

## Chapter 3 Literature Review

### ***3.1 Transportation Planning Models***

Transportation planning models have been used extensively by the professional community to forecast travel demand for a long time as early as 1950s.

#### **3.1.1 The Current Role of Sub Area Focusing in Planning**

While forecasting transportation demand for a region, some agencies may be interested in performing a more detailed investigation of traffic patterns within a sub area, such as the downtown area. Sub area focusing involves a precise representation of the site and neighboring streets, but uses coarse representations of the road system and urban development well away from the site. Sub area focusing requires many fewer zones and many fewer links than traditional region-wide travel forecasting. Only the incremental traffic from the site can be estimated by such a network

EMME/2 provides several tools to achieve sub area focusing by extracting sub-networks and the associated O-D matrices. Link attributes, which have been judiciously coded to identify the desired sub-networks, can be used to export any of the sub-networks in the form of an ASCII file which is in the proper format to be read into another EMME/2 data bank. If the link attributes do not contain this information, the desired sub-network can be identified by using an EMME/2 module which performs node and link scattergrams. The desired sub-network can be identified by changing node and/or link attributes (“cookie cutter” method) and then exporting the so identified sub-network as above. A feature of the equilibrium assignment of EMME/2 called traversal can be used to obtain, for the identified sub-network, an O-D matrix which is entirely consistent with the regional O-D matrix and its assignment on the regional network. The traversal matrix which is so obtained may also serve as input to traffic micro-simulation models.

To facilitate sub area analysis, TransCAD also provides a procedure that lets you create an O-D trip table for that sub area. The reduced O-D table may be used for performing a

traffic assignment on a sub area network which may be more detailed than the regional network.

### 3.1.2 The Limitations of Current Methods

From 1960s, the sequential models started to be widely accepted to carry out transportation planning. The widely used four-step procedure is a typical sequential model. There are major modules in four-step model, each representing a different aspect of the traveler's decisions. The *trip generation* module estimates how many trips will be made to and from individual analysis zones. The *trip distribution* module estimates where trips originating in various zones will be destined, linking the trip origins and destinations from the generation model. The *mode choice* module identifies whether each trip will be made by motor vehicle or mass transit, and it may estimate the size of carpools. The *traffic assignment* module allocates the trips for each mode to the most likely route, whether a roadway or a transit line.

One of the principal reasons for the much wider acceptance of the sequential modeling approach is that it seems to be easier to understand. Breaking the decision process into steps facilitates analysis of the several factors that influence travelers' decisions although it is somewhat contrived. This breaking down also eases the development and verification of the models because there are fewer factors of influence in each module. The relationship between the cause and effect of those factors are more likely to be apparent. The federal and many state governments provide technical support, including computer programs, documentation, and training, only for sequential models.

However, the aggregate transportation planning models have been severely criticized for their inflexibility and inaccuracy. These models at base attempt to represent the average behavior of a group of travelers instead of a single individual. Also note that conventional four-step travel demand models most clearly are not simulation models. They represent the supply side with aggregate link performance functions that are static in nature and do not represent the build up of queues in the network.

Disaggregate models appeared in 1980s offer substantial advantages over the aggregate counterparts. Disaggregate models at base represent the behavior of individuals. The disaggregate models are clearly superior to the grouping of behavior zonally and by predefined segments in aggregate models. It is fair to say that a broad consensus exists within the activity-travel demand modeling community that disaggregate modeling methods possess considerable advantages over more aggregate approaches (including minimization of model bias, maximization of model statistical efficiency, improved policy sensitivity, and improved model transferability – and hence usability within forecasting applications), and that they will continue to be the preferred modeling approach for the foreseeable future.

However, disaggregate transportation planning model being used for a large metropolitan has just been on the research aspect, not in the reality basis because it would involve a huge amount of data, which were neither available, nor manageable for a long time. Benefiting from the boom of computing capability of modern computers and more and more detailed census data, TRANSIMS as a disaggregate transportation planning model has become possible to be used in the real world.

### **3.1.3 The Advantages of TRANSIMS**

As disaggregate, behavioral, regional transportation planning package, TRANSIMS provides a number of unique benefits of the traditional 4-step travel demand modeling methodology:

- The unit of analysis in the 4-step methodology is a group of people residing within a Travel Analysis Zone (TAZ). TRANSIMS' analysis however is performed at the level of individual travelers and households. Location of every traveler is known at any given time. This micro level of analysis combined with a wealth of demographic information available for every simulated traveler allows the modeler to analyze policy effects on any segment of the population.

- Only major streets and highways are typically considered by the 4-step methodology. TRANSIMS, on the other hand, can analyze traffic over the entire transportation network of a metropolitan area, including local streets and highway ramps.
- Traditional methods consider only average speed or, at best, several speed bins for a large number of vehicles passing over a roadway segment during a significant time interval. TRANSIMS, on the other hand, provides precise speed for every single vehicle at any second of the day. This information is used to produce precise and highly detailed on-road emissions estimates at any level of analysis from an individual link and up to the entire metropolitan area.
- TRANSIMS provides detailed information on each vehicle's status and location. For example, it is known whether the vehicle is currently on the road or is parked somewhere; if the vehicle is parked, the parking location is known. Information about the number of starts and stops that the vehicle has undergone and how long the vehicle has been operational is available as well. This information can be used to produce detailed estimates of evaporative and off-road emissions.
- The 4-step modeling is typically performed for several large segments of the day, whereas TRANSIMS provides second-by-second information allowing for a much more precise analysis of time-of-the-day effects over 24 hour period.

## ***3.2 Interface of Planning Models with Transportation Operation Models***

### **3.2.1 Current Applications in Microsimulation Models**

Computer simulation is important for the analysis of freeway and urban street systems. Through simulation, transportation specialists can study the formation and dissipation of congestion on roadways, assess the impacts of control strategies, and compare alternative geometric configurations. Over the past three decades a considerable variety of

sophisticated computer models that are capable of simulating various traffic operations have been developed. Simulation models have different characteristics: static or dynamic, deterministic or stochastic, microscopic or macroscopic. Each simulation model has its own logic and use limitations, and is applicable to specific components of a transportation system.

A variety of traffic simulation models have been developed since the 1960s. The simplest model classification may be based on the classification of facilities that the model can analyze. Gibson classified simulation models as those for intersections, arterials, urban networks, freeways, and freeway corridors. The need for integrated control strategies has resulted in recent developments of simulation models for integrated freeway/signalized intersection networks. Each of these traffic subsystems, isolated, coordinated, or integrated, has unique problems and objectives.

Much like demand forecasting models, the classification of traffic simulation models is based on the level of aggregation. Microscopic models consider the characteristics of each individual vehicle and its interactions with other vehicles in the traffic stream. Therefore they can simulate traffic operations in detail but usually require extensive inputs and long execution times. Macroscopic models are characterized by continuum fluid representations of traffic flow in terms of aggregate measures, such as flow rate, speed, and density. These models lose detail but gain the ability to deal with large problems within short execution times. Analytical procedures are incorporated into both microscopic and macroscopic models to evaluate existing conditions and to predict performance under different design and control scenarios.

Typical microscopic simulation modeling methods are based on car-following and lane-changing theories that can represent the traffic operations and vehicles/driver behaviors in detail. The car-following theory describes the longitudinal movement of vehicles. The classical car-following approach is quite straightforward, that is, each vehicle attempts to go ahead. The lane-changing theory describes the lateral traffic behavior. This may be considered in terms of a number of perception thresholds governing the consideration of the risk of accepting a gap in a neighboring lane. A set of decision rules is used to

calculate whether a speed advantage may be obtained if a vehicle were to change lane. Microscopic simulation modeling incorporates queuing analysis, shock-wave analysis, and other analytical techniques. In addition, most microscopic simulation models are stochastic in nature, employing a Monte Carlo process to generate random numbers for representing the driver/vehicle behavior in real traffic conditions.

Macroscopic models model traffic as an aggregate fluid flow. Continuum models, simple or high order, are usually employed in macroscopic simulation modeling. The simple continuum model consists of a continuity equation representing the relationship among the speed, density, and flow-generation rate. The simple continuum model does not consider acceleration and inertia effects and cannot describe nonequilibrium traffic flow dynamics with precision. A high-order continuum model takes into account acceleration and inertia effects by using a momentum equation in addition to the continuity equation. This momentum equation accounts for the dynamic speed-density relationships observed in real traffic flow.

A limited number of simulations fall into the third category of mesoscopic models, a mixture of microscopic and macroscopic models.

### **3.2.2 Particular Focus on CORSIM**

CORSIM is a comprehensive microscopic traffic simulation, applicable to surface streets, freeways, and integrated networks with a complete selection of control devices (i.e., stop/yield sign, traffic signals, and ramp metering). CORSIM simulates traffic and traffic control systems using commonly accepted vehicle and driver behavior models. CORSIM combines two of the most widely used traffic simulation models, NETSIM for surface streets, and FRESIM for freeways. CORSIM has been applied by thousands of practitioners and researchers worldwide over the past 30 years and embodies a wealth of experience and maturity. Traffic Software Integration System (TSIS) is a sophisticated toolkit built around CORSIM. Its strength lies in its ability to simulate traffic conditions in a level of detail beyond other simulation programs.

The strengths of CORSIM can be categorized as follows:

- Its ability of simulate an integrated network of surface streets and freeways
- Microscopic vehicle simulation
- Sophisticated vehicle movement logic
- Detailed traffic signal control logic
- Animation output (TRAFVU)
- Long history of CORSIM component (NETSIM & FRESIM) application

As for CORSIM's design deficiencies, the following is worthy of major concerns:

- Unable to simulate large networks
- Different system design approaches in the surface street and freeway logic
- Limited "plug-n-play" capabilities to interface with other models and applications

### ***3.3 Evacuation Models in Context of Sub Area Focusing***

Traditional transportation analysis focuses on the classical peak travel demands of weekday morning journey-to-work and afternoon journey-from-work trips. A focus on those times when traffic is at the peak makes sense when attempting to provide acceptable levels of service throughout the day. However, it is important to recognize that traffic modeling and transportation system capabilities have been analyzed within the context of special events or circumstances as well. One of these special event circumstances involves emergency evacuation. Typically, evacuation planning is associated with a well defined scenario, like a radioactive release from a nuclear power plant or the evacuation of a low lying coastal zone that might be subject to a hurricane. The possible event, such as an evacuation of the area that surrounds a power plant or the low lying coastal region, generally has a footprint that is relatively easy to define in advance. The zone or footprint that is defined for the possible evacuation scenario is called the evacuation planning zone (EPZ). Much of the focus of evacuation planning involving transportation systems, such as streets, roads and highways has been directed at well defined large areas, e.g. coastal cities, where a possible need for evacuation might occur and might involve large numbers of people. To clear such large areas may take

many hours and require significant personnel resources, changes in signal operations, road closures, dedicated radio communications so that people are kept informed, preplanned staging areas for relief efforts, as well as many other elements. Recognition for the size of the evacuation problem and the need for advanced planning is the greatest for large EPZ areas.

The planning focus for events that may involve the evacuation of a small area typically centers on personnel training and resource planning. Because the size and the location of a disaster event, like a hazardous material spill or a terrorism is hard to predict, the focus has been on general planning and mock drills rather than attempting to develop neighborhood specific evacuation plans. There are, however, growing concerns for ensuring that safe evacuation of small areas, like neighborhoods, building complexes and schools or universities, can take place. This is especially true for those places that may face higher risks of a disaster.

Emergency evacuation can be a life or death situation, where the lack of safe exit routes and the time that it might take to safely exit can be directly related to lives lost. Depending on the type of event that precipitates the evacuation, like a hazardous material spill, some of the routes that people would normally take are obstructed in some way. Either the routes are too crowded, blocked by the disaster or damaged sufficiently enough to cause slower egress rates. An evacuation event can be defined according to a number of characteristics (e.g. one of three exits is blocked). It is common to define an event scenario as a set of specific characteristics. Scenarios are then defined to represent a range of possible instances of an event that underlies an evacuation. Each event scenario can then be modeled to identify the likely outcome of the scenario as well as help craft evacuation plans, designate evacuation routes, and identify mitigation strategies.

Over the last two decades there has been considerable interest in modeling evacuation for a well-defined zone and event scenario, like the evacuation of a low lying coastal zone that may be subject to a hurricane surge. To analyze an evacuation scenario for a well-defined footprint, or EPZ, a number of different approaches have been used. They range



from simple indices, e.g. the number of people on a ship divided by the number of seats provided in all life boats, to sophisticated simulation models. Most of the research has been concentrated on two distinct problems, evacuation of buildings and evacuation of large areas, like entire cities or coastal plains.

Evacuation modeling applied to large areas has involved the use of simulation approaches. An excellent review of evacuation modeling applied to large areas can be found in Southworth (1991). Simulation has been the preferred tool of choice. In the 1980's, few researchers in the transportation field addressed the shortcomings of the current evacuation procedures and set out to develop evacuation models that incorporated the traditional traffic assignment/simulation approach. Youssef Shefi, Hani Mahmasani, and Warren Powell from MIT developed the NETWORK emergency eVACuation model (NETVAC) that addressed the estimation of clearance times for areas surrounding nuclear power plants. KLD Associates, Inc. developed the DYNAMIC EVacuation model (DYNEV), a special purpose macroscopic evacuation model derived through the enhancement of a sub-model contained in TRAFLO, also a simulation model developed by KLD Associates, Inc. Pacific Northwest Laboratories developed The CLEAR (Calculating Logical Evacuation And Response) model. It estimates the time required to clear a certain disaster area for a specific population density and population distribution by simulating the movement of vehicles on a transportation network according to the conditions and consequences of traffic flow. The program also models the distribution of times required by individuals to prepare for an evacuation.

Hobeika et al. developed TEDSS (Transportation Evacuation Decision Support System) Model to target various evacuation planning and operation scenarios, such as natural disaster evacuations and man-made disaster evacuations. Evacuees are loaded onto the network based on the type of evacuation carried, the weather condition, and night or daytime, and slowly and quickly escalating evacuation. The user can modify transportation network to satisfy the evacuation conditions and has the option to change the major routes from two-way flow to one-way flow. The outputs show the evacuation times, the evacuation routes, and the expected bottlenecks in the network. The model

works in real time and can assist the user to change the evacuation plans according to the real world evacuation situation.

Even though there has been considerable work in modeling evacuation, it has been directed to different geographical scales than that of a neighborhood, namely large areas like cities and small places like buildings. Cova and Church (1995) were the first to analyze the potential for evacuation difficulty at the neighborhood scale. Subsequent work by Cova and Church (1997) and Church and Cova (2000) described how to search for neighborhoods that might be particularly vulnerable to evacuation difficulty and how to develop maps of potential evacuation difficulty. They developed a network partitioning optimization model that can be used to look for small contiguous areas within a network that have a large resident population compared to exit capacity. In applying their model to Santa Barbara, they identified several neighborhoods that have disturbingly high ratios of demand to exit capacity and therefore may be particularly vulnerable to an evacuation disaster. With the exception of this work, evacuation modeling at the neighborhood scale has been basically ignored. Even though a neighborhood might have a high ratio of resident population to exit capacity, it is still important to estimate clearing time, just as is done for buildings and larger areas. Possible approaches for this include capacity analysis techniques from the highway capacity manual and simulation techniques. Since the most widely accepted tool to do this is simulation, it makes sense to take neighborhood at high risk and simulate an evacuation as a proof of concept. Unfortunately, existing network evacuation simulation models involving cars and trucks are not geared to the scale and details of the neighborhood. For example, the level of characterization of the neighborhood elements in a system such as MASVAC would not match the level of characterization needed to make the model accurate at a neighborhood scale. To do this would require a micro-scale, multiagent transportation simulation model where individual vehicle behavior is modeled and where origin zones for traffic are represented by disaggregate activity locations which are directly associated with drive ways. Church and Sexton (2002) presented how a micro-scale traffic simulation models have been applied to a neighborhood evacuation problem using Paramics software, however no effort has been made to benefit from both the demand forecasting capability of a disaggregate

planning model and high fidelity operational simulation model to solve the small area evacuation problem . In Chapter 5, we present an application of a micro-scale transportation simulation model (TRANSIMS) and micro-scale traffic simulation model (CORSIM) analyzing evacuation at the neighborhood scale. We will also discuss how such a modeling approach can be useful in characterizing the problem.

Chapter 4 describes the effort that the author made on modeling subarea focusing methodology; followed by building and implementing an evacuation model and application to Virginia Tech main campus.