Chapter-3

3.1 TRANSPORT DEMAND: AN IN-DEPTH ANALYSIS

The previous sections have dealt with various nature of travel demand arising across cities of developed and developing countries wherein efforts towards highlighting the importance of estimating travel demand are attempted. Taking the cue from it, an attempt to delve deep into the demand aspect of travel in the light of the existing inventory of models considered relevant for the present research effort is made.

The discussion gets through with a reminiscence of the chronological development of the travel demand literature and the economic foundation behind the models. Next, the importance of choice in urban travel demand models is highlighted to have a grasp of the hierarchy of models arising from such choices. These models are then discussed in appropriate details to bring out their salient features. Following a knowledge of the inventory of models, efforts toward substantiating the choice of small and medium cities (as per the research topic) that forms the experimenting ground for applying the model(s) have been made. The particular cities of the two categories taken up for applying the model(s) are thereafter justified on various scale to show their amenability towards application of the chosen model.

3.2 A BRIEF HISTORICAL EXCURSUS

Though it may well be presumed that transportation demand analysis had been as old as the transportation demand itself, but the first documentation of it had been the study by Kohl (1850) that showed the relationship between the geography of resources and the shape of transportation network. In 1885, Ravenstein developed a study of migration pattern among cities through a model that could well be taken as the earlier generation of the gravity models (discussed in the latter part). Lille in 1891 proposed the law of travel (das Reisegestz) elucidating the interactions between points dispersed over space on the same footing as the gravity model of spatial interaction.

During the first six decades of the twentieth century, sociologists and social geographers contributed in enriching transportation demand analysis. Reilly’s work on retail gravitation in 1929, Stewarts work on demographic gravitation in 1948, the work by Stauffer in 1940 on interaction over space and the gravity model of intercity travel that signifies the
importance of travel-time by Zipf in 1946 are some of the contributions during the period that laid the foundation of more advanced models in later years. Thereafter, developments focussed on two aspects
(a) explanation of relationship between urban land-use and travel activities.
(b) articulating micro-economic paradigm of demand and supply to include transportation.
In the former, Mitchell and Rapkin's work (1954) remained seminal while in the latter; the work by Beckmann, McGuire and Winstein (1955) provided significant analysis developed in the latter years.

The spurt in transportation planning after World War II (as discussed earlier) was proportionally matched by accelerated developments in transportation demand analysis. Transportation studies carried out on urban areas of varying sizes provided sizeable empirical base for further study of transportation demand models of various types, developed thereafter.

During 1970 and the decade following it, behavioural approach to travel demand analysis based upon the assumption of micro-economic theory gained significance. Here the models were built on the assumption of utility maximization by rational travellers. The utility is derived from socio-economic activities including travel and transportation. Such utility is used to derive models of trip-generation, mode and route-choice. A major element in utility models is the study of the quantification of human attitudes towards attributes of demand and supply. The prime aspect of such study involves attempting to quantify aspects of traveller behaviours that are considered qualitative in nature e.g. psychological characteristics of the perception of transportation system attribute and preference that remained inexpessible in cardinal form. Work by Hensher (1976), Nicolaids, Wachs and Golob (1977), Recker and Golob (1976) and Kitamura in these aspects are considered praiseworthy. Another major element inherent in behavioural models is the accountability of random elements in travel decision process. Despite behaving rationally, a typical traveller's decision set always had elements of perturbations that cause behaviour not to repeat itself exactly when the decision process is allowed to repeat. Random utility models incorporating stochastic analysis helped predicting such randomness. Advances in these methods of model estimation and validation had remarkably raised the quality of prediction and hence had been boon to framing appropriate transportation policies. The works by McFadden (1974), Lerman and
Manski and Daganzo (1980) based on this concept and utilizing advances in probability theory in estimating randomness had been some of the important contributions.

3.3 THE MICRO-ECONOMIC FRAMEWORK FOR TRANSPORTATION DEMAND ANALYSES

Micro-economic demand theory in a modified form is utilized as a framework for analyzing transportation demand. Such modification arises due to the inherent distinction between transportation and other consumption activities. However, the complexity of transportation leads to some problems in the adaptation of micro-economic demand theory. These problems centers on three basic characteristics of transportation demand. They are

(a) demand for transportation (except the ones taken for its own sake) is a derived one obtained from the demand for other social and economic activities. Thus, the actual travel activities do not generate utility per se and hence the utility maximizing model becomes unacceptable.

(b) the inability to store and stockpile transportation.

(c) the methodological shortcomings in the micro-economic demand theory in specifying appropriate transport demand models along with the difficulties in validating them.

All these limitations fall through by changing the perception of analyzing them. In the case of first limitation, if it is accepted that the trip itself permits the trip-maker to partake of a socio-economic activity that generates utility and that transportation is simply a mean to overcome the spatial separation between the origin and the destination of the trip, then transportation can be thought of generically as an opportunity-cost to be incurred as a component of the total-cost of the consumption activity or whatever socio-economic activity is involved. The utility function is then to be perceived as a function of the number of trips and the associated socio-economic activities. The cost of transportation i.e. the transportation system attributes affecting the resources that must be committed to the trip, can then be included in either cost function or the budget equation or incorporated as favourable (or unfavourable) contributions to the utility function. Thus, theoretically the framework of micro-economic demand theory can be well adapted in the utility maximization models. The second limitation also is found to be not completely true. Many of the resources that are utilized in transportation can be stored until the transportation service is actually consumed. For example, in highway systems, the fixed costs are
incurred regardless of traffic but the variable traffic related costs are not. The traveller's travel-cost and travel-time is saved until the trip is actually made. Scheduling of transportation services is a type of stockpiling whereby services are offered when required. The third difficulty arises due to various uncertainties associated with consumption activities especially for passenger transportation. In urban transportation, innumerable choices, a typical household has to make with regards to possible combination of locations, trip-making rate, modes, routes and time of travel are replete with conjectures, uncertainties and assumptions. As a result complete quantification and modelling of them through micro-economic demand theory become difficult. Stochastic models of transportation demand based on the micro-economic theory with application of probability theory help remove the deficiency.

3.4 URBAN TRAVEL DEMAND MODELS---THE IMPORTANCE OF CHOICE

It is the demand for urban activities from which the demand for urban transportation emanates. The demand for these urban activities i.e. individual or household activities contained sets of all urban activities e.g. work, shopping, personal, etc. and are termed as activity demand sets. They are dependent on the socio-economic characteristics i.e. an individual's activity demand set is dependent on the income earned, the status of his employment, his age and so forth. Again, a household's activity demand set relies heavily on the household size, total income or the number of employed people along with their age, etc. It is only but natural that all the activities within the activity demand set shall not be undertaken by an individual or a household. The availability of opportunities determined by transport-costs from an 'activity supply set' that defines the totality of available urban activities at different transport costs, guides an individual or household in their choice of which and how many urban activities to undertake and the urban trips to be accomplished. It is this basis that explains the relatedness of travel with socio-economic characteristics and the transport system attributes. As explained above, the choice process plays a pivotal role in transport demand analyses and is related to the attributes of their travel activities through trips. In urban transportation, the majority of travel activities occur in daily cycles with difference between weekdays and the weekend days or holidays. On weekdays, travel attributes confined mainly to work are performed with relatively clockwise pattern, so also are the personal or recreational travels performed on weekends. Hence, estimation of demand on a daily basis is considered far more worthy than
estimating the same at a finer level of temporal detail. For a given nature of activity to be performed, the choice process expressed through trips are the

(a) total number of trips to be accomplished during a given time period
(b) the destination for a particular trip
(c) the mode of travel to use for a trip
(d) the route to be used between origin and destination comprising the trip
(e) the time at which the trip is to be undertaken.

It is quite likely that each of the above elements of the choice process is related to one another. In that case, the decision of a choice is assumed to be made either simultaneously or sequentially. The simultaneous assumption is assumed to be the most relevant as it takes account of the attributes of all the available alternatives in the determination of choice. However, in a complex, multimodal urban transport network, the innumerable number of attributes of the possible combination of alternatives is far too large so as to render degrees of limitations in such models. Under such constraint, the sequential assumption that relies on a hierarchical choice structure finds more relevance.

The presence of a hierarchical choice structure in an urban travel is borne out of constraints. For example, a trip-maker originating from a place with the availability of a single mode has no choice of modes except choosing the one available or if he has only one route to traverse to his destination then also he has to choose it irrespective of his choices. Again, if reaching the destination is considered primal then a hierarchy exists with the destination choice as the main objective followed by choices of other trip attributes being conditioned on the destination choice.

3.5 MODELLING APPROACHES IN URBAN TRAVEL DEMAND ANALYSES

The two types of choice processes (simultaneous and hierarchical) lead to two basic approaches in modeling urban travel demand, termed the direct approach and the sequential approaches. In direct approach, a single demand function obtains the number of trips of a specified region / zone on the basis of a set of demand and supply variables. In sequential approach, structuring a series of models of choice and finally combining them to predict the number of trips of various types is made use of. The direct approach towards modeling travel choices yields two types of models—

(a) direct aggregate models
3.5.1 AGGREGATE MODELS

3.5.1.1 DIRECT APPROACHES

Direct aggregate models: Here the total number of trips (round) by purpose and by mode between zonal pairs are expressed simultaneously through a single demand model. The attractiveness of the destination zone, measures of performance of the competing transport alternatives along with measures of socio-economic characteristics of the origin zone are the explanatory variables used in the model. Since the number of trips by mode is a function of the times and costs of both the mode being modeled and the competing mode, the model measures the effect of changes in the transportation system on both the total number of trips and the diversion between modes. These models are usually represented by

\[ T_{ijk} = f_n^k (L_{ijk}, S_i, S_j, A_i, A_j) \]

with the form of the equation \( f_n^k \) depending upon the mode \( k \) where, \( L_{ijk} \) represents the level of service of mode \( k \) available between the originating zone \( i \) and the destination zone \( j \); \( S_i \) represents the socio-economic characteristics of the origin zone; \( S_j \) represents the socio-economic characteristics of the destination zone; \( A_i \) represents the attractiveness of the originating zone and \( A_j \) represents the attractiveness of the destination zone.

The above model representation was applied for the first time in Kraft SARC North-east Corridor model (1963) where apart from socio-economic and attraction variables, the travel-times and costs of all the modes were considered. It measured the direct and cross-modal effects of each attribute of each mode on travel between each pair of origin and destination. Unlike the Kraft SARC North-east Corridor model, the Quandt-Baumol (or attribute mode models as ascribed by its developers) abstract mode model characterises modes in respect of their generic attributes i.e. the model is formulated not in terms of the attributes of all the modes in the system (as in the case of Kraft SARC Model) but rather in terms of the attributes of the mode that is being considered, relative to the attributes of the best available mode. Hence, none other except the best mode affects the demand for the mode being considered. Another version by Blackburn (1969) had its theoretical basis on the Quandt-Baumol approach. In it, a model of individual choice between alternative
ways of traveling and alternative number of trips is taken account of. These individual
demand functions are then aggregated to get an aggregate model of passenger demand.
The Charles River Associates Urban Direct Demand Model (1967) is an extension of the
Krafft SARC intercity model and is considered an important direct aggregate model. It
expressed the number of directed round trips between zonal pairs for a given purpose and
mode as a function of the number of individuals (or households) in the origin zone and
their socio-economic characteristics, the appropriate measure of the level of activity, round
trip travel-time and cost of the used and competing modes besides other relevant socio­
economic and land-use characteristics in the destination zone. However, two shortcomings
viz.

(a) the non-inclusion of the choice of the precise travel-time, e.g. the hour of the day
(b) dichotomous division of all existent modes into transit and auto despite
theoretically considering them all
renders certain degrees of restriction on the validity of the model.

3.5.1.2 SEQUENTIAL TYPE

(A) TRIP GENERATION

These types of models are characterized by the break-up of the travel demand process into
sub-models, each structuring a specific choice in the hierarchical choice structure utilizing
zonal data. The usual way by which these sub-models structure the travel-demand process
involved a four stage one. The first stage involved modeling the estimation of the total
number of trips originating from a typical zone as a function of the socio-economic
characteristics of that zone. Symbolically, it is represented as \( N_n^i = f_i (S.E.,) \) where, \( N_n^i \) is
the total number of trips originating from zone \( i \) for purpose \( n \), \( S.E., \) is the socio-economic
attributes of the originating zone \( i \). The model based on this framework is termed as trip­
generating models. The exclusion of transport variables allows the trip-frequency to be
totally independent of changes in transportation variables. The decision of travel
frequencies by the trip-makers also goes unaffected in the model besides the independent
variables often being interdependent thus losing the linearity status of the equation. Hence,
such models are considered non-behavioral and non-causal. Also, the absence of policy­
affecting variables renders policy-insensitiveness to the models.

(B) TRIP-ATTRACTION
Along with the trip-generating models, the number of trips terminating in each of the various zones is estimated from such characteristics of a typical zone e.g. employment or land-use description through the trip-attraction model. Symbolically, the model framework is represented as \( N_j = f_2(E_j, LU_j) \) where, \( N_j \) is the trips destining in zone \( j \); \( E_j \) and \( LU_j \) are the employment potential and the land-use pattern of the destining zone \( j \). The model like the preceding one is devoid of transportation variables, on the assumption that accessibility to any typical zone has no impact on the number of trips attracted to that zone. As a result of the absence of the policy variables, the model fails to orient itself with changes in policies.

\[ (C) \] TRIP-DISTRIBUTION

The next step in modeling the sequential choice is to distribute the predicted number of trips generated by a typical zone (say i) to each destination zone j. The estimation of these distributed trips is made on the basis of the trip-attraction equations along with the travel-impedance between a pair of origin and destination zone. The travel impedance variable provides linkages between origins and destinations. Existence of four classes of relevant trip-distribution models can be found in travel demand literature. They are

(a) growth-factor models
(b) gravity models
(c) opportunity models
(d) preferential equilibrium models

**Growth-factor Models:** This type performs an extrapolation of the future situation from present prevailing conditions. Their framework is represented as \( T_{ij}^t = f(T_{ij}^0, F_i, F_j, F) \) where, \( T_{ij}^t \) is the number of trips originating from zone \( i \) and terminating in zone \( j \) projected at time \( t \); \( T_{ij}^0 \) is the total number of trips originating from zone \( i \) and terminating in zone \( j \), at the time of conducting the survey; \( F_i \) and \( F_j \) are the growth factors for the origin and the destination zones respectively while \( F \) is the growth factor of the urban area in question whose travel demand is being determined.

Symbolically, \( F = T^t/T^0 \); \( F_i = T_{ij}^t/T_{ij}^0 \); \( F_j = T_{ij}^t/T_{ij}^0 \); \( T^t = T_{ij}^t \) such that, \( T_{ij}^0 \) and \( T_{ij}^t \) are the number of departure and arrival points for the trips in zone \( i \) at the time of surveying and at time \( t \) respectively. These types of model however, suffer from two major defects

(a) they do not take any direct account of the existing transport network (except by the exchanges resulting from it)
(b) the effect of inter-zonal flows in the future periods are not taken account of, if it remain absent during the period of analysis.

Gravity Models: An impedance factor $T_{ij}$ dependent on the generating and destinig trips and framed as an increasing function of transport cost is developed in these groups of models. Symbolically, the model framework is represented as $T_{ij} = A_i B_j O_i D_j (C_{ij})$ where, $O_i$ is the number of trips originating from zone ‘i’; $D_j$ is the number of trips destining in zone ‘j’; $C_{ij}$ represents the generalized costs between zones ‘i’ and ‘j’; while $A_i$ and $B_j$ are parameters dependent on the characteristics of the generating and attracting zones. Assuming there are ‘n’ zones, the influence of a typical trip remained confined on the characteristics of its point of generation and attraction implying a zero influence by the characteristics of the (n-2) zones, as per the model. Entropy-maximizing techniques (Wilson) applied in the latter versions of these models provides them with a refinement.

Opportunity Models: The choice of individuals culminating their trips to each particular zone are studied in these groups of models to have a knowledge of the accessibility of the various zones of an urban area.

Preferential Equilibrium Models: A variant of the gravity models discussed earlier, these models are framed by keeping in view the settlement of the trip-makers. Accordingly, these models take into consideration three types of users,

(a) those who chose their place of work on the basis of their residential zone
(b) those who conversely chose their place of residence on the basis of their workplace
(c) those who chose their place of residence irrespective of their place of work

The trip-distribution models however suffer from limitation. The travel impedance factors (considered to be of focal importance) are typically based on auto travel characteristics. The full range of travel-time (and cost factors) for all relevant modes of transportation are seldom made part of the impedance factors. Besides, the travel impedance mechanism is usually based on a fixed distribution of trip-length (in minutes). As a result of the above constraints, an accurate prediction of trip-distribution, especially when a change in transport system occur, remain elusive through this type of model framework.

(D) MODAL SPLIT:
Next in line with the trip-distribution is the modal-split model. It allocates the total number of trips distributed between zonal-pairs into two dichotomous modes—transit and auto (into which all competing modes are grouped) on the basis of relative travel times and costs between modes beside selected socio-economic characteristics of the origin zone and land-use characteristic of the destination zone. Its peripheral framework is denoted as 

\[ N_{ij}(\text{auto})/N_{ij}(\text{transit})=F(T_{ij}(\text{auto}), T_{ij}(\text{transit}), S,E,i,U_j) \]

Since, the model includes explanatory variables that provides descriptive information about zones it is only indirectly associated with travel-time and costs of the commuters. Hence, all the door-to-door components of travel-time and costs are not tallied with it. Thus, the domain of the model gets shortened up losing its behavioral status to some extent.

**(E) ROUTE ASSIGNMENT**

The last step in the sequential choice process is the route assignment modeling framework that determine the optimal distribution of flows over a network. Symbolically, the model structure is represented as 

\[ N_{ij}=f(\text{minimum time path, capacity}) \]

where, \( N_{ij} \) is the total number of trips between the origin zone 'i' and the destination zone 'j' by auto mode. The modes operating in a road network along with the routes they follow are weighted on the basis of an impedance function to ascertain the quality of service (in terms of traveling, waiting and interchange time besides travel-costs along with qualitative factors like comfort, safety, etc.) they provide.

A shortest road algorithm (kerby once through method) is applied to obtain the optimal route between two modes. The capacity restriction of each route are then looked into by taking account of the existing possibilities and using an iterative process to load the route until the network reaches a state of equilibrium.

### 3.6 DEFICIENCIES IN AGGREGATE MODELLING APPROACHES

The two groups of aggregate models discussed above, suffer from numerous faults and shortcomings, thus leading to retardation in the attainment of the objectives, they aim at. These deficiencies are as follows:
(a) the hallmark of these models lies in their non-behavioral attitude. They replicate the conditions existing at the time of survey hence entailing almost zero-guidance to the effects on travel-decisions of changes in traveller’s circumstances or in terms upon which they are offered competing alternatives in the transportation environment.

(b) in almost all the sub-groups of models, the inclusion of variables that are beyond the purview of control by planners leading to an element of insensitivity in them. The very few of models where the variables retain the responsive character have only a limited and mechanical role in responding to the prescriptions of the analysts.

(c) the temporal specification of travel remains outside the purview of these class of travel demand models.

(d) Except the group of route assignment models, equilibration remains ignored in all other

(e) All these models are based on data representing zonal aggregates of trips and socio-economic conditions. Usage of aggregate data obscures quite a significant proportion of information thus impeding the generalization of the models.

3.7 WAIVING THE DEFICIENCIES—NEED FOR AN ALTERNATIVE MODELLING APPROACH

The deterrent to successful travel demand estimation thus necessitates a more coherent approach involving both behavioral and a policy responsive element to be admixed in the modal set-up.

3.8 INCORPORATING THE ELEMENTS OF BEHAVIORALNESS AND POLICY-SENSITIVENESS

The behavioral quality of the model framework shall incorporate the decisions that trip-makers make when confronted with alternative choices, i.e. portraying the causal relationship between socio-economic, transport system characteristics on one hand along with trip-making decision of the traveler on the other. The competing alternatives could either be the various modes of transportation in existence in a typical area or the temporal details of the day of travel or the competing destinations. Only when travel demand model attains the truly behavioral status, the parameter in it shall be significant enough to reflect
the motivations of people in general rather than the influence of the urban area characteristics used in framing the model. The elements of policy sensitiveness is ensured through usage of variables that are flexible enough to be controlled by policy-makers. It is only then the planners would be able to address the following queries:

- effect of changes in travel impedance factors like travel-time and cost on the demand for various modes
- extent to which selective changes in travel-time and/or costs had an impact on the diversibility of the travelers from peak to off-peak hours trips
- the influence of spatial distribution of residential, work-place and shopping outlets on future traffic flows
- alteration in the distribution of trips through changes in the transit system
- whether transfer or access time are more onerous to transit-users than in-vehicle line haul times or whether savings in costs are considered more significant to trip-makers than to savings in time

Incorporating the above defined elements of behavioral ness and policy-sensitiveness shall thus involve a need for a method of projecting travel-demand under a variety of different assumptions about price, speed, frequency and convenience of service etc. of the different modes in a transportation system. Also, the existing framework shall have the requisite elasticity to allow the absorption of new technology relating to travel that may arise in future.

3.9 DISAGGREGATE MODEL FRAMEWORK—A PRACTICABLE APPROACH IN DEPICTING TRAVEL DECISIONS

Keeping these objectives into consideration, the Williamsburg Conference on urban travel demand forecasting held in 1972 concluded “travel demand forecasting is entering a new era in which are emerging a stronger behavioral basis for travel demand models, a coherence and unity of directions of current work and the potential for major improvement in practical capabilities for forecasting future travel in the context of today’s urban transportation decision making needs.”
3.10 DISAGGREGATE MODELS—THEIR MAIN FEATURES

In keeping with the objectives and to serve as an alternative to the aggregative or conventional models, by fulfilling the deficiencies, the disaggregate models are framed. The following sections draw up a detailed discussion of the typicality of such models.

During the seventies, disaggregate models are conceived of as “emerging technique” that addresses not only the shortcomings of the conventional models but also opens up new vistas in the area of traveler-response predictions considered vital for transportation policy evaluation. The prime features that enable the disaggregate models to score over its predecessors are

(a) **Policy-sensitiveness**—the models enable more accurate travel response predictions to a wider range of operating and construction options.

(b) **Explicit theory of individuals choice behaviour**—the models are based on the assumption that the process of travel demand to have arisen directly from individual decision maker’s choice with every observed trips to be the result of a selection made by individual traveller from among feasible choices.

(c) **Explicit structure of all relevant travel related decisions**—the model framework takes care of a wide range of socio-economic and transport variables like employment location, residential location, housing choice, automobile ownership, mode to work, frequency, destination, mode, time of day and route choice. Hence, a basic working hypothesis for the operation of the various models always is ready at hand.

(d) **Statistical efficiency**—usage of household data renders these models more statistically viable as compared to the aggregate models where aggregate zonal data fail to reflect the variability inherent in the existing data sets. Also disaggregate estimation reduces the potential of biases in the estimation of model coefficients as a result of the existence of the simultaneous link from travel demand to level of service attributes.

(e) **Explicit aggregation**—using available aggregate input-data, an aggregate is obtained through usage of disaggregate models through a variety of procedures.

(f) **Equilibration of travel demand and transportation system performance**—by employing efficient iterative network equilibration techniques the performance of the transport system attributes are tallied with travel demand estimates.
 Wide range of application—apart from their applications in sub-area and wide area analysis or for short / long range predictions, other areas where these models find applications in framing policy options are in the field of

--car pooling incentives --public transportation system in
   sub-urban areas
--pollution control strategies --demand responsive transit
--auto restricted zones --dual mode / transit feasibility
--parking restrictions --bridge tolls
--downtown circulation system --transit fare structure
--feeder bus services to rail-station --ramp metering and preferential lanes
--effect of highway supply on vehicle --miles of transit

3.11 TYPES OF DISAGGREGATE MODELS

To bring in the advantages of the disaggregate models for a more behavioral estimation of travel demand, it is necessary to mould the various stages of the sequentially aggregate models in the light of these disaggregate models.

As specified previously, the key role of choice among various options of trip attributes like destination, mode and route in the trip making decision process are portrayed quantitatively through the sequential models. Such a portrayal involves certain assumptions upon which two types of disaggregate models emerged.

3.11.1 DETERMINISTIC CHOICE MODELS

The assumption of choice process being deterministic and reproducible along with another assumption that the decision rule used by a potential traveler being consistent and stable led to deterministic choice models. While the first assumption implied that a potential traveler repeatedly faced with similar set of alternatives will consistently make the same choice, the second one permits structuring of well-defined decision rules that are based on demand-supply characteristics of the traveler and of the alternatives available.

3.11.2 STOCHASTIC CHOICE MODELS

These assumptions can be relaxed with the notion that the choice-process itself is not deterministic but subject to random influences that cannot be completely accounted for.
These influences originate from inconsistencies in the behaviour of choice-makers as a result of lack of information regarding the attributes of the alternatives available or to the stochastic fluctuations in the manner by which these attributes are perceived. Such stochastic fluctuation arises a result of the absence of a rational and consistent decision rule. The models based on this assumption are found to be conceptually more appealing than the deterministic ones and are termed as stochastic models.

3.12 CHOOSING THE BOUNDS OF THE RESEARCH QUERY

With the above discussion developing a concise view of the two primary classes of urban travel demand models that abound the travel demand literature, the focus of discussion is shifted towards validating the reasons for selecting the small and medium cities. But the prerequisite for such an exercise is to have an operational definition of the size of the urban area/town, tallying with the required sizes as posed by the research query.

3.13 DEFINING THE SIZE OF THE URBAN AREA

It is the purpose of definition that influences the definition of urban areas. For transportation analysis, the extension of an urban area shall include, to account for all important traffic movements, i.e., the areas of residence that generate traffic to the urban region of interest. So in transportation demand analysis, the focus centres on important traffic movements rather than the very few movements through exceptionally long distances. Consequently, it is necessary to define an urban area for the purpose of transportation demand analysis where all major economic activities of most people engaged in these economic activities live. Urban area defined for the purpose of travel demand analysis, on the same assertion implied the region where the residential areas of the majority inhabitants engaged in daily travel activities are located. Based on such scale, town size can be specified as small, medium, and large.

As per the report of the National Transport Policy Committee procedure by the Planning Commission, Government of India on May 1980, towns in India with a population of less than three (3) lakhs are termed as small-sized while those between three (3) to ten (10) lakhs are medium-sized and towns with population above that range are considered large towns or cities.
3.14 THE SITUATION PREVALENT IN WEST BENGAL AND THE FOCUS OF THE PRESENT RESEARCH EFFORT

A look at the road network of the state of West Bengal showed the total road length per lakh of population at 99.1 Kms. (as on 31st March, 1997), the lowest in the country along with a 46.29% rise in motor vehicles (all types) between the years 1991 and 1997. Hence, the severity of the pressure that confronts the state's road transportation network and the future trend that emanates from there can well be perceived. To alleviate the impact of such an imbalance, meticulous road transport plan for the whole state becomes necessary. The progress by the State Govt.'s transport department in this direction leaves much to be desired. The principal focus has been on Kolkata Metropolitan area with the small and medium towns (distinguished on the basis of population and hence activities) getting secondary attention in appropriate planning process. The economic activities of the small and medium towns have however risen manifold during the last decade. This led to proportionate rise in the travel demand as a result of heightened activities of the inhabitants of these cities. The consequence leads to increased social cost like congestion, pollution and accidents. Hence, the need for comprehensive transport plans of these areas like the big cities that takes account of such enhanced transport demand has become indispensable. These considerations have been the influencing ones in considering such categories of cities for the present course of analysis.

3.15 THE SELECTED TOWNS

Following the above guidelines, Haldia Municipal Area with a population of 150,429\textsuperscript{(a)} comprising 24 wards as on 1998 is classed as a small town while Howrah Municipal Corporation with a population of 953,543\textsuperscript{(b)} in 50 wards as on 1995 is chosen under the medium town category.

*Specifying the urban areas central to the analysis*

Brief discussions of the major features of these two cities including their present transport structure helps in evaluating the implication of choosing the towns.
3.15.1 *Haldia Municipal Area*

The urban area of Haldia lies in the south-west region of the state of West Bengal in the district of West Midnapore and on the confluence of river Hooghly—Haldi, Hijli and tidal canals. From Kolkata (Calcutta) the capital of West Bengal, its spatial separation measures six (6) nautical miles downstream south-west (of the river Hooghly).

**AREA AND POPULATION**

An enclosed area of 109 square kms. with a population of 150,429 in the year 1998, as estimated by the Haldia Municipality under whose administrative control, the area is under. The town is divided into 24 wards for bringing in administrative efficiency. The wards together accommodate 30,007 households comprising 11% of the total developed area (which is 20% of the total area). The town witnessed a mercuric rise in population growth rate during the past four decades (1951 to 1991). The population sprang up from 23,252 in 1951 to 100,347 in 1991 as per the Census report of 1991 (See Appendix B.1).

Such an influx of population was contributed mainly to the area’s growing importance as a major industrial growth centre since the commissioning of the Dock facility way back in 1977. Such a dock paved the way for cargo handling of various types of traffic, especially the bulk cargo like petroleum products. The structures have hence been an influencing factor in increasing the probability of setting up more new industries. Henceforth, various large, medium and small companies have been set-up in the area. Haldia Oil Refinery, Haldia Fertilizers Corporations, Haldia Petro-chemicals company, Hindustan Lever Limited, Shaw Wallace and Co. Limited are some of the distinguished companies besides scores of other that have changed the landscape of the area. Of them, Petroleum Companies despite itself running into various functional complicacies had the potential of becoming the base for growth of large number of down stream industries. Hence the economic importance of the town has been on a rising graph since quite a long time.

**TRAFFIC AND TRANSPORTATION SYSTEM**
Until the year 1989, about 205 of the total area under municipality jurisdiction had been developed. Within the developed region, transportation (rail, road & port) infrastructure occupies 48% of the total. The 80% of the under developed region which is to be developed in the near future will have 22% of it earmarked for transport infrastructural facilities.

Road and Road Transport

At present six (6) prominent roads cris-crosses the township. They are

(a) the National Highway-41 originating at Kolaghat (from National Highway-6) and terminating at Haldia.

(b) Panskura—Durgachak State Highway originating at Panskura and terminating at Durgachak.

(c) Geonkhali to Terapakhyia via Mahisadal.

(d) Kukrahati to Balurghata through Chaitanyapur and Brajalalchak.

(e) Petro-chemical Link roads connecting National Highway-41 with Panskura—Durgachak Road.

(f) Geonkhali to Chaitanyapur via Basulia.

Besides there are several roads connecting Haldia town with Durgachak—Basudevpur township offering linkages to various companies that have been set-up. The predominant mode of intra-town travel is by buses. There are 25 bus routes from Haldia to various destinations within the town. For short distances, Intermediate Public Transport (IPT) modes like cycle-rickshaws forms the main carrier.

Rail

Haldia is connected by a 69 Kms. railway line to the main South-eastern railway line at Panskura. Within the Haldia Municipal Area exists five (50) stations—Haldia, Silpapravesh, Durgachak town, Durgachak and Basulia. At present, two pairs of EMU local trains ply between Haldia and Panskura daily, one pair of EMU local train ply between Sealdah and Haldia daily while an Express train traverses between Shalimar and Haldia daily.
River Transport

Haldia is accessible from Diamond Harbour in the 24 Parganas (South) through ferry that links between Raichak and Kukrahati over the river Hooghly. A riverine link between Haldia and Kolkata (Calcutta) is maintained through a hovercraft service plying on a daily basis.

3.15.2 Howrah Municipal Corporation Area

Towards the end of the seventeenth (17th) century, settlements along the west bank of the river Hooghly came into existence so as to supplement the needs for increasing activities of Kolkata (Calcutta). The settlement acquired the name of Howrah in 1714 as validated from the records of the East India Company. A manifold increase of its importance was seen on and from 1854, the year of the establishment of the railway terminus. By 1914, connection of almost every Indian town was established with the terminus that led to a further boost in its importance. As a result an utmost need for a planned improvement of the area was felt. The established of the Howrah Improvement Trust (HIT) in 1956 for attaining that end was viewed with optimism. The urban settlement was brought under the administrative control of a municipality and identified as Howrah Municipal Area for efficient control of the planning procedures.

AREA AND POPULATION

The administrative area of the Municipality spread over an area of 51.74 sq. Kms. is bounded by river Hooghly on the east and south, National Highway (NH)-6 on the west and Kali Mazumdar Road and Guha Road on the north. The area had a population of 953543 as per Census report of 1991 spread over 50 wards. The population rose from 431000 in 1951 to the above figure in 1991 on an average decadal growth rate of over 20% (Appendix B.8). As could be perceived from the above discussion, the increase in population was mainly attributed towards accommodating the spillover of the excess labour force from Kolkata (Calcutta) area which failed to house them. Besides long periods of industrialization also favoured such an expansion (Appendix B.8).
In proportion to such population growth and their increased activities, there remained an acute deficiency in available road network. The land-use distribution of Howrah Municipal Area revealed a 15% of total allocation for both road and rail transportation as per the Howrah Area Development Plan (1966—1986) prepared by Calcutta Metropolitan Planning Organisation (CMPO).

**TRAFFIC AND TRANSPORTATION SYSTEM**

The transport network of Howrah consists of road, rail and ferry services.

**Road and Road Transport**

Looking at the road network of Howrah Municipal Area, a single thoroughfare along the North-South direction—the Grand Trunk (G.T.) Road, serves the major traffic carrying corridor that also divides the town into two parts. Other roads that play major role in traffic movement, connecting the city to its hinterland are Beneras Road, Howrah-Amta Road, Andul Road and Kona Expressway.

The predominant modes of transport within the municipal area is by bus / mini-bus with Intermediate Public Transport (IPT) modes following it.

**Rail Transport**

Howrah Municipal Area has two rail corridors—South-Eastern Railway and Eastern Railway approaching it. Both have their terminus at Howrah Station. However, of the two, South-Eastern Railway solely serves the Howrah Municipal Area with four (4) stations falling within its jurisdiction (Appendix B.9). About seventy-two (72) pairs of sub-urban and thirty-two (32) pairs of non sub-urban trains pass through these stations each day.

**River Transport**

Apart from the road and rail services, ferry services provided by the West Bengal Surface Transport Corporation (WBSTC) and supplemented by a large number of co-operative organizations, e.g. the Hooghly Nadi Jalpath ParibahanSamity (HNJPS) helped in
commuting passengers from various ferry ghats of Howrah Municipal Area to different ferry ghats of Kolkata (Calcutta). Through these ferry ghats, about 1.5 lakh passengers commute daily between Howrah and Kolkata (Calcutta) on an average day. The transit ghats within Howrah Municipal Area (HMC) and the destining ghats in Kolkata (Calcutta) along with the passenger ferried each day are known from Appendix B.10.

In both these two towns a measure of the prominent negative externalities showed a rising trend over years.

3.15.3 PROMINENT NEGATIVE EXTERNALITIES

3.15.3.1 Haldia Municipal Area

A measure of the prominent negative externalities (as discussed earlier) helps in estimating the efficacy of the presently employed road transport planning. Hence, the state of these externalities for the Haldia Municipal Area was examined to the extent possible.

A) Accidents

Data on the vital social cost like accidents showed a rising trend between 1995 to 1999 for prominent locations within Haldia Municipal Area (See Appendix B.2)

B) Congestion

Regarding the influence of social cost of congestion, a measure of the degree of congestion as well as congestion-index of various prominent road stretches was looked into by RITES. The degree of congestion is the relative value of the maximum posted observed speed on the road stretch to the peak hour speed on that stretch. The congestion-index on the other hand is the indicator of the combined effects of the traffic volume, road width available for traffic movements and the degree of congestion (which represents the journey speed on the network). The degree of congestion conducted on seven (7) prominent roads showed that on three (3) of them, it was above the acceptable value of 40 (I.R.C.:1990) with another three roads in all likelihood to cross it in the foreseeable future,
assuming the pace of economic activity in Haldia town do not back-track from that of the present (See Appendix B.3). The Congestion-Indices on the same road showed two (2) of the roads crossing the acceptable limit of thirty (30) \{I.R.C.:1990\} with one of them more than three (3) times the acceptable value. Three (3) other roads showed the tendency to cross the permissible limit in a short span of time if no corrective steps are taken up to improve the situation (See Appendix B.4). As could be summarized from the portrayal of the two (2) social costs (except the social cost like pollution whose trend cannot be predicted due to lack of data)—accidents and congestion, both are found to be in the range where they merit immediate attention of the town planners so as to bring them below the bounds of a break-even point. The present study of modal choice of travel demand for the Haldia town is an endeavour in that direction.

3.15.3.2 Howrah Municipal Area

Leaving aside the rail and river transport the absence of a hierarchy in the road network leads to passage of all traffic from north, west and south India to Kolkata (Calcutta) via Howrah. The effect of such a heavy volume of traffic movement leads to steep social-costs like congestion / bottlenecks, accidents and pollutions of varied proportions. It is obvious that such social costs cast a negative impact in the execution of a smooth traffic flow. The extent of such social costs can well be perceived from the various measures of them described as follows.

[A] Accidents

The available data on accidents showed an increasing trend with years. The data also showed the number of persons dying of fatal accidents to have risen with maximum death recorded in 1998 (1.101 per fatal accidents) as compared to 1.006 per fatal accidents in 1996 (Appendix B.11).

[B] Congestion

As compared to accidents, the congestion level is found to be proportionally high. A measure of it is obtained from the “Degree of Congestion” and the “Congestion Index”. The measurement of the former along major road stretches within IIMC area showed G.T.
Road from Beneras Road in the north to Jagat Banerjee Ghat Road in the South, J.N.Mukherjee Road, Salkia School Road, Howrah-Amta Road, N.S. Road to have values much above the acceptable value of forty (40). The problem assumes more significance by considering the fact that the main thoroughfares have one-way traffic operation. The same picture emerges in the case of Congestion-Index (C.I.). For major road links, it was found to be above the acceptable limit of thirty (30).

[C] Pollution

Regarding another important social-cost pollution, no reliable data could be obtained and hence no precise forecast about its social influence could be made. However, the proportional incidence of pollution especially air and sound with congestion points toward an admissible trend.

The high incidence of social-costs entails the present planning effort so far taken up by the HIT and CMPO to have a second look. To that objective, the drawbacks inherent in the present planning need to be waived. A precise estimation of the mode-choice of the travelers within HMC seemed congenial towards that end. The following part tries to achieve that act.

Hence these two cities are selected for applying specific model(s) from the inventory above that seems congenial from computational point as well as provide an edge over other competing models in reversing the diseconomies of scale.

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*a Traffic and Transportation study report (2000): Haldia Notified Area, RITES  