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Dept. of Civil Engineering

Internal Assessment Test II – December 2021

Sub: Urban Transport Planning				Code: 17CV751/18CV745
Date: 20/12/2021	Duration: 90 mins	Max Marks: 50	Sem: VII	Branch (sections): CIVIL (A and B)

Answer any Five Questions

		Marks	OBE CO	OBE RBT
1.	What is Trip generations and Trip attractions? Also explain factors influencing Trip Generation and Attraction.	[10]	CO3	L2
2.	Explain Multiple linear regression analysis and its two types	[10]	CO3	L2
3.	Write a note on a) Gravity model & b) Opportunity model	[10]	CO2	L2
4.	A study area consists of three zones. The data have been determined as shown in the following tables. Assume a Kij =1.	[10]	CO4	L3

Data:

a) Zone Productions and Attractions

Zone	1	2	3	Total
Trip Productions	140	330	280	750
Trip Attractions	300	270	180	750

b) Travel Time between zones (min)

Zone	1	2	3
1	5	2	3
2	2	6	6
3	3	6	5

c) Travel Time versus Friction Factor

Time (Min)	82	52	50	41	39	26	20	12
F	1	2	3	4	5	6	7	8

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Time (Min)	82	52	50	41	39	26	20	12
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5.	A self-contained town consists of three residential areas A, B, C and two industrial estates X and Y. Trip generation equation shows that for a design year in question, the trips from home to work generated by each residential area per day are as follows: A 1000 B 2250 C 1750 There are 3500 jobs in industrial estate X and 4300 in industrial estate Y. It is known that the attraction between zones is inversely proportional to the square of journey times between zones. The journey times in minutes from home to work are given below. Zone X Y A 15 20 B 15 10 C 10 10 Calculate and tabulate the inter-zonal trips for journeys from home to work.	[10]	CO4	L3
6.	Define modal spilt and explain in brief the factors affecting modal split.	[10]	CO2	L2

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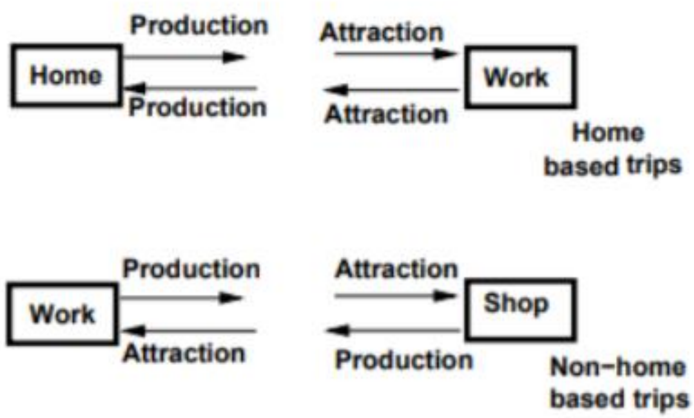
Answers

1. Trip generation is defined as all the trips of home based or as the origin of the non home based trips. An attraction is the non-home end of a home based trip and is the destination of a trip with neither end home based.



Factors influencing Trip Generation and Attraction

1. **Income**
   Family income which represents its ability to pay for a journey affects the number of trips generated by a household. A general trend is that the higher the income the higher is the trip generation rate.

2. **Car ownership**
   A car represents easy mobility, and hence a car owing household will generate more trips than a non-car-owing household. By the same reasoning, the more cars there are in the household, the more the number of trips generated. Of course, number of cars owned is itself related to the income of the family, which has been listed earlier as a factor.

3. **Family size and composition**
   The bigger the family, the more trips there are likely to be generated. Apart from the size, the composition of the family itself is important. For instance, if both the husband and wife are employed, the trips generated will be more than when only the husband is employed. If there are many school-going children, the number of school-purpose trips will be large. The age structure of the family also governs the trip rates. Old persons are not expected to generate as many trips as younger ones

4. **Land use Characteristics**
   Different land uses produce different trip rates. For example, a residential area with a high density of dwellings can produce more trips than one with a low density of dwellings. On the other hand, low density areas may represent dwellings of the well-off society, which may produce a large number of private car trips. The rateables value of the dwelling and type of dwelling units affect the trip generation rates. The most important assumption made in transportation planning is that the amount of travel is dependent on land use.

5. **Distance of the zone from the town center**
   The distance of the zone from the town center is an important determinant of the amount of travel that people might like to make to the town center. The farther the town center, the less the number of trips are likely to be.

6. **Accessibility to public transport system and its efficiency**
The accessibility to a public transport system and its efficiency determine to some extent the desire of persons to make trips. An easily accessible and efficient public transport system generates more trips.

7. **Employment opportunities, floor space in the industrial and shopping units and offices**
The employment potentially of an industrial or shopping unit or an office establishment directly governs the trip attraction rate. Similarly, another factor to which the trip attraction rate can be related is the floor space in the premises of industries, shops and offices.

2.

METHODS OF TRIP GENERATION ESTIMATION

Trip generation models are based upon the following methods:

1. **Regression Analysis**
   - ***Zonal Regression methods***
   - **Household Regression methods**
2. **Category Analysis**
3. **Person trip models**

MULTIPLE LINEAR REGRESSION ANALYSIS

The most common technique employed in establishing trip generation is multiple linear regression which fits mathematical relationships between dependent and independent variable. In the case of trip generation equation, the dependent variable is the number of trips and the independent variable are the various measurable factors that influence trip generation like land use and socio-economic characteristics. The general form of the equation can be expressed in the following form:

$$Y_p = a_1X_1 + a_1X_2 + a_3X_3 + \ldots\ldots a_nX_n + U$$

- $Y_{p=}$ number of trips for specified purpose p
- X_1, X_2, X_3,……., X_n=independent variables relating to for example, land-use, socio economic factors etc.
- a_1, a_2, a_3,……, a_n= Coefficients of the respective independent variables X_1, X_2, X_3,……., $X_{n,}$ obtained by linear regression analysis
- U= Distribution term, which is a constant and representing that portion of the value of Y_p not explained by the independent variables.

The equation of the above form is developed from the present-day data pertaining to independent variables and dependent variables and the dependent variables, using statistical techniques of "least squares "fitting. The equation thus developed is used for determining the future values of trips, knowing the estimated future values of the independent variables.

Example:

Y = 2.18 + 3.404 A + 0.516 H + 0.0119 X1 – 0.343 X2
Where

Y= average trips per occupied dwelling unit
A= car ownership
H=household size
X1= social rank index
X2= urbanization index

Zonal Regression Method (Aggregated Analysis)

In the case of zonal regression, the study area is divided into a number of zones. Each traffic zone is treated as one observation. The aggregated analysis which is most widely used is based on the assumption that contiguous households exhibit a certain amount of similarity in travel characteristics. The dependent variable is some measure of the zonal trip ends and the independent variables are typically the number of households, number of workers, number of cars, total incomes etc. Alternatively, the variables are expressed as mean values for the zones. This assumption allows the data in a zone to be grouped and the mean values of the independent variable used in further calculation. Sufficiently large survey data is needed to get reliable results.

Disadvantages of Zonal Regression Models:

Among the prominent drawbacks of the zonal regression models are the followings

i) The analysis masks the variation in the data
ii) Inefficient utilization of data.
iii) Dependency of the models on the type of zoning system adopted.
iv) Inadequate capabilities for prediction of situations where real differences exist between calibrated and forecast data.
v) The zone sample mean is not a reliable estimate of the population mean.
vi) The assumption that zones are to a large extent homogeneous with respect to characteristics is not found to be generally correct. The within zone variance associated with travel demand are large in relation to between zone variances. In other words, these parameters exhibit a degree of heterogeneity within zones.
vii) Sometimes there are ecological correlations associated with zonally aggregated relationships.
viii) Simple reduction in zone size leads to enormous increase in sampling errors which are not permitted, besides a large number of smaller zones present problems at subsequent stages of trip distribution and assignment models. Therefore, this, severely restricts the usefulness of models for small scale planning applications.

Household least squares regression analysis (Disaggregated Analysis):

The logical extension to the arguments favouring a reduction in zone size is to develop data base that makes no reference to zone boundaries. One consideration is to treat this at household level. The dominating Influence of the head of household implies that the trip making activity of the household members can only be accurately predicted through a knowledge of total household characteristics. It would appear, then, that the household can reasonably be considered as a behavioural trip-making unit and therefore, treated as the basis for the trip end estimating procedure.

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In the household regression analysis, each household is considered as a separate input data, so that the wide observed variation in household characteristics and household trip making behaviour is incorporated into the models. The attempt, here, is to explain the total variation between households, as against the variation between zones, explained by zonal models.

The variables considered are between the number of trips per household per day and the household characteristics such as family size (persons), employees per household, car ownership per household, household income etc.

Compared to aggregated analysis, disaggregated analysis produces better results and is considered more likely to be stable over time and to provide more reliable future estimates.

Disadvantages of multiple-linear regression analysis technique

Some of the disadvantages associated with the assumptions made in the linear regression technique are as follows:

- The equation derived is purely empirical in nature and fails to establish a meaningful relationship between the dependent and independent variables.
- The technique is based on the premise that the regression coefficients initially established will still remain unchanged in the future and can be used in the regression equation for predicting future travel. How far the prediction is valid in future is a main question
- Difficulties arise in evaluation the effect of statistical problems relating to non-linearity of the response surface and high correlation amongst the explanatory variables.

1. Gravity model

One of the well-known synthetic models is the Gravity Model. Based in Newton's concept of gravity, the model as proposed by Voorhees assumes that the interchange of trips between zones in an area is dependent upon the relative attraction between the zones and the spatial separation between them as measured by an appropriate function of distance. This function of spatial separation adjusts the relative attraction of each zone for the ability, desire or necessity of the trip maker to overcome the spatial separation. Whereas the trip interchange is directly proportional to the relative attraction between the zones, it is inversely proportional to the measure of spatial separation.

A simple equation representing the above relationship is of the following form:

$$T_{i-j} = \frac{KP_i A_j}{d_{ij}^n}$$

Where,

T_{i-j} = Trips between zones i and j

P_i = Trips produced in zone i

A_j = Trips attracted to zone j

d_{ij} = Distance between zone i and j, or the time or cost of traveling between them

K = A constant, usually independent of i

n = An exponential constant, whose value is usually found to lie 1 & 3

k = Total number of zones

The following formulation was also used in earlier studies dispersing with the proportionality constant:

$$T_{i-j} = P_i \times \frac{\dfrac{A_j}{(d_{i-j})^n}}{\dfrac{A_j}{(d_{i-j})^n} + \cdots\cdots + \dfrac{A_k}{(d_{i-k})^n}}$$

Where, $T_{i\text{-}j}$, P_i, A_j, $d_{i\text{-}k}$ and n have the same meaning as given earlier.

In order to simplify the computation requirements of the model, the following formulation has been frequently used;

$$\left[T_{(i-j)m} = \frac{P_i A_{jm} F_{i-j} C_{i-j}}{\sum_{x=1}^{k} A_{km} F_{(i-k)} K_{(i-k)}} \right]_p$$

Where,

$T_{i\text{-}j}$ = Trips produced in Zone i and attracted to zone j

P_i = Trips produced in zone i

A_j = Trips attracted to zone j

$F_{i\text{-}j}$ = Empirically derived travel time factor which expresses the average area-wide effect of spatial separation on trip interchange between zones i and j

$K_{i\text{-}j}$ = A specific zone-to-zone adjustment factor to allow for the incorporation of the effect on travel patterns of defined social or economic linkages not otherwise accounted for in the gravity model formulation

k = Total number of zones

m = Iteration number

p = Trip purpose

The above relationship can be used for determining the trip interchange for each trip purpose and each mode of travel.

3. Opportunity Model

Opportunity models are based on the statistical theory of probability as the theoretical foundation. The concept has been pioneered by Schneider and developed by subsequent studies.

The two well-known models are:

1. **The intervening opportunities models;**
2. **The competing opportunities model.**

The opportunity models can be represented by the general formula:

$$T_{ij} = O_i \, P\,(D_i)$$

Where,

$T_{i\text{-}j}$ = Predicted number of trips from zone i to j.
O_i = Total number of trips originating in zone i.
$P(D_j)$ = Calculated probability of a trip terminating in zone j.
D_j = Total trip destinations attracted to zone j.

3.1 Intervening Opportunities Model

In the intervening opportunities model, it is assumed that the trip interchange between and origin and a destination zone is equal to the total trips emanating from the origin zone multiplied by the probability that each trip will find and acceptable terminal at the destination. It is further assumed that the probability that a destination will be acceptable is determined by two zonal characteristics: the size of the destination and the order in which it is encountered as trips proceed from the origin. The probability functions in above equation $P(D_j)$, may then be expressed as the difference between the probability that the trip origins at *i* will find a suitable terminal in one of the destinations, ordered by closeness to *i*, up to and including *j*, and the probability that they will find a suitable terminal in the destination up to but excluding j. The following equation represents mathematically this concept:

$$T_{i-j} = Q_i \left(e^{-LB} \cdot_{-e}{}^{-LA} \right)$$

Where,

$T_{i\text{-}j}$ = Predicted number of trips from zone i to j
Q_i = Total number of trips originating in zone i
L = Probability density of destination acceptability at the point of consideration

A = Number of origins between i and j when arranged in order of closeness
B = Number of destinations between i and j when arranged in order of closeness

It may be noted that:

$$A = B + D_j$$

3.2 Competing Opportunities Model

In the competing opportunities model, the adjusted probability of a trip ending in a zone is the product of two independent probabilities, *viz.*, the probability of a trip being attracted to a zone and the probability of a trip finding a destination in that zone. A form of this model is given below:

$$T_{i-j} = \frac{P_j \dfrac{A_i}{\sum A_j}}{\sum \left(\dfrac{A_j}{\sum_j A_j} \right)}$$

6.

MODAL SPLIT

Modal split is the process of separating person-trips by the mode of travel. It is usually expressed as a fraction, ratio or percentage of the total number of trips. In general, modal split refers to the trips made by private car or public transport (road or rail). An understanding of modal split is very important in transportation studies. Further transportation pattern can only be accurately forecast if the motivations that guide the traveler in his choice of the transportation modes can be analyzed. Though the factors that govern the individual choice of mode are complex, a study of the same is of great utility.

FACTORS AFFECTING MODAL SPLIT (MODAL SPLIT ANALYSIS)

Factors influencing mode choice of urban travelers:

1. **Characteristics of the trip.**
2. **Household characteristics.**
3. **Zonal characteristics.**
4. **Network characteristics.**

1.Characteristics of trip

i) Trip purpose: the choice of mode is guided to a certain extent by the trip purpose. To give an example, home based school trips have a high rate of usage of public transport. On the other hand, home based shopping journeys can have a higher rate of private car usage, for the simple reason that it is more convenient to shop when travelling in a personalized transport.

ii) Trip length: the length can govern an individual's choice of a particular mode. A measure of the trip length is also possible by the travel time and the cost of travelling.

2. Household characteristics

i) Income: the income of a person is a direct determinant of the expenses he is prepared to incur on a journey. Higher income groups are able to purchase and maintain private cars, and thus private car trips are more frequent as the income increase.

ii) Car ownership: car ownership is determined by the income and for this reason both income and car ownership are inter-related in their effect on modal choice. In general, families which own a car prefer private car trips, and in contrast families without car patronize public transport in the absence of any other alternative.

iii) Family size and composition: the number of persons in the family, the number of school-going children, the number of wage earns, the number of unemployed, the age-sex structure of the family, and some other factors connected with the socio- economic status of the family profoundly influence the modal choice. Some of these factors are responsible for certain captive trips in public transport, such as those due to old age pensioners, school children, crippled and infirm persons and those who do not wish to drive.

3. Zonal characteristics

i) Residential density
ii) Concentration of workers
iii) Distance from CBD

The use of public transport increases as the residential density increases. This is because of the fact that areas with higher residential density are inhabited by persons with lower income, lower levels of car ownership. It is also found that higher density areas are served well by public transport system and such areas are oriented towards a better use of public transport system.

4. Network characteristics

i) Accessibility Ratio

It is a measure of the relative accessibility of that zone to all other zones by means of mass transit network and highway network.

$$acci = \sum_{i=1}^{n} a_j f_{ij}$$

Where:

acci: accessibility index for zone i.

a_j: number of trips attractions in zone j.

f_{ij}: travel time factor for travel from zone i to zone j for the particular mode being considered.

n: number of zones in the urban area.

ii) Travel Time Ratio (TTR)

The ratio of the travel time by public transport and travel time by private car gives a measure of the attractiveness or otherwise of public transport system.

$$TTR = \frac{a + b + c + d + e}{f + g + h}$$

<u>where:</u>

a: time spent in the public transport vehicle.

b: transfer time between public –transport vehicles.

c: time spent waiting for public transport vehicle.

d:walking time to public transport vehicle.

e:walking time from public transport vehicle.

f: car driving time.

g: parking delay at destination.

h: walking time from parking place to destination.

iii) Travel Cost Ratio (TCR)

The ratio of cost of travel by public transport and cost of travel by car is one of the most important factors influencing modal choice. The importance of travel cost is related to the economic status. People with high incomes are unmindful of cost and prefer most expensive modes.

$$CR = \frac{i}{(j + k + 0.5l)/m}$$

where:

i: public transport fare.

j: cost of petrol.

k: cost of oil, lubricants, etc.

l: parking cost at destination, if any.

m: average car occupancy.

iv) Service Ratio (SR)

The relative travel service was characterized by the ratio of the travel excess travel times by public transport and car. The excess travel time was defined as the time spent outside the vehicle during a trip. Thus, the Service Ratio was defined as follows:

$$SR = \frac{b + c + d + e}{g + h}$$

then, using TTR, CR, and SR, modal split curves were developed for work trips.

Solution

First, determine the friction factor for each origin-destination pair by using the travel times and friction factors given in the problem statement.

Fij as Determined from Travel Time			
Zone	1	2	3
1	39	52	50
2	52	26	26
3	50	26	39

$$t_{ij} = P_i \frac{A_j K_{ij} F_{ij}}{\sum_x A_x K_{ix} F_{ix}}$$

Once you have the friction factors for each potential trip, you can begin solving the gravity model equation as shown below. Solving for the A*F*K term in a tabular form makes this process easier. Study the equation below and the following table.

$$T_{ij} = P_i \left[\frac{A_j F_{ij} K_{ij}}{\sum_{j=1}^{n} A_j F_{ij} K_{ij}} \right]$$

$$T_{11} = 140 \left[\frac{300\times39}{(300\times39)+(270\times52)+(180\times50)} \right] = 47$$

$$T_{12} = 140 \left[\frac{270\times52}{(300\times39)+(270\times52)+(180\times50)} \right] = 57$$

$$T_{13} = 140 \left[\frac{180\times50}{(300\times39)+(270\times52)+(180\times50)} \right] = 36$$

$$P_1 = 47 + 57 + 36 = 140$$

Zone to Zone First Iteration:

zone	1	2	3	p
1	47	57	36	140
2	188	85	57	330
3	144	68	68	280
A	379	210	161	750
Given A	300	270	180	750

- This first iteration is "singly constrained " in that the computed productions match the given productions
- However , the attractions do NOT converge at the zonal level
- Consequently ," new " attraction values should be calculated for each zone

$$A_{jk} = \frac{A_j}{C_{j(k-1)}} A_{j(k-1)}$$

To produce a mathematically correct result, repeat the trip distribution computation using the modified attraction values.

For example, for zone 1:

$$A_{12} = 300 \times \frac{300}{379} = 237$$

$$A_{22} = 270 \times \frac{270}{210} = 347$$

$$A_{32} = 180 \times \frac{180}{161} = 201$$

Zone	1	2	3	
Aj1	380	209	161	
Given A	300	270	180	
Aj2	237	349	201	

Zone to Zone Second Iteration

zone	1	2	3	p
1	34	68	38	140
2	153	112	65	330
3	116	88	76	280
A	303	268	179	750
Given A	300	270	180	750

Upon finishing the second iteration, the calculated attractions are within 5% of the given attractions. This is an acceptable result and the final summary of the trip distribution is shown below.

The resulting trip table is:

zone	1	2	3
1	34	68	38
2	153	112	65
3	116	88	76

5.

(5)

$$T_{A-B} = t_{A-B}\left(\frac{P_A}{p_A}\right)\left(\frac{A_B}{a_B}\right)\left(\frac{t_{AB} + t_{AC} + t_{AD}}{t_{AB} \times E_B + t_{AC}E_C + t_{AD}E}\right)$$

$$= 10\left(\frac{80}{40}\right)\left(\frac{114}{38}\right)\frac{(10+12+18)}{(10\times3+12\times1.5+18\times1)} = 36.36$$

$$T_{A-C} = 12\left(\frac{80}{14}\right)\left(\frac{48}{32}\right)\frac{40}{66} = 21.81$$

$$T_{A-D} = 18\left(\frac{80}{40}\right)\left(\frac{38}{38}\right)\frac{40}{66} = 21.8$$

$$T_{B-A} = 10\left(\frac{114}{38}\right)\left(\frac{80}{40}\right)\frac{(10+14+14)}{(10\times2+14\times1.5+14\times1)} = 41.45$$

$$T_{B-C} = 14\left(\frac{114}{38}\right)\left(\frac{48}{32}\right)\left(\frac{38}{55}\right) = 43.5$$

$$T_{B-D} = 14\left(\frac{114}{38}\right)\left(\frac{38}{38}\right)\left(\frac{38}{55}\right) = 29.0$$

$$T_{C-A} = 12\left(\frac{48}{32}\right)\left(\frac{80}{40}\right)\frac{(12+14+6)}{(12\times2+14\times3+6\times1)} = 16$$

$$T_{C-B} = 14\left(\frac{48}{32}\right)\left(\frac{114}{38}\right)\times\frac{32}{72} = 28$$

$$T_{C-D} = 6\left(\frac{48}{32}\right)\left(\frac{38}{38}\right)\frac{(12+14+6)}{72} = 4$$

$$T_{D-A} = 18\left(\frac{38}{38}\right)\left(\frac{80}{40}\right)\frac{(18+14+6)}{18\times2+14\times3+6\times1.5} = 15.7$$

$$T_{D-B} = 14\left(\frac{38}{38}\right)\left(\frac{114}{38}\right)\frac{(18+14+6)}{18\times2+14\times3+6\times1.5} = 18.3$$

$$T_{D-C} = 6\times1\times\left(\frac{48}{32}\right)\left(\frac{38}{87}\right) = 3.9$$

Summary

Zone	A	B	C	D	Sum of Prod of trips & GF	Desired Trip	Ratio
GF	2	3	1.5	1			X
Zone A							
1	–	10	12	18			
2	–	30	18	18	66	80	1.21
3	–	36.4	21.8	21.8	80		
Zone B							
1	10	–	14	14		114	2.07
2	20	–	21	14	55		
3	41.5	–	43.5	29	114		
Zone C							
1	12	14	–	6			0.667
2	24	42	–	6	72	48	
3	16	28	–	4	48		
Zone D							
1	18	14	6	–			0.437
2	36	42	9	–	87	38	
3	15.8	18.3	3.9	–	38		