportioned to various modes of transport. The four stage simulation processes concludes with trip assignment module that takes estimated trips that have been generated, distributed and sorted by mode and loads it on to various segments of the transport network.

Factors affecting transport land use relationship

1. Urban land development
2. Dominance of private vehicle ownership
3. Context of land use and transportation decision making
4. Different time contexts for response.

CLASSIFICATION OF LAND USES

The representation of this impression requires a typology of land use, which can be <u>formal or functional</u> as explained below:

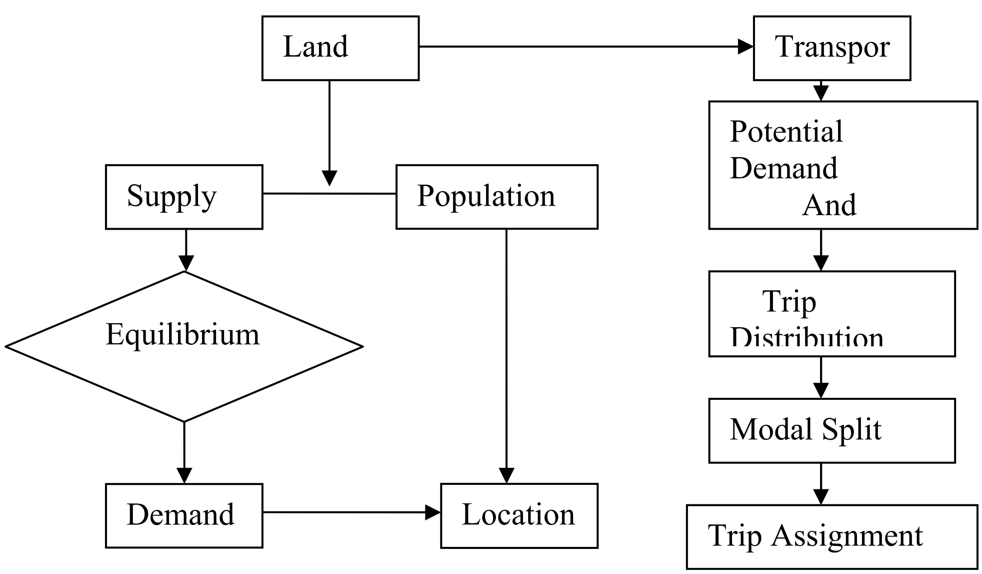
Formal land use representations are concerned by qualitative attributes of space such as its form, pattern and geographical aspects and are descriptive in nature.

Functional land use representations are concerned by the level of spatial accumulation of economic activities such as production, consumption, residence, and transport, and are mainly a socioeconomic description of space.

Land use, both in formal and functional representations, implies a set of relationships with other land uses e.g. commercial land use has relationships with its supplier and customers. While relationships with suppliers will dominantly be related with movements of freight, relationships with customers would also include movements of passengers. Since each type of land use has its own specific mobility requirements, transportation is a factor of activity location, which in turn is associated with specific land uses.

LAND USE AND TRANSPORTATION

The movement of people and goods in a city, referred as traffic flow, is the joint consequence of land activity and the capability of the transportation system to handle this traffic flow exactly like that of principle of demand and supply. There is a direct interaction between the type and intensity of land use and transportation facilities provided. Ensuring efficient balance between land use activity and transportation capability is primary concern of urban planning. Land use is one of the prime determinants of movement and activity i.e. trip generation which needs streets and transport systems for movement. This will lead to increased accessibility which further enhances value of land and land use.



Different Land Use Models

The purpose of land use transport models is to assess the policy impacts in terms of the implications of the future growth patterns on both land use and travel related issues .For this purpose, several researchers have developed various models with different theoretical backgrounds and data requirements. From the early developments of land use transport models to the latest state of art, can be broadly classified into three categories
(i)Early models (ii) Intermediate era models (iii) Modern era models.

Early Land Use Transport Models

There are several techniques which are representatives of earliest efforts in the development of urban development models and which continue to serve (either in original or modified form) a great number of transportation studies .These techniques are quite simple generally deal with aggregate relationships .These are developed primarily for location of residential activities. In addition many of these techniques can be applied without using computer or simple programs can be prepared for use on a computer .These simple techniques are considered most practical use in smaller urban areas because they require less time, cost and data.

1. The **Activity Weighted Technique** allocates activity growth in population to share of the particular activity which already exists in the zone .This technique assumes that the present trends continue and allocates activity growth in proportion to the present share .Therefore, the zone with highest present share will be allocated with major share in future. It is clear that existing size as a proxy for the future development potential leads biased allocation. This technique is suitable for short term planning.

2. The **Density Saturation Gradient Method** (Hamberg, 1959) is based upon the axiom that there are regularities in the in the activity distribution about the central place. The Density Saturation Gradient Method (DSGM) can be used as a tool for the analysis of existing land use structure and also for use in forecasting land use structure. The forecast is basically a trend projection of the existing land use and density structure in the region. The method is based essentially on the regularity of

the decline in density and the percent saturation with the distance from the Central Business District (CBD).This method depends equally upon the relationship between distance and present saturation. Though the DSGM is complete in itself, this technique demands more subjective inputs and allows only for a cursory and limited consideration of policy and other planning decisions.

3. The simple **Accessibility Model** (Hansen, 1959) is based upon concept that the more accessible an area is to various activities and the more vacant land area has greater growth potential. Thus growth in a particular area is hypothesized to be related to two factors; the accessibility of the area to some regional; activity distribution, the amount of land available in the area of development. This accessibility of an area is an index representing the closeness of area to all other activity in the region .All the areas compete for the aggregate growth and share in proportion to their comparative accessibility positions weighted by their capacity to accommodate development as a measure by vacant usable land.

4. The **Intervening Opportunities** (Lathrop, *et al*, 1965) model, spatial distribution of an activity is viewed as the successive evaluation of alternative opportunities for sites which are rank ordered in time from an urban center .Opportunities are defined as the product of available land and density of activity. This model presumes that the settlement rate per unit of opportunity is highest at the point of maximum access. The concept of an opportunity for a unit of activity involves both land and measure of the intensity of use of that land.

5. The **Delphi Technique** is a methodology for eliciting and refining expert or informed opinion .The general Delphi technique involves the repeated consulting with a group of individuals as to their best judgment as to when or what type of an event is most likely to occur and providing with them systematic reports as to the totality of judgments submitted by the group. The responses of all participants are assembled, summarized and returned to the group members, inviting them to reconsider. This information and revised estimates may be circulated to the participants for additional

anlysis.The procedure varies considerably among specific applications but the primary result is that it produces a consensus of the judgments of a majority of informed individuals while avoiding the bias of leadership influences , face-to-face confrontation, or group of dynamics. Group of participants, are expected to clarify their own thinking and the final decisions, according to the theory, it will tend to converge by narrowing the range of estimates in response to the most convincing arguments. Delphi is likely to involve more time and expense than the conventional methods of forecasting.

All the early models are often considered as low cost models using simple theories. Early developments of land use theory are simple techniques without much complexity. Each of them has a sound basis and provides a reasonable estimate of land use. How ever they do not cater for interaction of many variables. Some of these techniques have been improved later for much better modeling strategy. It may be seen from the inherent theories of this group of models, there is a broad city-wide philosophy which operates the model and then zonal allocations are derived by proportioning. Each of these models appears logical for urban land use forecasting or activity allocation.

Intermediate Era Models:

This was the golden era of developments in land use transport modeling. Although , a special group of models like 'empiric model' has been developed and applied, the most wide group of models is lead by the work of I. S. Lowry(1964).There are many variants of one or more of these models as applied to particular area..

1. The **Empiric Model** (Hill, 1965) developed for Boston Regional Planning Project is designed to distribute or allocate exogenously supplied growth forecasts of activities such as population and employment along the zones and sub divisions of the region considered for the study. This process of allocation considers the local changes in the quality of public services and transportation network as well as changes over time in the local activities .Although this model deals with population and employment other activities can be incorporated into the model.

2. The **Lowry Model** (Lowry, 1964) incorporated within its structure both generation and allocation of activities .The activities which the model defines are population, service employment and these activities correspond to residential, service and industrial land uses. Some of the salient features of Lowry model are
   a) It assumes an economic base mechanism where employment is divided into basic and non -basic sectors. Basic employment is defined as that employment which is associated with industries whose products are largely used outside the region, where as the products of the service employment are consumed within the region.
   b) It is assumed that the location of basic industry is independent of the location of residential areas and service centers.
   c) Population is allocated in proportion to the population potential of each zone and service employment in proportion to market potential of each zone.
   d) The model ensures that populations located in any zones dose not violate a maximum density or holding capacity constraint is placed on each category of service employment.
   e) Lowry model relates population and employment at one particular time horizon.

3. **Garin** expressed the fundamental Lowry algorithm in matrix format (Garin, 1966) .Using this notation, the iterative process used by Lowry to generation population, serving employment was replaced by elementary matrix operation to obtain an exact rather than an approximate solution. The Garin formulation does not comprehend the constraints which Lowry imposed .Neither the maximum size constraint for population serving employment nor the maximum density constraint for residential development was included in the matrix operations.

4. **Time Oriented Metropolitan Model (TOMM)** was one of the first derivatives of the Lowry model (Crecine, 1964).Some of the characteristics of this model are
   a) The model was developed in an incremental form contrary to static equilibrium form taken by Lowry.

b) It attempts to disaggregate the locating population into several populations into several types .It was felt that by disaggregating the model, the explanatory power of the model would be increased.
c) Limitation of the study area to within city boundary.
d) There are different versions of TOMM; the structure of the revised model is basically the same as original model although the allocation mechanisms have been made more realistic.

5. **Wilson Model** based on entropy maximization is a break through contribution in the urban spatial allocation models. It has enlarged the frameworks of spatial interaction models. Wilson offered solutions to several problem areas by using the concept of entropy maximization to generalize the problems. The concept of entropy was originally developed in statistical mechanics and later proposed as general, information applicable to most systems. The derivatives and the introduction of entropy to urban and regional theory can be found in (Wilson ,1970) and (Wilson, 1974).The focus of the model includes
   a) different household income groups
   b) different wage levels by location of employment

6. **Projective Land Use Model** (Goldner, 1968) as another family of Lowry derivative models. Projective Land Use Model (PLUM) is designed to yield projections of the zonal level distribution of the population, employment and land use within an area based upon the distributions of these characteristics in base year, coupled with a series of simple and intitutively appealing allocation algorithm .There are different versions of PLUM .Allocation incorporates auto and transit mode separately and disaggregated local serving categories are allocated by different processes. The allocation algorithms are derived from original Lowry model. This model can distinct both basic and local-serving employment. The allocation function used in the model has two components,
   a) The first component is the probability of making a trip for a given trip purpose of particular length

b) The second component is the measure of attractiveness of the destination

The total PLUM model is divided into four phases: initial allocation, revised allocations of incremental employment, reallocations and increments, projections

The outputs of PLUM consist of total housing units, residential population, total number of employment residents, and total employment.

7. **Hutchinson's Model** (Hutchinson, 1975) is being presented as a asset of land use transport equations, refining more on transport aspects .These equations are capable of analyzing alternative development strategies in sufficient detail to allow their transport and serving implications to be examined .A procedure for corridor traffic assignment analysis has been described, which uses the transport demand estimates produced by land use model.

8. **Sarna's Model** (Sarna, 1979) is essentially a land use transport model which was developed for Delhi, which was first of its kind and nature for application in India. The model is based on the iteratively solved version of the Lowry model which consists of a residential activity allocation sub model and a population serving employment serving sub model.

The model deals with

- Disaggregation by socio-economic group
- Disaggregation by spatial groups
- Simplified calibration procedure

Modern Era Models:

1980s has seen a very interesting development in the area of land use transport modeling. During the intermediate era, modeling of transport demand and supply has been enhanced with a lot of innovative ideas. The land use / transport modeling also embraced them foe better representation of demand and supply scenario in relation to location. Thus although the basic allocation mechanism emanated from Lowry model was largely used in most models., very complex developments on location process can be found in the models proposed. A significant assimilation of all such developments was taken up by TRL(UK) through a consolidation study reported in 1988.The ISGLUTI (International Study Group On Land-Use/Transport Interaction) study refers to nine models developed originally for different cities of varying sizes and they have been comparatively evaluated for all modal features (Webster, *et al*, 1988). This has also been tested for geographical transferability. Some of the new land use models like cellular automata are also discussed in the report (Timmermans, 2003).

The relationship between land use and transport means that any policy, whether relating specifically to land use development or to the provision of transport facilities, will inevitably affect the other dimension though not necessarily on the same time scale.

1. **AMERSFOOT** was developed to represent Amersfoot, a Dutch town of population about 180,000 populations with the intention of examining land use planning policies
    - It is a spatial interaction model of the entropy maximizing type originally formulated by(Wilson, 1970),though the general structure is similar to the Lowry model
    - It takes the distribution of employment as given and the number of newly built houses of different types is exogenously determined for ach zone on the basis of structure plans and building plans formulated by the various municipalities.
    - The population is disaggregated into three income groups , and the model recognizes four types of locational behaviour of household changing
        a) Jobs but not home
        b) Home but not job
        c) Both home and job
        d) Neither of them
  - This model allocates workers from the zones containing their work place to residential zones which are chosen in accordance with zonal attractiveness and an exponential function of distance between residence and work place
  - There is no modal split, transport network or calculation of generalized travel costs, because the intention is to provide a simple model which makes only

light demands which makes only light demands on computer storage or time and to concentrate on land use policies.

2. **CALUTAS (Computer Aided Land-Use Transport Analysis System)** has been developed to forecast the future location of housing, industrial and commercial activities and the land use and travel patterns, within a large metropolitan area .As applied to Tokyo , it represent a huge population of some 28 million within an area of 15000 sq. km. In the model land uses are classified into the following four types according to their locational characteristics:

    - priority location type(e.g. large scale basic industries)
    - optional locational type(e.g. business areas , housing)
    - subsequent location type(e.g. neighborhood stores , schools)
    - passive location type(e.g. agricultural areas, forests)
    - The allocation and amount of use is determined a priori on the basis of an existing development plan. Allocation of optional land uses is described by three five models
        a) The industrial location sub model
        b) Business location sub model
        c) Activity within each of the zones
        d) Local land use sub model
        e) The transport sub model

3. **DORTMUND** is part of a compressive model of regional development organized in three spatial levels (Wegner, 1982).A macro analytic model of economic and demographic development of 30 zones .A misanalysis model of intra regional; location and migration decisions in 30 Zones. A micro analytic model of land use development in any subset of 171 statistical tracts within Dortmund. For these many number of zones, the model simulates the inter-regional location decisions of industry, residential developers and households. The resulting migration and travel

patterns, the land use developments and the impacts of public policies in the field of industrial development, housing and infrastructure. This is done by six models

a) The transport sub model (calculates work, shopping, service and education trips for four socio economic groups)
b) The ageing sub model (computes all those changes of stock variables which are assumed to result from biological, technological or long term socio-economic trends originating outside the model)
c) The public programmes sub model (possess a large variety of public programmes specified by the model user in the fields of employment, housing, health, welfare, education, recreation and transportation)
d) The private construction sub model considers investment and location decisions of private developers
e) The employment change sub modes (models intraregional labour mobility as decisions of workers to change their job location in the regional labour market
f) The migration sub models (simulates inter-regional migration decisions of households as search processes on the regional housing market.

4. **ITLUP (Integrated Transportation and Land Use Package)** model contains both location and transportation models and has been the subject of a long sequence of development and application projects since 1971.The four principal models are
    a. EMPAL (Employment Location). EMPAL forecasts employment location in each five year simulation period as a function of access costs by population in different income groups for each zone
    b. DRAM (Simultaneous household location and trip distribution). The household (residence) location model allocates households to the zones using a modified version of the standard singly constrained spatial interaction model. Allocation of households of different types then depends upon this attractiveness and the access cost to employment to different types .In current version of ITLUP new locaters , include a separate model LANCON to calculate land consumption using a

simultaneous multiple regression formulation. Trip generation and distribution are also calculated in DRAM simultaneously with household location.

c. MSPLIT for modal split calculation. The trip matrices produced in DRAM are split into trip matrices for each mode in MSPLIT using multinomial logit formulation for the modal split calculation.
d. NETWK for trip assignment. The trips are then assigned to a capacity constrained highway network in NETWK.

5. **LILT (The Leeds Integrated Land-use/Transport Model)** (Macket, 1983) represents the relationship between transport supply (or cost) and the spatial distribution of population, housing, employment, jobs, shopping and land utilization. It is applied to a study area divided into zones, with an external zoning system to ensure the closing of the spatial system (Macket 1974).The main use of this model is to allocate exogenously specified totals of population, new housings and jobs to zones taking into account the existing land use pattern and the cost on travel and any constraints on land use.

6. **OSAKA** has been developed to investigate the evolution of land use patterns in an area where the land market is complex so that it was considered essential to incorporate mechanisms which simulate the market and studies the land values. OSAKA is an example of linear regression model in the EMPIRIC tradition. Primarily it was considered to study land use effects rather than transport, the impact of transport changes on urban development is of interest. The model provides no predictive representation of either modal split or travel patterns.

7. **SALOC** (Landqvist and Mattsson, 1983) (Single Activity Model Allocation) is an important model related to Herbet-Stevens model in that it maximises an objective function and in general total interaction cost plays a major role. However, there are certain deviations .It does not assume that all households wish to strictly minimise

their transportation cost, it contains other components such as neighborhood density and infrastructure cost in the objective function.

a) SALOC allocates total population rather than net population growth and specifies the cost of expanding the infrastructure. However, constraints can be applied to the future population residing in the housing cost of the base year, so that, in effect only the net population growth allocated.
b) One of the main aim of SALOC is to identify short term developments which will keep a maximum number of good options open for longer term future when the prevailing condition may change.
c) It uses work trip pattern to accessibility of zones.
d) It does not calculate interzonal trip matrix, instead calculates a composite travel time (cost) index for each zone as a weighed average of travel times (cost) to the given set of work places and service centers.
e) Basic philosophy is to provide a method of assessment which integrates multiregional development with urban analysis, land use with transport and normative planning with individual behaviour.

8. **TOPAZ** (Technique for Optimal Placement of Activities in Zone) is a general planning model which allocates activities to zones of the study area in a way which optimizes some weighted objective function of the cost establishment, on the other hand the cost of operation which depends on the accessibility of the other.Special applications to land-use/transport interaction studies, facility location and facility layout. Paths between locations e.g. roads, rail network; costs (and benefits) of location, eg. construction, operation, maintenance, Cost of interaction paths, e.g. transportation costs, time periods for staging of developing or change. TOPAZ treats the city as a system and the basic components of the city and their interactions are matched by the components and the interactions of the model which assigns activities to zones and the interactions to a network of flows.

9. **The MEPLAN Model** was developed by Echenique and Partners through a series of studies in different countries in the world. It started with a model of stock and activities followed by incorporation of a transport model developed for Santiago, Chile, in the incorporation of an economic evaluation system for Sao Paulo, the representation of market mechanisms in the land use model for Tehran the incorporation of an input-output model again for Sao Paulo and the more compressive model developed for Bilbao.

   At the heart of the system is an input-output model to predict the change in demand for space .A spatial system is used to allocate the demand to spatial zones, using random utility concepts .An equilibrium model is derived by solving all the equations, subjected to constraints .Given transport demand type and flow, the transport model predicts modal split and assignment, with adjustment for times for capacity constraints. Again random utility concepts are used in the transport model. Information about costs , travel time due to congestion, etc are fed back into the land use model to provide time lag measures of accessibility, (Hunt, 1994). Echenique (Echenique, 1994) used the model to simulate the effects of urban policies.

10. The **TRANUS** integrated land use and transport-modeling system was developed to simulate the probable effects of applying particular land use and transport policies and projects and to evaluate their social, economic, financial, and environmental impacts. A detailed explanation can be found in (De la Barra, 1989). Tranus has a land use or activity model and a transport model. It is assumed that activities compete for real estate, resulting in equilibrium prices, but also by accessibility, generated by transport system. The location of activities is modeled in the land use system .The transport model uses travel demand as input and assigns it. The land use model generates a set of matrices of flows representing potential transport demand .The purpose of the transport model is to transform potential demand into actual trips and to assign these to the transport supply options.

11. **MUSSA and RURBAN** developed by (Martinez,1992) and (Martinez,1997) received some interest because of spatial allocation of land uses is handled using a bid function

.The model is not a fully integrated model, but can accept as input the total demand (growth) from the households and firms and a transport model. Central to the model then is to predict the location of households and firms and the resulting rents. Ellickson (Ellickson, 1981), showed that the spatial probability distribution obtained from the bidding function is identical to the probability distribution obtained by the maximization of individuals (consumers) surplus, emphasizing the equivalence of the bid and choice approaches, given the traditional set of assumptions.

12. The model **DELTA** was developed by David Simmonds Consultancy, MVA Consultancy and the Institute of Transport Studies, Leeds during the period 1995-1996. Consequently, it is not an integrated package, but a link of separate models. Input to the land use model is that accessibility from each zone to alternative destinations for each variety of purposes. The model predicts the location of activities that are mobile as a function of accessibility, transport-related change in the local environment, area quality and rent of space.

13. The initial design of the **UrbanSim** model was founded by the Oahu Metropolitan Land –Use Model as a part of larger effort to undertake the development of new travel models. The project involved the development of a travel model system based on modeling tours rather than trips. This model was further elaborated in 1996 when Oregon Department of Transportation, launched the Transportation and Land Use Model Integration Project (TULMIP) to develop analytical tools to support land use and transportation planning. The model was extended and the prototype was implemented. The model was calibrated for a case study in Eugene-Springfield. Later the dynamic aspects of the model were calibrated and the model was applied in Utah and Washington (Alberti and Waddell, 2000; Waddell, 2002).

14. The Integrated Model of Residential and Employment Location (**IMREL**) were developed in connection with office of Regional Planning and Urban Transportation of Stockholm (Anderstig and Mattson, 1998; Boyce and Mattsson, 1999). The model starts with the total number of households and the total number of workplaces given

at the regional level. These are not predicted as a part of the model but exogenously given these totals are then distributed across a system of zones through a process of interactions between the residential and an employment location sub model. These sub-models use as input data, among other things, travel times and travel costs between zones by available models of transport as calculated by a traffic assignment module of a linked travel demand model.

15. Using similar utility concepts, the same group also developed the **TILT** model (Eliasson and Mattsson, 2001).Unlike IMREL; this model is descriptive by nature. It models how the households, workplaces, shops, service establishments would locate and interact, without any claim that the aggregate behaviour is optimal.

16. **Uplan** (Johnston, *et al*, 2003) allocates the increment of additional land in user specified discrete categories consumed in future years. The model allocates future development starting with the highest valued cells .As the higher valued cells are consumed, the model looks for lower-valued cells until all hectares of projected land consumption are allocated. In a recent test application for the Sacramento region, plan was linked to a travel demand model to include the effects of changing accessibility measured in terms of logsum (user benefit).

17. Integrated Land Use Transportation and Environment (**ILUTE**)modeling system which is under development by a consortium of researchers in Canada from the universities of Toronto,Calgary,Laval and McMaster (Miller and Savini, 1998).It is an activity based integrated land use and transport model which represents an experiment in the development of a fully microsimulation modeling framework for the comprehensive , integrated modeling of urban transportation-land use interactions and among other outputs the environmental impacts of these interactions.

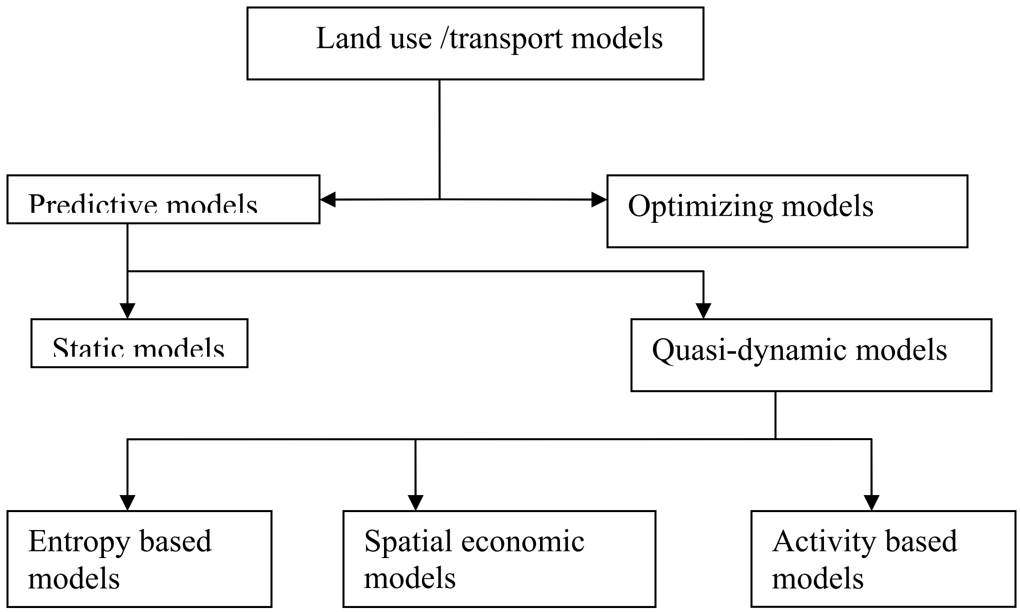
18. The model **Ramblas** is developed to estimate the intended and unintended consequences of planning decisions related to land use, building programs and road constructions for households and firms (Veldhuisen, *et al*, 2000). The model allows

the planners to assess the likely effects of their land use and transportation plans on activity patterns and traffic flows. It can simulate population of 16 million people.

19. The **Irvine Simulation Models**, of activity patterns that closely resembles to the core of the Ramblas model. One important difference however is that the model is based on a classification of representative activity-travel patterns. Some key aspects of such patterns are extracted from the data and used to simulate activity travel patterns in a particular environment. More recently the group is exploring the use of multi agent systems (Rhindt*, et a*l, 2003).

20. **ILLUMAS** is an integrated land-use modeling and transportation system simulation project aims at a microscopic dynamic simulation of urban traffic flows into a comprehensive model system, which incorporates both changes in land use and the resulting changes in transport demand (Moeckel, *et al*, 2002).

21. Cellular Automata and Multi-Agent Models, in most of the cellular automate models the transport component is weak. Typically a network is assumed but traffic flows are not simulated. More recently, some scholar announced plans link their cellular automata model with transport model. Central to these models is the use of cells that can occupy particular states. Cell states may evolve according to transition rules, which can either be deterministic or stochastic. Traditionally, dynamic process over space were simulated for eight neighboring cells , but more recently applications which use circular neighborhoods of a wider radius have been suggested (Engelen, *et al* ,1997). In applications to land use patterns interaction mechanisms are usually depicted in terms of distance decay functions. (Arentze, *et al*, 2003) have developed a prototype of a system called Absolute.

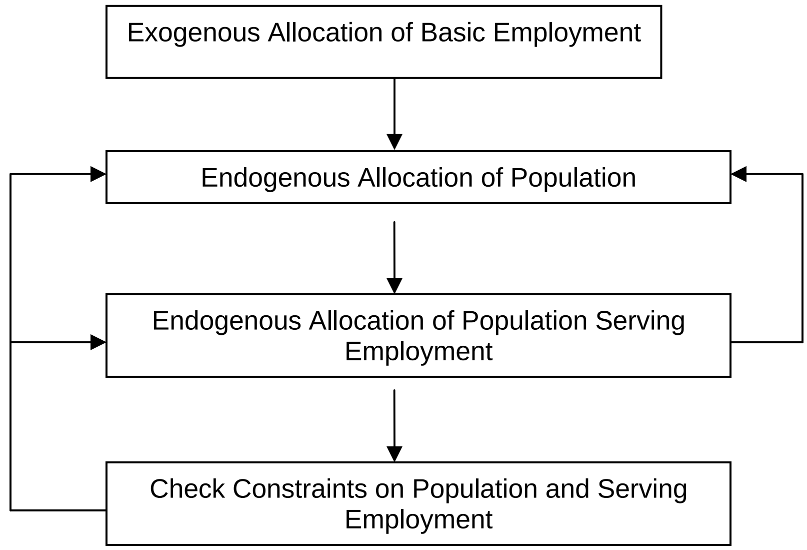


Classification of models

LOWRY LAND USE MODEL

The original Lowry was published in 1964 and since then several important extensions of the original model have been applied to practical planning problems (Hutchinson, 1974). The Lowry model conceives of the major spatial features of an urban area in terms of three broad sectors of activity i.e. basic employment sector, the population serving employment and the household sector. The basic employment is employment whose products and services are utilized outside the study area.

With Lowry model, spatial distribution of basic employment is allocated exogenously to the model while the other two activity sectors are calculated by the model by applying an iterative procedure, until the constraints, which are maximum no. of household for each zone and minimum population serving employment for any zone, are satisfied. The flow diagram for this model is shown below.



Sequence of Activities in the Lowry model

The model views the spatial properties in terms of:

1. Employment in basic industries
2. Employment in population serving industries
3. Household or population sector

Basic Employment: - employment in those industries whose products or services depend on markets on external to the region under study.

The location of service employment is dependent on the population distribution of the region.

Equation System

The above sequence of activities can be expressed in equation as follows**.**

$P = eA$ --**(1)**

$e^s = PB$ --**(2)**

$e = e^b + e^s$ ---**(3)**

where

P =row vector of population or household within each of the n zones

e =a row vector of the total employment in each zone

e^s =a row vector of the population-serving employment in the zone

e^b = a row vector of the basic employment in each zone

A = an nxn matrix of the workplace-to-household accessibility

B =an nxn matrix of the household-to-service center accessibility

The A accessibility matrix may be expanded as:

$$A = \left[a'_{ij}\right]\left[a_j\right] \text{---(4)}$$

where

$\left[a'_{ij}\right]$=an nxn square matrix of the probabilities of an employee working in i and living in j

$\left[a_j\right]$=an nxn diagonal matrix of the inverses of the labour participation rates, expressed either as population per employee, or households per employee

The B accessibility matrix may be expanded as:

$$B = \left[b'_{ij}\right]\left[b_i\right]$$

where

$\left[b'_{ij}\right]$= a nxn square matrix of the probabilities that the population in j will be serviced by population serving employment in i

$\left[b_i\right]$= a nxn diagonal matrix of the population serving employment-to-population ratios.

The equations can be illustrated using the following example:

Total employment vector $e = [126,177,64,216]$

Basic employment vector $e^b = [100,150,40,200]$

Journey to home function: $\left[a'_{ij}\right]=\begin{bmatrix}0.35 & 0.30 & 0.20 & 0.15\\ 0.25 & 0.35 & 0.20 & 0.20\\ 0.15 & 0.10 & 0.35 & 0.40\\ 0.10 & 0.25 & 0.20 & 0.45\end{bmatrix}$

Journey to shop function: $\left[b'_{ij}\right]=\begin{bmatrix}0.50 & 0.25 & 0.10 & 0.15\\ 0.30 & 0.45 & 0.15 & 0.10\\ 0.15 & 0.20 & 0.40 & 0.25\\ 0.20 & 0.25 & 0.35 & 0.20\end{bmatrix}$

Labour participation rate: $\left[a_j\right]=\begin{bmatrix}0.80 & 0 & 0 & 0\\ 0 & 0.80 & 0 & 0\\ 0 & 0 & 0.80 & 0\\ 0 & 0 & 0 & 0.80\end{bmatrix}$

Service employment ratio: $\left[b_i\right]=\begin{bmatrix}0.20 & 0 & 0 & 0\\ 0 & 0.20 & 0 & 0\\ 0 & 0 & 0.20 & 0\\ 0 & 0 & 0 & 0.20\end{bmatrix}$

The A and B matrices can be computed as:

$$A=\begin{bmatrix}0.28 & 0.24 & 0.16 & 0.12\\ 0.20 & 0.28 & 0.16 & 0.16\\ 0.12 & 0.08 & 0.28 & 0.32\\ 0.08 & 0.20 & 0.16 & 0.36\end{bmatrix}\qquad B=\begin{bmatrix}0.10 & 0.05 & 0.02 & 0.03\\ 0.06 & 0.09 & 0.03 & 0.02\\ 0.03 & 0.04 & 0.08 & 0.05\\ 0.04 & 0.05 & 0.07 & 0.04\end{bmatrix}$$

The household vector may be calculated as:

$$\left[126,177,64,216\right]\begin{bmatrix}0.28 & 0.24 & 0.16 & 0.12\\ 0.20 & 0.28 & 0.16 & 0.16\\ 0.12 & 0.08 & 0.28 & 0.32\\ 0.08 & 0.20 & 0.16 & 0.36\end{bmatrix}=\left[95,128,101,142\right]$$

The service employment vector may be calculated as:

$$\left[95,128,101,142\right]\begin{bmatrix} 0.10 & 0.05 & 0.02 & 0.03 \\ 0.06 & 0.09 & 0.03 & 0.02 \\ 0.03 & 0.04 & 0.08 & 0.05 \\ 0.04 & 0.05 & 0.07 & 0.04 \end{bmatrix} = \left[26,27,24,16\right]$$

Original total employment vector $e = \left[126,177,64,216\right]$

$e^b + e^s = \left[100,150,40,200\right] + \left[26,27,24,16\right] = \left[126,177,64,216\right]$ **ok!**

Lowry-Garin Model

Garin proposed a formulation of Lowry's model which prevents the need for the iterative solution to the equations described above.

Garin has proposed a formulation of the Lowry model, which obviates the need for the iterative solution of to the equations. The following equations can be written:

$$P^b = e^b A$$

$$e^{s(1)} = P^b B = e^b (AB) \text{ --- }\mathbf{(1)}$$

$$P^{s(1)} = e^{s(1)} A = e^b (AB) A$$

$$e^{s(2)} = P^{s(1)} B = e^{s(1)} (AB) = e^b (AB)(AB) = e^b (AB)^2$$

Successive iterations will yield:

$$e^{s(x)} = e^b (AB)^x$$

$$P^{s(x)} = e^b (AB)^x A$$

Total employment and total population vectors are given by:

$$e = e^{b} + e^{s(1)} + \ldots + e^{s(x)} + \ldots = e^{b}\left[I + AB + (AB)^{2} + \ldots + (AB)^{x} + \ldots\right]$$

$$P = P^{b} + P^{s(1)} + \ldots + P^{s(x)} + \ldots = e^{b}\left[I + AB + (AB)^{2} + \ldots + (AB)^{x} + \ldots\right]A$$

Garin has shown that under certain conditions on the product matrix AB will converge to the inverse of the matrix $(I - AB)$ and the resulting equations will be:

$$e = e^{b}(I - AB)^{-1} \text{--(2)}$$

$$p = e^{b}(I - AB)^{-1}A \text{--(3)}$$

where

I =identity matrix

Garin argues that if this were not the case then an infinite amount of population serving employment would be generated by a finite number basic employment.

Garin-Lowry model may be illustrated by the extension of the simple example given above.

$$AB = \begin{bmatrix} 0.052 & 0.0480 & 0.0340 & 0.0260 \\ 0.0480 & 0.0496 & 0.0364 & 0.0260 \\ 0.0380 & 0.0404 & 0.0496 & 0.0320 \\ 0.0392 & 0.0464 & 0.0456 & 0.0288 \end{bmatrix}$$

which leads to:

$$(I - AB)^{-1} = \begin{bmatrix} 1.0607 & 0.0569 & 0.0416 & 0.0313 \\ 0.0567 & 1.0585 & 0.0441 & 0.0313 \\ 0.0464 & 0.0491 & 1.0575 & 0.3740 \\ 0.0477 & 0.0522 & 0.0534 & 1.0342 \end{bmatrix}$$

The total employment vector will be: $e = \left[126,177,64,216\right]$

The household vector can be obtained as: $P = \left[102,128,101,142\right]$

Sarna's Land Use Model

A critical problem in most Indian cities is the inadequacy of the transport infrastructure which is further aggravated by the increasing demands for intra city travel due to rapid growth in both population and employment. These demand based on travel forecasts led to recommendation for high capacity facility, requiring large capital as well as operating expenditure. The large investment required by the transport systems recommended for Indian metropolitan cities have simulated an approach to land use transport planning which attempts to minimize travel demands through the manipulation of land use (Sarna , 1978).Dr Sarna's model considers Delhi as three districts as inner district, middle district, outer district and different socioeconomic groups according to their income.

The Land Use Transport Model

The model, which is used by Dr Sarna, is a relatively solved version of Lowry activity model, which consists of residential activity allocation sub-model and a population serving sub-model.(Sarna, 1979).

The works to home linkages of the residential sub-model are calculated by the following equation.

$$l_{ij}^{km} = e_i^k a^k pr^{wkm}\left[h_j^k \exp\left(-\alpha_i^k d_i^m\right) / \sum_j h_j^k \exp\left(-\alpha_i^k d_{ij}^m\right)\right] \qquad \text{………………. (3.1)}$$

l_{ij}^{km} = The number of household (or persons) who are supported by employees of income group k work in zone i and live in zone j and travel there by mode m.

e_i^k = The total number of employees of income group k who works in zone i.

a^{k}= The inverse of the activity rate of for income group k in terms of households (or population) per employee.

pr^{wkm} = The probability that employees in income group k will choose mode m for the journey to work.

h_j^k = the attractivity of zone j as a location for income group k households

α_i = the work zone specific parameter which reflects the influence that travel time d_{ij} has on residential location selection by income group k employees

The number of household allocated to each zone are calculated from

$$p_j^{\ k} = \sum_i \sum_m l_{ij}^{\ km} \qquad \text{.......} \quad (3.2)$$

Where $p_j^{\ k}$ j=the number of households (or persons) of income group k allocated to zone j.

The home to service opportunities linkages of the population serving employment sub model are calculated from

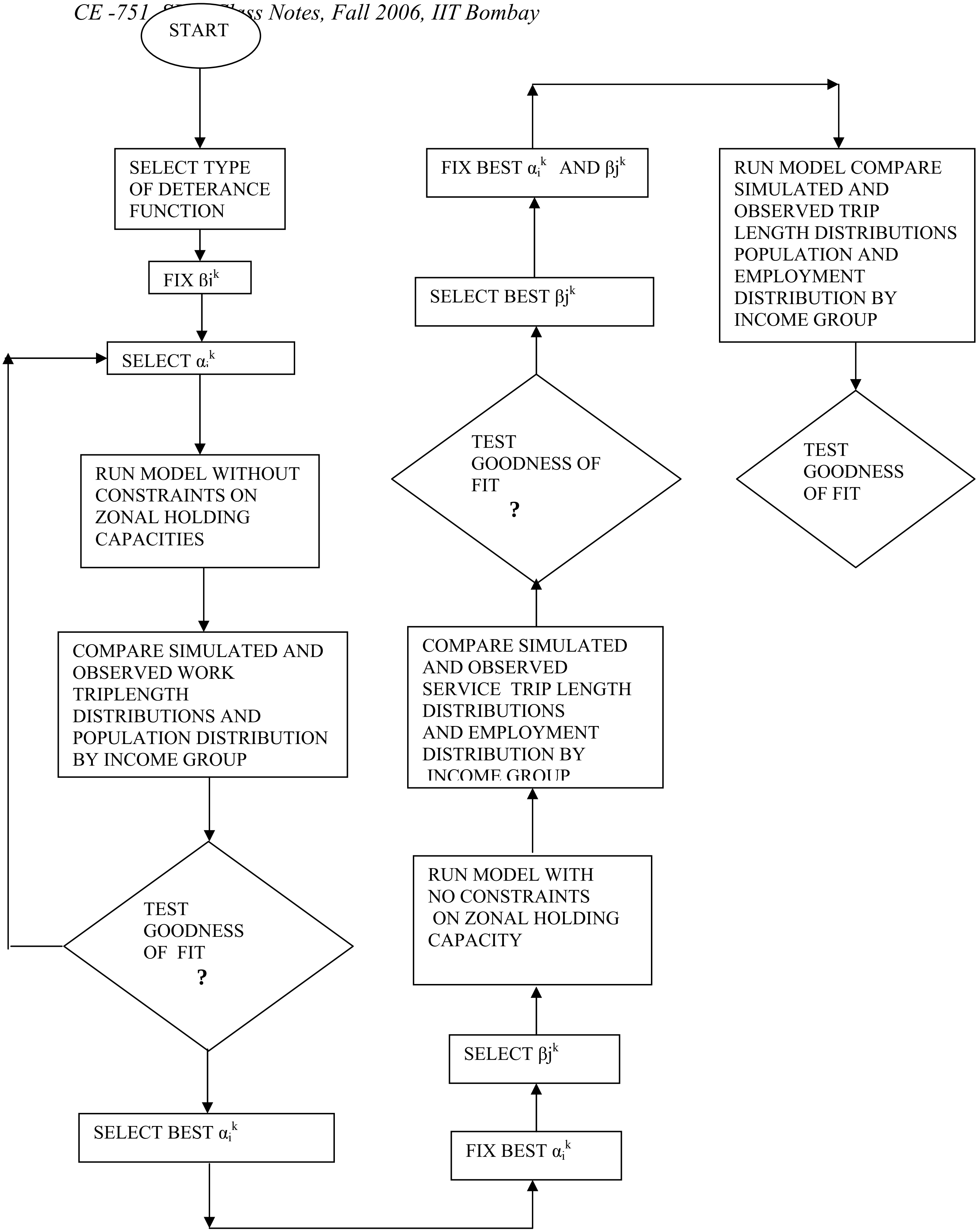
$$l_{ij}^{rkm} = p_j^k b^{kr} pr^{rkm} \left[s_i^r \exp\left(-\beta_j^{kr} d_i^m\right) / \sum_i s_i^r \exp\left(-\beta_j^{kr} d_{ij}^m\right) \right] \qquad \text{.......} \quad (3.3)$$

$l_{ij}^{\ rkm}$ = the number of population serving employees of type r in zone j where the service trips by residents of zone j are performed by mode m.

$p_j^{\ k}$ = the number of households in income group k allocated to zone j by the residential sub model.

$s_i^{\ r}$ = The attractivity of zone I for the location of type r service employment used in the previous iteration of the service employment sub-model.

The home based work and service trip tables associated with the activity allocations calculated by the above equations may be calculated by multiplying equation (3.1) and (3.1) by the appropriate trip generation rates. Equation (3.1) and (3.3) rely on trip end type modal split estimation in that the socio-economic characteristic of trip makers are assumed to dominate modal choice decisions. Modal split Probabilities that are specific to each *i-j pair* for each socio-economic group may be substituted readily into the above equations.


START
SELECT TYPE OF DETERANCE FUNCTION
FIX βi^k
SELECT α_i^k
RUN MODEL WITHOUT CONSTRAINTS ON ZONAL HOLDING CAPACITIES
COMPARE SIMULATED AND OBSERVED WORK TRIPLENGTH DISTRIBUTIONS AND POPULATION DISTRIBUTION BY INCOME GROUP
TEST GOODNESS OF FIT ?
SELECT BEST α_i^k
FIX BEST α_i^k
SELECT βj^k
RUN MODEL WITH NO CONSTRAINTS ON ZONAL HOLDING CAPACITY
COMPARE SIMULATED AND OBSERVED SERVICE TRIP LENGTH DISTRIBUTIONS AND EMPLOYMENT DISTRIBUTION BY INCOME GROUP
TEST GOODNESS OF FIT ?
SELECT BEST βj^k
FIX BEST α_i^k AND βj^k
RUN MODEL COMPARE SIMULATED AND OBSERVED TRIP LENGTH DISTRIBUTIONS POPULATION AND EMPLOYMENT DISTRIBUTION BY INCOME GROUP
TEST GOODNESS OF FIT

Model Calibration

The general procedure used to estimate the (α) and (β) magnitudes for the model is shown in the figure.3.1. The magnitudes of (α) and (β) were varied until the model activity allocations and simulated trip length frequency distribution were in general agreement with the characteristics observed in the base year.

The goodness of fit of the model was assessed principally by a subjective appraisal of the model residuals. While more formal calibration techniques have been proposed and used, it was felt that these more sophisticated measures of the goodness of the fit of the model could not be justified in this investigation .The following criteria were used in estimating (α) and (β) magnitudes

- A minimum total absolute error between the given and model simulated household and employment distributions and the absence of any systematic spatial bias in the model residuals.
- Good agreement between the observed and simulated work and service trip length frequency distributions in terms of mean trip lengths.

Behaviour of the Model

The value of the parameters obtained from this model is being represented in relation to the socio-economic group and the spatial distribution of the study area. The following table provides a comparison of certain characteristics of the various versions of the model examined for the base year conditions when the residential sub-model operated in an un-constrained way. The information presented in the table 3.1 is the parameter values calibrated independently for the two sub-models i.e. residential sub-model, population serving employment sub-model, table 3.2 shows the Comparative Performance at various levels of disaggregation. Flowchart shows the comparative performance of the model at various levels of disaggregation without constraints .It includes the percent absolute model error in allocating activities, the

Parameter values by income group for each district (Sarna, 1979)

District	Income Group		
	Lower	Middle	High
Inner	0.040 (α)	0.030	0.050
	0.100 (β)	0.130	0.140
Middle	0.150	0.130	0.130
	0.140	0.140	0.150
Outer	0.160	0.150	0.100
	0.130	0.140	0.150

Comparative Performance at various levels of disaggregation (Sarna, 1979)

Model Outputs		Aggregated	Spatial Disagg-regation	Level of Disaggregation				
				Socio economic Disaggregation				
				Income Group				
				Low	Middle	High	All	Low
Households	%Model Error	18.7	13.3	34.1	35.1	32.7	27.6	22.2
	Correlation Coefficient	0.973	0.974	0.920	0.866	0.847	0.953	0.945
Employment	%Model Error	12.9	17.3	28.6	29.1	27.8	28.4	22.5
	Correlation Coefficient	0.984	0.973	0.916	0.915	0.917	0.916	0.953
Work Trip length Ratio Observed/Simulated		0.979	0.941	1.042	1.078	1.005	----	0.956
Service Trip Length		1.014	1.022	0.994	1.001	0.812	-----	0.987

Ratio Observed/simulated							

Simple correlation coefficient between the observed and modeled allocated activity vectors and the ratio of the observed to simulated work and the service trip lengths.

Strategic Land Use Transport Model for Madras Metropolitan Area (MMA)

A Lowry type Land use model has been developed for the MMA region in order to test alternative development strategies together with their transport implications for a horizon year of 2011.This model of land use transport interaction is developed at the strategic level, utilizing an aggregated system of 65 zones with compatible transportation network for testing the development strategies (IIT Bombay, 1993).

Area of Study

The city has sprawled over 172 sq km. with a number of urban roads The urban agglomerations there have been a lot of developments in the form of additions ribbon developments along the principal transport corridors has extended further inspite of efforts made to plan and guide the developments. This study is aimed at arriving at a suitable land use transport development strategy for Model for Madras Metropolitan Area as a whole.

Scope and Objectives

Madras Metropolitan Development Authority (MMDA) desired to have a very comprehensive Traffic and Transportation Study (CTTS) to fit with in the new structure plan under preparation. It has therefore has been to prepare the land use transportation strategy for MMA as the first step before taking up a detailed CTTS for the year 2011.The goals are as follows

- Development of transport network proposals to achieve increased and more equitable accessibility to employment and education opportunities and induce optimum land use.

- Increased efficiency in the use of resources and economy in the public funds. Conservation of human and natural resources .In general, this should involve minimizing the overall cost of transportation.

The scope of the study for achieving the above mentioned objectives will be that

- The model disaggregated for service employment will simulate the population and employment distributions for the study area within the alternative development constraints set for future.
- Transport linkages derived from population and service employment allocations mechanisms will generate transport flow patterns for the network due to the development policies
- Alternative blends of transport and land use strategies will thus get evaluated on the basis of likely and desirable trends of growth.

Land Use Transport Model

The model used for this study is based on Lowry model according to which two major functions are given by

- It relates three elements of the urban/regional system, population, employment and transport and relate their interactions
- It incorporates within its structure both allocation and forecasting procedures
- It assumes an economic base mechanism where employment is divided into basic and non-basic(service)sectors
- The basic employment sector includes those economic activities, the produce of which is utilized mostly outside the region e.g. manufacturing and other heavy government offices, the state head quarters, national financial institutions, university etc. All other are accounted as non-basic (sector population serving employment).
- The model assumes that the basic sector, both its location and magnitude is controlled exogenously.
- The model then determines the level and location of population and service (non-basic) within the region.

The notations used are

α=Population multiplier (inverse of labour participation rate)

β^k=Service employment ratio by type = E^k/P

E^k =Service employment by type k

E^b = Basic employment

P = Population

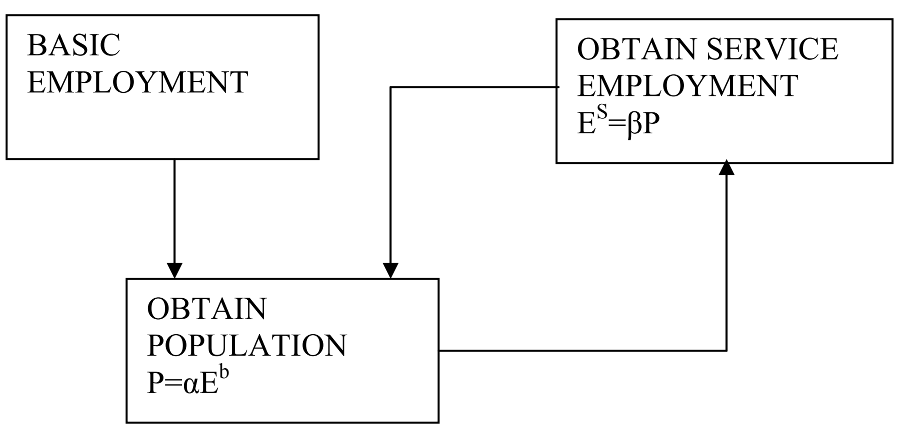
Since the total employment is

$E = E^b + \sum E^k$

The loop of generating service and population will produce the total employment and population as follows

$E = (1 - \alpha \sum_1^k \beta^k)^{-1}$, and

$P = \alpha E^b (1 - \alpha \sum_1^k \beta^k)$.



Economic Base Mechanisms (IITBombay, 1993)

Allocation Mechanism

(A) Residential location is a function of employment location and the trip making behaviour of the population. The basic employment is allocated to residential zones for using a singly constrained gravity model.

$$T_{ij} = A_i E_i H_j \exp(-\lambda c_{ij})$$

$$A_i = [H_j \exp(-\lambda c_{ij})]^{-1}$$

E_i=is the employment in zone i (initially it is the basic employment)

T_{ij}=number of people working in zone i and located in zone j for housing

H_j=attraction variable

c_{ij}= travel cost between i to j to be obtained from the network (in this case travel time between zones)

λ =deterrence parameter of the allocation function to be calibrated with respect to the base year work trip matrix

A_i=is the balancing factor

(B) The model uses the second allocation mechanism to locate the service as a function of the location population and travel time. The functional form is given by

$$S_{ij} = B_j P_j F_i \exp(-\mu^k c_{ij})$$

$$B_j = [F_i \exp(-\mu^k c_{ij})]^{-1}$$

Where

S_{ij} = is the flow of people from residential zone j to service zone i

P_j=is the population distributed to zone j by the residential allocation mechanism

F_i= attraction variable of service center at zone i.

B_j=Balancing factor

The total number of people demanding services in zone i (S_i) is therefore as follows

$$S_i = \sum_j S_{ij}$$

The level of service employment required for each zone is estimated using service ratios. Thus the service employment located in zone i for different service categories will be

$$E_i^1 = \beta^1 S_i$$

$$E_i^2 = \beta^2 S_i$$

Calibration Mechanism

The model is to be calibrated on the basis of given land use and transportation data. Its aim being to simulate the distributed population and employment in the study area

/region. Thus the three parameters λ, μ^1, $\mu 2$ will be estimated to satisfy the observed land use distributions and travel matrices.

While calibrating the model to base year observed data the model will try to match the observed distribution of population and categorized service employments. Thus it will be working with constraints to match the land use and for this reason; the constraint in population location will be applied. Any violation in allocation of population by exceeding observed population modifies the attraction variable so that the allocation in the following iteration gets corrected as follows.

$H_j^* = H_j\,(P^c{}_j/P_j)$

Where $P^c{}_j$=population holding capacity (for calibration this will be observed population in base year.) obtained from residential land available and policy on development with respect to density

The violations in service employment are considered at lower end in terms of viability (minimum size) constraint. Service employments allocated to zones are checked for minimum size .For those zones where it is les than allowable minimum , these are provided zero allocations and total of their allocations relocated in remaining zones of higher allocations

$E_i^{k*} = 0$ for zones where $E_i^k < E^k{}_{(min)}$

$E_i^{k*} = Eik$ for zones where $E_i^k > E^k{}_{(min)}$

Only after the land use constraint are fully met, the model enters the transport loop where it tries to match the observed work trip and service trip distributions .If it fails to satisfy the defined limit of error the deterrence parameter of each distribution work trip, education trip, and all other trip) will be corrected /modified/improved and the model proceeds for the next iteration. The model starts afresh from the land use allocation as the deterrence parameters control the accessibility in allocation function. This procedure continues till all constraint on location of population and employment as well as those related to trip matrices is fully met.

Five stage Land Use Transport model

The five-stage land use transport model (Lyon, 1992) has its decisions taken on instead of the conventional four-stage land use transport model, it is based on

- Destination
- Transport mode
- Route
- Mobility and
- Location

And all of these are considered to be interdependent.

Mobility: It is the defined as the number of trips made a person and also as the type of the trips made by a person. This is estimated by linear trip generation models by using socio economic variables and the accessibility (Keoing, 1975, Dalvi, 1976, Martin, 1976).

Location: The existing land use transportation models are very much complex (Webster, 1988).so the proposed approach uses Bid choice model which is to be fully and consistently integrated with the transport models using an extended decision chain of 5 components.

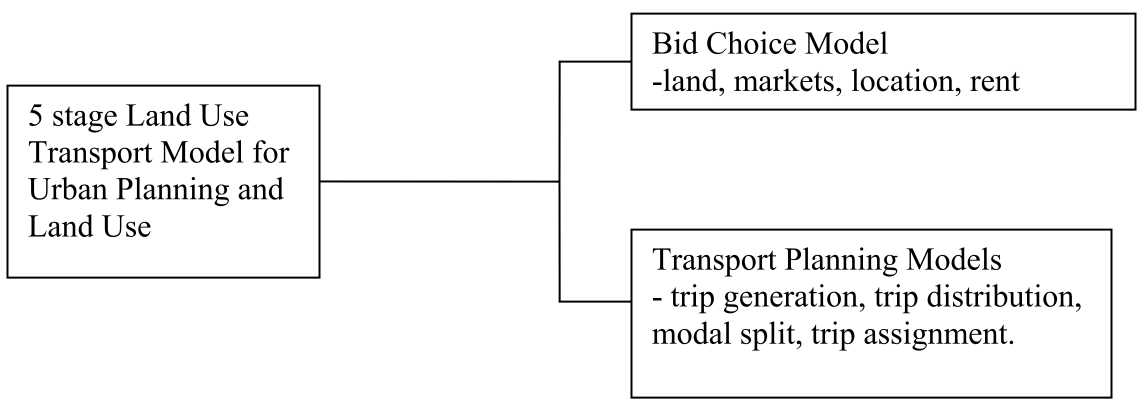
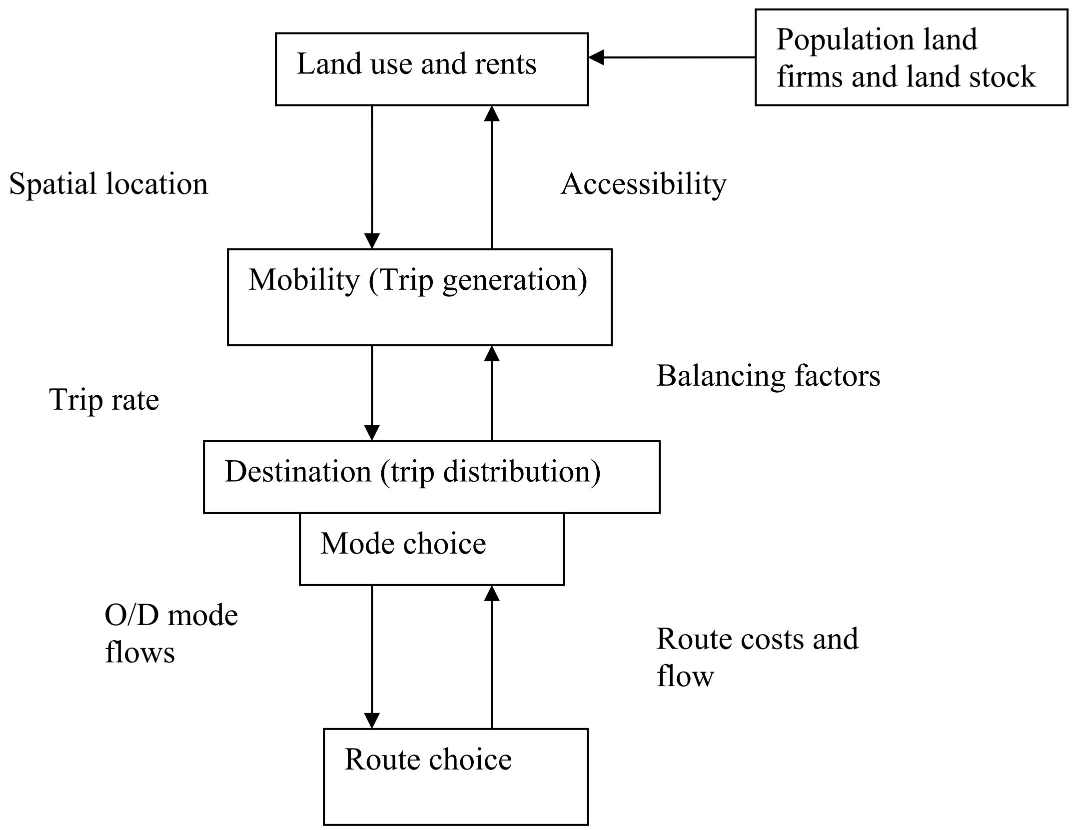


Fig 3.5 Outline of the 5 Stage Land Use Transport Model(Martinez, 1992)

General assumptions:

- The consumer takes decisions on location and travel to achieve maximum utility
- Consumer is willing to pay to enjoy the benefits of higher accessibility
- Accessibility measures are revealed by consumer preferences in transportation and in economic framework.
- Mode choice decision can be taken care of in an economic framework by re interpreting user benefits, land rents, and long term advantages of the transport schemes.

- Consumers are all possible buyers of urban land, including types of household and firms and possible to take care of tastes and priorities of all members involved.
- The land is sold in land lot units, the land lot units are described by their r cultural environment and it is assumed that human beings cannot change the attributes such as view, accessibility, etc at their will.



Land Use Model Structure (Martinez, 1992)

Models capable of being implemented in developing countries

The ISGLUTI study has brought together most of the fully integrated land use transport models in current use .The formulations of the individual ISGLUTI models are not surprisingly highly dependent on the interests and backgrounds of their modelers, the reasons for developing the models in the first place, the type of city which the model has been applied, the type of data available and the policy questions to which they were intended to provide solutions.

No single model can claim to embody all that is best in the current state of the art or to represent a universally optimal arrangement of components or of the various levels of aggregation of the main parameters, though naturally each model provides what the modeler considered to be the best representation of reality within his own particular constraints.

Nevertheless, most models offer considerable flexibility within their considerations and could be "modified fairly and readily" if desired to suit to the other country conditions to

- Cope with different types of data
- To give more detail on different aspects
- To deal with different policy questions
- To provide different types of information for policy makers

Policy Areas addressed by the models

Although the individual models were developed with a specific purpose in mind, they represent land-use and transport evolution in a very general way and their applicability to particular policy aspects is usually much wider than the application originally envisaged. The table 2.1 indicates the different policy areas which can be addressed, at some useful level of detail, by the various models.

Key:

✓ The policy is addressed by the model.

a The model represents distribution of the population

b The employment must be located exogenously

	Policy areas						
Models	Housing	Employment	Retail	Public Infrastructure	Land-use	Transport	Taxation
AMMERSOFT	✓	b	c		✓	d	e
CALUTAS	✓	✓	✓	✓	✓	✓	✓
DORTMUND	✓	✓	✓	✓	✓	✓	✓
ITLUP	a	✓	✓		✓	✓	e
LILT	✓	✓	✓		✓	✓	✓
MEP	✓	✓	✓	✓	✓	✓	✓
OSAKA	a	✓	✓	✓	✓	d	✓
SALOC	a	✓	✓	✓	✓	d	E
TOPAZ	a	✓	✓	✓	✓	✓	E

c Not in ISGLUTI, but examined in another model

d Some transport policies can be addressed, but comprehensive information on trip behaviour is not available

e Some taxation/financing schemes affecting transport costs and car ownership.

Policy testing

1. Population change and land use restrictions:

Policy tests concerned with population change (Webster, *et al*, 1988)

Test	Model results available
Population grows at 2% p.a	
No restrictions on land use	A C D L M O T
With restrictions on peripheral land use	A C D L M T
Zero population growth	
No restrictions on land use	A D L M T
With restrictions on peripheral land use	A D L M

2. Employment location policies

Policy tests concerned with employment location (Webster, *et al*, 1988)

Test	Model results available
Half of non service jobs moved from inner areas to outer areas	A C D L M O T
Half of non service jobs moved from inner areas to peripheral industrial estate	A C D L M O T
Non service jobs redistributed in proportion to population	C D L M

3. Location of shopping facilities and financial inducements

Policy tests with shopping and financial inducements (Webster, *et al*, 1988)

Test	Model results available
Location of new facilities	
City centre shopping floor space halved	C D L M O T
New shopping center equivalent to one quarter of city centre floor space set up in accessible location	D L
Financial inducements	
Unlimited free parking for city centre shoppers	L
Free public transport to city centre shops	L

4. Cost of travel

Policy tests concerned with cost of travel (Webster, *et al*, 1988)

Test	Model results available
All travel costs up 50%	A D L M
All travel costs up 100%	D L M
Car costs quadruple	D L M
CBD parking cost= travel cost	D L M
CBD parking cost=3 * travel cost	A D L M
Public transport free	D L M
Public transport fares up 50%	D L M
Public transport fares up 100%	D L M

5. Speed and network changes

Policy tests with speed and network changes (Webster, *et al*, 1988)

Test	Model results available
Speed Changes	
1.Speeds of all mechanized modes increased by 20%	A C D L M O T
2. Speeds of all mechanized modes reduced by 20%	A C D L M O T
3. Bus speeds increased by 20%, speeds of other modes decreased by 20 %	D L M O T
4. Speeds down by 15% in inner areas, 25% in outer areas	D L M
Network changes	
1.New outer orbital motorway, speed is 80km/h	D L M
2.New inner road ring, speed is 60km/h	D L M
3.New cross town transit line, speed is 40km/h	D L M
4. As per 3 with speed 60km/h	D L M
Car Ownership	
1.Growth in car ownership no extra investment in transport network	D L M
2. As per 1 but car ownership grows by 2% more slowly	D L M
3. As per 1 but car ownership grows by 2% more rapidly	D L M

6. Economic climate

Policy tests concerning with Economic climate (Webster, *et al*, 1988)

Test	Model results available
Employment cut by 20%, travel costs increased by 20%	D L M T
All travel costs up by 50%	A D L M
All travel costs up by 100%	D L M
All people placed in same group of disposable income	A D M

Key:

A - AMMERSOFT

C - CALUTAS

D - DORTMUND

L - LILT

M - MEP

O - OSAKA

T - TOPAZ

Mechanisms to be considered

The criteria, which are to be considered in transferring the model from one place to another depends upon many factors like

- Employment Location
- Residential Location
- Car Availability
- Competition for land
- Time and Space
- Representation of travel
- Model construction

Reliability of the models

Reliability depends upon many factors like its transferability satisfying criteria, its behaviour after implementation etc. Reliability does not necessarily increase with complexity or disaggregation, though the models which are too simple and global cannot hope to fully replicate a complex situation. If the various mechanisms are thoroughly understood and the strengths of the are known then the added complexity resulting from the inclusion of more detail is likely to be justified.

Urban Goods Movements

Introduction

The urban goods movement, consisting mainly of truck transportation has been given very little attention in transportation-planning studies. But in recent years the transport planners, freight carriers, shippers etc. has understood the immense need of including the commodity movements in the urban planning.

Goods movement demands are created by the economic activities of production and consumption. It involves serious thinking regarding identification of principle economic units in an area and developing an understanding their internal structures. A lot of understanding is required in this regard because vehicle demand analysis is much more complex than travel demand analysis and involves factors like separate routes for goods movements, location of freight terminals and segregation of goods into small assignments for distribution within urban area. The simple conceptualization of economic activities can be shown by the diagram below.

Freight Movement Problems

The following four major problems have been identified regarding urban freight transportation.

I. The interaction between commodity flows and land uses.
II. The general efficiency and economy of goods movement.
III. The environment problems of noise and air pollution.
IV. The truck movement in CBD.

Factors Considered In Goods Movement Forecasting

The factors important in forecasting of urban movements of goods are following.

I. Changing patterns of urban developments and structures

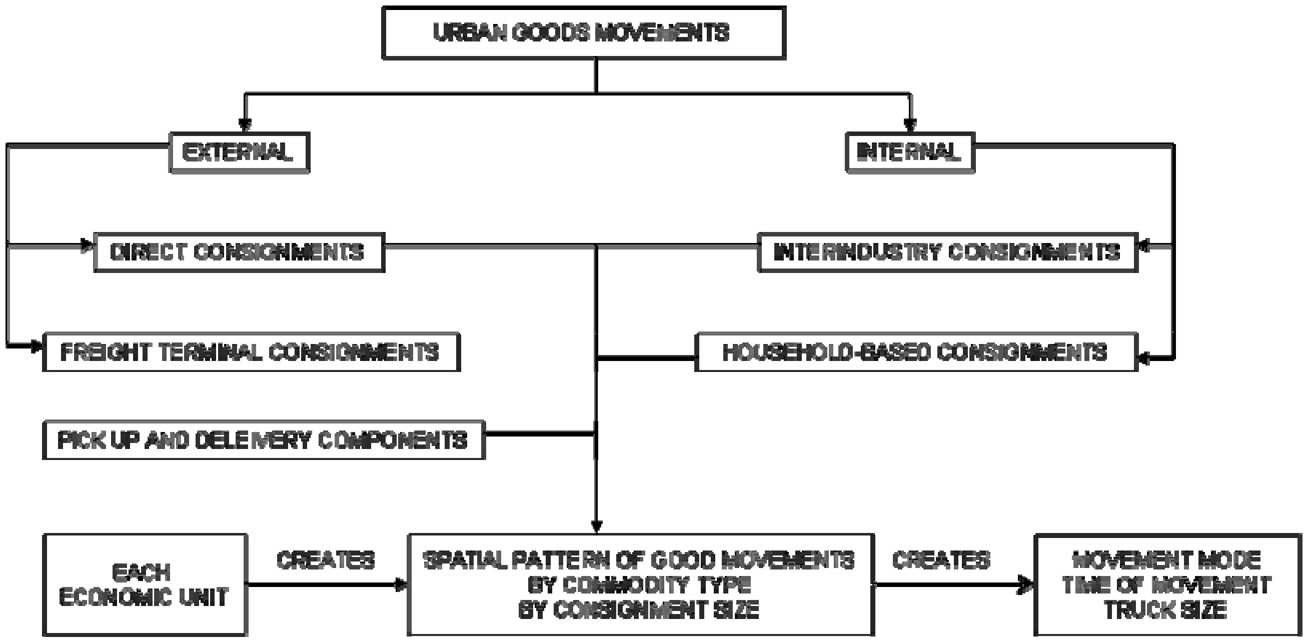
II. Location of terminals and transfer points
III. Land use patterns
IV. Changing costs and economics of goods movements industry
V. Labour practices within the industry
VI. Technological innovations in goods movements
VII. Effects of govt. police, aids and regulations
VIII. Social and environment considerations
IX. Inter-industry transactions etc.

Classification Of Urban Goods Movements

The classification of urban goods movements can be done at three broad levels as following.

I. The first level classification is based on the spatial pattern of demand. This may be further divided into groups like goods movements between urban area and external locations, Inter-industry goods movements within an urban area and household-based goods movements within an urban area.
II. The second level classification is based on commodity type which can be perishable and non-perishable commodity and other such classifications depending upon the type of industrial product.
III. The third level classification is by consignment size which is usually expressed in terms of weight of the consignment.

The following diagram on the next page shows the broad classification of urban goods movements.



External Commodity Movements

The commodity movements to and from external locations are of two broad types i.e. direct consignments which are mainly made by trucks and consignments via a freight terminal which involves pick up and delivery components by trucks. The proportion of these two types is affected by freight pricing rules. Other mode of travel may be airlines, rail and ships etc. Depending upon the trip length, the particular mode is selected as shown in the table below.

Trip length	**Transportation type**
≤300 miles	Road Transport
300 – 900	Rail Transport
≥900	Water Transport

Input-Output Table

It highlights the economic structure of the industry. It consists of *direct requirement matrix*. Each column of this matrix shows the dollar value of the inputs that is required by a particular industry, being shown at the top of that particular column, from other industries in order to produce one dollar of total output.

The input-output can be extended to include other important sectors like warehousing, retailing, commercial etc. The necessary technical coefficients required to connect these additional sectors can be established with the help of survey.

The input-output table provides a broad view of the average economic characteristics of various industrial sectors. The annual inputs in terms of commodity type to a particular zone may be obtained from equation as

$$\mathbf{a_j^e = [a_{ef}]\, p_j^e}$$

Where a_j^e = a column vector of the cash value of annual consumption by commodity type e by industry in zone j.

$[a_{ef}]$ = The direct requirement matrix of the input –output table for e input and f output industries.

p_j^e = a column vector of the cash values of the annual production of commodity e in region j.

Input-Output Table

Input Sector	**Output Sector**										
	Construction		Wholesale Trade						Retail Trade		
	Building	Other than building	Hardware, construction Materials	Fuels	Shop and Office fittings	Machinery equipment and supplies	Pulp, paper and its products	Other	M/ vehicles	Other consumables	Deptt. And Variety stores
Wholesale Trade											
Hardware, construction Materials											
Fuels											
Shop and Office fittings											
Machinery equipment and supplies											
Pulp, paper and its products											
Other businesses											

Direct Requirement Matrix (pp.412 Hutchinson)

INDUSTRY SECTOR	**INDUSTRY NO.**					
	1	2	3	4	5	6
1- Print/Publishing	0.03	.0001	0.0003	0.0	0.0006	0.0005
2-Iron, steel Mills	0.0					
3-Primary Metals						
4- Structural Metals		0.0	0.0	0.0	0.0	0.01
5-Metal Stamping				0.0		
6-Other Fabric Ind.						
7- Wages and Salary	0.15	0.29	0.11	0.24	0.14	0.127

Leontief and Strout Model

They have proposed the following gravity type expression for estimating interregional commodity flows.

$$t_{ij}^{e} = \frac{p_i^{e} a_j^{e}}{\sum_j a_j^{e}} q_{ij}^{e}$$

Where

t_{ij}^{e}= the cash value of annual flow of commodity e from region i to region j

q_{ij}^{e}= empirically determined coefficient which characterized interregional flow of commodity e.

Wilson Model

It is a modification of the Leontief and strout model. The model can be expressed by the equation as given below.

$$t_{ij}^{e} = \frac{p_i^{e} a_j^{e} \exp(-\mu^{e} c_{ij})}{\sum_j a_j^{e} \exp(-\mu^{e} c_{ij})}$$

Where μ^{e} = a parameter that expresses the importance of transport costs C_{ij} on the distribution pattern of commodity type e.