It has already been mentioned in the introductory chapter that spatial development determines the need for spatial interaction in terms of transport. On the other hand, by the accessibility it provides, transport also determines spatial development in terms of land use. However, it is difficult to empirically isolate impacts of land use on transport and vice-versa because of the multitude of concurrent changes of other factors. So, the natural question in road traffic planning is, can we integrate both and predict its effects? That is, to find out the likely impacts of integrated land use and transport policies to reduce the demand for travel. Actually, there are principally three methods to predict those impacts (Hensher and Button, 2004). The first is to ask people how they would change their location and mobility behavior if certain factors, such as land use regulations or transport costs, would change (‘stated preference’). The second consists of drawing conclusions from observed decision-making behavior of people under different conditions or how they would be likely to behave if these factors would change (‘revealed preference’). The third is to simulate human decision behavior in mathematical models (‘simulation’).

The current state-of-the-art in any transportation planning process is the use of travel demand forecasting models. These models are generally accomplished through computerized network simulations of a transportation system. Such models are complex and require extensive inputs on current information about roadway and transit system characteristics and operations, as well as current and projected demographic information.

4.1 Transportation planning models

From the studies like that of Maerivoet, 2006, it is found that the urban models relating to transportation planning were introduced in the 1960s, with the aim of solving land use and transportation questions (Maerivoet, 2006). They are also employed with the goal of addressing a wider range of urban problems. Regarding the modelling approach, the general practice of most organisations dealing with regional transportation plans and program is based on four sequential steps or processes. They are – (i) trip generation – forecasts the number of trips that will be made, (ii) trip distribution – determines where the
trips will go, (iii) mode usage – predicts how the trips will be divided among the available modes of travel and (iv) trip assignment – predicts the routes that the trips will take, resulting in traffic forecasts for the highway system and ridership forecasts for the transit system.

Now, before going into any detail, it is worthwhile to take a look at where transportation planning models operate. The rationale behind transportation planning systems is that the travelers within these systems are motivated by making certain decisions about their wishes to participate in social, economic, and cultural activities (Maerivoet, 2006). The ensemble of these activities (i.e., the activity system) determines the demand for travel, and the transport system determines the supply to fulfill the current demand. Here, the activity system consists of the socio-economic and demographic characteristics of the region. It also includes land use policies and characteristics. The transport system, on the other hand, includes modes of transport, different technologies of transport, infrastructure, institutional set-up and policies concerned with the transport system. In the bulletin of the World Health Organisation, 2003, Tiwari presented the relationship between these two systems with a simplified model as given in Figure 4.1.

![Fig. 4.1: Transport and activity system](reproduced from Tiwari, Bulletin of the World Health Organisation, 2003, 81 (6)).

In the above model, Tiwari shows a feedback loop from a flow subsystem to a transport system as well as an activity system. That is, the types of flow should determine the characteristics of transport systems and the modes and infrastructures required in the
future, as well as land use patterns and spatial and temporal spread of activities. The model also shows that the feedback loop has a filter. It means that the policy-makers, decision-makers and ‘technical experts’ weigh various options and the trade-offs involved and permit only a few flow patterns to be fed into the overall transportation and activity system. He has also mentioned that the improvements in transport systems in the future should be such that they can fulfill the varied demands of various flows (Tiwari, 2003).

4.1.1 Land use-transportation models

Land use-transportation models are composed of independent land use and travel models with the mechanisms for coupling the two — either loosely or in a more integrated fashion. In these models, land use models are used to predict demographic and economic measures of land-based activities i.e., the population (usually in terms of income and employment) and built-space environment (e.g., floor space) for a given urban area. Travel models (specifically, travel demand models), on the other hand, are used to predict travel patterns on a transportation network. This class of models aim at simulating travel patterns as a function of human activities (commonly considered in terms of land uses) as well as the characteristics of the transport network (commonly considered in terms of accessibility) (Miller et al., 1998). Thus, the integrated land use-transportation models are used to simulate the interaction of the land use system and the transport system and this is generally done by means of feedback mechanisms.

The following discussion deals with several kinds of land use models from the perspective of transport planning. In general, they seek to explain the growth and layout of urban areas. But, they are also devised to gain insight into the general patterns that govern growth and evolution of a city.

4.1.1.1 Land use models

One of the oldest known models describing the relation between economic markets and spatial distances is that of Johann Heinrich von Thünen in 1826. It pointed out that transport costs determine the location of agricultural activities and projected the consequences and differentiations of dairy, vegetable, forest and crop production according to distance from the market (Saikia and Saikia, 2006). The spatial layout of the model relates to an isolated state (self-sustaining and free of external influences), in which a
central place is surrounded by concentric regions of different land uses. To him, these concentric rings arise because all farmers in the isolated state acted for maximum profits, and transportation cost was proportional to distance, determining the land use around the central place. Some 100 years later, Ernest W. Burgess (1923) also suggested that cities grow outwards from the CBD in a series of concentric belts of land use. This model was based on a study of land use in Chicago. Fifteen years after Burgess, a study of residential areas done by Homer Hoyt (1939) in North America, concluded that land use pattern was not a random distribution, nor sharply defined rectangular areas or concentric circles, but rather sectors. Thus, the effect of direction and time was added to the effect of distance. Communication axes, such as rail lines and major roads, are mainly responsible for the creation of sectors, thus transport has directional effect on land use. A city would thus, grow along its major axis.

Fig. 4.2: Typical examples of two models relaying the evolution of land use. A: the sector model of Hoyt and B: the concentric zone model of Burgess. In both, CBD corresponds to the central business district, I to the industrial factories, L, M, and H to the low middle and high class residents respectively. In the Burgess model, C denotes the commuter zone.

In 1945, Harris and Ullman introduced a more effective generalization of urban land uses (Fig. 4.3). They brought forward the idea that many towns and nearly all large cities do not grow around one CBD, but are formed by the progressive integration of a number of separate nuclei in the urban pattern.
From among other classical land use models, the model of Peter Mann developed in 1965 is worth noting. He considered a hybrid model for land use representation. He combined the Burgess’s and Hoyt’s models. A notable feature of his model is the fact that he considered industries to be on one side of the city, with high-class residents occupying the diametrically opposite side. The study of Waddell and Ulfarsson (2004) also shows that the activities related to working, living and recreation appear to occur at substantially different spatial locations and, consequently, the emphasis on the geographical aspect of a city becomes less important during its evolution (Waddell and Ulfarsson, 2004). This study suggests that the modern land use models should approach the integration of an activity system from a completely different perspective, where the growth of a city is represented as the evolution of a ‘multi-agent system’, in which a whole population of individual households can be simulated. Due to the tremendous increase in computational power over the last few decades, these large scale simulations are now possible. A good example of such an all-encompassing approach is the work related to the Urban-Sim project, where researchers try to interface existing travel models with new land use forecasting and analysis capabilities. This has been developed, improved and refined by the Centre for Urban Simulation and Policy Analysis at the University of Washington (Maerivoet, 2006).

Keeping aside the land use models, most of the transportation planning process, however, seems mainly to rely on travel demand forecasting. These types of models involve
predicting the impacts that various policies and programs are likely to have on travel in urban areas. The following is a discussion on such models.

4.1.1.2 Travel models

In general, travel demand forecasting models attempt to quantify the amount of travel on the transportation system. Demand for transportation is created by separation of urban activities. The supply of transportation is represented by service characteristics of highway and transit networks. There are many models available to forecast this travel demand. But the major categories are that of trip-based and activity-based models.

Trip-based transportation models

Trip-based models are well known as the conventional four-step models (4SM) or the classic transportation models. They are currently the most commonly used models worldwide. The trip-based approach uses individual trips as the unit of analysis. In this conventional modelling process, various characteristics of the traveler and land use-activity system (and to a limited degree, the transportation system) are evaluated, calibrated and validated to produce a non-equilibrated measure of travel demand, so as to locate this demand onto the transportation network. In other words, the model predicts future travel demand and its implications on the transportation system. Inputs into the model include existing and planned land use and socio-economic variables as well as the planned road network. Through a sequence of computations the model is able to predict the future volume of traffic on each transport network link as well as provide other indicators such as total number of trips, vehicle speeds, travel times and congestion per link among others (Hensher and Button, 2000). Transport planners use these indicators to evaluate the impact of proposed policies, plans or projects on the performance of the transport system. On this basis, the four step model is seen as an important planning and decision support system.

The four basic phases or steps in the above mentioned traditional travel demand forecasting model are:

Step I: Trip generation

Trip generation is a general term used in the transportation planning process to cover the field of calculating the number of trip ends in a given area. The objective of the trip generation stage is to understand the reasons behind the trip-making behavior and to
produce mathematical relationships to synthesize the trip-making pattern on the basis of observed trips, land use data and household characteristics (Kadiyali, 2004).

In this stage, the zone wise analysis of trip generation in the study area gives the planner the amount of trips that are produced by each zone and the amount attracted by each zone. And thus, this stage comprises factors that are called the ‘productions’ and ‘attractions’, which can be derived by using techniques based on regression analysis, category analysis, or even logit models. As different models can be used to derive the number of productions and attractions, an *a posteriori* balancing is performed that equalizes both results. In the end, step I gives the magnitude of the total travel demand on the network. In addition, the planner also gets the idea of the purposes for the trips because the trips are put into several categories, like trips from home to work, or home to shop etc.

**Step II: Trip distribution**

After trip generation, the analyst knows the number of trip productions and trip attractions each zone will have. But, where do the attractions in Zone I come from and where do the productions go? What are the zone-to-zone travel volumes? Trip distribution procedures determine where the trips produced in each zone will go and how they will be divided among all other zones in the study area.

So the second step of transportation planning connects trip origins to their destinations by distributing the trips. The result of stage II is then the construction of a complete origin destination table (OD table).

There are several types of trip distribution analysis. For example, the Fratar method, the intervening opportunity model, and the gravity model etc. (Maerivoet, 2006). Again, considering the fact that an OD table contains a large amount of unknown variables, several techniques have been introduced to deal with this problem. For instance, if an OD table for a previous period (base table) is known, then a new OD table can be derived by using a so-called growth factor model. Another method is by using gravity models (Helbing and Nagel, 2004), which are based on travel impedance functions.

One of the problems that still remain unresolved is how to deal with the so-called through trips, i.e., trips that originate or end outside the study area. To this end, Horowitz and Patel (1999), directly incorporate rudimentary geographical information system and
measured link flows into a model that allows deriving through-trip tables. Application of this methodology in the case of Wisconsin and Florida resulted in certain reasonable estimates of link flows that are comparable with empirically obtained data (Horowitz and Patel, 1999).

**Step III: Mode choice / modal split**

Once the origin-destination table for the given network and time period is available, the next step deals with the different modes of transportation that people choose between. In other words, this phase of travel demand forecasting analyzes people's decisions regarding mode of travel - auto, bus, train, etc. Generally three broad categories of factors are considered in mode usage: the characteristics of the trip maker, the characteristics of the trip, and the characteristics of the transportation system.

The planner looks at how these characteristics interact to influence the trip maker's choice of mode. When the relationships are discovered, the planner can predict how the population of the future will choose from among the modes that will be available to them. The discrete choice theory is a popular tool in this respect that allows a disaggregation based on the choice of individual travelers (Maerivoet, 2006).

**Step IV: Trip assignment**

Trip assignment is the procedure by which the planner predicts the paths which the trips will take. For example, if a trip goes from a suburb to downtown, the model predicts which specific roads or transit routes are used. The trip assignment process begins with constructing a map representing the vehicle and transit network in the study area. The intersections (nodes) on the network map are identified, so that the sections between them (links) can be identified. After the links are identified by nodes, the length, type of facility, location in the area, number of lanes, speed, and travel time are identified for each link. If transit is available, additional information, which identifies fares, headways (time between vehicles), and route descriptions, are included on a separate network. This information allows the computer to determine the paths that the traveler might choose between any two points on the network and to assign trips between zones to these paths.

Generally all the travelers will endeavor to take the shortest route between their respective origins and destinations. For this, the planner has to identify a suitable measure
of distance so that a shortest path algorithm, e.g., Dijkstra's algorithm (Dijkstra, 1959), can calculate the possible routes. In a general setting, the distance can be considered as a cost, whereby travelers then choose the cheapest route. But in practice, distance typically means both the physical length of an individual link (spatial component) and the travel time on this link (temporal component).

Using these analyses of trip generation, trip distribution, mode usage, and trip assignment, the planners can obtain realistic estimates of the effects of policies and programs on travel demand. Once travel demand is known, the planners can assess the performance of alternative transportation systems and identify various impacts like congestion, pollution, accident etc. that the system will have on the urban area. With information on how transportation systems perform, and the nature and degree of their impacts, planners can provide decision-makers with the information that they need to evaluate alternative methods of supplying transportation services.

**Activity-based transportation models**

The historic roots of the activity-based approach can probably be traced back to 1970, particularly to the works of Torsten Hägerstrand. He asserted that researchers in regional sciences should focus more on the intertwining of both disaggregate spatial and temporal aspects of human activities, as opposed to the more aggregate models which neglect the temporal dimension. This scientific field was commonly known as time geography; it encompasses all time scales (from daily operations to lifetime goals), and focuses on the constraints that individuals face rather than predicting their choices (Miller, 2004). The notion of so-called space-time paths of individuals' activity and travel behavior was the central focus of Hägerstrand's work. He traced out the journey of an individual in a three-dimensional space-time structure, with two spatial dimensions make up the physical world plane, and the temporal dimension as the vertical axis. Repeated visits to certain locations are joined by a curve, with vertical segments denoting places where the individual remained stationary during a certain time period. The complete chain of activities is thus joined by individual trip legs. The space-time path thus represents the revealed outcome of a behavioral process. An example of such a path was presented (fig 4.4) by Dettloff in 2001. In his figure, one can observe that a woman going from her home in Boulder, Colorado,
USA to the university campus, followed by a visit to the post office and grocery store, and finally returning home (Dettloff, 2001).

![Space-time path diagram](image)

**Fig. 4.4:** Example of a space-time path showing an individual’s activity and travel behaviour in the space-time volume (reproduced from D. Dettloff, 2001).

In contrast with the development of the trip-based approach that culminated in the four-step model, there is no clear general framework to encapsulate the activity-based modelling scheme. There were, however, comprehensive studies on human activities and their related travel behavior (Jones et al., 1983). Certain ingredients like the generation of activities, modelling of household choices or the scheduling of activities could also be recognized in the study made by Axhausen (Axhausen, 2000). In 2001, an excellent overview of models that encompass activity scheduling behavior is given by Timmermans, who makes a distinction between simultaneous and sequential models (Timmermans, 2001). The former category is based on full activity patterns, whereas the latter is based on an explicit modelling of the activity scheduling process. Simultaneous models comprise utility-maximisation models and mathematical programming models. Examples of such models are: Recker’s household activity pattern problem model (Recker, 1995), Bowman and Ben-Akiva’s discrete choice model (Bowman and Ben-Akiva, 1995) etc. Sequential models are often implemented as computational process models (CPM), acknowledging the belief that individuals do not arrive at optimal choices, but rather employ context dependent heuristics. An example of a complete activity based system is ALBATROSS (A Learning Based
Transportation Oriented Simulation System) of Arentze and Timmermans (Arentze and Timmermans, 2000).

The principal critique on these models' operations was their need for an extensive amount of purposively generated data that encompass Hagerstrand’s concepts. But just as with the four-step model, these data are difficult to obtain (Miller, 2004).

4.1.1.3 Integrating land use and transportation in models

For the purpose of longer-range forecasting, transportation planning models need to be tied to a broad-based land use plan for the same region. The fact that necessitates the linkage between transportation and land use planning exercise is that almost all urban centres are growing at a brisk pace. As a result, the relative advantage of locations within them are also bound to change because of the growing demand for goods and services, the build-up in traffic congestion and the further development of the transportation system in response to the emerging situations. There are two main ways of linking land use and transport models. The first is through an instantaneous link at the trip distribution stage of the model. Here, the land use system provides the transport system with estimates of the location and volume of potential trips. The second is through a time-lagged link to the activity location stage of the model via the notion of accessibility. At this level, accessibility affects travel costs, which in turn influences the urban activity location. The inclusion of these feedback mechanisms in integrated models marks a departure from conventional four-step models.

4.2 Some of the operational land use-transport models

In the following section, some of the integrated land use-transport models are reviewed. They are operational in the sense that they have been implemented, calibrated and used for policy analysis for at least one urban area. In this regard, it may be mentioned that Lowry's (1964) Model of Metropolis was the first attempt to implement the urban land use transport feedback cycle in an operational model. This essentially consists of a residential location model and a service and retail employment location model nested into each other (Geraldes et al., 1978). After this, a wide range of different approaches to model urban land use and transport have been evolved and these can be witnessed in the volumes edited by Hutchinson et al. (1985) and in the reviews made by Wegener (1998) and others.
Here, for this review, we have divided the models into five groups, as has been done by Bates and Oosterhaven (1999) in their report to The Standing Advisory Committee on Trunk Road Assessment, Department of the Environment, Transport and the Regions, London (Figure 4.5) (Bates and Oosterhaven, 1999).

In the above figure, optimizing models are intended as tools which can find a 'design' to optimize a particular function. They may be informative for research and long-term planning, but in general, they are difficult to link with the practical planning problems of individual cities or regions. So far the predictive models are concerned; they may be divided into static and quasi-dynamic models. Static models represent a single point in time, whereas quasi-dynamic models run for a series of time periods with transport changes generally taking one or more such periods to have an impact on the land use.

Much of the early works in the evolution of land use models consisted of static models which attempted to predict the location of certain variables taking other variables as given (Lowry, 1964, and the whole range of Lowry-inspired models considered in Batty, 1976). Such models obviously cannot represent in any realistic way the processes of urban change which, by their nature, take time to react to any changing situation. For this reason, static models had ceased to represent the state-of-the-art by 1980s (Mackett, 1992 and Wegener, 1994). Static models have, however, retained some relevance to cases where a dynamic land use-transport model is unaffordable.
Referring to Figure 4.4, distinctions can be made within the category of quasi-dynamic models. These distinctive classes are: (i) models based on the analogies with statistical mechanics pioneered by Alan Wilson in the 1970s; (ii) models based on the integration into a spatial (multi-zonal) form of separately developed (and often non-spatial) economic models; and (iii) models based on representation of the different processes affecting the different types of activities considered.

4.2.1 Static models: DSCMOD, IMREL and MUSSA

Static models in use today are typically developed as a means of adding a land use impact dimension to existing transport models, without embarking on the extra work needed to create a dynamic model (Bates and Oosterhaven, 1999). The static models can be divided into two sets: one, which estimates the pattern of land use given by one set of transport inputs; and the other, which estimates changes in land use given by two sets of transport inputs. The models like IMREL (Static land use model developed in Sweden, 1991) or MUSSA (Land use model of Santiago, Chile by Martínez, 1992) are representatives of the single-input approach, while DSCMOD (David Simmonds Consultancy’s static urban and regional modelling package, 1990) is the representative of the two-input approach.

DSCMOD was developed by David Simmonds Consultancy (DSC), UK, in 1990 for the practical purpose of adding a land use dimension to what would otherwise be only transport studies (Simmonds, 1992). MUSSA, as developed by Martínez and his colleagues in Chile, 1992, is primarily a research tool. IMREL, which was developed by Anderstig and Mattsson in Sweden, 1991, is used for both the purposes. IMREL and MUSSA estimate equilibrium patterns of land use corresponding with the accessibilities output by the transport model. In the case of MUSSA, the full process involves iteration between the land use model (MUSSA itself) and the corresponding transport model i.e. ESTRAUS (Transport model of Santiago, Chile, linked with MUSSA land use model) within the future year represented (Martínez, 1992).

DSCMOD, in contrast, assumes that the "base case" land use forecast is in equilibrium with the "base case" transport strategy, and calculates changes in land use from the accessibilities produced by alternative transport strategies. These accessibility changes may be the only influence on location choice, or may be combined in a more complex
mechanism with floor space constraints and market clearing using rent adjustments. In MUSSA, the market process is critical, as the model is developed from research on the integration of different theories about residents’ and landlords’ choices. These models are generally urban models. However, a regional employment version of DSCMOD (Simmonds, 1992; Simmonds and Jenkinson, 1993) has been developed which represents only employment and uses a measure of economic potential to relocate jobs.

MUSSA adopts a unified economic framework. It is closely connected to a four-stage transport model. It represents firms rather than employment with demand for space, determined by a willingness-to-pay measure (Martínez, 1992). To this model, households attempt to maximise their consumer surplus, while developers attempt to maximise the price appraisal of master plan for paid. MUSSA is not, however, available as a commercial package.

4.2.2 Quasi-dynamic models

*Entropy-based models: LILT*

LILT (Leeds Integrated Land use Transport package, Mackett 1979, 1983) is the main UK model of this type, and has been applied in Leeds, Dortmund and Tokyo (as part of ISGLUTI). This model is based around a Lowry model formulation and linked to a traditional four-stage transport model. It allocates exogenous totals of population, jobs and employment on a spatial framework. Though, further development of this model has ceased, a similar, but simpler, US model, DRAM (Residential sub-model of former ITLUP package)/EMPAL (Employment sub-model of former ITLUP package) (Putman, 1995) has been widely applied in the USA.

DRAM/EMPAL allocates households on a similar basis to LILT. But it allocates employment on the basis of a zonal attractiveness measure to the workforce and previous employment by zone.

*Spatial-economic models: MEPLAN, TRANUS and METROSIM*

MEPLAN (Marcial Echenique & Partners Ltd., Cambridge, land use/transport modelling package, 1984) (Echenique et al, 1990) and TRANUS (Modelistica land use/transport modelling package) (De la Barra, 1989) are the commercial packages developed from a set of models devised at the Martin Centre, University of Cambridge,
Cambridge. Both MEPLAN and TRANUS have been applied in policy and research studies in the UK and abroad since the 1980s. Each package includes both a land use model and a multi-modal transport model, and is usually implemented as a quasi-dynamic model. There are many similarities in the broad approach adopted by the two packages, to the extent that for policy analysis purposes they can be treated as one. This review concentrates on MEPLAN, because information on this is more readily available and TRANUS is rather less developed in its treatment of economic relationships.

MEPLAN is a multi-purpose software package developed originally by ME&P in 1984. It differs from models discussed so far in that the land use and transport elements are fully integrated. The interactions ('economic trade') between activities are determined by input-output analysis, and these interactions are used to derive the demand for transport. Location choices, transport mode choices and assignment are determined by a consistent multi-level logit choice structure based on random utility theory. The location behaviour of households, firms and property developers is based on competitive markets, with incomes and rents determined endogenously in each time period.

In urban applications of MEPLAN (such as LASER – Williams, 1994, or ME&P, 1995), particular attention is paid to residential location and the journey to work, shopping and schools. For regional implementations, the 1994 special issue of the journal Environment and Planning from the Martin Centre 25th Anniversary Conference may be consulted.

A new easy to use package MENTOR (Marcial Echenique & Partners Ltd, Cambridge, land use/transport modelling package, 1998), designed specifically for local authority use, is also currently in use in the UK. It is a pure land use package that can be interfaced to existing transport models. It builds on the theoretical structures of MEPLAN but operates at a more detailed level of segmentation of activities and is more straightforward to set up and calibrate. It retains the key characteristic that the distribution of transport demand is explicitly derived from the interactions modelled within the land use model.

In 1982, Alex Anas developed yet another model called the METROSIM (Land use transport modelling package, 1982) (Anas, 1982). It differs from other models in that it
reviews all the land use and transport choices simultaneously in a micro-economic framework. METROSIM is currently being applied to New York City in the USA. It is more comprehensive than previous economic models (Anas and Arnott, 1993) and represents the property development, market and employment location. It is to be noted that the model as implemented finds the equilibrium state for housing, floor-space, labour and travel for a forecast year, and is therefore a static model. The package is, however, capable of operating over time, and we have therefore considered it as a dynamic model. Several other model development projects underway in Japan also are looking into simultaneous transport and land use choice models, but as yet they have rarely been used in policy related studies, and are not available as packages.

**Activity models: DELTA and URBANSIM**

Activity based models are defined by their focus on the different processes of change which affect activities and the spaces they occupy. They are, therefore, the opposite of general equilibrium modelling. These models tend to be characterized by more detailed segmentation of activities, and more elaborate treatment of both the decision to move and location choice. In contrast to other models, they do not relocate all activities in a time period, but separate the decision to move and the search for a new location. These models also represent demographic change in more detail than any of the models so far considered. The examples of this type of model are DELTA (David Simmonds Consultancy's quasi-dynamic land use modelling package, 1994) and URBANSIM (Urban land use model developed by Waddell, 1998). DELTA has been developed by David Simmonds Consultancy, UK, since 1994 and applied to Edinburgh and Greater Manchester. URBANSIM has been developed by Waddell, 1998 and is being applied to Eugene/Springfield and Oregon. These models are designed to be linked to transport models developed in separate packages. Each of them incorporates a development model, a demographic model and a random utility discrete choice location model.

In DELTA, households follow a utility maximizing formulation and the market adjusting prices within a time period, while in URBANSIM households maximize a consumer surplus measure and use a bid-choice function derived from the equilibrium type developed by Martínez (1991). The other key difference between DELTA and URBANSIM
is that DELTA works with the changes in past transport and land use conditions, while URBANSIM is based on a cross-sectionally calibrated relationship.

**Activity models with micro-simulation: IRPUD**

The IRPUD (The urban land use/transport model of Dortmund developed by Wegener and others) model has been applied only to Dortmund, Germany (Wegener, 1985). It treats households’ choices in even more detail than the DELTA model discussed above. Its most distinctive feature is that it uses micro-simulation techniques to deal with the complexity of the migration processes within the housing market sub-model. Housing search is modelled in a stochastic framework to generate intraregional migration flows by household category between housing by zone. There are plans to eventually convert the rest of the model to operate using micro-simulation techniques, starting with the transport sub-model (IRPUD, website: [http://irpud.raumplanung.uni-dortmund.de/irpud/pro/](http://irpud.raumplanung.uni-dortmund.de/irpud/pro/)).

4.3 Using integrated land use models in policy-making: an assessment

The root causes of travel growth in the urban areas are found in the development of urban land – what it is used for and how intensely it is used. So public policies intended to produce sustainable forms of travel must encompass a better understanding of the broader topic of urban land use, and in particular the way transportation and other forms of urban land use interact. From this perspective, if we were to evaluate currently operational land use transport models (TLUM), they would get quite high marks on incorporating latest theories within their frameworks. Methodologically also, they make use of non-linear mathematical programming methods as well as the latest developments in econometric and micro-simulation modelling of the demand for travel, residence and employment. The more comprehensive models also tackle demographic change in the urban population, and some also model physical stocks other than the transportation infrastructure. Another important aspect is that these models represent the events using an extensive database, resulting in the allocation of traffic volumes and speeds over detailed link-node representations of multi-model urban transportation networks.

But, it is found that in contrast to the considerable effort made to develop the theoretical aspect of the relationships between transportation and spatial structure, the practical application of models has been relatively neglected. So, the fact is that, the
application of many of these techniques is much less widespread within the planning profession than what might be expected. In this regard, the review by Cambridge Systematics and Haque Consulting, in 1991, found that only a handful of 18 metropolitan areas were using integrated models in their planning process. The review has also found that the problem in employing these models relates to their analytical complexity, significant data requirements and demands on computational resources. While computers can provide much of the computing power required, cost of data collection remains as the major constrains.

4.4 Views of Buchanan on the transport planning

In 1963, Professor Colin Buchanan in the ‘Traffic in Towns’ (popularly known as the ‘Buchanan Report’) had explained the traffic planning in such a way that it has received appropriate treatment. It had produced a new design for towns and according to the report this design was meant for contriving the efficient distribution, or accessibility of large number of vehicles to large number of buildings it in such a way that a satisfactory standard of environment is achieved (Buchanan, 1963).

While recognizing the adverse effect of traffic on the environment and that large increase in capacity can exacerbate congestion problems, the report signified some fundamental shifts in attitudes to roads. The following few paragraphs from Wikipedia, the free internet encyclopedia, will highlight the main recommendations of the report, its response and legacy.

The report recommended that the urban redevelopment should look to the long term, and avoid parsimonious short-termism. Further, it stresses that certain standards should always be met, including safety, visual intrusion, noise, and pollution limits. But, if a town or city is both financially able and willing, it should rebuild itself with modern traffic in mind. However, if circumstances meant that this was not possible, it would have to restrain traffic, perhaps severely. According to this report, planners should set a policy regarding the character being sought for each urban area, and the level of traffic should then be managed to produce the desired effect in a safe manner. This would result in towns with a lattice of environmentally-planned areas joined by a road hierarchy, a network of distribution roads, with longer distance traffic being directed around and away from these areas. In the case of
small and medium sized towns, it recommended the selective use of bypasses around small and medium sized towns to alleviate congestion in the centres. However, it recommended that the road user should not be denied too much access, and that restricting through congestion charging would not normally be the right approach, unless and until every possible alternative had been tested.

The report recommended that some areas should change their outlook. Rather than facing the street, shops could face onto squares or pedestrianised streets, with rooftop or multi-story parking nearby. Urban areas need not consist of buildings set alongside vehicular streets; instead multiple levels could be used with traffic moving underneath a building deck, with snug pedestrian alleys and contrasting open squares.

The report looked at a range of scenarios based on real towns, and suggested treatments that would balance the desire to enrich people's lives through car ownership. In the case of small towns, for instance, the report took the example of Newbury town. It showed the possible way that could be taken to redevelop the town in a pattern with vehicles easily integrating into the urban scenery. The suitability of this approach has been proved when the A34 Newbury Bypass was proposed, alongside extensive pedestrianisation and road changes within the town. The new roads dramatically reduced the impact of motor vehicles on the town and accompanied the reinvigoration of Newbury which had managed to retain its historic core [(PDF) Historic Newbury fit for the future, West Berkshire Council, 2006].

However, as towns were developed according to the Buchanan's blueprint, several issues emerged. For instance, some of the grand plans that were called for have had a poor reputation in their implementation. Similarly, public accountability required by local government officers was sometimes stretched, with accusation of corruption with the private sector developers and contractors responsible for putting the plans into action. Another point of criticism was the courage needed to develop the schemes proposed in the report. The recognition of environmental issues was also less well understood in the 1960s. The considerations in the report were more for the human environment, rather than the natural issues which have tended to confound some subsequent road proposals. Critics also pointed out that the motor vehicles, moving onto dedicated routes, no doubt, reduces the
interaction with pedestrians or cyclists, but this will cause higher speed than before and thus be far more hazardous.

4.5 Conclusion

The study of works related to transportation planning reveals that the conventional way of understanding the phenomenon of traffic flow and planning, is to observe how vehicles move in a stream of traffic, which is followed by collecting data of such movement. These observations and the data are then used to synthesize the characteristics of traffic flow using analytical approach or mathematical models of system approach.

The analytical approach includes techniques like the speed-density-flow relationships, the hydrodynamic analogy model, car-following theory, queuing theory etc. However, the main drawback of this approach is that it requires field data collected on a large scale. For example, if a proper understanding of the complex traffic on urban roads is to be achieved, real world observations will have to be conducted on all types of roads on a complete range of vehicle type and their composition in traffic, along with a total coverage of volumes and speeds of traffic. Such a procedure is tedious, time consuming and expensive. Another problem is that, at the end of the effort, it often happens that a reliable relationship does not emerge.

The other approach, i.e. the system approach, is the result of the activity called the 'operations research'. It is mainly concerned with optimizing the performance of the complex whole transport system. So, it is a comprehensive look at transportation problems. It involves the inventory of land use, economic activities, existing travel pattern and transport facilities and then, synthesis and model-building thereon through four major steps: trip generation, trip distribution, trip assignment on the existing network and modal split. The predictions of future traffic flows produced by this four stage sequence are then used to identify planning options. But, the main drawback of such an approach is the voluminous work involved. The time frame and cost in such a process is also high.

Thus, to gain a better understanding of the behavior of urban areas, several operational transportation-land use models (TLUM) have been adopted. Broadly taken, such a model is an information construct used to represent and process relationships between a set of concepts, ideas and beliefs. These models have a language, an intended use and a
correspondence to reality. At present, there are a wide variety of TLUM, most of which were developed during the quantitative revolution, which transformed geography substantially during 1960s and 1970s. Among the best known TLUM are Integrated Transport Land use Package (ITLUP), Transport Economic Land use System (TELUS) and Marcial Echenique and Partners Planning Model (MEPLAN) etc. But, these models are also not ahead of problems regarding their application. The analytical complexity, data requirements and significant demands on computational resources on the one hand and the cost of data collection on the other remains as the major constrains.

Keeping aside the TLUM or any other approach, if one recourses to the approach taken by Professor Colin Buchanan in his famous ‘Traffic in Towns’ (1963) for the solution of traffic related problems of the urban streets of England, one would find that this approach seems to be more applicable also in the case of small towns of Assam. The reason for this can be simple. It requires modest data that can be generated with reasonable resources and most importantly, a large part of the data may be available from the census reports and other such sources.