Module 2

2.1 **Transportation Planning Process**

The transportation planning process has a lot of similarity to the problem solving process. The following table gives the major differences between the two processes.

Sl No	**Problem Solving**	**Transportation Planning**
1	Problem solving lacks foresight ness to take advantage of the forthcoming innovations	Problem definition and Objective relevant to planning condition. They change themselves, so innovations are used
2	It is not Programmed Basis	Usually Programmed basis
3	Our concern may be for the dimension and performance of a vehicle to be replaced within a shorter period of time from now	We may be concerned with about location and capacity of Mass Transit
4	Breadth of problem: i.e. parking, congestion	Study of broader situation i.e. whole city
5	Immediate solution is required .so it is completed within shorter period	Implemented Sequentially

2.2 Types of Planning Methodologies

1. Projective planning.
2. Deductive planning.
3. Objective planning.

Projective planning:

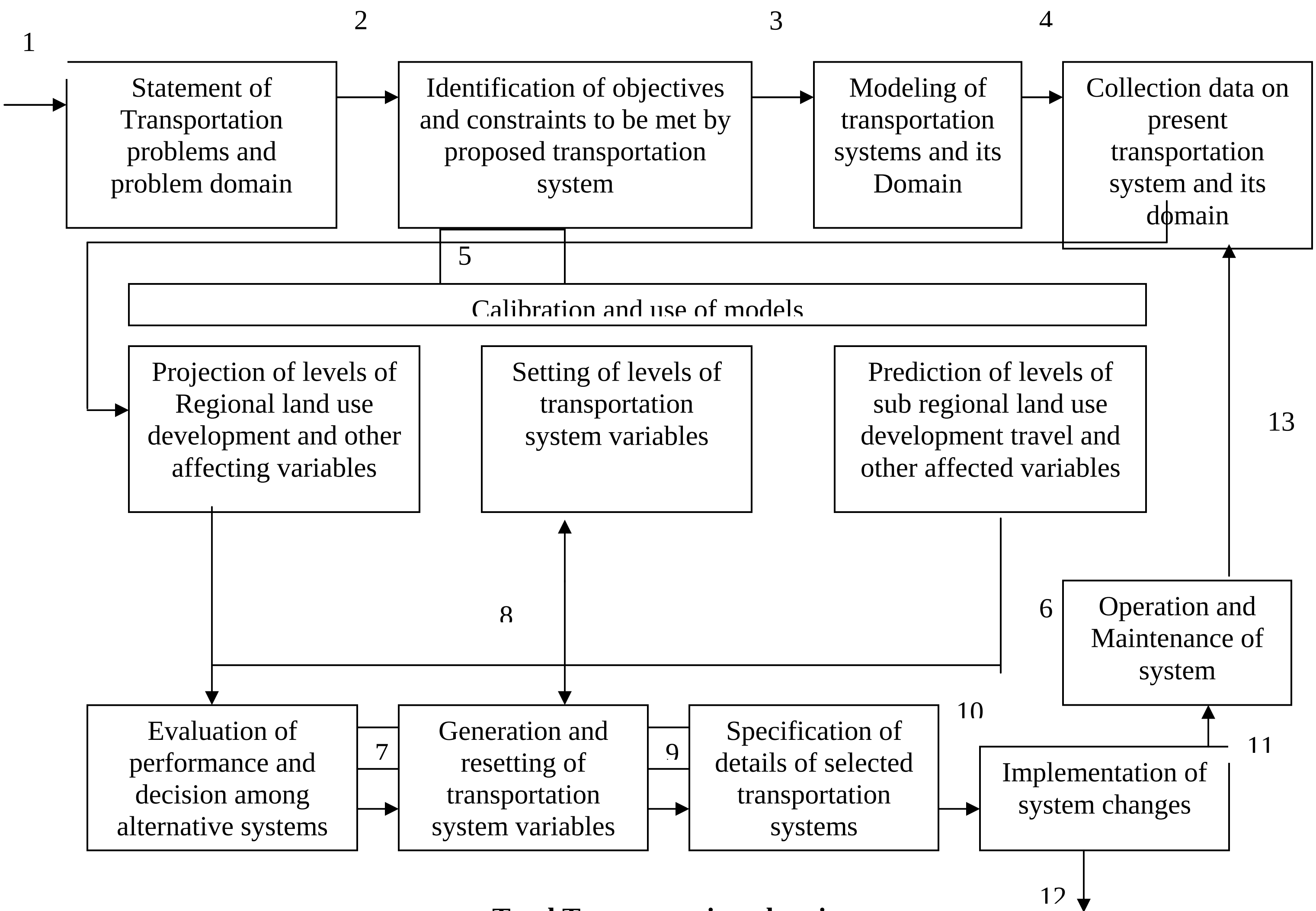
It is a base for planning. It is an open Extrapolation method.

Example: Traffic flows, Vehicle ownership, Residential Densities, Population trends, Economic Growth, Socio- economic indices.

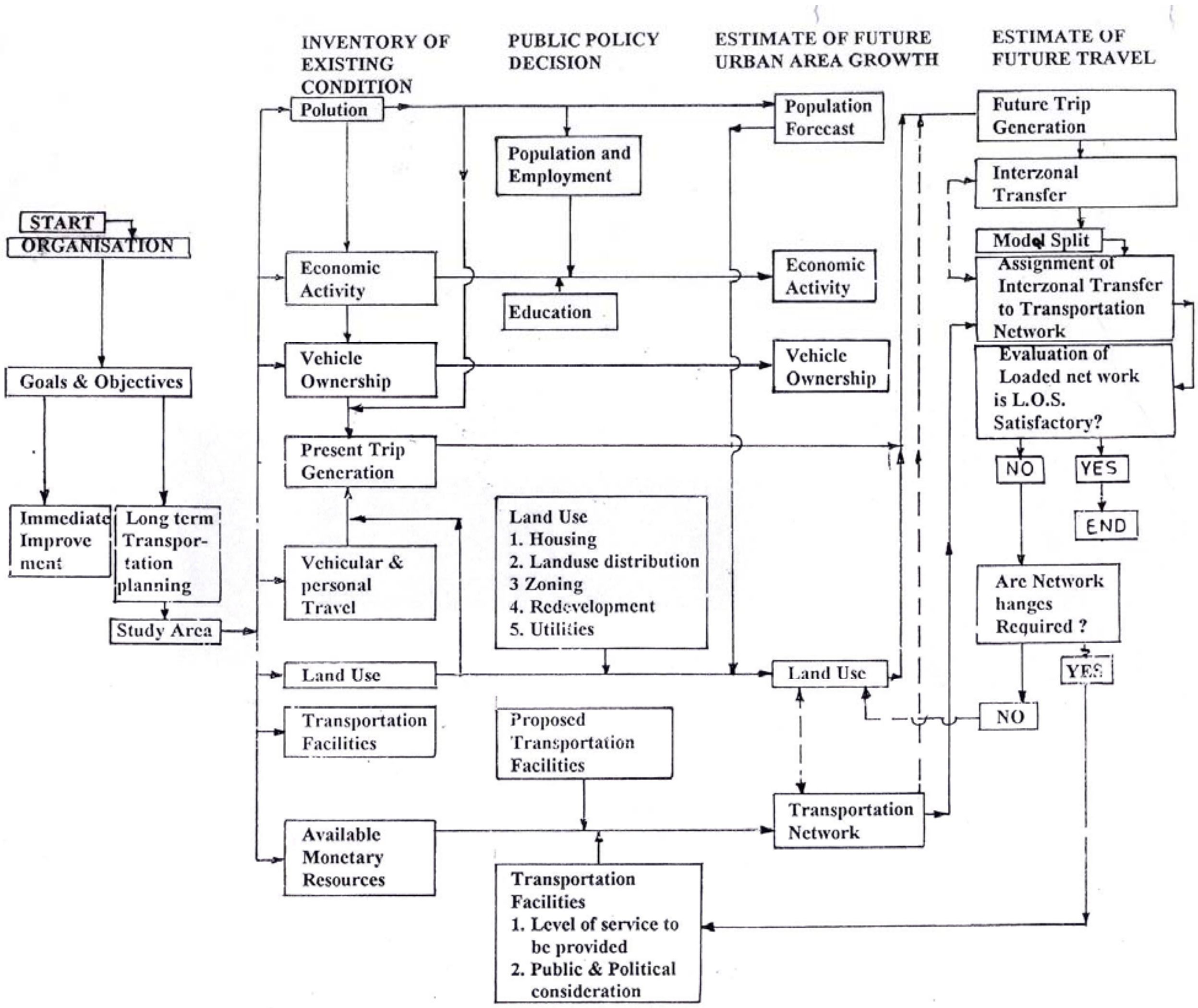
Deductive planning: Synthesis the future state of the system from laws, equations or models that are one in its behaviour.

Example: Analysis of specific projects and operational activities such as bypasses, regional centers, transport terminals, one-way streets can be effectively analyzed deductive planning process.

Objective planning: Planner sets some goals and with a certain objective and with constraints. It will be difficult to take into account the uncertainties.



Total Transportation planning process

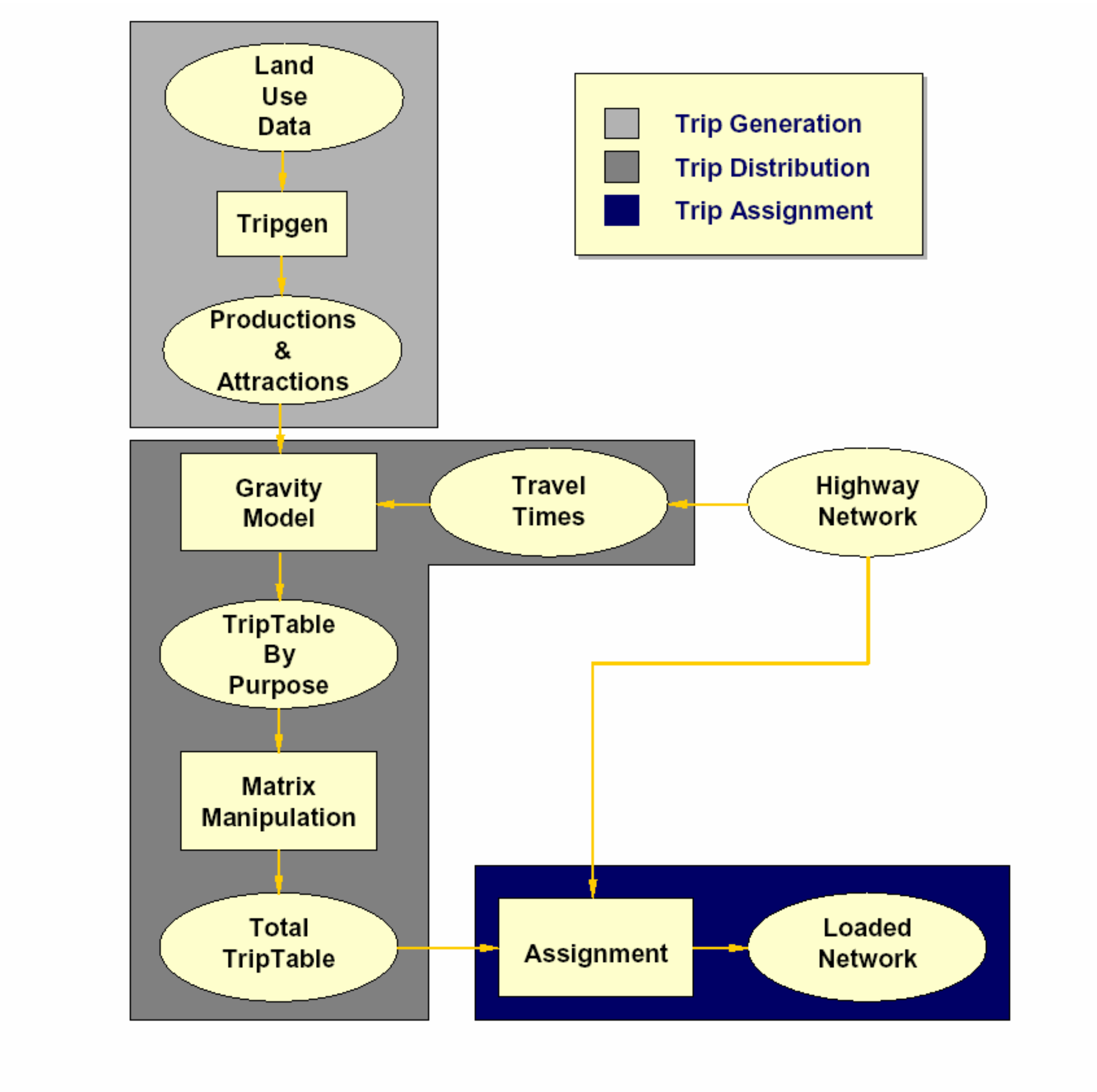


Deductive Planning Process

2.3 Travel demand modelling:

There are four steps of travel demand modelling. They are

1. Trip generation
2. Model split
3. Trip Distribution
4. Trip assignment



Steps of Travel Demand Modelling

2.3.1 Trip-Generation Analysis: -Two types of trip-generation analysis are carried out and these are trip production and trip attraction.

Trip Production: -is reserved for trips generated by residential zones where these trips may be trip origins and destinations.

Trip Attraction: -is used to describe trips generated by activities at the non-home end of a home-based trip such as employment, retail service, and so on.

The first activity in travel-demand forecasting is to identify the various trip types important to a particular transport-planning study. The trip types studied in a particular area depend on the types of transport-planning issues to be resolved. The first level of trip classification used normally is a broad grouping into home-based and non-home-based trips.

Home-based Trips: - are those trips that have one trip end at a household. Examples journey to work, shop, school etc.

Non-home-based trips: -are trips between work and shop and business trips between two places of employment.

Trip classification that have been used in the major transport-planning studies for home-based trips are:

a. Work trips
b. School trips
c. Shopping trips
d. Personnel business trips, and
e. Social-recreational trips

Factors influencing Trip Production

Households may be characterized in many ways, but a large number of trip-production studies have shown that the following variables are the most important characteristics with respect to the major trip trips such as work and shopping trips:

1. The number of workers in a household, and
2. The household income or some proxy of income, such as the number of cars per household.

Factors Influencing Trip Attraction

Depending on the floor areas, the trip attraction can be determined from retail floor area, service and office floor area and manufacturing and wholesaling floor area.

Multiple Regression Analysis

The majority of trip-generation studies performed have used multiple regression analysis to develop the prediction equations for the trips generated by various types of land use.

Most of these regression equations have been developed using a stepwise regression analysis computer program. Stepwise regression –analysis programs allow the analyst to develop and test a large number of potential regression equations using various combinations and transformations of both the dependent and independent variables. The planner may then select the most appropriate prediction equation using certain statistical criteria. In formulating and testing various regression equations, the analyst must have a thorough understanding of the theoretical basis of the regression analysis.

Review of Regression Analysis Concept

Some of the fundamental of regression analysis: - The principal assumptions of regression analysis are:

1. The variance of the Y values about the regression line must be the same for all magnitudes of the independent variables.
2. The deviations of the Y values about the regression line must be independent of each other and normally distributed.
3. The X values are measured without error
4. The regression of the dependent variable Y on the independent variable X is linear.

Assume that observation of the magnitude of a dependent variable Y have been obtained for N magnitudes of an independent variable X and that on an equation of the form $Y_e = a + bX$ is to be fitted to the data where Y_e is an estimated magnitude rather than an observed value Y.

From the least-squares criterion, the magnitude of the parameters a and b may be estimated.

$$b = \frac{\sum xy}{\sum x^2}$$

$$a = \overline{Y} - b\overline{X}$$

where

$$x = X - \overline{X} \text{ and } y = Y - \overline{Y}$$

$\overline{X}, \overline{Y}$ =the means of the X and Y observations respectively.

$$\sum y^2 = \sum y_d^2 + \sum y_e^2$$

Where

$\sum y^2$ = total sum of the squares of the deviations of the Y observations about the mean value

$\sum y_d^2$ =the sum of the squares of the deviations of the Y observations from the regression line.

$\sum y_e^2$ =the sum of the squares of the deviations of the estimated Y_e magnitude about the mean value.

The ratio of the sum of the squares explained by the regression to the total sum of squares is known as *the coefficient of determination and denoted by r^2*.

$$r^2 = \frac{\sum y_e^2}{\sum y^2} \qquad 0 \le r^2 \le 1$$

- if r^2 =1 implies no variation remaining that is unexplained by the independent variable used in the regression.
- If r^2 = 0 implies the independent variable used would not explain any of the observed variation in the dependent variable.

The square root of the coefficient of determination is termed as the *correlation coefficient.*

A second useful measure of the validity of a regression line is the standard error of the estimate, which is estimated from:

$$s_e = \sqrt{\frac{\sum y_d^2}{(N-2)}}$$

where

$(N-2)$ is the degree of freedom associated with the sum of squares $\sum y_d^2$

The regression coefficient b is the statistical estimate and is therefore subject to error.

$$s_b = \frac{s_e}{s_X}\sqrt{N}$$

where

s_X is the standard deviation of the independent variable.

Statements about the confidence that might be placed in an estimated coefficient is given by:

$$t = \frac{\text{regression coefficient}}{\text{standard error of the regression coefficient}}$$

Partial or Multiple Regression Equation

It has equation of the form:

$$Y_e = a + b_1 X_1 + b_2 X_2 + ... + b_p X_p$$

where there are p independent variables and the regression coefficients b_1, b_2,…, b_p are referred to as *partial regression coefficients*.

The coefficient of multiple determinations, $R^{2\,2}$ is given by:

$$R^2 = \frac{\sum (Y_e - \overline{Y})^2}{\sum (Y - \overline{Y})^2}$$

where R^2 is known as the multiple correlation coefficients.

$$s_e = \frac{\sum y_e^2}{[N-(P+1)]}$$

$$s_b = \frac{s_e^2}{[s_{Xi}^2 N(1 - R_{Xi}^2)]}$$

Where s_{Xi} is the standard deviation of the independent variable X_i and R_{Xi} is the coefficient of multiple correlations between X_i and all other independent variables.

Table 1: Linear Regression

Y	X	$y = Y - \overline{Y}$	$x = X - \overline{X}$	xy	x^2
9428	9482	7502.125	7473.375	56066193.42	55851334
2192	2010	266.125	1.375	365.921875	1.890625
330	574	-1595.88	-1434.63	2289482.172	2058149
153	127	-1772.88	-1881.63	3335885.922	3540513
3948	3836	2022.125	1827.375	3695180.672	1827.375
1188	953	-737.875	-1055.63	778919.2969	-1055.63
240	223	-1685.88	-1785.63	3010340.547	-1785.63
55	36	-1870.88	-1972.63	3690534.797	-1972.63
2064	2223	138.125	214.375	29610.54688	214.375
280	272	-1645.88	-1736.63	2858267.672	-1736.63
52	50	-1873.88	-1958.63	3670218.422	-1958.63
230	209	-1695.88	-1799.63	3051939.047	-1799.63
420	410	-1505.88	-1598.63	2407329.422	-1598.63
9654	11023	7728.125	9014.375	69664216.8	9014.375
450	527	-1475.88	-1481.63	2186693.297	-1481.63
130	183	-1795.88	-1825.63	3278594.297	-1825.63
$\overline{Y}$	$\overline{X}$				
1925.875	2008.625			Σ=160013772.3	Σ=61445839
b	2.604143	a	-3304.87		

Category analysis:

Category analysis is a technique for estimating the trip production characteristics of households, which have been sorted into a number of separate categories according to a set of properties that characterize the household. Category analysis may also be used to estimate trip attractions.

Zonal trip productions may be estimated as

$$p_i^q = \sum h_i(c)tp(c)$$

Where,

p_i^q = The number of trips produced by zone i by type q people.

$h_i(c)$= number of households in zone i in category c

tp(c)= trip production rate of a household category c.

Zonal trip-attractions may be estimated as

$$a_j = \sum b_j(c)ta(c)$$

Where,

a_j = number of work trips attracted by zone j.

$b_j(c)$ = number of employment opportunities in category c.

ta(c) = trip attraction rate of employment category c

And the summation is over all employment types if work trip attractions are to be estimated.

2.3.2 Modal Split

The second stage of travel demand forecasting process has bee identified as captive modal split analysis. The second stage of modal split analysis was identified as occurring after the trip distribution analysis phase. Two submarkets for public transportation services have been labelled as captive transit riders and choice transit riders. The aim of captive modal split analysis is to establish relationships that allow the trip ends estimated in the trip generation phase to be partitioned into captive transit riders and choice transit riders. The purpose of choice modal split analysis phase is to estimate the probable split of choice transit riders between public transport and car travel given measures of generalized cost of travel by two modes.

The ratio of choice trip makers using a public transport system varies from 9 to 1 in small cities with poorly developed public transport systems to as high as 3 to 1 in well developed cities.

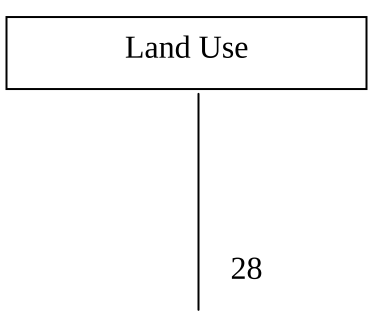
Major determinants of Public Patronage are

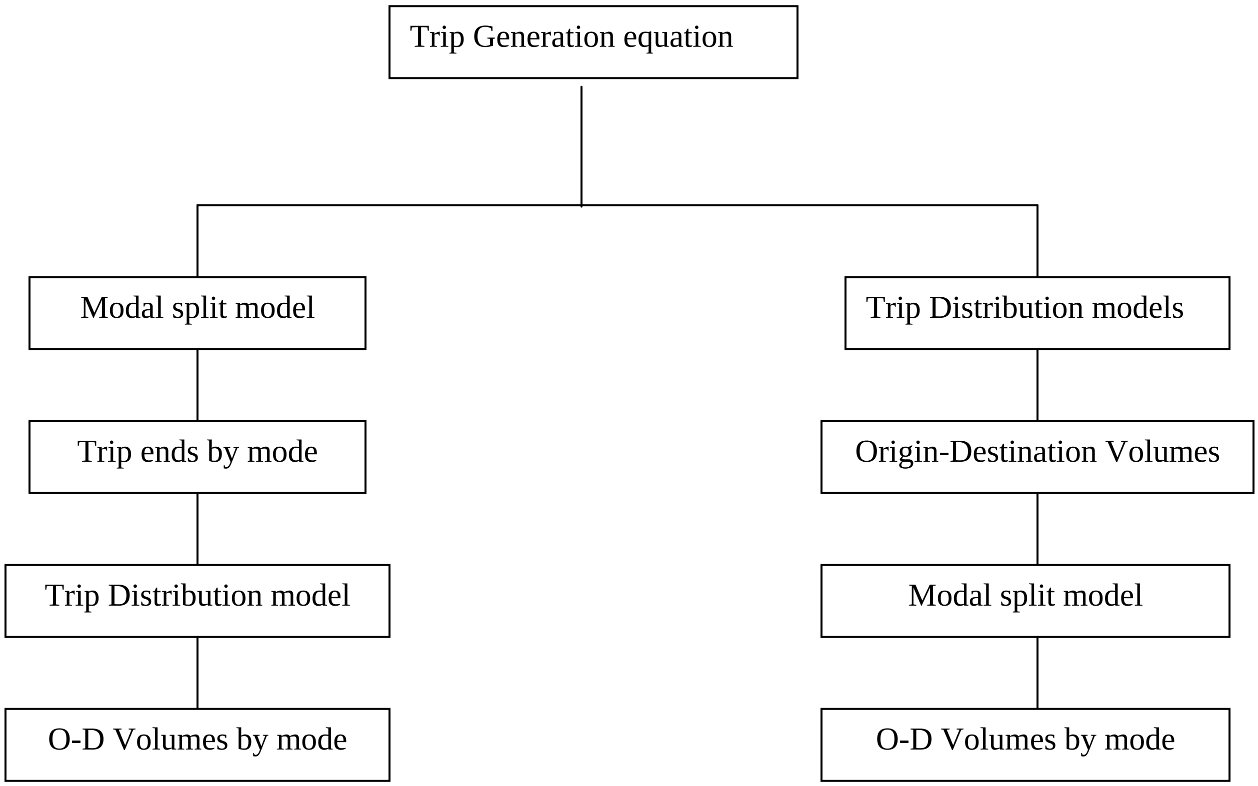
1. Socio economic characteristics of trip makers
2. Relative cost and service properties of the trip by car and that by public transport.

Variables used to identify the status at the household level are

1. Household income or car ownership directly
2. The number of persons per household.
3. The age and sex of household members.
4. The purpose of the trip.

The modal split models, which have been used before the trip distribution phase, are usually referred to as trip end modal split models. Modal split that have followed the trip distribution phase are normally termed trip interchange modal spit models. Trip end modal split models are used today in medium and small sized cities. The basic assumption of the trip end type models is that transport patronage is relatively insensitive to the service characteristics to the transport modes. Modal patronages are determined principally by the socio economic characteristics of the trip makers. Most of the trip interchanges modal split models incorporate measures of relative service characteristics of competing modes as well as measures of the socio economic characteristics of the trip makers. The modal split model developed during the southeastern Wisconsin transportation study is an example of trip end type model. The model-split model developed in Toronto is an example of trip interchange modal split model.





Trip End Type Modal Split Model **Trip Interchange Type Modal Split Model**

These factors, including time and cost, can be grouped into three broad categories.

- Characteristics of the traveler -- the trip maker;
- Characteristics of the trip; and
- Characteristics of the transportation system.

Southeastern Wisconsin Model:

This Model consisted of seven estimating surfaces that related the percentage of the trip ends that will use transit services from a particular traffic analysis zone to the following variables: trip type, characteristics of trip maker and characteristics of the transport system. The trips made by public transport services are classified as Home based work trips, home based shopping trips, home based other trips and non-home based trips. The socioeconomic characteristics of trip makers were defined on the zonal basis in terms of average number of cars per household in a zone. The characteristics of a transport system relative to given zone were defined by an accessibility index which is given by:

$$acc_i = \sum_{j=1}^{n} a_j f_{ij}$$

Where

acc_i = accessibility index for zone i

a_j = No of attractions in zone j

f_{ij} = Travel time factor for travel from zone I to zone j for a particular mode being considered.

The transport service provided to a particular zone by two modes was characterized by accessibility ratio.

Accessibility Ratio = Highway accessibility index / Transit accessibility index.

Toronto Model:

Trip interchange modal split models allocate trips between public transport and private transport after trip distribution stage. The split between two modes is assumed to be a function of the following transportation variables between each pair of zones, as well as the socioeconomic characteristics of the people who avail themselves of the alternatives

Relative Travel Time (TTR)

Relative Travel Cost

Economic status of the Trip maker

Relative travel service

$$TTR = \frac{X_1 + X_2 + X_3 + X_4 + X_5}{X_6 + X_7 + X_8}$$

Where

X_1 = Time spent in transit vehicle

X_2 =Transfer time between transit vehicles

X_3 = Time spent in waiting for a transit vehicle

X_4 = Walking time to a transit vehicle

X_5 = Walking time for transit vehicle

X_6 = Auto driving time

X_7 = Parking delay at destination

X_8 = Walking time from parking place to destination

This represents the door to door travel time to train to that of automobiles

$$CR = \frac{X_9}{(X_{10} + X_{11} + 0.5X_{12}) / X_{13}}$$

Where

X_9 =Transit Fare

X_{10} =Cost of gasoline

X_{11} =Cost of oil charge and lubrication

X_{12} =Parking Cost at destination

X_{13} = Average Car Occupancy

The denominator indicates that auto cost must be put on a person per one way trip basis in order to be comparable to the costs for transit.

The variable EC is defined in terms of medium income per worker in the zone of trip production. The variable D is designed arbitrarily as

$$D = \frac{X_2 + X_3 + X_4 + X_5}{X_7 + X_8}$$

MODAL SPLIT MODEL WITH A BEHAVIOURAL ANALYSIS

The focus of these models is on individual behavior rather than on zonally aggregated modal choice behaviour. Central to these methods is the concept of trip disutility or the generalized cost of using different modes of transport.

Generalized cost of travel:

The concept of generalized travel cost is derived from the notion that the trip making has a number of characteristics which are unpleasant to trip makers and that the magnitudes of this unpleasantness depend on the socioeconomic characteristics of the trip maker. The generalized cost or disutility of a trip may be estimated from:

$$z_{ij}^{m} = a_n x_{nij}^{m} + b_w u_w + c$$

n=1,…………….n,

w=1,…………….w.

Where,

z_{ij}^{m} = generalized cost of travel between zones I and j by mode m.

x_{nij}^{m} = the nth characteristic of mode m between zones I and j which gives rise to the cost of travel by mode m.

u_w = the wth socioeconomic characteristic of a tripmaker.

c = constant.

a_n, b_w = coefficients that reflect the relative contribution that system and tripmaker characteristics make to the generalized cost of travel.

For a binary modal choice situation the following generalized cost difference may be calculated from the above equation.

$$z_{ij}^{*} = a_n \Delta x_{nij} + b_w u_w + c$$

n=1,……………….n,

w=1,……………….w.

where,

z_{ij}^{*} = the difference in generalized costs of travelling between zones i and j.

Δx_{nij} = the difference in the nth system characteristic between the two modes.

If trip makers are classified into a number of socioeconomic groups, then may be expressed as

$$z_{ij}^{*} = a_n \Delta x_{nij} + c$$

n=1,……………,n

if z_{ij}^{*} is the difference in cost between transit and car travel then c may be regarded as a mode penalty reflecting the inferior convenience and comfort of transit relative to car.

Wilson and his associates reported the following generalized cost relationship from studies in England.

$$z_{ij}^{m} = 0.66 d_{ij}^{m} + 1.32 e_{ij}^{m} + a_3 s_{ij}^{m}$$

Where

z_{ij}^{m} = The generalized cost of travelling between zones i and j by modes m

d_{ij}^{m} = The in vehicle travel time in minutes by mode m between zones i and j.

e_{ij}^{m} = The excess travel time in minutes by mode m between zones i and j.

s_{ij}^{m} = The distance in miles by mode m between zones i and j.

a_3 = 2.0 for car travel

2.18 for train travel

3.06 for bus travel.

BINARY CHOICE STOCHASTIC MODAL SPLIT MODELS:

This is one of the models which deal with the generalized costs of travel for competing modes. Three types of mathematical concepts have been used to construct stochastic modal choice functions for the individual behaviour**:**

- Discriminant analysis
- Probit analysis
- Logit analysis.

Discriminant analysis

The basic premise is that the choice of tripmakers in an urban area may be classified into two groups according to mode of transport used. The objective is to find a linear combination of explanatory variables that possesses little overlap. The best discriminate function is the one that minimizes the number of mis classifications of trip makers to the observed transport modes.

Quarmby, has developed an equation for estimating car bus modal split for work trips to central London:

$$pr(c/z) = \frac{2.26e^{1.04(z-0.431)}}{1+2.26e^{1.04(z-0.431)}}$$

pr(c/z)= the probability of choosing the car mode- given that the travel disutility is z.

The disutility measure was developed as a function of differences in total travel time, excess travel time, costs and income related variables.

Talvitie model:

$$pr(m=1/ij) = \frac{e^{z+\ln(x/y)}}{1+e^{z+\ln(x/y)}}$$

$$pr(m=2/ij) = \frac{1}{1+e^{z+\ln(x/y)}}$$

z is assumed to be normally distributed.

Where

Pr(m/ij) = the probability that an individual will use mode m given that the trip is between zones i and j.

x, y = The a priori probabilities of membership in groups m=1 and m=2 respectively.

Probit Analysis

The basic premise is that as choice trip makers are subjected to changing magnitudes of relative trip costs, the proportion of trip makers that respond by choosing a particular mode of transport will follow a linear relation.

Lave has developed the following equation for estimating the probability of bus-car modal patronage for Chicago area.

$$Y = -2.08 + 0.00759kW\Delta T + 0.0186\Delta c - 0.0254IDC_c + 0.0255A$$

$R^2 = 0.379$

Where

Y= binary variable with positive magnitudes denoting transit riders and negative magnitudes denoting car riders.

$kW\Delta T$ = time difference between modes multiplied by the tripmaker's wage rate and his marginal preference for leisure time.

IDC_c = a binary valued comfort variable multiplied by income and trip distance.

Logit Analysis:

Stopher model.

$$pr(m = 1/ij) = \frac{e^{z_{ij}^*}}{1 + e^{z_{ij}^*}}$$

$$pr(m = 2/ij) = \frac{1}{1 + e^{z_{ij}^*}}$$

where

z_{ij}^* = some function of the generalized costs of travel by modes m=1 and m=2

Two Stage Modal Split Model

Vandertol et al. have developed a simple two stage model which recognizes explicitly the existence of both captive and of choice transit riders. The model first identifies both the production and attraction trip ends of transit captives and choice transit riders separately. The two groups of trip makers are then distributed from origin to destinations. The choice transit riders are then split between transit and car according to a choice modal split model, which reflects the relative characteristics of the trip by transit and the trip by car.

In most cities, the transit captive is severely restricted in the choice of both household and employment locations. Studies in a number of cities have shown that the trip ends of the transit captives tend to be clustered in zones that are well served by public transport. The challenge is to develop is to formulate a technique that uses information normally available in urban areas.

Zonal work trip productions disaggregated by the captive and the choice transit riders may be estimated from

$P_i^{\ q} = h_i tp^q$

Where

$P_i^{\,q}$ = no of work trips produced in zone i by type q trip makers

h_i = the no of households in zone i

tp^q = work trip production rate for trip maker group q which is a function of economic status of a zone and the average no of employees per household.

The work trips attracted to each zone j by trip maker type q may be estimated from

$$a_j^q = [pr_c^q]\,[r_{ct}]\,[e_{tj}]$$

Where

a_j^q= the no of work trips of type q trip maker attracted to zone j

$[pr_c^q]$ = A row vector of the probability of the trip maker type q being in occupation category type c.

$[r_{ct}]$ = A c*t matrix of the probabilities of an occupation category type c within an industry type t.

$[e_{tj}]$ = a t*j matrix of the no of jobs within each industry type t in each zone j.

2.4 TRIP DISTRIBUTION

A trip distribution model produces a new origin-destination trip matrix to reflect new trips in the future made by population, employment and other demographic changes so as to reflect changes in people's choice of destination. They are used to forecast the origin-destination pattern of travel into the future and produce a trip matrix, which can be assigned in an assignment model of put into a mode choice model. The trip matrix can change as a result of improvements in the transport system or as a result of new developments, shops, offices etc and the distribution model seeks to model these effects so as to produce a new trip matrix for the future travel situation.

Trip distribution models connect the trip origins and destination estimated by the trip generation models to create estimated trips. Different trip distribution models are developed for each of the trip purposes for which trip generation has been estimated.Various techniques developed for trip distribution modeling are

- Growth Factor Models
- Synthetic Models

Growth Factor Models

- Uniform Factor Method
- Average Factor Method
- Detroit Method
- Fratar Method
- Furness Method
- Furness Time-function Iteration

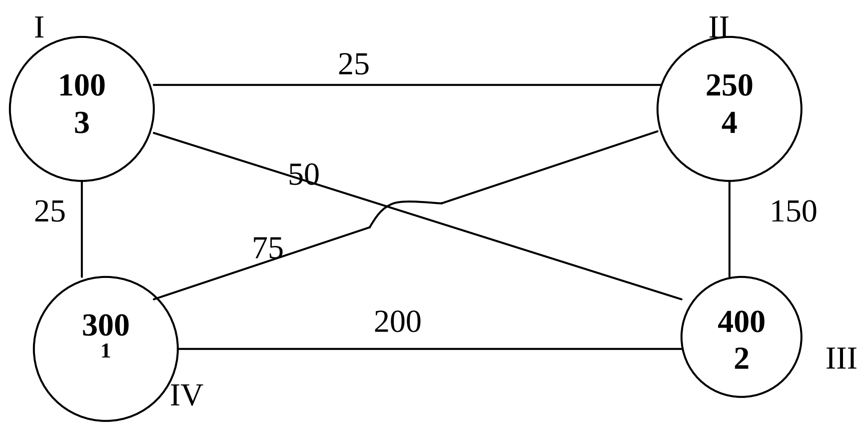
Synthetic Models

- Gravity/Spatial Interaction Models
- Opportunity Models
- Regression/Econometric Models
- Optimization Models

2.4.1 Growth Factor Models

1. Uniform Growth Factor Model

A single growth factor for the entire area under study is calculated by dividing the future number of trip ends for the horizon year by trip ends in the base year. The future trips between zones I and j are then calculated by applying the uniform factor to the base year trips between zones i and j.



The origin and destination matrix can used to represent the given network.

	I	II	III	IV
I	0	25	50	25
II	25	0	150	75
III	50	150		200
IV	25	75	200	

From the above origin-destination matrix, we can the following in matrix form.

	I	**II**	**III**	**IV**	**ti**	**Fi**	**Ti**	**Tcal**
I		25	50	25	100	300	300	229
II	25		150	75	250	1000	1000	571
III	50	150		200	400	300	800	914
IV	25	75	200		300	300	300	686
Tj	300	1000	800	300	1050		2400	2400

Uniform growth factor $F^{(1)}$ = 2400/1050 = **2.286**
Tcal is tabulated using the calculated growth factor in the last column.

Uniform growth factor $F^{(2)}$ = 2400/1050 = **2.286**. Since the growth factors remain equal, there is no need of further iteration

There are some drawbacks of using this method. These are:

1. The assumption of a uniform growth rate for the entire study area is not correct as the growth factor varies across zones.
2. The land use pattern changes with time, but not uniformly as assumed. Hence growth factor changes with time.

2. Average Growth Factor Model:-

In this method, the growth factor represents the average growth associated with both the origin and destination zones. If Fi and Fj are the growth factors for the zones I and j respectively, then:

$$T_{ij} = \frac{t_{ij}(F_i + F_j)}{2}$$

Where Fi = Ti/ti and Fj = Tj/tj

After the first distribution, it may be found that the sum of the trips from zones are not equal to the projected trip ends for the respective zones. This discrepancy has then to be removed by successive iterations as:

$$F_i' = T_i/t_i' \text{ and } F_j' = T_j/t'_j$$

where ti' and tj' are the generation and attraction of zone I and j respectively obtained from the first stage of distribution. This can be illustrated using the network given Above

Iteration 1: -T11 =0(3+3)/2 =0 T12=25(3+4)/2=87 and so on

	I	**II**	**III**	**IV**	**ti'**	**Ti**	**Fi'**
I		87	125	50	262	300	1.145
II	88		450	187	725	1000	1.379
III	125	450		300	875	800	0.914
IV	50	188	300		538	300	0.5576
tj'	263	725	875	537	2400		
Tj	300	1000	800	300		2400	
Fj'	1.145	1.379	0.914	0.5576			

Iteration 2: -The second iteration can be done in tabular form also.

	I	**II**	**II**	**IV**	**ti''**	**Ti**	**Fi''**
I		110	129	43	282	300	1.064
II	111		516	181	808	1000	1.2376
III	129	516		221	866	800	0.9238
IV	42	182	220		444	300	0.5576
tj''	282	808	865	445			0.6756
Tj	300	1000	800	300		2400	
Fj''	1.064	1.2376	0.9238	0.6756			

Iteration 3: -The third iteration can be done in tabular form also.

	I	**II**	**III**	**IV**	**ti'''**	**Ti**	**Fi'''**
I		128	128	37	293	300	1.024
II	128		557	174	859	1000	1.164
III	128	557		177	862	800	0.929
IV	36	174	176		386	300	0.5576
tj'''	2923	859	861	386			0.777
Tj	300	1000	800	300		2400	
Fj'''	1.024	1.164	0.929	0.777			

Iteration 4: -The fourth iteration can be done in tabular form also.

	I	**II**	**II**	**IV**	**ti''''**	**Ti**	**Fi''''**
I		140	125	33	298	300	1.0067
II	140		582	169	891	1000	1.1233
III	125	582		151	858	800	0.9324
IV	33	169	151		353	300	0.5576

tj''''	298	891	858	353			0.8498
Tj	300	1000	800	300		2400	
Fj''''	1.0067	1.1233	0.9324	0.8498			

Iteration 5: -The fifth iteration can be done in tabular form also.

	I	**II**	**II**	**IV**	**ti'''''**	**Ti**	**Fi'''''**
I		149	121	31	301	300	0.99
II	149		599	166	914	1000	1.09
III	121	599		134	854	800	0.93677
IV	31	166	134		331	300	0.906
tj'''''	301	914	854	331			
Tj	300	1000	800	300		2400	
Fj'''''	0.99	1.09	0.93677	0.906			

Since the results obtained from the two successive iterations give approximately equal growth factors, I can stop the iteration.

The disadvantages of this model are:

1.The factors do not have real significance.

2.Large number of iterations is required.

3. Detroit Model: -

This method is an improved version of the average growth factor method and takes into account the growth facor for the zones and average growth factor for the entire study area.

$$T_{ij} = \frac{t_{ij} * F_i F_j}{F}$$

where Fi =Ti/ti and Fj = Tj/tj and F= Total Tij/Total tij

Iteration 1: -F1 = 2400/1050 = **2.2857**

	I	**II**	**III**	**IV**	**ti'**	**Ti**	**Fi'**
I		131	131	33	295	300	1.017
II	131		525	131	787	1000	1.27
III	131	525		175	831	800	0.9627
IV	33	131	175		339	300	0.885
tj'	295	787	831	339	2252		
Tj	300	1000	800	300		2400	
Fj'	1.017	1.27	0.9627	0.885			

Iteration 2: -F2=2400/2252=**1.066**

	I	**II**	**II**	**IV**	**ti''**	**Ti**	**Fi''**
I		159	120	28	307	300	0.972
II	159		602	138	899	1000	1.1124
III	120	602		140	862	800	0.925
IV	28	138	140		306	300	0.9804
tj''	307	899	862	306	2374		
Tj	300	1000	800	300		2400	
Fj''	0.972	1.1124	0.925	0.9804			

Iteration 3: -F3=2400/2374=**1.010952**

	I	**II**	**III**	**IV**	**ti'''**	**Ti**	**Fi'''**
I		171	108	26	305	300	0.9836
II	171		615	149	935	1000	1.0695
III	108	615		126	849	800	0.9423
IV	26	149	126		301	300	0.9967
tj'''	305	935	849	301	2390		
Tj	300	1000	800	300		2400	
Fj'''	0.9836	1.0695	0.9423	0.9967			

Iteration 4: -F4=2400/2390=**1.0042**

	I	**II**	**III**	**IV**	**ti''''**	**Ti**	**Fi''''**
I		179	100	25	304	300	0.9868
II	179		617	158	954	1000	1.0452
III	100	617		118	835	800	0.9581
IV	25	158	118		301	300	0.9967
tj''''	304	954	835	301	2394		
Tj	300	1000	800	300		2400	
Fj''''	0.9868	1.0452	0.9581	0.9967			

Iteration 5: -F5=2400/2394=**1.0025**

	I	**II**	**III**	**IV**	**ti'''''**	**Ti**	**Fi'''''**
I		185	94	25	304	300	0.9868

II	185		618	165	968	1000	1.03305
III	94	618		112	824	800	0.9709
IV	24	165	112		302	300	0.9934
tj'''''	304	968	824	302	2398		
Tj	300	1000	800	300		2400	
Fj'''''	0.9868	1.03305	0.9709	0.9934			

since the ratio is approximately equal to 1, I can stop the iteration.

4. Fratar Method

The total trips emanating from a zone are distributed to the interzonal movements and according to the relative attraction of each movement, locational factors for each zone are calculated. Then

$$T_{ij} = \frac{t_{ij} * F_i * F_j (L_i + L_j)}{2}$$

The location factor values are computed below for the first iteration:

$$L_1 = \frac{100}{25*1+50*2+25*4} = \mathbf{0.444}$$

$$L_2 = \frac{250}{25*3+150*2+75*1} = \mathbf{0.556}$$

$$L_3 = \frac{400}{150*4+50*3+200*1} = \mathbf{0.421}$$

$$L_4 = \frac{300}{25*3+75*4+200*2} = \mathbf{0.387}$$

Iteration 1: -

	I	**II**	**II**	**IV**	**ti'**	**Ti**	**Fi'**	**Li'**
I		150	130	36	316	300	0.949	1.018
II	150		586	161	897	1000	1.1149	1.14
III	130	586		186	904	800	0.8849	0.9792
IV	36	161	186		385	300	0.7792	1.0131
tj'	316	897	904	385	2502			
Tj	300	1000	800	300		2400		
Fj'	0.949	1.1149	0.8849	0.7792				
Lj'	1.018	1.14	0.9792	1.0131				

Iteration 2: -The values in the table above can be used for this iteration.

	I	**II**	**II**	**IV**	**ti''**	**Ti**	**Fi''**	**Li''**

I		171	109	27	307	300	0.9772	0.9829
II	171		612	150	933	1000	1.0718	1.048
III	109	612		129	850	800	0.9411	0.9562
IV	27	150	129		306	300	0.9804	0.9917
tj''	307	933	850	306	2396			
Tj	300	1000	800	300		2400		
Fj''	0.9772	1.0718	0.9411	0.9804				
Lj''	0.9829	1.048	0.9562	0.9917				

Iteration 3: -The values in the table above can be used for this iteration.

	I	**II**	**II**	**IV**	**ti'''**	**Ti**	**Fi'''**	**Li'''**
I		182	97	25	304	300	0.9868	0.9893
II	182		619	161	962	1000	1.0395	1.0292
III	97	619		116	832	800	0.9411	0.9737
IV	25	161	116		302	300	0.9934	0.9948
tj'''	304	962	832	302	2400			
Tj	300	1000	800	300		2400		
Fj'''	0.9868	1.0395	0.9615	0.9934				
Lj'''	0.9893	1.0292	0.9737	0.9948				

The main drawbacks for this method are:
1. It is tedious for even moderate sized problems
2. It does not take into account the effect of changes in accessibility of the study area.

5. Furness Method: -

This method estimates the future traffic originating and terminating at each zone and hence yields the origin growth factor and destination growth factors for each zone. The traffic movements are made to agree alternatively.

Tij=tij*Ti/Total Tj and then Tij' = Tij*Ti/Total Tj' and Tij"=Tij*Ti/Total Tj"

Iteration 1: -Multiplying by the origin growth factors

	I	**II**	**II**	**IV**	**ti**	**Ti**
I		75	150	75	300	300
II	100		600	300	1000	1000
III	100	300		400	800	800
IV	25	75	200		300	300
tj'	225	450	950	775	2400	

Tj	300	1000	800	300		2400
Fj'	1.333	2.222	0.8421	0.387 1		

Iteration 2: -Multiplying by the destination growth factors

	I	**II**	**II**	**IV**	**ti''**	**Ti**	**Fi''**
I		167	126	29	322	300	0.9317
II	133		506	116	755	1000	1.3245
III	133	667		155	955	800	0.8377
IV	34	166	168		368	300	0.5152
tj''	300	1000	800	300	2400		
Tj	300	1000	800	300		2400	

Iteration 3: -Multiplying by the origin growth factors

	I	**II**	**II**	**IV**	**ti'''**	**Ti**
I		156	117	27	300	300
II	176		670	154	1000	1000
III	111	559		130	800	800
IV	28	135	137		300	300
tj'''	315	850	924	311	2400	
Tj	300	1000	800	300		2400
Fj'''	0.9524	1.1765	0.866	0.964 6		

Iteration 4: -Multiplying by the destination growth factors

	I	**II**	**II**	**IV**	**ti''''**	**Ti**	**Fi''''**
I		183	101	26	310	300	0.9677
II	168		580	149	897	1000	1.115
III	106	858		125	889	800	0.899
IV	26	158	119		304	300	0.9868
tj''''	300	1000	800	300	2400		
Tj	300	1000	800	300		2400	

Iteration 5: -Multiplying by the origin growth factors

	I	**II**	**III**	**IV**	**ti'''''**	**Ti**
I		177	98	25	300	300
II	187		647	166	1000	1000
III	95	592		113	800	800

IV	26	157	117		300	300
tj'''''	308	926	862	304	2400	
Tj	300	1000	800	300		2400
Fj'''''	0.974	1.08	0.928	0.9868		

Successive iterations are done until growth factors approach unity.

6.Time Function Method: -

This method assumes that the trip distance is influenced by the journey times and row and column totals the trip ends.

	I	II	III	IV	Current Origin
I		25	50	25	100
II	25		150	75	250
III	50	150		200	400
IV	25	75	200		300
Current Destination	100	250	400	300	

	I	II	III	IV	Current Origin	Ultimate Origin
I		1	1	1	3	100
II	1		1	1	3	250
III	1	1		1	3	400
IV	1	1	1		3	300
Current Destination	3	3	3	3		
Ultimate Destination	100	250	400	300		

Successive iterations are performed by alternately matching with the ultimate origins and destinations and finding the adjustment factors for column and row totals respectively.

Iteration 1: -

	I	II	III	IV	Current Origin	Ultimate Origin
I		100	100	100	300	300
II	333		334	333	1000	1000
III	266	267		267	800	800
IV	100	100	100		300	300

Current Destination	699	467	534	700	2400	
Ultimate Destination	300	1000	800	300		2400
Adjustment Factor	0.629	2.141	1.498	0.428 6		

Iteration 2: -

	I	II	III	IV	Current Origin	Ultimate Origin	Adjustment Factor
I		214	150	43	3	300	0.7371
II	143		500	143	3	1000	1.2722
III	114	572		114	3	800	1
IV	43	214	150		3	300	0.7371
Current Destination	300	1000	800	300	2400		
Ultimate Destination	300	1000	800	300		2400	

2.4.2 Synthetic Models

Gravity Model

The trip distribution models found most often in practice today are "gravity models," so named because of their basis in Newton's law.

The gravity model assumes that the trips produced at an origin and attracted to a destination are directly proportional to the total trip productions at the origin and the total attractions at the destination. The calibrating term or "friction factor" (F) represents the reluctance or impedance of persons to make trips of various duration or distances. The general friction factor indicates that as travel times increase, travelers are increasingly less likely to make trips of such lengths. Calibration of the gravity model involves adjusting the friction factor.

The socioeconomic adjustment factor is an adjustment factor for individual trip interchanges. An important consideration in developing the gravity model is "balancing" productions and attractions. Balancing means that the total productions and attractions for a study area are equal.

Standard form of gravity model

$$T_{ij} = \frac{A_j F_{ij} K_{ij}}{\sum_{allzones} A_x F_{ij} K_{ix}} x P_i$$

Where:

Tij=trips produced at I and attracted at j

Pi = total trip production at I

Aj = total trip attraction at j

F ij = a calibration term for interchange ij, (friction factor) or travel time factor (F ij =C/t_{ij}^{n})

C=calibration factor for the friction factor

Kij = a socioeconomic adjustment factor for interchange ij

I=origin zone

n = number of zones

Before the gravity model can be used for prediction of future travel demand, it must be calibrated. Calibration is accomplished by adjusting the various factors within the gravity model until the model can duplicate a known base year's trip distribution. For example, if you knew the trip distribution for the current year, you would adjust the gravity model so that it resulted in the same trip distribution as was measured for the current year.

CALIBRATION OF GRAVITY MODEL

The most widely used technique for calibrating the form of the gravity model defined in equation

$$T_{ij} = P_i \{(a_{ij} f_{ij}) / \sum_j a_j f_{ij}\}$$

is that developed by Bureau of Public Roads. The purpose of the calibration procedure is to establish the relationship between f_{ij} and z_{ij} for base year conditions. This function is then used along with equation to develop a trip interchange matrix that satisfies the constraint equations. The Bureau of Public Roads calibration procedure is directed toward the development of a travel time factor function, which is assumed to be an area wide polynomial function of interzonal travel times.

Figure below shows the sequence of activities involved in the calibration of the gravity model .the first step involves the estimation if inter centroid travel time for each centroid pair.

It is suggested that the gravity model simulated and observed trip-length –frequency distributions should exhibit the following two characteristics:

(1) The shape and position of both curves should be relatively close to one another when compared visually.
(2) The differences between the average trip lengths should be within ± 3 percent.

If the trip length frequency distribution produced by the gravity model does not meet these criteria, then a new set of travel factors may be estimated from the following expression:

$$f' = f * (OD\%)/(GM\%)$$

Where

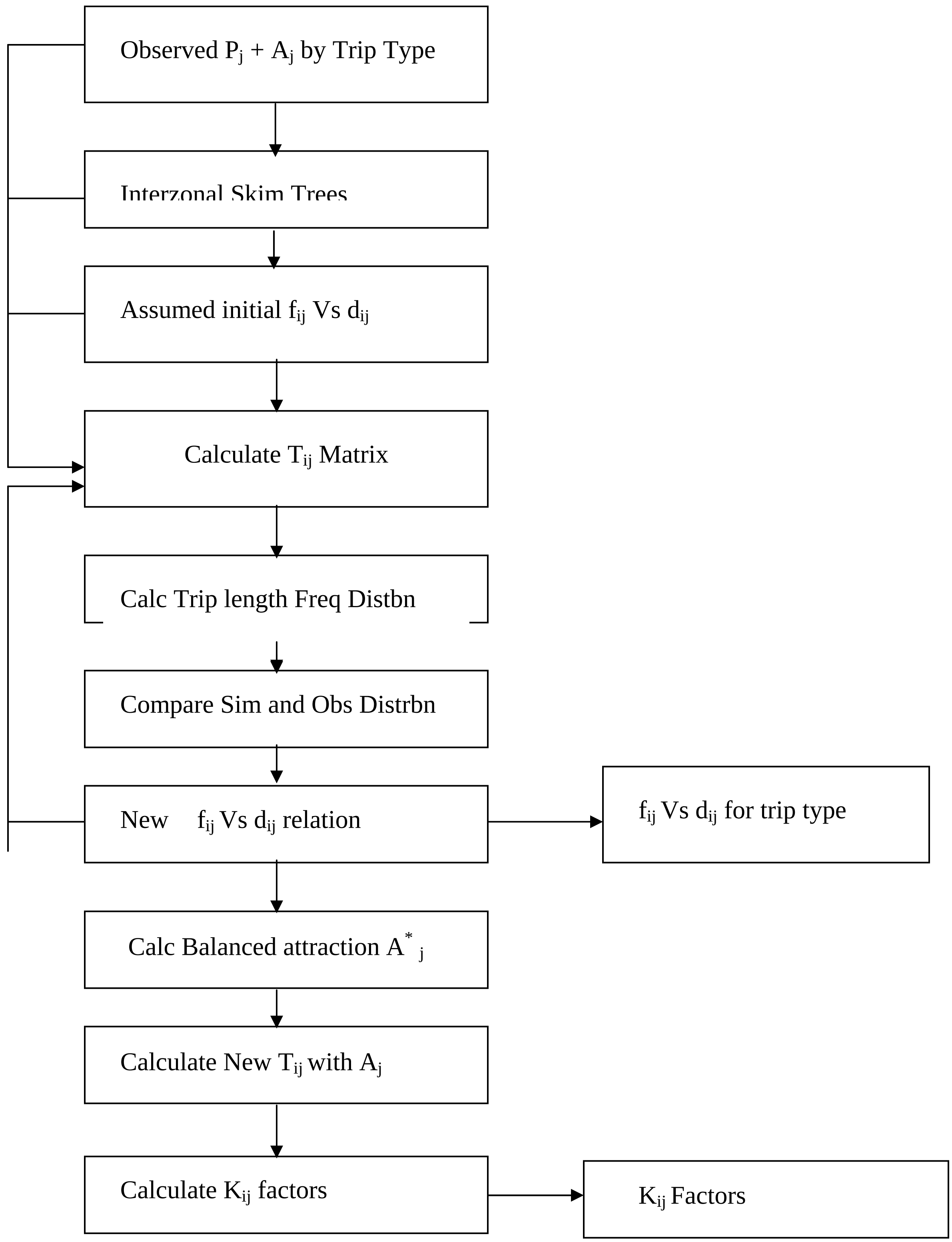
f' = the travel time factor for a given travel time to be used in next iteration.

f = the travel factor used in the calibration just completed.

OD% = the percentage of total trips occurring for a given travel time observed in the travel survey.

GM%= the percentage of total trips occurring for a given travel time observed in the simulated by the gravity model.

CALIBRATED PARAMETERS



The final phase of BPR calibration is to calculate zone to zone adjustment factors k_{ij}.These factors are calculated from the following expressions:

$k_{ij} = r_{ij}\,[(1-x_{ij})/(1-x_i r_{ij})]$

where k_{ij} = the adjustment factor to be applied to movements between zones I and j.

r_{ij} = the ratio t_{ij} (o-d survey)/t_{ij} (gravity model)

x_{ij} = the ratio t_{ij} (o-d survey)/p_i

The final gravity model simulated trip interchange matrix is given by

$t_{ij} = p_i\,[\,(a_j^{*} f_{ij} k_{ij})/ \sum a_j^{*} f_{ij} k_{ij}\,]$

An horizon year trip interchange matrix is calculated from the given equation with the following inputs:

(1) The horizon year trip production and trip attraction rates,

(2) The horizon year intercentroids skim trees.

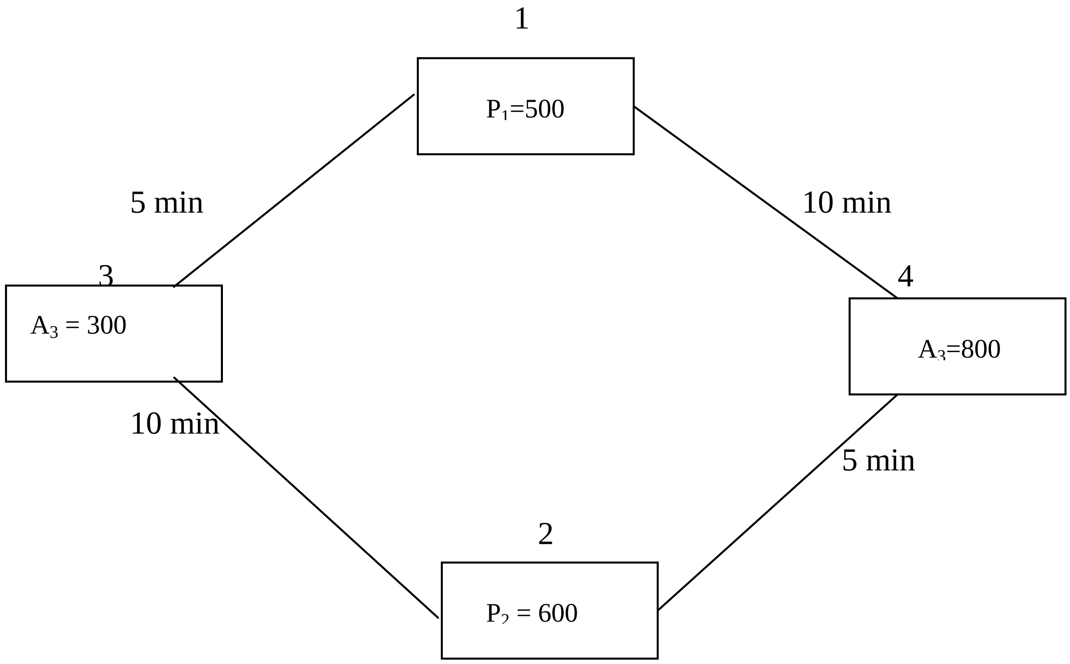
(3) The base year travel time function.

(4) The k_{ij} magnitudes that are expected to hold for the horizon year.

Limitation:

The limitation of procedure described is it requires that two criteria be satisfied by a base year calibration. These two criteria are: agreement between observed and simulated trip length constraint equation .A principal difficulty wit this calibration procedure is that the travel time factor function and associated trip length frequency distribution are assumed to be constant for each zone of a study area.

Calibrate the Gravity Model for 4-network problem



t_{13}	t_{14}	t_{23}	t_{34}
200	300	100	500
5	10	10	5

Iteration 1

Travel Time	t_{ij}	$f_{ij} = (1/dij)^2$	t_{ij} (GM)	f_{ij} = f X t_{ij} (OD)/ t_{ij} (GM)
5	700	0.04	849	0.032
10	400	0.01	251	0.015
Iteration 2				
5	700	.032	735	.0304
10	400	.015	365	.016

Iteration 1:

Calculation	Destination		
Attraction	3	4	Σ
Origin 1			
tt	5	10	
$f_{ij} = (1/dij)^2$	0.04	0.01	
a_j x fij	12	8	20
$(a_{ij}f_{ij})/\sum_j a_j f_{ij}$	0.6	0.4	1
$P_i\ a_{ij}f_{ij}/\sum_j a_j f_{ij}$	300	200	500
Origin 2			
tt	10	5	
$f_{ij} = (1/dij)^2$	0.01	0.04	
a_j x fij	3	32	35
$(a_{ij}f_{ij})/\sum_j a_j f_{ij}$	0.085	0.915	1
$P_i\ a_{ij}f_{ij}/\sum_j a_j f_{ij}$	51	549	600

Iteration 2

Calculation	Destination		
Attraction	3	4	Σ
Origin 1			
Tt	5	10	
$f_{ij} = (1/dij)^2$	.032	.015	

a_j x fij	9.6	12	21.6
$(a_{ij}f_{ij})/ \sum_j a_j f_{ij}$	0.45	0.55	1
$P_i\, a_{ij}f_{ij}/ \sum_j a_j f_{ij}$	225	275	500
Origin 2			
tt	10	5	
$f_{ij} =(1/ dij)^2$	0.015	0.032	
a_j x fij	4.5	25.6	30
$(a_{ij}f_{ij})/ \sum_j a_j f_{ij}$	0.15	0.85	1
$P_i\, a_{ij}f_{ij}/ \sum_j a_j f_{ij}$	90	510	600

LOW'S METHOD

Basic Concept:

In this model volumes are determined one link at a time, primarily as a function of the relative probability that trips would use one link in preference to another link. First trip probabilities are determined for every combination of origin and destination zones in the area.

The probability of a trip between zone I and zone j can be linked to the gravitational pull of two masses and the distance separating them as

$$\frac{m_i * m_j}{d_{ij}^2}$$

Considering home work trip if mass at home end as employment E_j ,then the trip probability becomes $\frac{P_i E_j}{t_{ij}^m}$

Input Information

The Low's model needs the following information

1. Pattern and intensities of land use development now and as anticipated in the future. This should include population and employment by zone etc but there will be of no values unless reasonable estimates of future patterns and intensities of land estimates of future patterns and intensities of land use development can be made in similar detail.

2. Transportation network characteristics including network configuration, link speeds etc.

3. Representative traffic volumes from ground count throughout the network.

4. Volume and Patterns of trips with one or both ends outside area under study.

Formation and Use of the Model

Current external volumes:

Current external trip data gathered in the road side interview survey are first assigned to the existing network to produce estimates of current external volumes throughout the network.

Current Internal Volume:

These volumes on links throughout the network are computed by subtracting the assigned external traffic volumes from the corresponding ground counts.

Internal Volume Forecasting Model:

Inter zonal trip opportunity matrices of the form A_i and B_j are developed Where A and B are parameters that are logically related to trip productions and attractions. Using Travel time as the measure of separation the friction factor can be expressed as $1/ t^m_{ij}$

The product $F_{nij}= A_i B_j / t^m_{ij}$ is called inter zonal trip probability matrix. The probability matrices are then assigned separately to the current network just as if they were trips. Multiple regression techniques are used to develop equation of the following form

$$V = a_1 + b_1F_1 + b_2F_2 + b_3F_3 + ... + b_nF_n$$

Where V is the internal traffic volume on a link

a and b are constants

F_n is the trip probability factor volume as assigned to that link.

Future Internal Volume:

Future zonal socioeconomic data are used to develop future trip opportunity matrices and future friction factors from the future network to be tested are applied to the trip opportunity matrices to produce future trips.

Advantages of Low's Method

- They are easily understood and applied requiring only as inventory of present day trip origins and destinations and estimations of simple growth factors.
- The simple process of iteration quickly produces a balance between postulated and computed trip ends.
- They are flexible in application and can be used to distribute trips by different modes for different purposes at different times of the day and can be applied to directional flows.
- They have been well tested and have been found to be accurate when applied to areas where the pattern and density of development is stable.

Disadvantages of Low's Method

- They cannot be used to predict travel patterns in areas where significant changes in land use are likely to come and the assumption that the present day travel resistant factors will remain constant into the future is fundamentally weak.
- These models cannot satisfy the requirements modern urban transportation studies, which are usually designed to cater for conditions of continual and rapid changes in the pattern of development and the way of life of population generally.