CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

In order to support the study undertaken in this thesis, a review of existing literature was performed. First, a survey was performed to chronicle past research efforts on the status of traffic information. Next, using the probe data to generate traffic information was discussed. Then, simulation techniques used for traffic information survey were discussed. Lastly, a discussion of literature associated with field studies was performed along with a discussion of probe vehicle technology issues to be addressed in this thesis.

2.2. CURRENT STATUS OF TRAFFIC INFORMATION

Traffic information such as travel time during road congestion, will give the road user some peace of mind as they can decide which road to take or to avoid and the best time to travel to get to their destinations easier, faster and safer. Hence, as one of the solution to develop an efficient traffic control as well as to perform a good management strategy, it is essential to provide reliable traffic information. Generally, the traffic information can be classified into two categories that are real time and predictive. Real time information provides updates on prevailing traffic conditions on streets such as the spot mean speed, link speed or incident information measured or estimated or close to the time of receiving the information. In contrast, the predictive information includes forecasts of traffic flow, speed and travel time between any two desired locations. Recently, the interest in manipulating traffic data is focusing on real time traffic data with the help of the implementation of Intelligent Transportation System (ITS) which has resulted in the development of systems that capable of monitoring roadway conditions and disseminating traffic information to travelers in a network. One of the examples of real time project is in Japan where ATIS (Advanced Traffic Information Service) was installed by Tokyo Metropolitan Police Department to provide graphic traffic information in real-time for subscribed home and business offices by means of current available new media, in other words, PC communication network or Facsimile network (Okamoto, 1993).

Essentially, traffic information mainly travel time data may be recorded through variety of methods. Tuner et al. (1998) have discussed about several advanced techniques for travel time data collection, including electronic distance-measuring instruments, computerized and video license plate matching, cellular phone tracking, automatic vehicle identification, automatic vehicle location, and video imaging. More commonly, the applicable methods where the individual travelers are not involved to determine the travel time is make use of license plate recognition, toll-gates, in car systems (Van Grol et al., 1999) and (Taylor, Bonsall and Young, 2000). However, to be easy in isolating this technology, Taylor, Bonsall and Young (2000) have stated that the measurement methods can be simply divided into two types that are 1) logging the passage of vehicles from selected points along a road section (site based methods) or 2) using moving observation platforms traveling in the traffic stream itself and recording information about their progress (vehicle based methods). For the first type, the methods include registration plate matching, remote or indirect tracking and input-output methods and etc. D'Este, Zito and Taylor (1999) have stated that stationary observer techniques include loop detectors, transponders, radio beacons, video surveillance, etc. These site based methods are capable of collecting information such as vehicle volumes, time mean speeds, headways, classifications, and lane occupancy (Turner and Holdener, 1995). The moving observer methods (vehicle-based methods) include the floating car, volunteer driver and probe vehicle methods.

As discussed by Turner et al., 1998, the ITS probe vehicle can be divided into five different approaches that are sign-based Transponders, AVI Transponders, Ground-based

Radio Navigation, GPS as well as the Cellular Phone Tracking. The use of available equipment may limit the data collection to one of several techniques. Some agencies may have analysis tools that are capable of exploiting certain data collection techniques. For example, agencies with geographic information systems (GIS) capabilities should consider many advantages of GPS data collection. Using GPS Probe vehicle, the cost per unit of data may decrease. Conversely, it may increase the availability of the consumer product even though the sample may depend on equipped vehicles only. The most common and useful information that probe vehicles collect is point-to-point travel time (Turner and Holdener, 1994). Travel time is being selected for the purposed of analysis because travel time is an important piece of information for Intelligent Transport System despite of the fundamental traffic state variable (Nanthawichit and Nakatsuji, 2004). Travel time is the most common way that users measure the quality of their trip. Besides, it is the important traffic variable that can be directly measured and is a simple measure to use for traffic monitoring. The following sections will discussed about the probe vehicle technique as a source of travel time data collection used in this study.

2.3 TRAFFIC DATA GATHERED FROM PROBE DATA

2.3.1 General Discussion about Probe Vehicle

Recently, using probe vehicles to collect traffic information is expected to be one of potential systems for effective collection of traffic information in the city where detectors have never been fully activated (Fukuda, Narupiti and Ishizaka, 2002). Probe vehicles are fitted with equipment for collection of time stamped location and speed data. Probe vehicle techniques involve the use of a data collection vehicle which an observer records travel time at predefined checkpoints. In case of data collected using Global Positioning Systems (GPS), the exact location of the probe vehicle is captured at specific time intervals. Normally, buses and taxis are widely equipped with the GPS, for their management purposes. The number of probes on the network is called the market penetration rate and the reliability of the probe data is strongly dependent on the penetration rate.

Respectively, probe vehicles provide data intermittently at locations determined by the location of the probe equipped vehicles and the reporting source. Specifically, probe vehicles will provide travel time for links when they complete traversals of those links (Koppelman et al., 1994). There are several different methods, depending on the technology and driving style. The three most common driving styles are:

i. Average Car – the probe vehicle tries to capture the average of the traffic stream by passing as many vehicles as passes it.
ii. Chasing Car – the probe vehicle selects one vehicle to be representative of the traffic stream and follows it.
iii. Maximum Car – the test vehicle attempts to drive at the posted speed limit unless impeded by traffic.

2.3.2 Evaluation Probe Vehicle as a Source for Traffic Information Survey

Previous studies have displayed ample sources of data that can be used in order to measure the traffic data to yield more useful traffic information. In fact, the expected outputs are not only the summary of traffic data such as average travel time, but also traffic condition estimation and even prediction. They are literatures that had associated with the use of probe vehicle as a source of traffic information. In case of probe vehicle, Kolbi et al. (2002) compared results of motorway performance when using probe vehicle and other motorway flow detection techniques. Travel time was measured using induction MIDAS system and number plate matching techniques together with probe vehicles on United Kingdom motorway. Their results show the influence of the measurement system in terms of counting and headway, travel speed as well as travel time. Linnartz and Westerman (1994) have discussed a method of monitoring a metropolitan freeway system using probe vehicles and random access radio channel at

San Francisco Bay area. In their study, probe vehicles were used to collect real time traffic data and transmitted the data on the same common radio channel. Their results concluded that random access (ALOHA) transmission of traffic reports was an inexpensive and a flexible data collection method that could provide accurate real time link travel times and could perform the Automatic Incident Detection.

In addition, Cohen, Bosseboeuf and Schwab (2002) presented the dimensioning of a fleet of probe vehicles on motorway equipped with fixed measuring station. Their interests were focused on the probe vehicle sample sizes for travel time estimation on motorways. Despite that work, Li and McDonald (2002) proposed link travel time estimation using single GPS equipped probe vehicle. Estimated travel times were calculated by mathematical model, which combined travel time of probe vehicles and movement characteristics, based on analysis of speed profile. With an increasing of road users, it is a need to provide accurate, timely traffic information especially using probe vehicle system. Take into account regarding this situation, Ferman, Blumenfeld, and Dai (2003) tested the feasibility of such a system using the development of a simple analytical or statistical model. Their results revealed that a real-time traffic information system based on probe vehicles was very feasible, and should work for highways at penetrations over 3%, while surface roads requiring more than 5%. Besides, Chen and Chien (2001) used Kalman Filter technique to carry out dynamic travel time prediction using probe vehicle data which consisted of link and path based analysis. They have proved that by adding link travel times may propagate the variance of the path travel time in link based method when the variance of system measurement remains the same.

Paradoxically, to date, there are also studies that examine the combination of probe vehicle and another source of traffic information data collectors such as detector based to provide traffic information. El Geneidy and Bertini (2004) studied about the importance to find the optimal spatial resolution for loop detector placement and the optimal temporal resolution for detector data reporting. They used a combination of loop detector and automatic vehicle location (AVL) data from a bus fleet to compare speeds and revealed the potential to improve speed data reported by inductive loop defectors using the median speed reported by the detectors to represent segment speed during each temporal window. In addition, Cheu, Lee, and Xie (2001) have presented a model designed to provide arterial link speed estimation through fusing data from probe vehicles and loop detectors. The model has been developed, tested and validated with simulated data. In spite that, (Thomas and Dia, 2004) also used simulated probe vehicle and loop detector data for incident detection with the exploit of neural network data fusion.

2.3.3 Advantages and Disadvantages of Using Probe Vehicle Data

One of the issues that related to probe vehicle is that it is difficult to measure day to day variability (Toppen and Wunderlich, 2003). In order to measure day-to-day variability, travel time measurements need to be taken across multiple days at the same time. Furthermore, it is not easy to control precisely when the probe vehicles enters the segment for which travel time is measured. The fundamental performances of probe vehicles, such as coverage area and frequency per each link, deeply depend on the running pattern of vehicles selected as probe vehicles and they would differ by size, network configuration, etc. Thus, the vehicle, which can collect traffic information efficiently at the lowest possible cost, should be selected as a probe vehicle. But, it is difficult to reveal its performance unless field test is conducted.

Besides, even though a relatively small number of probe vehicles traveling in the traffic stream can potentially provide valuable information about current travel times, too few probe vehicles can provide erroneous or misleading data, weakening the credibility of the transportation agency and eroding public confidence in the traveler information or traffic management system. The past travel time research shows that, probe vehicle improve the travel time prediction accuracy hugely but after achieve a particular density of probe vehicle, the accuracy of the prediction cannot be improved efficiently by adding more probe vehicles (Sen et al., 1997). On the other hand, too many probe vehicles on road might affect the real travel environment. Table 2.1 presents the pros and cons of using probe vehicle technology in terms of the cost and accuracy as compared to detector based data collection.

Table 2.1 Pros and cons of using probe vehicle technology as compared to detector based in terms of the cost and data accuracy (Turner et al., 1998)

Data Collection Technology	**Costs**			**Data Accuracy**	**Limitation**
	Capital	**Installation**	**Data Collection**		
Loop detector systems	Low	Moderate	Low	Low	High failure rate and inaccurate estimations
AVI Systems (Probe)	High	High	Low	High	Probe density and antenna sites

Despite the disadvantages of using probe vehicle for data collection, there are advantages.of using them. Data can be collected over wide area with a low initial cost for probe vehicle (Toppen and Wunderlich, 2003). As the probe vehicles do not require instrumentation to be set up on the roadway, it can easily collect data on any part of the network. Moreover, it requires a cheap equipment to be installed in the car for collecting the data.

2.4 TRAFFIC MICROSIMULATION

2.4.1 Introduction to Simulation

Simulation is defined as dynamic representation of some part of the real world achieved by building a computer model and moving it through time (Drew, 1968 cited in Pursula, 1999). The increased emphasis on simulation studies and the corresponding lack of experience on the part of some people who attempt to apply the method can lead to a type of pseudo simulation. Some rules to follow in avoiding these drawbacks are no assumption should be made before its effects are clearly defined, no variables should be combined into a working system unless each one is properly explained and its relationships to the other variables are set and understood and it must be remembered that simplification is desirable but oversimplification can be fatal (Drew, 1968 cited in Pursula, 1999). Transportation systems are typical man-machine systems, where the activities in the system include both human interaction (interaction between driver-vehicle- elements) and man-machine-interactions (driver interaction with the vehicle, with the traffic information and control system and with the physical road and street environment). In addition, the laws of interaction are approximate in nature; the observations and reactions of drivers are governed by human perception and not by technology based sensor and monitoring systems (Pursula, 1999). Figure 2.1 and 2.2 illustrated the basic driver perception-action process and the vehicle object's interactions in a simulation system.

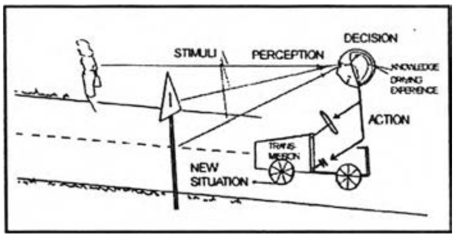

Figure 2.1 Basic driver perception-action

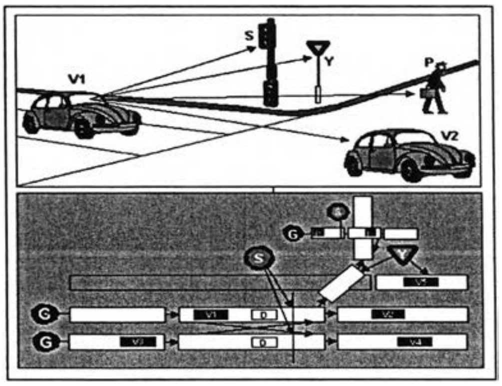

Figure 2.2 Vehicle object's interactions in a simulation system (Kosonen, 1996 cited in Pursula, 1999)

In traffic and transportation system analysis, computer is a main tool and is widely used for simulation purposes with a variety of applications from scientific research to planning, training and demonstration. The use of computer simulation started when D.L.Gerlough published his dissertation: "Simulation of freeway traffic on a general-purpose discrete variable computer" at the University of California, Los Angeles, in 1955 (Kallberg, 1971 cited in Pursula, 1999). Simulation is a valuable decision support tool for evaluating transportation facilities or systems (Paul and Kevin 1994 cited in H.E.Lin, 2004). The application of simulation in transportation field is varied from as small as optimizing the traffic signals at an individual intersection to as large as evaluating the national transport strategy. Transport simulation provides a path for a planner to evaluate their transport designs or strategies through a computer model. Many tests that are difficult to be examined, real life can be analyzed easily now (Marcelo 2002 cited in H.E. Lin 2004). Today, both computer power and communication techniques progress massively. It provides a benefit for developing modeling with computers as the process of modeling becomes faster and easier than before. Some research try to generate traffic data from simulator to do their research (Anderson and Bell, 1998) as simulation has the ability to trace entities through a system of multiple processes and operations. However, even though using the simulation particularly microsimulation is useful tool to be treated with respect, it is easy to draw the wrong conclusions if not fully familiar with the model (Brunner et al.1998). Traffic planners and engineers are conservative by nature, and many of them view microsimulation with doubt. Some consider it as a radical approach with insufficient integrity, thus continue to struggle with systems designed to address issues of an earlier age (Druitt, 2000). Besides, practitioners and clients, who have used microsimulation software for analysis, have been highly satisfied with the outcomes.

In microsimulation, the term "micro" applied to traffics models of individual junctions or small confined networks (Pursula, 1999). Traffic relates to movement or number of vehicles. In dictionary, the definition of simulation is to reproduce in order to conduct experiment or to imitate. Therefore, the full explanation of microscopic traffic simulation is a reproduction of events to imitate the movement of individual vehicles along a road network. In the past, few microsimulation studies of emergency evacuation procedure have been documented in the literature especially before 1990s. The lack of microsimulation procedures was largely due to the fact that modeling traffic flows at the individual vehicle level was a computationally challenging task, and there were inadequate computer technology and advanced software engineering to easily simulate the complexity of traffic flow involving a large number of vehicles. Previously, the "microscopic simulation" or "microsimulation" has been limited to small areas because of high computational demands, however, recent advances in both hardware and software are now making this accuracy available for all sizes of models (Pursula, 1999). Moreover, nowadays, some software is capable of providing users with the capability to visualize the progress of vehicles along the road network while the simulation is running.

2.4.2 The Utilization of Microsimulation Traffic Information Survey

In this study, microsimulation technique generated artificial data for the analysis due to the difficulties in gathering the real data. The reason why micro simulation model has been accepted is because it can consider dynamic running pattern of each vehicle (Fukuda, Narupiti and Ishizaka, 2002). Some previous research studies have used traffic simulators, such as VISSIM, to generate pseudo–detector data (Anderson and Bell, 1998). Various simulations were set up (Ivan et al. 1994-1998 cited in H.E Lin 2004) to collect both probe and loop detector data. Nanthawichit, Nakatsuji and Suzuki (2003) had used Kalman filter technique to integrate probe vehicle data into fixed detector data by using macroscopic model. Microsimulation model was used to estimate the minimum number of probe vehicles (Chen and Chien, 2000). Nevertheless, since the network consists of only one freeway with 5 intersections, the dynamic distribution of probe vehicles was not considered. There was also a study using the microsimulation model for the road network of the Clemeti town area in Singapore (Cheu, Xie, and Lee, 2002). Besides, Taylor, Woolley and Zito (2002) combined the microsimulation modeling and probe vehicles for traffic study. They used the model to analyze the performance of the corridor when incident occur in terms of traffic condition and gas emissions. The microsimulation software, Paramics was used to allow a representation of the probe vehicle in the network.

Other literatures have dealt with microsimulation in examining traffic data. For example, (Sisiopiku et al., 1994) studied the performance of arterial travel time estimation by examining the use of detector output from simulation and field studies. They bridge the gap between arterial travel time and flow and occupancy data in order to create an alternative source of travel time information becomes available. These travel time data can then be used in a data fusion process expected to take place within the Advanced Traveler Information Systems (ATIS) framework. Data fusion is a function that combines travel time data from various sources (on-line or off-line) to produce reliable estimates of travel time for route guidance applications.

In addition, Inokuchi, Kawakami and Ogino (2003) have developed a simulation system that is corrected using on-line data to raise the accuracy of the simulation. The simulation system was developed by using the microscopic road traffic simulation system CaTS (Car-following-based Traffic Simulation). The simulation was applied to the Hongo area, Japan. In the study, since no on-line data were obtained, it was executed using virtual on-line data, and the usefulness was shown.

2.4.3 Using Paramics Microsimulation

One of the version of microsimulation model is Paramics which is an acronym derived from *Microscopic Simulation on Parallel Computers*, although such machines are only necessary for the representation of very large areas, such as Tokyo (Druitt, 2006). Paramics is a suite of software tools including Modeler, Processor, Monitor, Analyzer and Programmer for performing time-stepping, microscopic and stochastic traffic simulation (Lee, Chandrasekar and Cheu, 2001). In Paramics Modeler, the user can use the simulation engine that provides the user with a 3D graphical interface to describe the network as well as to specify the demand and signal control, perform and monitor each simulation. On the other hand, the Processor is batch simulation management utility which allows scenario testing and variability measurement. Conversely, the Monitor and Analyzer are utilities that used to measure and visually analyze the system performance during or after simulation. Throughout the software, the Programmer (API) acts as the interface between users and core simulation process in the Modeler through programs coded in order to provide extra information or to extract some data from Paramics.

In Paramics, individual vehicles are modeled in fine detail for the duration of their entire trip thereby providing accurate traffic flow, journey time and congestion information. The suite also enables the modeling of the interaction between motorists and Intelligent Transport Systems (ITS). Paramics can accurately simulate the traffic impact of signals, ramp meters and loop detectors (linked to variable speed signs) (McKay, 2000). The suite also has the capabilities to replicate the behavior of in-vehicle messages advising of network problems and re-routing suggestions. Vehicle re-routing in the face of ITS is controlled through a user definable behavioral rule language for maximum flexibility and adaptability. The Paramics development process is driven by contract work throughout the world leading to the incorporation of new technology in real world transport systems. At present, development is underway in the areas such as detailed modeling of noise and exhaust pollution, multi modal transport simulation and also the provision of predictive traffic information for in vehicle services.

The other important feature in Paramics is that it offers a unified approach to traffic modeling which is reliable with the nature of the problem (Druitt, 2000). This program is relatively easy to use. The basic construction of the model is fast and easy. The underlying theories on which the model is based are fairly easy to explain to the layperson. A very detailed micro-model can be constructed in a fairly short time (Pursula, 1999). Besides, with the use of Paramics, the transportation professional can study the effects of a development such as a change in the road network and any other future scenarios on any multiple levels that may be affected (Pursula, 1999). It closely simulates the actual driver behavior and also randomness that is experienced in the real world.

Despite that, it produces changes in traffic patterns where it can illustrate graphically the typical measures of effectiveness on the simulation itself to further demonstrate its usefulness. The animation of traffic network can take place over either an AutoCAD drawing file or an aerial photo to enhance the realism of the display. All are modeled to scale, this makes for a very effective presentation, even including pedestrians (with the help of pedestrian plug in) in the animation. Figures 2.3, 2.4 and 2.5 display layouts in Paramics micro simulation software.

Figure 2.3 Example of using Paramics program starting from aerial photo, network coding, and input data (such as O-D demands, signal timing)

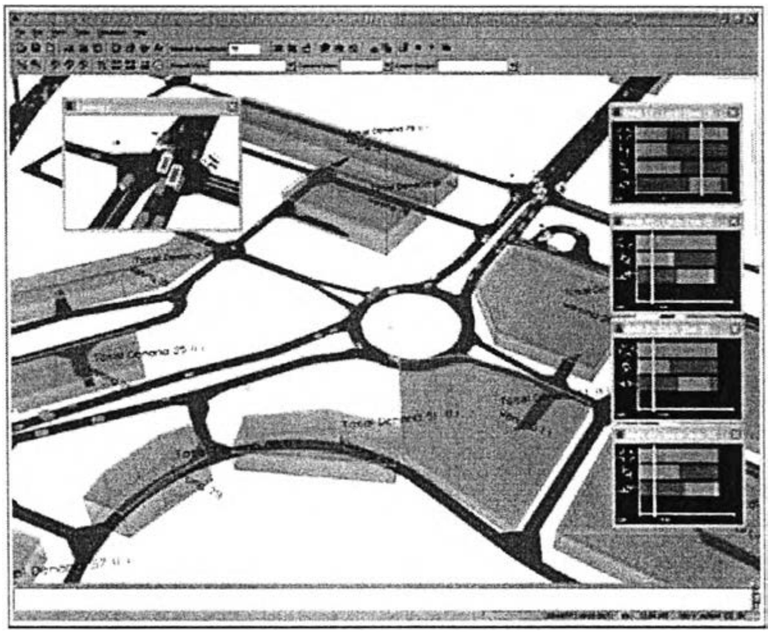

Figure 2.4 Display of Paramics includes the movement of each vehicle move and signal phasing

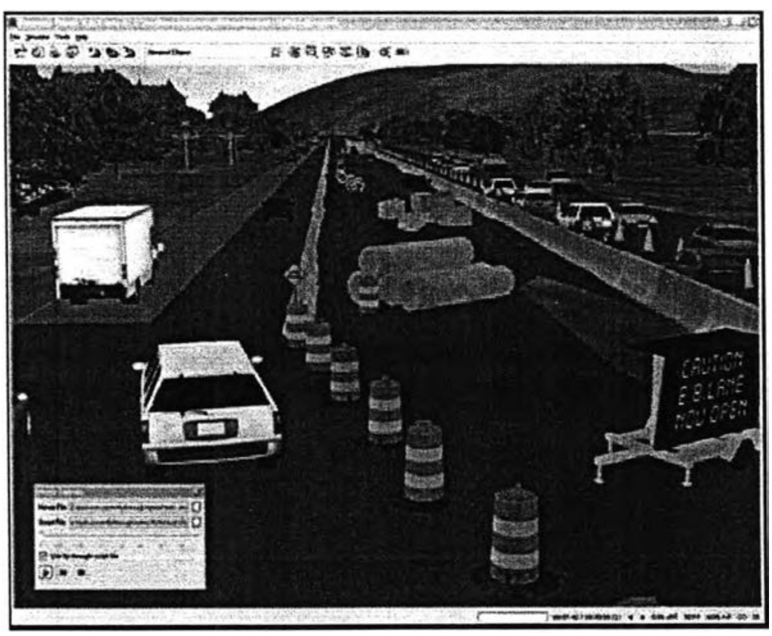

Figure 2.5 High details as in the pictures in Paramics

2.4.4 The Overview of Paramics V5 Software Package

The Paramics Project Suite V5 consists of Paramics Modeler, Paramics Processor, and Paramics Analyzer as well as Paramics Programmer. Paramics Modeler provides a visualization of road networks and traffic demands using a graphical user interface (GUI). The screen layout for Paramics layout is illustrated in Figure 2.6. Geographic and travel data are input to the program which then simulates the lane changing, gap acceptance and car following behavior for each vehicle. The speed of the simulation is governed by the computer processing power, the size of the network and the number of vehicles on the network at any time. Modeler provides the three fundamental operations of model build, traffic simulation (with 3-D visualization) and statistical output accessible through a powerful and intuitive graphical user interface. Every aspect of the transportation network can be investigated in Modeler including the mixed urban and freeway networks, right-hand and left-hand drive capabilities, advanced signal control, roundabouts, public transportation, car parking as well as incidents and truck-lanes, high occupancy vehicle lanes.

Paramics Modeler requires two main inputs that are the road network data and the travel demand data (Quadstone Paramics V5.0 Modeler User Guide, 2003). Road network data consists of geometric layout, junction descriptions, lane markings and turning movement information while the junction or intersection descriptions are stored in the model as "node" data where each junction is allocated a node number or name. The connection between two nodes is called a "link". In addition, the study area can be divided into sub-areas known as "zones" which may be distinct geographical boundaries, socio-economic boundaries or boundaries specific to local model conditions for example to accommodate internal screen lines. The skeleton network with nodes, link and zone is illustrated in Figure 2.7 while Figure 2.8 shows the Paramics development cycle when creating a new road network test as in Pursula, 1999.

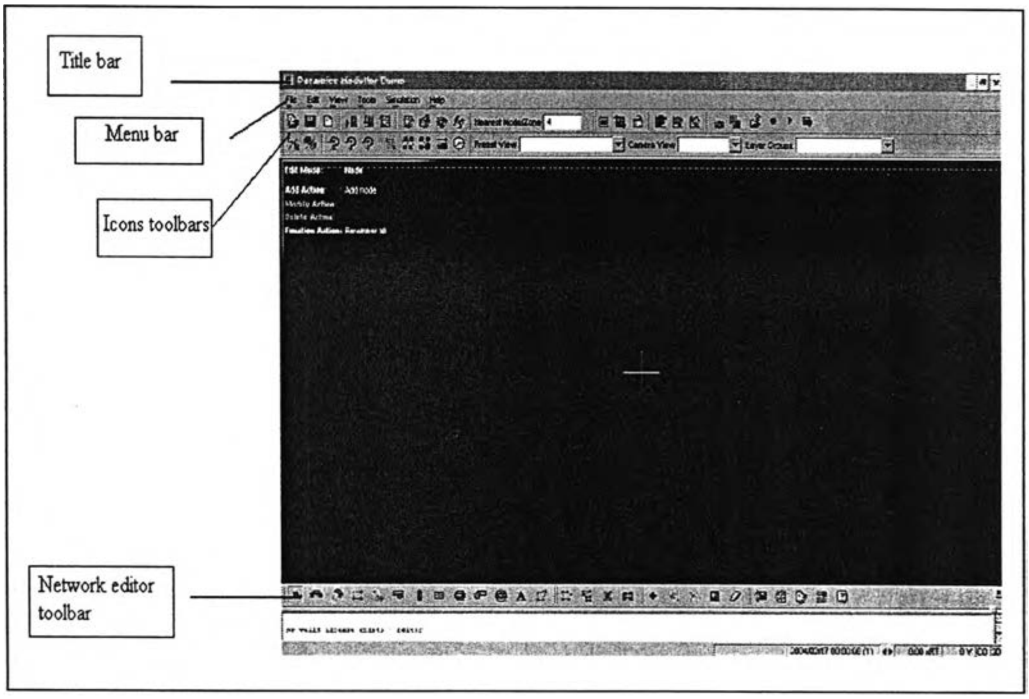

Figure 2.6 Paramics Modeler screen layout

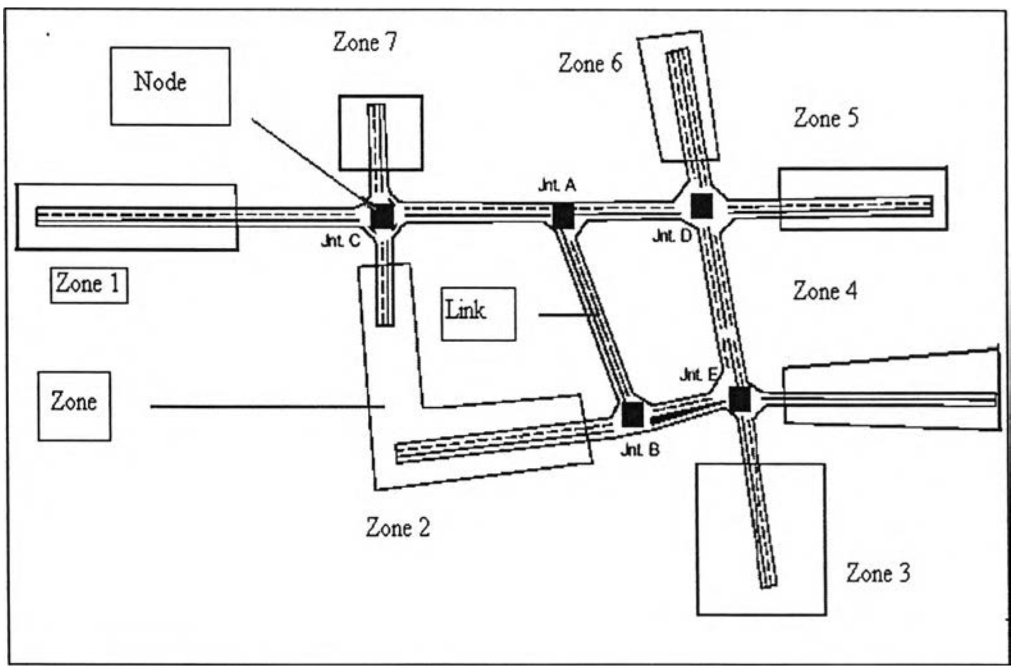

Figure 2.7 Skeleton road network

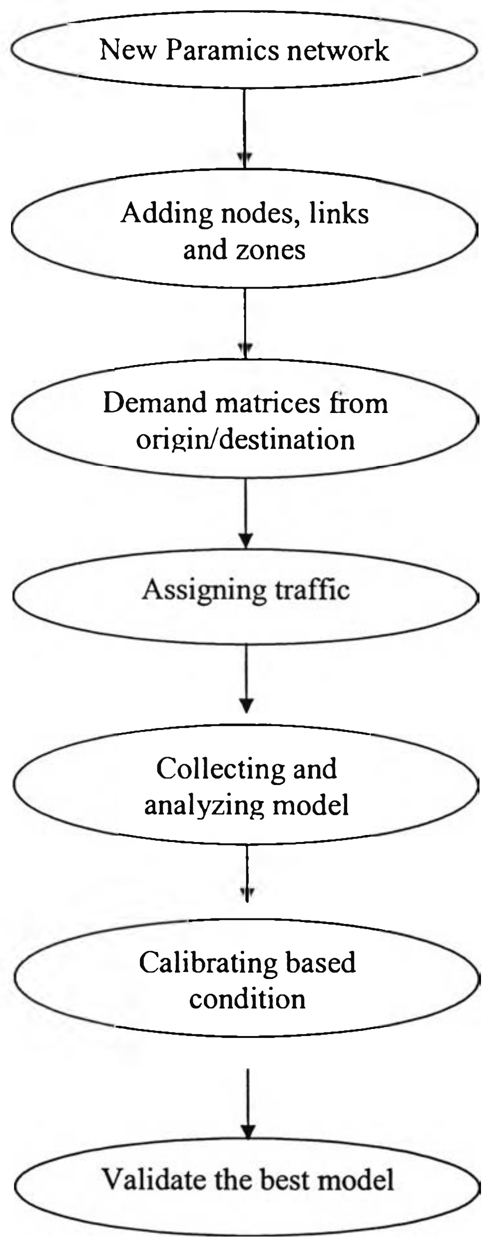

Figure 2.8 Paramics development cycle (Pursula, 1999)

Paramics Processor configures and runs the traffic simulation in batch mode without visualization of the network through the GUI. This dramatically increases the speed of simulation and is used to collect simulation results for the numerous test options and sensitivity tests required. Paramics Analyzer reads output from the simulation model and provides a GUI to compare post processing simulation results to observed data and to contrast and analyze different test results.

In contrast to Paramics Programming, some data such as travel time cannot be extracted directly from the simulation. Therefore, the use of API for generating the data is very important. C++ language is used in Paramics API to classify certain function in convenient way to allow interfacing with other program or data. Paramics Programming is comprised of several functions which handle various tasks related with traffic modeling. The tasks are called in every time step of the simulation. By using API, these functions can be replaced or modified. Therefore, API is often referred to as the functional interface whereas GUI is called as the data interface.

2.4.5 Paramics API Function

There are certain aspects of Paramics that need to be implemented according to Chu, Liu and Recker (2003). In their study, they have revealed that routing, real time traffic information, signal control, ramp metering control, database connection, performance measure are the aspects of Paramics that can be improved through API programming as shows in Figure 2.9. Since probe vehicle is used for collecting traffic information, some programming efforts through Paramics API need to be done in order to extract the data. Extracting data for probe vehicle cannot be done without API programming due to the concept of probe vehicles that needs Paramics to track a certain percentage of probe vehicles and extract travel time information from them.

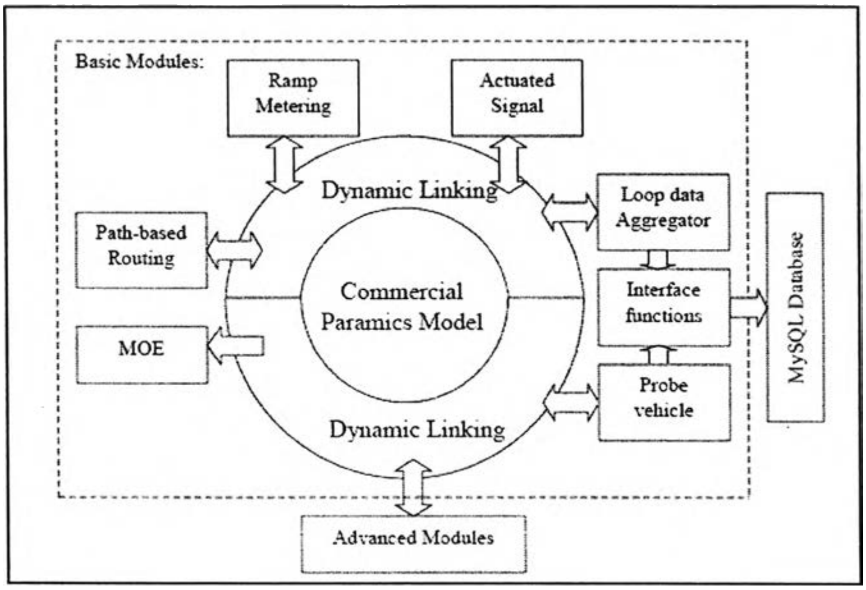

Figure 2.9 Framework of the capability-enhanced Paramics simulation

2.5 GAPS FROM PREVIOUS RESEARCH

An extensive review of previous studies has helped to find out the idea using probe vehicle to measure traffic information data mainly travel time. However, in spite of all these facts, there are lacks of concern in terms of the accuracy and credibility of the data. How accurate does the traffic information that gathers from the source, given that the source of data is limited? Previous research focused on efforts made to collect traffic information from purely probe vehicle travel time or focus on speed data as a performance measure to calculate travel time and statistically method was used to manipulate the traffic data that needed to be examined. However, very few studies explicitly reported results by combining the probe vehicle and utilization of microsimulation techniques. In spite of that, most of previous research has usually used the data that collected in real network, however, in this research the data was gathered through the help from microsimulation software as a test-bed.