This chapter deals with the review of papers in the area of Trip Production & Attraction and presents the contribution by different researchers and deficiencies therein. Section 2.1 reviews the traditional travel demand models and section 2.2 reviews the Models for Simultaneous Travel Demand behavior and section 2.3 presents the consolidated review on the urban transport system

2.1. Traditional Models

2.1.1. Gravity Model Based Model

In the year 1961, Lansing makes use of gravity models for New York and Chicago. The initial gravity model described the relationship between the total traffic between each of these two cities and the demographic and socio-economic characteristics of the city pairs. Per capita income, population, and distance were included as independent variables in this model. In the year 1969, Quandt enhanced the early model. Afterward, it was employed in the Northeast Corridor Project to forecast the ridership on potential and existing modes of intercity travel along the Washington DC - New York - Boston corridor [14, 41].

2.1.2. Models for Direct Demand

Another type of early demand model was the direct demand model. This model combined trip production, trip attraction, trip distribution between the cities, and mode choice in a single demand equation. Data utilized for the models are the data on geographic aggregates. Most of the direct travel demand models were developed in connection with the Northeast Corridor Project. Kraft-SARC model are of most interest, the Quandt Baumol abstract mode model,
and the Blackburn model [15, 16]. The number of observed round trips by purpose and by mode between zonal (or city) pairs are used in this class of models as the units of observation. Hence, it circumvents the trip distribution and separate modal split problems. Meyer showed that the Kraft-SARC Model is, in its implicit form, an example of a direct and specific model[15, 17].

Following is the Kraft-SARC Model:

\[
T_{ijm} = \beta_{m0} \prod_{r} A_{ijr} \prod_{m} \pi_{C_{ijms}}
\]

\(m=1,2,\ldots,M\)

Where:

\(T_{ijm}\) = Travel demand between zone i and zone j by the mode m.

\(A_{ijr}\) = Observation on the \(r^{th}\) socio-economic activity for the zone pair (i,j) and

\(C_{ijms}\) = Observation on the \(s^{th}\) generalized cost variable for m from zone i to zone j.

R is socio-economic activity variables for the zone pair, and s is generalized cost variables of mode m. The Kraft-SARC model implies the presence of cross elasticity among modes. The model includes travel time and travel cost by all modes available in the city pair.

Because of this, it is more applicable to intercity travel analysis than the Baumol abstract mode model[41].

Following is the Baumol model:

\[
\log\text{RPM}_i = b_0 + b_1 \log X + b_2 \log F + b_3 \log (F_i/F) + b_4 \log S + b_5 \log (S_i/S) + b_6 \log D + b_7 \log (D_i/D) + E
\]

where:

RPMi: The number of revenue passenger miles carried on mode i,

X : The number of characteristics of the city pairs that influence demand but of no concern here,
F: The mode with lowest fare,

Fi/F: The relative fare of mode i,

S: The speed of the fastest mode,

Si/S: The relative speed of mode i,

D: The departure schedule of the most frequent mode, and

Di/D: The relative schedule of mode i.

Here, the Revenue Passenger Miles (RPM) are related to characteristics of the city pairs, the lowest fare of all modes, the speed of the fastest mode, and the departure schedule of the most regular mode. In Baumol model, the travel characteristics of the best mode, based on the highest speed, lowest fare and determine the quantity of travel between city pairs.

2.2. Models for Travel Demand Behavior

The sequential four-step model has been employed. Mainly, this is due to the fact that it is easy to implement in practice. However, the sequential method is not consistent with the individual's decision-making process, since decisions of whether to make a trip, the destination, and the travel mode are seldom undertaken by an individual in stages. Therefore, a simultaneous model is becoming more widely used.

Near the beginning simultaneous models were either aggregate or disaggregate. Basically, the aggregate simultaneous model incorporates feedback into the four-step travel forecasting procedure. It results in a combination of trip distribution, modal split, and traffic assignment [18]. Also, the other aggregate simultaneous model is an equilibration procedure which provides a simultaneous solution to the trip production and attraction, distribution, mode-choice, and assignment problems [33]. This modeling approach was applied to intercity transportation planning in Egypt [2]. In these studies, it was concluded that the approach was
able to predict rational behavioral responses of users to policy specifications. The first disaggregate simultaneous model estimates the combined probability of destination and mode choices within a joint logit model [12]. This model can estimate the joint probability that an individual will take a trip to a certain destination by a particular mode. In this structure, choice set contains all combinations of destinations and modes that are feasible for an individual. The multinomial logit model (MNL) was used to estimate the choice probability. However, the joint model may violate the IIA assumption.

Later in 1976, Adler and Akiva extended the nested logit model to include trip production and attraction in addition to destination and mode choice. However, the trip frequency was restricted to one or zero. It doesn’t tackle the problem of a big choice set resulting from all possible combinations of trip frequency, mode, and destination. The following are some recent models that are similar to this model [12].

2.2.1. Urban Travel Demand Model by McFadden

In the year 1996, Domencich and McFadden developed a model for urban travel demand analysis that is close to the model for direct demand [5]. This work examined the number of directed round trips between any zonal pair for a given purpose and mode as a function of the number of individuals and socio-economic factors, the appropriate measure of level of activity, and other relevant factors, such as the costs and travel times. Individual components of model are "interrelated" through the attributes of the trip-time and cost variables, so that the separate components link together in an overall demand model. The distilling of facts on the attributes across a broad, despite the fact that distinct set of choice alternatives into a single "desirability index" of travel is considered as the success of the nested logit model. Obviously, the model is not completely interrelated because the utility is assumed to be
separable. Different components are estimated separately, while they share the same variables such as inclusive cost. It only considers the choice between no trip and one trip due to limitations in the case study. The model allowed shopping trip frequency allows just zero or one shopping trips per household per day that is the limitation in many applications.

2.2.2. Intercity Model

Damodaran proposed another conceptual framework for intercity travel behavior under which a nested logit model structure was developed to combine mode choice and trip production and attraction [21]. The arrangement is shown below in Figure 2.1.

![Figure 2.1 Structure of Model](image)

The model for trip production and attraction and mode choice was linked through the inclusive utility-value, but this utility-value is only included in the initial stage of the nested logit model for trip production and attraction. In the Damodaran's work, the trip production
and attraction model was based on a model proposed by Sheffi for nested or ordered alternatives [22]. There were limitations when faced with many trips per study period. This model represents the linkage between conditional probabilities through a structure of decision-making. Although the decision-making is assumed to be sequential, it is possible to estimate the simultaneous structure through the simultaneous maximum likelihood method. The nests can be different subdecisions of choice or different dimensions within one subdecision, and the higher choice model incorporates a composite variable that represents the inclusive utility of the individual across the lower level, which is used by Ben-Akiva, Sobel, and McFadden [12, 23, 24]. The structure is similar to the nested model for trip frequency, except that the destination choices and mode are also repeated for every trip. In this structure, each trip can be considered independent of the previous one. This simplification was made to avoid the replication of mode choice for every additional trip. So, one mode choice model is used for any number of trips. The estimation order is as follows. The mode choice is first estimated. A binary logit for a zero or greater than one trip model is estimated with an inclusive utility from the mode choice model. Another binary logit model for 1 trip and more-than-2 trips are estimated without any inclusive value. Many binary logit models are similarly estimated sequentially. Again, in this structure, the burdensome work results from the large amount of binary logit estimations when the trip frequency is high, while the mode-choice model and trip production and attraction are both based on the utility maximization theory and they are combined through the inclusive utility.
2.2.3. Multidimensional Model

In the year 1989, Koppelman proposed a hierarchical structural system that includes trip frequency, trip destination, modal split, and service class choice [25]. The structure is shown in Figure 2.2.

![Multidimensional Model Diagram](image)

Figure 2.2 Multidimensional Model

The sub-models are considered to be interdependent. Travel choices in the hierarchy are interconnected. Links present among the models are used to represent associations among travel choice. Every choice of travel is made in the hierarchy and conditional upon all higher-level choices. Lower levels choice influenced the choice at the higher level. This interrelationship is embodied through inclusion of composite variables that represent the combined attributes of all alternatives in the lower-level of the hierarchy. However, in a trip production and attraction model, a linear regression approach is used due to the somewhat cumbersome formulation of a choice model for frequency choice. The composite variable that would represent the service characteristics of destinations is excluded. Here, the trip
production and attraction is not based on utility maximization and the interrelationship between the trip frequency and mode choice is not included.

2.3. Urban Transport System

The Urban Transport system consists of four sub-models these are: Trip generation (trip production and attraction), Trip distribution, Mode-choice and trip assignment.

2.3.1. Trip Generation

Trip Generation predicts the number of trips produced and attracted to each traffic analysis zones i.e. how many trips are made to and from each zone of the study area. Also, trip production and attraction is the first module that provides the option for the next steps, such as trip distribution, mode-choice etc.

The early trip production and attraction models, based on aggregate data, predicted total trips between city pairs [26]. The modeling methods generally include, cross-classification analysis, regression models or a combination of both. These methods still have applications due to their mathematical feasibility, data availability, and ease of interpretation [14].

Disaggregate trip production and attraction models were developed to be consistent with other components of the transportation demand modeling system, such as destination choice models and modal split models. Trip production and attraction was assumed to be a process of choosing one option from the following alternatives for making zero, one or two trip(s) and so on. Hence, these models predict the probability of an individual making a certain number of trips within a given period.

A trip can be home-based or non-home-based. According to Ortuzar, trip can be also classified by its purpose, like trips to work, trips to college or school, social trips, shopping trips and recreational trips and some other trips as well [4]. A trip is generally categorized as a
non-business trip or a business trip. Trip production and attraction analysis requires classification of the characteristics that directly affect trip production and attraction process. More often, the variables taken into account are factors that characterized the passenger, and trip attraction process, as well as the factors of alternatives. The characteristics of passengers include car ownership, household income, household size and structure. The trip attraction characteristics include the industrial factors, destination's socio-economic factors. The numbers of trips are influenced by performance of the available alternatives, particularly for inter-city trips (non-business). For example, decrease in travel time or cost may encourage more common trips. The reverse may decrease trip frequency. The special effects of changes in mode attributes on trip frequencies may also apply effects on mode choice for some purpose of the trip [5]. In the year 1995, Domencich and McFadden created a binary logit model to find out the probability of a person undertakes a shopping trip on a particular day. In this model, the inclusive price, which is defined as a weighted average price over all possible destinations, was used as an independent variable [5].

This is an attempt to impart betterment in the trip production and attraction modeling behavior, which does not provide any significant advancement since this aspect simply utilize the different independent variables, such as the number of drivers having license minus total number of workers present in the household. This was also stated that purpose of the logit model to such choice set would create a problem because of the logit model's necessary assumption of Independence of Irrelevant Alternative (IIA). IIA states that the relative probability of every pair of alternatives is only related to the characterizing factors of that pair of alternates and also, not dependent of the characteristics of all other alternatives.
Kiron Chatterjee focused on the alternative for the Great Britain future scenarios in the year 2030 and the implications they have for transport provision and travel demand. Kiron Chatterjee developed a National transport model to predict the national road traffics. In order to take income as a constraint for estimating trip production and attraction there is no mathematical model under this aspect. Also, in the developing countries like India wide income disparity is there which can also plays a leading role in trip production and attraction process [27].

In the year 2013, Daniel developed a inter-urban trip generation model for Akwa Ibom, Nigeria, which is based on the multiple regression analysis model for forecasting future patterns. However, in a trip production and attraction model, based on regression approach is used due to the somewhat cumbersome formulation of a choice model for frequency choice. The composite variable that would represent the service characteristics of destinations is excluded. Here, the trip generation is not based on utility maximization and the interrelationship between the trip frequencies [28].

2.3.2. Trip Distribution

The origin and destination ends of the trips are linked, generated by the trip distribution model. The commonly applied trip distribution model is the gravity model which is based on the production and attraction of each zone and the impedance in travelling from origin to destination zone.

Gravity model is signifying the idea of establishing trip distributions process. In Gravity model, the entries of the Origin-Destination matrix are understood to be a feature of the trip counts. The main problem of the gravity model is in the measurement of travel cost. This model has been corroborated numerous times as a basic underlying aggregate association [8].
For the analysis zones separated by a sizeable distances, the gravity model can work properly. But, the denominator approaches to infinity as the distance between locations decreases.

Dantzig created the Linear Programming problem as well as offered the simplex method as its solution of Linear Programming. A simplex method is an iterative process which works along the boundaries of the problems in feasible region to find a solution of the problem. Also, the simplex method still remains the widely known solution finding technique for solving Linear Programming problems. But, the available option on the bases of Linear Programming was not successful in practice. Estimation of trip distribution is a challenging task for future period [9].

Oak Ridge National Laboratory prepared trip distribution system called the Oak Ridge Evacuation Modeling System (OREMS). This model was designed to help the planner identify the migration or permission times and the traffic operational factors (e.g., bottlenecks, average speed, and other information to prepared effective migration plans). Trip distribution phase is simulated and updated through traffic assignment. But, the lack of realistic illustration of driver performance with respect to destination selection, route selection and departure delays has been a serious problem with this model [29].

In order to compare the performance of intervening opportunity model, gravity model, intervening opportunity model, Wilmot was conducted a study. With the help of this comparison of observed trips and predicted trips, the study recommended that the traditional urban transportation planning trip distribution models are able to model trip distribution at the cumulative level, and that all models traditional models have achieved similar performance and they similar bottlenecks as well [10].
2.3.3. Mode Choice Analysis

Modal Split analysis forecast the number of passenger’s trips from each source to each destination that will use each mode of transportation. Obviously modal split has considerable implications for transportation policy, particularly in big metropolitan areas.

In the year 1973, Watson developed the first disaggregate model for intercity mode choice, in which he discussed two alternatives (rail versus auto) using the information regarding individual travelers on the Edinburgh-Glasgow route in Scotland. It was concluded that the use of behavioral, stochastic and disaggregate models in a predictive structure is preferable to the aggregate approach because the predictions of disaggregate models are very promising. Consequently, there were a large number of studies on disaggregate mode choice within the intercity framework [30, 31, 32, 33, 34, 35]. The studies contain probabilistic models which only focus on making a particular choice, once the trip-maker has decided to make a trip. Research progressed from binary logit model to the multinomial logit model and after that to the nested logit model. The first model developed was a binary logit model which was employed within the New York City-Buffalo corridor in the U.S. In this model, (n-1) binary models should be calibrated if n modes are to be evaluated. Later, the concept of a binary logit model was extended to a multinomial logit model [36], which was used to model the choice of one among a set of mutually exclusive alternatives. It’s simple and elegant mathematical structure makes it easy to estimate and interpret. Most importantly, it is consistent with utility maximization theory. However, the Independence of Irrelevant Alternative problem of this model drove the researchers to relax the assumption.

Models with non-independent or non-identical random components commonly use different distributions to model the error terms [32]. The normal distribution for non-independent, non-
identical error terms those results in a multinomial probit model. The type I extreme value distribution to model the identical, non-independent random components leads to a nested logit model. The nested logit model, is designed to capture correlations among alternatives. Recently, the nested logit model has become extensively popular [12]. This model also relaxes the Irrelevant Alternative problem assumptions across alternatives. In recent times, some researchers are developing a Mixed Logit model. The model contains both probit-like disturbances and an additive independently and identically distributed extreme value disturbance within the multinomial logit model. It is a highly flexible model that can approximate any random utility model. Mixed logit is considered to be the most promising state-of-the-art discrete choice model [37, 38, 39].

Anthony Chen presented a basic planning tool particularly targeted at small (Metropolitan Planning Organization) MPOs was proposed to model the system traffic for the planning applications. This tool made use of PFE (Path Flow Estimator) for both the base year estimation as well as the future year predictions with some accessible field and planning data that can be available in public domains. For this tool no formal validation is done [40].

Richter presented a model based on the logit model [42]. The model is complex. The logit modal choice association states that the probability of selecting a mode for a trip is depend on the relative values of numerous factors such level-of-service, and travel time etc. The complex part of employing the logit modal choice model is to estimating the parameters that can be assigned for the variables presents in the utility function, so the accuracy of this logit model is not ensured [43, 44, 45, 46].