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Airport Related Traffic and Mobile Emission Implications

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16. Abstract

This research intends to develop a microscopic framework to model the airport related traffic and emission implications. An approach to calibrate the driving behavior parameters of the traffic simulation model in the framework is proposed. A case study for Intercontinental Airport of Houston (IAH) is presented. The microscopic framework integrates a microscopic traffic simulation model and a modal emission model. A GA-based calibration approach defines the index of simulation accuracy as the Sum of Squared Errors (SSE) between the collected speeds and the simulated speeds at the pre-defined cross-sections along the road. The computer program implementing the GA-based approach is developed to search for the optimal parameters values. The field speed data are collected using the GPS system. It is found that the calibrated optimal values of the VISSIM driving behavior parameters result in a 50% decrease of the SSE value. The produced emissions of each vehicle show that the emission profiles reflect well the trends of the acceleration/deceleration. The emission results show that in the year 2002, the vehicles going in and out of IAH terminal area generate 2948 tons of CO_2, 1.3 tons of HC, 13 tons of CO and 3.0 tons of NO_x. These results can be referred by urban transportation planners when they conduct the airport-involved travel demand forecasting. The microscopic framework can not only assist in the operational-level analysis of the mobile source emission implications around the airport, but also provide a powerful tool to assist in the overall airport design and planning. The GA-based calibration approach can be used not only for airport roads, but also for other road networks.

17. Key Words
Airport, Traffic, Emission, Microscopic Simulation, VISSIM, CMEM, Genetic Algorithm, Calibration, Driving behavior, GPS

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Notice

The United States Governments and the state of Texas do not endorse products or manufacturers. Trade or manufactures' names appear herein solely because they are considered essential to the subject of this report.

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Summary

Air transportation has grown in a very rapid speed during the past decades and the number of air travelers is projected to increase significantly in the next number of years. Much of the projected growth is expected to disproportionately concentrate at large commercial service airports in major metropolitan population centers, which are the point of transition between the air and surface modes of transportation for both passengers and cargos. One of the impacts of the growth in air transportation is its contribution to traffic congestion and air pollution problems in areas surrounding the airport.

The current practice in the urban transportation planning process does not address the traffic and emission problems around the airport appropriately. The airport is simply treated as a special generator in the overall travel demand forecasting and the emissions estimation. Travel demands, to and from the airport, are forecasted based on the traditional four-step sequential procedure. Emission factors are normally generated from the emission factor model MOBILE, which virtually reflects the average urban driving conditions. This type of modeling practice is unable to capture the unique driving behaviors, parking, and curbside traffic activities at the airport. The errors of estimated mobile-source emissions in the planning process around the airports are unavoidable.

The objectives of this research are: (1) to develop a microscopic simulation framework to study the traffic and emissions around the airport terminal areas; (2) to develop a feasible and effective approach to calibrate the simulation model; and (3) to evaluate the integrated framework with a case study.

The developed microscopic framework integrates a microscopic traffic simulation model and a modal emission model, which can be used to assist in the operational-level analysis of the mobile-source emission implications around the airport. The components of the framework include: (1) identifying the airport road network; (2) selecting the appropriate microscopic traffic simulation model and the modal emission model; (3) collecting the field data for the airport; (4) coding the simulation network for the airport; (5) calibrating the traffic simulation model for the airport; (6) validating the traffic simulation model; (7) defining the modeling scenarios; (8) executing the network simulation; (9) transferring the traffic simulation outputs to the modal emission model in an automatic manner; (10) calculating emissions of each vehicle second by second; and (11) summing the emissions for all scenarios.

VISSIM is the selected traffic simulation model and CMEM is the modal emission model. A computer program is developed in ACCESS to transfer data from VISSIM to CMEM automatically. The interface of CMEM is revised to calculate the emissions of each vehicle second-by-second, and the total emissions of each vehicle and all vehicles. The designed modeling scenarios can be hourly, daily, weekly, monthly or yearly. The implementation of the framework requires the inputs of data of the network configuration, traffic volumes by vehicle types, turning ratios at intersections, the stop time in front of the terminal, and vehicles' instantaneous speeds and acceleration/deceleration rates.

As for the calibration of traffic simulation, the Genetic Algorithm (GA) based approach is developed to calibrate the 10 driving behavior parameters in VISSIM. The proposed GA-based approach defines the index of the simulation accuracy as the Sum of Squared Error (SSE) between the vehicle speeds collected and the vehicle speeds simulated at pre-defined cross-selections at a 10-meter interval along the road. The objective of calibration is to minimize the SSE. The complex and non-linear relationship between SSE and the 10 driving behavior parameters are expressed using a simulation procedure AUTOSIM, which generates SSE output with a set of inputs of 10 parameter values. A computer program is developed in Visual Basic to implement the AUTOSIM procedure automatically. The GA-based calibration process can minimize the SSE in obtaining the 10 optimal parameter values simultaneously. This calibration process utilizes the virtue of GA as an optimization tool adapted for this application to search for the 10 optimal parameter values. A computer program is developed in MATLAB to implement the GA-based calibration process.

The case study for Intercontinental Airport of Houston (IAH) is conducted to implement the proposed microscopic framework and the calibration approach. The IAH road network has two entries and one exit, connecting four terminals, five parking lots and a hotel. The field data collected include: (1) the vehicle instantaneous speed on the loop using GPS; (2) traffic volumes and turning ratios by vehicle types at 2 entries and 16 intersections; and (3) projected hourly traffic volumes of one week. The simulation network is coded in VISSIM. The computer program for the GA-based approach is run to calibrate the driving behavior parameters for the IAH network. The traffic simulation with the calibrated parameters is run for all scenarios. The revised CMEM is run to transfer data from VISSIM to CMEM, and calculate the emissions for each scenario.

It is found in this research that the calibrated optimal values of the VISSIM driving behavior parameters result in a 50% decrease of Sum of Square Error (SSE) value. The produced individual vehicle emission profiles can well match the trends of the vehicle acceleration/deceleration. The emission estimation results show that in the year of 2002, the vehicles going in and out of IAH terminal area generated a total of 2948 tons of CO_2, 1.3 tons of HC, 13 tons of CO and 3.0 tons of NO_x. It is expected that these results are referable to urban transportation planners when the airport-related travel demand forecasting is conducted.

The proposed microscopic framework can not only assist in the operational-level analysis of the mobile source emission implications around the airport, but also provide an efficient tool to assist in the overall airport design and planning. The GA-based calibration approach can be easily extended to networks other than airport roads. In the future research, it is suggested that more parameters will be included into the index function of simulation including travel time, queue length, etc. More simulation models besides VISSIM can also be tested in the simulation process. To increase the accuracy of the emission estimation, it is recommended the suitable on-board emission testing devices be used to detect the actual emissions of different types of vehicles, and then further calibrate the estimated emissions in the proposed framework.

CHAPTER 1

INTRODUCTION

1.1 Background of Research

In the preceding half century, air transportation has grown to become an indispensable component of both the global economy and social interaction among large numbers of people around the world. At present, the ability and capacity of air transportation to move people and property over considerable distance, quickly and safely, have permanently altered living standards, values and expectations across a wide spectrum of services and life styles.

Globally, airlines from the 185 contracting members of the International Civil Aviation Organization (ICAO), transported about 1.448 billion passengers, and moved some 26 million tones of freight in 1997 (ICAO Journal, 1998). The top twenty-five of the 1,146 airports, open to international civil aviation around the world at the end of 1997, accounted for some 968 million passengers in 1997 (ICAO Journal, 1998).

Since 16 of the world's top 25 airports are located in the United States, it is quite clear that air transportation and the airports from which air transportation services are provided are of tremendous importance to the U.S. Airports in the U.S. provide nearly eight million jobs and $575 billion of economic impact to the local communities they serve (ACI-NA, 1999). The said jobs and economic impact are generated by airports in the process of collectively serving over half a billion passengers and handling nine million tones of cargo annually (ACI-NA, 1999). On a larger scale, one in fifteen persons employed in the U.S. owe their employment to civil aviation and $1 in $16 of the nation's GNP is attributed to civil aviation (ACI-NA, 1999). In the postindustrial economy of the U.S., transportation collectively represents 17 percent, or about a trillion dollars of GDP, and the transportation capital stock in the U.S. is valued at $2.4 trillion dollars (Pena, 1994). Air transportation at 565 airports in the 650 cities that receive scheduled air carrier service in the U.S. has become "the number one common carrier in the interstate passenger business" (Kane, 1996).

Changes precipitated and sustained by air transportation, and increased reliance on technology by modern society, have in turn fueled and sustained the growth of air transportation. The ICAO has projected an annual growth rate of 5 percent in worldwide traffic between 1999 and 2005 (Nygard, 1999). With an average annual traffic growth of 5%, it is estimated that by 2010, airports would transit 2.3 billion passengers per year, representing 4.6 billion departures and arrivals supported by airports (Rodrigue, 2003).

Much of the expected growth in air traffic would generate additional service demands on airports – the point of transition between air transportation and surface modes of transportation for both passengers and cargo. It is also necessary to recognize that much of the projected growth can be expected to occur primarily at large commercial service airports in major metropolitan population centers whose transportation systems are already stressed. The extant literature suggests that the ground transportation at airports is dominated by private transportation in privately owned automobiles that cause serious congestion on ingress and egress infrastructure within the airport terminal complex (Nettey, 1995; Lehrer and Freeman 1998). Such vehicular traffic and congestion in the airport terminal complex may constitute a rather significant generator of mobile source emissions worthy of examination.

Designation of several cities in Texas as non-attainment areas by the Environmental Protection Agency in concert with other federal agencies because of violations of air quality standards and regulations creates added urgency to issues related to emissions. The existence of several metropolitan centers in Texas, and the unparalleled presence of several large commercial service airports amidst equally substantive numbers of general aviation and reliever airports in

Texas, creates an appropriate laboratory for effective research in airport issues, especially those pertaining to airport-related traffic and mobile emission implications.

Unfortunately, there is a paucity of research and scholarship on airports that underscore the appropriate role and importance of airports (Nettey, 2000). Even more critical is the fact that research and scholarship in adjunct disciplines that impact airports tend to overlook airport or treat the significance of airports in simplistic fashion. With the increasing significance of airports as economic centers and traffic generators, the associated lacuna in airport research and scholarship is steadily becoming more problematic.

The current practice in the urban transportation planning process does not appropriately address the traffic and emission problems around the airport. The airport is simply treated as a special generator in overall travel demand forecasting and emissions estimation. Figure 1 shows a traditional four-step travel demand forecasting process in which the airport is treated as a special generator. Figure 2 shows the emission estimation process in the urban transportation planning process where the airport is totally overlooked. Therefore, the modeling practice in the urban planning process is unable to address the traffic and emission modeling requirements at the airport.

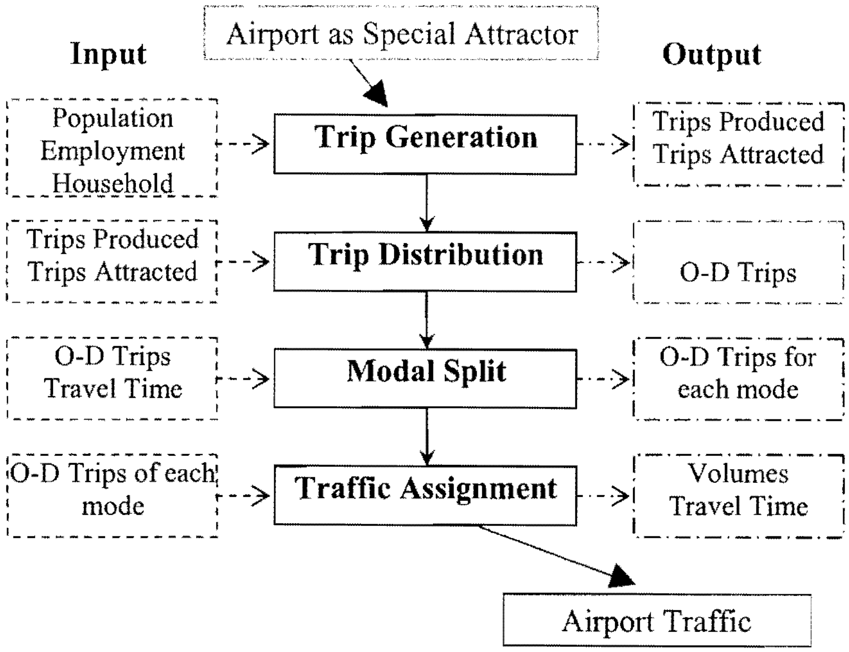


FIGURE 1 Travel demand forecasting in urban transportation planning.

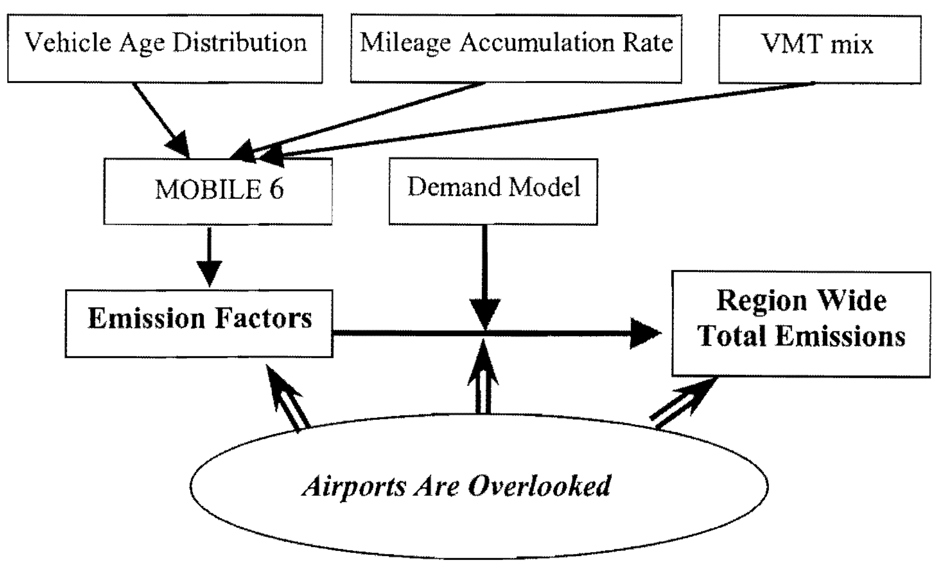


FIGURE 2 Mobile emission estimation in urban transportation planning.

1.2 Objectives of Research

The research in this report is intended to develop a modeling approach to address the traffic and emission problems around the airport. To this end, the following research objectives are developed:

1. Develop a microscopic simulation framework to study the traffic and emissions around the airport terminal areas,
2. Develop a feasible and effective approach to calibrate the simulation model, and
3. Evaluate the integrated framework with a case study.

1.3 Outline of This Report

The next chapter of this report provides an extensive review of the state-of-the-art of airport-travel-demand modeling, airport-traffic simulation and airport-emission modeling, as well as the practice of NCTCOG and HGAC in order to establish the context for this research. Chapter 3 describes the developed framework, which integrates the traffic simulation and emission modeling. Chapter 4 develops a calibration approach with the Genetic Algorithm. Chapter 5 presents a case study on Intercontinental Airport of Houston. Finally, Chapter 6 presents the conclusion and recommendation to this research.

CHAPTER 2

REVIEW OF STATE-OF-THE-ART AND STATE-OF-THE-PRACTICE

This chapter reviews the state-of-the-art on airport-travel-demand modeling, airport-traffic-simulation, and airport-emission modeling. These modeling topics are significantly related to the development of the framework in this report. The current practices used by Metropolitan Planning Organizations (MPOs) on travel demand forecasting and emission estimations are also reviewed.

2.1 Airport Travel Demand Modeling

Airport-travel-demand forecasting constitutes an important determinant of airport planning, design, and operation. Errors in forecasting could be costly. Underestimating demand leads to increased congestion, delay, and inadequate airport facilities. Overestimating demand may create serious economic problems for airport authorities. It is, therefore, very important for airport and even urban planners to develop reliable forecasting models and to understand possible limitations of the forecasting accuracy of these models. Out of a rich literature, there are very few papers and work reports dealing directly with airport related transportation demand. Nevertheless, several research concentrations undergoing in parallel are identified, each of which are summarized as follows.

The problem of estimating airport travel demand inbound to and outbound from a certain metropolitan area has not been directly dealt with in literature. However, the need for air-travel-demand forecast has long been identified, and small-scale problems closely related to it have been studied. Kaemmerle's (1991) research had focused on estimating the demand for scheduled commercial passenger services in small communities. A methodology for selecting the most probable alternative airport when choices are present was included. Although it focused on demand estimation of a small community, it lent insight into the nature of air-travel-demand generation. In that research, the multiple regression models were specified to estimate enplanements.

Another research focus has been on capturing the temporal relationship between the upcoming demand and the historical demand. Karlaftis, et al. (1995) presented a methodological framework for air-travel-demand forecasting. In particular, they presented an analytical framework for developing economic models and used the post-fact analysis to test the accuracy of the models. Models developed in this paper were applied to two international airports, Frankfurt and Miami International Airport. Their results showed that simple models with few independent variables perform as well as more complicated and costly models. The results also showed that external factors have a pronounced effect on air-travel-demand.

The only literature explicitly dealing with the fluctuation of demand in relation to the airport facility planning is the one by Odoni and Neufville (1996). Although the airport planning has a different focus from that of urban transportation planning, they both need an accurate forecasting of air-travel-demand. They indicated that forecasts are in any case significantly inaccurate. This has been shown by retrospective analysis comparing forecasts to what actually occurred (US Office of Technology Assessment, 1982; Ascher, 1978 and Newfville, 1976). In response to the inaccuracy of the forecast, Odoni and Neufville (1996) concluded that it makes more sense to concentrate on professional effort in investigating the implications and effects of the uncertainties. Thus the design effort should create a set of scenarios, with plausible ranges both for the levels of traffic and for key parameters that affect the design. According to Odoni and Neufville (1996), a few airport planning studies have already used scenarios with broad estimates of traffic; so far, however, these are exceptional.

Demand untruncation is another important research approach that is worthy of note. It is related to a deep understanding of the difference between demand and traffic. Traffic is a revelation of demand subject to network capacity constraints. People often take the forecasted demand, based on the current travel behavior, as the true travel demand. In fact, current travel behavior just reflects a constrained demand. There has been interesting research on untruncation of demand in the airline industry. The reason for why may be that this is more significant in airlines industry than in any of the other areas. One of the efforts can be seen on the airport planning in King Country, WA (King County International Airport, 2002).

2.2 Airport Traffic Simulation

Traffic simulations can be conducted at either macroscopic or microscopic scope. A macroscopic traffic simulation aggregates the parameter and variable values of the simulation network. It does not capture the microscopic variations of traffic behaviors. On the other land, a microscopic traffic simulation is able to trace each vehicle's trajectory in a step-by-step manner. In order to capture the microscopic and unique features of the traffic inside the airport, microscopic simulation models need to be adopted. In addition, since a microscopic-simulation model can normally simulates the movements of individual vehicles on a second-by-second basis. It is also possible to calculate the vehicle fuel consumption and emissions. The microscopic traffic simulation changes, in a realistic fashion, the amount of fuels used and mobile emissions according to each vehicle's speed and acceleration. A comprehensive review of the microscopic traffic models with respect to their advantages and disadvantages, and their applicability to simulate the airport vehicular activities has found that there exist few simulation models that are developed specifically for dealing with airports. However, there exist numerous general traffic simulation models that could possibly be used for airport traffic networks. These traffic simulation models can be classified into four types: for urban streets, for freeways, for urban and freeway combined, and for others. The widely used microscopic traffic simulation models are illustrated in Table 1.

TABLE 1 Existing Microscopic Traffic Simulation Models

Urban	Freeway	Combined	Others
CASIMIR	AUTOBAHN	AIMSUN2	ANATOLL
DRACULA	FREEVU	CORSIM	PHAROS
HUTSIM	FRESIM	FLEXSYT II	SHIVA
MICSTRAN	MIXIC	INTEGRATION	SIMDAC
NEMIS	SISTM	MELROSE	
NETSIM		MICROSIM	
PADSIM		MITSIM	
SIGSIM		PARAMICS	
SIMNET		PLANSIM-T	
SITRA-B$^+$		TRANSIMS	
SITRAS		VISSIM	
THOREAU			

Urban simulation models and freeway simulation models are categorized according to the network they simulate. Urban and freeway networks differ significantly both in physical nature of the network and the behavior of drivers. Compared to freeway networks, urban networks are characterized by shorter links and more significant effects from intersections and their controls on delays and levels of service. The presence of public transit, bicyclists, pedestrians, and on-street parking further complicates the modeling of urban networks. The combined model is eligible for both of urban and freeway conditions. Based on a further review and evaluation, several models that have the highest potential to be applied to airport networks include CORSIM, INTEGRATION, PARAMICS, and VISSIM.

CORSIM is a combination of two micro-simulators: urban micro-simulator NETSIM and freeway micro-simulator FRESIM. The combination has resulted in a simulation model that is capable of representing traffic flow in large urban areas containing both surface streets and freeways (CORSIM User's Guide, 2001).

INTEGRATION provides a single model that can represent many isolated functions used in other traffic-simulation and assignment models (INTEGRATION Release 2.30 for WINDOWS: User's Guide, 2001). The model uses the same logic to represent both freeway and signalized link. But the driver behavior cannot be changed by users.

VISSIM models transit and traffic flow in urban areas as well as interurban motorways on a microscopic level (VISSIM Version 3.60 User's Guide, 2001). VISSIM is one of the few comprehensive microscopic traffic simulators applicable to a wide range of traffic situations, including traffic and transit on urban roads and motorways.

A further literature review shows that very limited efforts have been made to simulate traffic inside the airport. Chang and Haghani (1992) proposed a computer simulation model that can assist airport planners and managers in conducting detailed operational analyses of the airport terminal roadway traffic and curbside vehicle parking activities. The model embeds vehicular traffic generation, vehicle movement, lane selection and changing, curbside parking space selection, and pedestrian crosswalks logics. TransSolutions (1998) developed simulation models of all passenger flows and processing facilities, inbound baggage handling, and curbside traffic to help the New Bangkok International Airport evaluate the ability of its terminal design to accommodate passenger demand at its requisite service levels. Tunasar, et al. (1998) used the discrete event simulation in modeling the curbside vehicular traffic at airports. It provided numerical results as well as graphic animations of the roadway that have been proven to be very useful in planning and design of the new airport. Of all these efforts, vehicle emissions have not been considered, not to mention the fact that their applications to real-world scenarios are very limited.

In summary, there are many traffic simulation models available to simulate the traffic on urban streets and freeways. Since the traffic around airports has some unique characteristics, such as the unique driving behavior, traffic operational characteristics, and parking activities, the simulation model selected for applications to airports must be flexible enough to let users easily modify the driving behavior and other parameters. The outputs from the simulation should also be in a format that can be integrated with a mobile-source emission model.

2.3 Airport Emission Modeling

The mobile source emission is a major source of the air pollutions, which attract more and more attentions from various government agencies. Airport traffic contributes a significant portion of the overall emissions due to its large amount of vehicular activities. The emission estimation is an important step in emission controls. Possible consequences of inaccurately characterizing motor-vehicle emissions include the implementation of insufficient controls that endanger the environment and public health or the implementation of ineffective policies that impose excessive control costs. Billions of dollars per year in transportation funding are linked to air-quality attainment plans, which rely on estimates of mobile-source emissions. At present, a number of emission models are available for the emissions estimation.

The Mobile Source Emissions Factor Model (MOBILE) is a computer program developed by the U.S. Environmental Protection Agency (EPA) for estimating emissions from on-road motor vehicles (U.S. Environmental Protection Agency, 2002). MOBILE is used in air quality planning and regulation for estimating emissions of carbon monoxide (CO), volatile organic compounds (VOCs), and nitrogen oxides (NO_X), and for predicting the effects of emissions-reduction programs. Because of its important role in air-quality management, the accuracy of MOBILE is critical.

While the emission-factor model MOBILE has been widely used for the city-wide urban transportation planning purpose, it is not applicable to airport-related emission estimations, especially for the operational analysis of the airport, because it is a macroscopic model, which cannot capture the unique vehicular activities around the airport.

In light of the inability of the MOBILE to support the microscopic analysis, there are many on-going research efforts world-wide in developing microscale mobile-source emission models, which bring hopes for possible applications to airport-related emission analysis. Barth et al. (2000) has developed the Comprehensive Modal Emission Model (CMEM) under sponsorship of the National Cooperative Highway Research Program (NCHRP Project 25-11). Bachman et al. (2000) developed a modal emission model in a Geographic Information System (GIS) framework. Yu (1998) developed an emission model named ONROAD by using remote sensing of vehicle exhaust emission. These microscopic-level emission models can account for the acceleration and deceleration of vehicles, and compute vehicle emissions on a second-by-second basis. These models can be used to perform the microscopic-level emission analysis for a specific area, such as the airport. Such an application to the airport, however, has not yet been attempted by existing studies.

EPA is undertaking an effort to develop a new set of modeling tools for the estimation of emissions produced by on-road and off-road mobile sources (U.S. Environmental Protection Agency, 2003). The new generation model will not necessarily be a single piece of software, but instead will encompass the necessary tools, algorithms, underlying data and guidance necessary to meet the stated objectives. This modeling system would be put forward by the agency for use in all official analyses associated with regulatory development, compliance with statutory requirements, and national/regional inventory projections. The new model allows for analysis at different scales, depending on the desired application.

2.4 Current Practice in HGAC and NCTCOG

The current practice of the North Central Texas Council of Governments (NCTCOG) and the Houston – Galveston Area Council (HGAC) in performing the urban transportation planning is based on a traditional four-step method including trip generation, trip distribution, modal split, and traffic assignment. A survey to these two agencies was conducted to identify the methodologies they are using to deal with the airport-related traffic and emission estimations.

A summary from the survey to NCTCOG is provided in the following. For more details of the surveyed questions and their responses, please refer to Appendix A.

1. The internal-external trip is used to include the trip of local residents to airport;
2. The airport is treated as a special trip attractor;
3. The regional vehicle mix rather than the airport-specific vehicle mix is used; and
4. The regional travel demand model uses the average weekday traffic during the school season.

In the practice of NCTCOG, a post-processing program is used to calculate emissions, the required vehicle miles of travel, and travel speeds on all coded roadway links. Regional vehicle mixes rather than airport-specific vehicle mixes are used for the emissions modeling. In addition, the MOBILE model required by EPA is used to compute emission factors.

A summary from the survey to HGAC is provided in the following. For more details of the surveyed questions and their responses, please refer to Appendix B.

1. The employment and enplanement data are used to generate the trip rates by local residents to the airport;
2. The only specific impact is the fact that the trips made by people who are not residents or employees of the region are present but hard to account for; and
3. The mix of vehicles associated with airport trips is based upon the types of facilities used to access the airports.

The practice of the emission estimation of HGAC uses a method similar to that of NCTCOG. The MOBILE model required by EPA is suitable for modeling in the regional area, but too coarse for modeling in the airport area, as the average vehicle speed is used.

The responses from NCTCOG and HGAC highlight an important fact, which is that characteristics of the airport should be used in the airport demand forecasting process. In addition, it is significant, though it is hard, to account for the trips made by non-residents of the region.

2.5 Summary

This chapter reviewed the state-of-the-art regarding the airport-travel-demand modeling, airport-traffic-simulation and airport-emission modeling, as well as the practice of NCTCOG and HGAC. The results show that the airport is treated as a special generator in the current practice of urban transportation planning. In the process of the demand-modeling and emission-estimation, the traffic and vehicle activities, such as driving behavior, parking activity and curbside activity, have been ignored.

The microscopic simulation models calculate the movements of individual vehicles on a second-by-second basis. The review has found that there exist few simulation models that are developed specifically for dealing with airports. However, there exist some general traffic simulation models that could possibly be used for simulating the airport traffic. Nevertheless, these models need to be calibrated by real time traffic data collected on airports.

Many of the recent developments on microscopic-level emission models can account for acceleration and deceleration of vehicles, and compute the vehicle emissions on a second-by-second basis. These can provide more accurate emission estimation and air quality analysis. But these have not been applied to modeling the traffic around airports.

The reviews have fount that a reliable and consistent methodology for studying the airport ground transportation and emissions either does not exist or needs to be substantially improved. Therefore, developing an appropriate framework to address the issue of airport-related traffic and emissions is needed. It is anticipated that the framework will lay a solid foundation to the future study of various airport-related transportation issues in addition to providing the necessary means to capture the mobile source emissions.

CHAPTER 3

MICROSCOPIC FRAMEWORK

3.1 General Description of Framework

The proposed microscopic framework is shown in Figure 3. This framework integrates a microscopic traffic-simulation model and a modal-emission model to model the traffic and mobile-source emissions implications in and around an airport. This microscopic framework can be used for conducting the operational-level analysis of the mobile-source emissions for airports, and assisting in the overall airport design and planning.

The components of this framework include: (1) identifying the airport road network; (2) selecting the appropriate microscopic traffic simulation model and the modal emission model; (3) collecting the field data for the airport; (4) coding the simulation network for the airport; (5) calibrating the traffic simulation model for the airport; (6) validating the traffic simulation model; (7) defining the modeling scenarios; (8) executing the network simulation; (9) transferring the traffic simulation outputs to the modal emission model in an automatic manner; (10) calculating emissions of each vehicle second by second; and (11) summing the emissions for all scenarios.

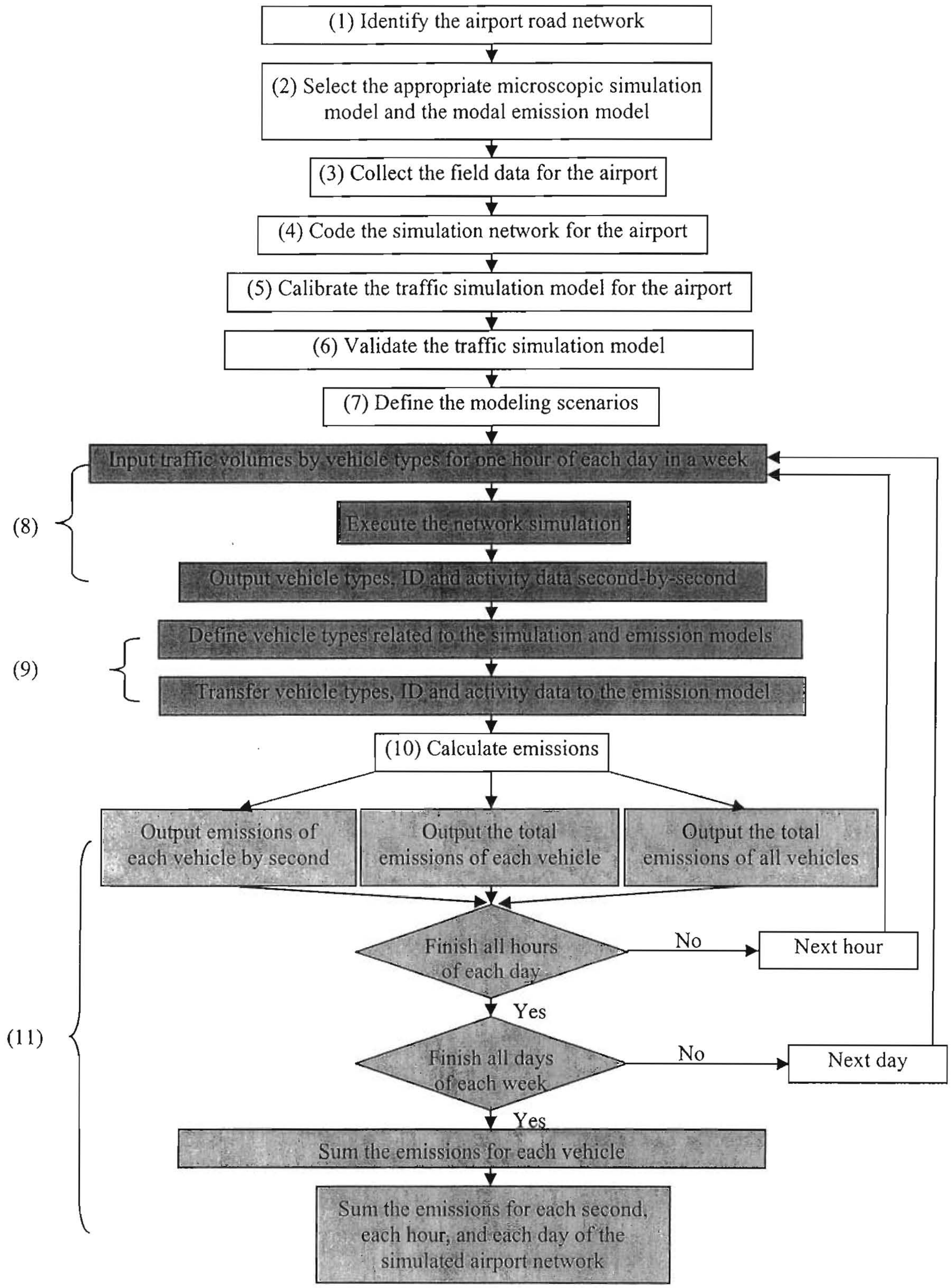


FIGURE 3 Microscopic framework for modeling traffic and emissions around the airport.

Identifying the Airport Road Network

Identifying the airport road network is the first step in the framework. The geographic domain of the modeled area is defined here. The modeled area may only refer to one single terminal. It may also be a larger area that includes several terminals and parking lots, which are connected by a loop road and some connectors. The even larger area can include the long-term (such as weekly) parking lots, car-rental centers, and hotels, which may be built separately from the airport terminals.

Selecting the Appropriate Microscopic Traffic Simulation Model and the Modal Emission Model

The unique traffic and vehicle activities in the airport are different from those on urban streets or freeways. In such a small area, there are various types of vehicles that are running on the terminal loop with low speeds (usually the speeds are lower than the speeds on urban streets or freeways). These activities may be modeled with traffic simulation models, such as VISSIM, CORSIM, INTEGRATION, PARAMICS, and so on. It is required that the selected traffic simulation model should be widely accepted, and the selected model could be calibrated for airport.

Most of existing modal-emission models are still in the process of improvements in terms of applicability, accuracy, complexity and other attributes. As a dominant emission model, MOBILE is widely adopted by EPA, but cannot provide vehicle emissions on a second-by-second basis. So, the selected emission model should be more functional on the microscopic view.

Collecting the Field Data for the Airport

According to the input requirements of the traffic-simulation model and emission model, the field data for the airport should be collected, such as geometric configuration of the airport road network, vehicle types, hourly traffic volumes for the modeled period, vehicle waiting time in front of terminals, vehicle instantaneous speed and travel time.

Coding the Simulation Network for the Airport

The way of coding the simulation network is dependent on the selected traffic simulation model. Usually, the first step is to develop the airport road network and input traffic control and regulations (such as speed limit, stop sign, yield sign, signal, etc.) data. The second step is to define vehicle types and vehicle compositions. Then, traffic volumes and turning ratios at intersections are input. Finally, the coded network is run to identify any problems that may occur during the simulation.

Calibrating the Traffic Simulation Model for the Airport

Driving behavior models, which include the car-following model and lane-change model, are the core of any traffic simulation model. The calibration of the traffic simulation model is to determine values of the essential model parameters with an attempt to make the simulated results consistent with the field observations. The traffic simulation for the airport network requires this calibration step, simply because the unique traffic and vehicle activities of the airports would require a different set of parameter values from the urban or freeway networks. The calibration should be conducted for different airports, and even on different types of roads of the same airport.

Validating the Traffic Simulation Model

The validation of the traffic simulation model is to determine whether the simulated results match the field observations. One item to be considered is the variable to be used for the validation, which could be traffic volume, average travel time, average travel speed, traffic density, or queue length. Another item to be considered is the validation criterion, which could be set as the confidence range of the observed values. For example, the acceptable simulated traffic volumes can be defined as the $\pm 5\%$ of the observed traffic volumes.

Defining the Modeling Scenarios

Based on the analysis purpose, various modeling scenarios should be defined. The modeling scenarios can be defined as hourly, daily, weekly, monthly or yearly. The longer the period defined, the longer the simulation time needed.

Executing the Network Simulation with the Calibrated Parameters

For each designed scenario, the traffic simulation with the calibrated parameters is run to produce the necessary outputs, such as the vehicles' instantaneous speeds and acceleration and deceleration rates, for use in the emission estimation.

Transferring the Simulation Outputs to the Modal Emission Model

The basic data that should be transferred from the traffic simulation to the modal-emission model are vehicle's instantaneous speeds and acceleration/deceleration rates. Other data such as vehicle type, simulation time, and vehicle ID may be needed depending on the type of modal-emission model selected. Sometimes vehicle types need to be converted when the traffic simulation and emission models use different vehicle-type definitions.

Calculating Emissions

The selected modal emission model is used to calculate the emissions. The initial result is the second-by-second emissions of each vehicle.

Summing the Emissions for all Scenarios

There are three ways of aggregating the emissions: by vehicles (vehicle types), by time period, or by geographical domain of the defined parts of the airport. The second-by-second emissions of each vehicle can be summed according to the defined scenarios.

3.2 Traffic Simulation in the Framework

3.2.1 Selection of the Traffic Simulation Model

The selection of an appropriate traffic simulation model is very important in the proposed framework. The geometric design of the transportation network in and around the airport plays an important role in determining the vehicular characteristics, which in turn lead to different mobile emissions. As a result, a traffic simulation model featuring the specific geometric design of the airport should be selected. In order to capture the unique driving behaviors, parking, and curbside vehicle activities at the airport, the following features of the simulation model are important:

- Car following behavior;
- Vehicular specific characteristics such as acceleration and deceleration;
- Distribution of speeds at which vehicles drive through the terminal;
- Distribution of arrival times at the airport; and
- Distribution of waiting times inside the airport.

3.2.2 Selected Traffic Simulation Model - VISSIM

VISSIM is a microscopic, time-step and behavior-based simulation model developed to analyze the full range of functionally classified roadways (including roundabouts) and transit operations. It can model integrated roadway networks found in a typical corridor as well as transportation modes consisting of general-purpose traffic, buses, HOV, light rail, heavy rail, trucks, pedestrians, and bicycles. It can address the specific geometric design of any transportation network, including an airport. It also includes a driving behavior model that is needed to capture the microscopic driving behavior of vehicles in the airport. The VISSIM is selected in this research to perform the case study. However, the proposed framework does not limit the use of VISSIM. The selection of VISSIM does not mean that the other models are inferior to VISSIM. It is selected only because it has the features that are needed to achieve the research objectives.

The VISSIM simulation generates an online animation of traffic operations and offline output files gathering statistical data such as travel time and queue lengths. The traffic simulator is a microscopic traffic-flow simulation model including car-following and lane-change logic. The signal state generator is signal control software polling detector information from the traffic simulator on a discrete time step basis (as small as one-tenth of a second). It then determines the signal status for the following second and returns this information to the traffic simulator. VISSIM simulates traffic flow by moving “driver-vehicle-units” through a network. Every driver, with his/her specific behavior characteristics, is assigned to a specific vehicle. As a consequence, the driver’s behavior corresponds to the technical capabilities of the vehicle.

3.3 Emission Estimation in the Framework

3.3.1 Selected Emission Model - CMEM

In order to model the emissions of the airport in the proposed microscopic framework, a modal emission model is needed. The Comprehensive Modal Emissions Model (CMEM) has been recently developed and widely used (Barth, An, Younglove, Scora, Levine, Ross and Wenzel, 2000; Hung and Tong, 2001). Further, this model is implemented through a computer program developed in MS ACCESS, with a friendly user interface as shown in Figure 4.

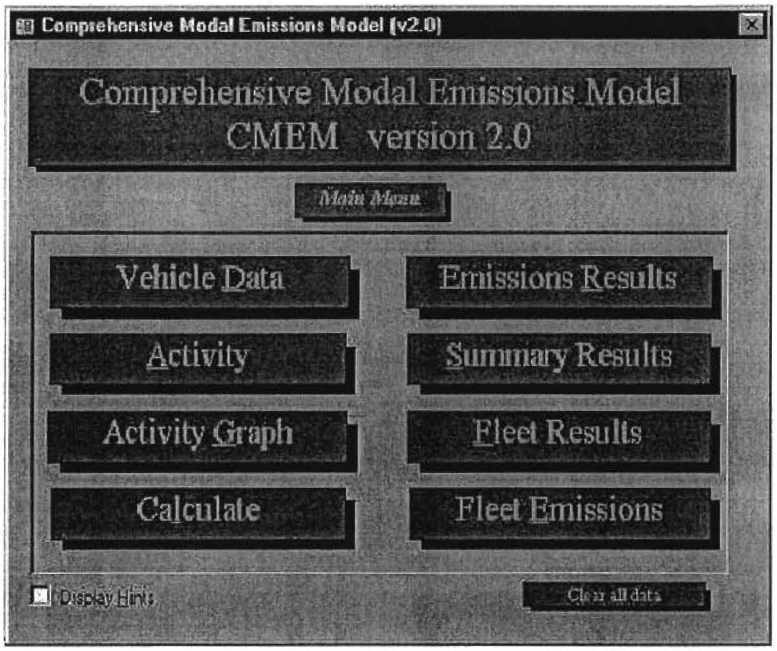


FIGURE 4 Original CMEM-Access main menu form.

In CMEM, 24 vehicle categories are identified based on fuel and emission control technology of the vehicles. The second-by-second vehicle tailpipe emissions are modeled as the product of three components: fuel rate (FR), engine-out emission indices ($g_{emission}/g_{fuel}$), and time-dependent catalyst pass fraction (CPF):

$$tailpipe\_emissions = FR * (\frac{g_{emission}}{g_{fuel}}) * CPF \qquad (1)$$

FR is the fuel use rate in grams/s, engine-out emission index is grams of engine-out emissions per gram of fuel consumed, and *CPF* is the catalyst pass fraction, which is defined as the ratio of tailpipe to engine-out emissions. *CPF* is usually a primary function of the fuel/air ratio and engine-out emissions.

The entire modal emissions model is composed of six modules, as indicated by the six square boxes in Figure 5 (Barth, An, Younglove, Scora, Levine, Ross, and Wenzel, 2000): 1) engine power demand; 2) engine speed; 3) fuel/air ratio; 4) fuel-rate; 5) engine-out emissions; and 6) catalyst pass fraction. The model requires two groups of input (rounded boxes in Figure

5): A) input operating variables; and B) model parameters. The output of the model is tailpipe emissions and fuel consumption.

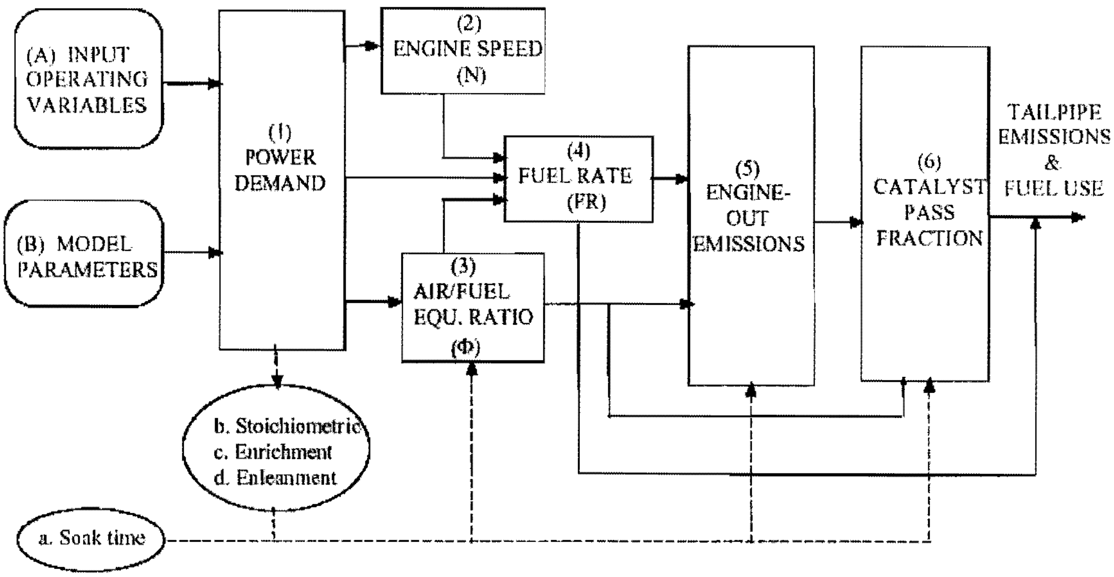


FIGURE 5 Modal emissions model structure.
(Source: "User Guide: Comprehensive Modal Emission Model (CMEM), Version 2.0" by Barth, An, Younglove, Scora, Levine, Ross, and Wenzel)

3.3.2 Emission Estimation with CMEM

The inputs of CMEM are vehicle data (including vehicle ID, vehicle types and the vehicle belonged fleet) and activity data (including time, vehicle ID, velocity, acceleration, grade and sload) of each vehicle. There are three kinds of outputs that can be generated from CMEM:

Emission results

It is possible to get a list of the second-by-second emission output for each vehicle. This list is a result of an Microsoft Access query and is in a table format that can be printed and exported. A series of valuable information is stored in this table, which includes time, vehicle ID, vehicle speed & acceleration rate, amount of tailpipe HC, CO, NOx, CO_2 and fuel use.

Summary results

This is a summary of the first file, which provides the total emissions and fuel use for each vehicle during the time period running. It provides the total driving distance for each vehicle.

Fleet results

This is the highly summarized file, which contains only the total amount of emissions and fuel use of each vehicle fleet.

3.4 Data Transfer from VISSIM to CMEM

When inputting the vehicle data and activity data to CMEM using the provided interface manually, only data of one vehicle can be input each time. However, the VISSIM simulation outputs usually contain several hundreds or thousands of vehicles. For example, VISSIM.FZP, a output file generated from a 245Kb VISSIM file, usually falls between 20Mb and 30Mb for only one-hour data. It is impossible to input these vehicle data and activity data using the original CMEM interface. So a computer program is developed in this research to transfer data from VISSIM to CMEM automatically.

The data transferred from VISSIM to CMEM include vehicle type, simulation time of each vehicle, vehicle ID, and vehicle speed and acceleration/deceleration. All of these data are generated from VISSIM after the network simulation runs.

The data transfer process provides an integration of VISSIM and CMEM, as shown in Figure 6. A computer program is developed to integrate the VISSIM, the data transfer and CMEM, and thus the integration of VISSIM and CMEM can be executed in a fully automatic manner.

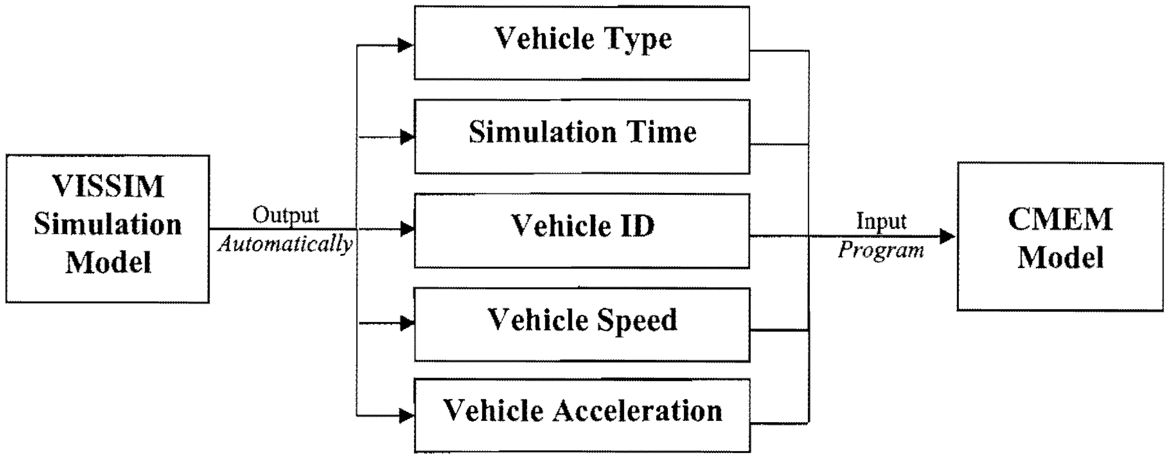


FIGURE 6 Integration of VISSIM and CMEM.

The flowchart of the data transfer program is shown as Figure 7. This program is developed in Microsoft Access. The principle is to write the five kinds of data from the FZP file generated from VISSIM into Table "definition" and Table "activity" in CMEM. The other data for each vehicle type are also obtained from Table "default" and written to Table "definition." Because the vehicle types classified in VISSIM and in CMEM are different, a relationship is identified to transfer the vehicle types. When reading data from VISSIM FZP file, several hundreds or thousands records are obtained for each vehicle but only one record allowed to be written into Table "definition." The code of this program is listed in Appendix E.

In order to implement the calculation of emissions using VISSIM and CMEM, the main interface of CMEM is revised as shown in Figure 8. The data transfer program is executed by clicking the Box "Input VISSIM data and calculate."

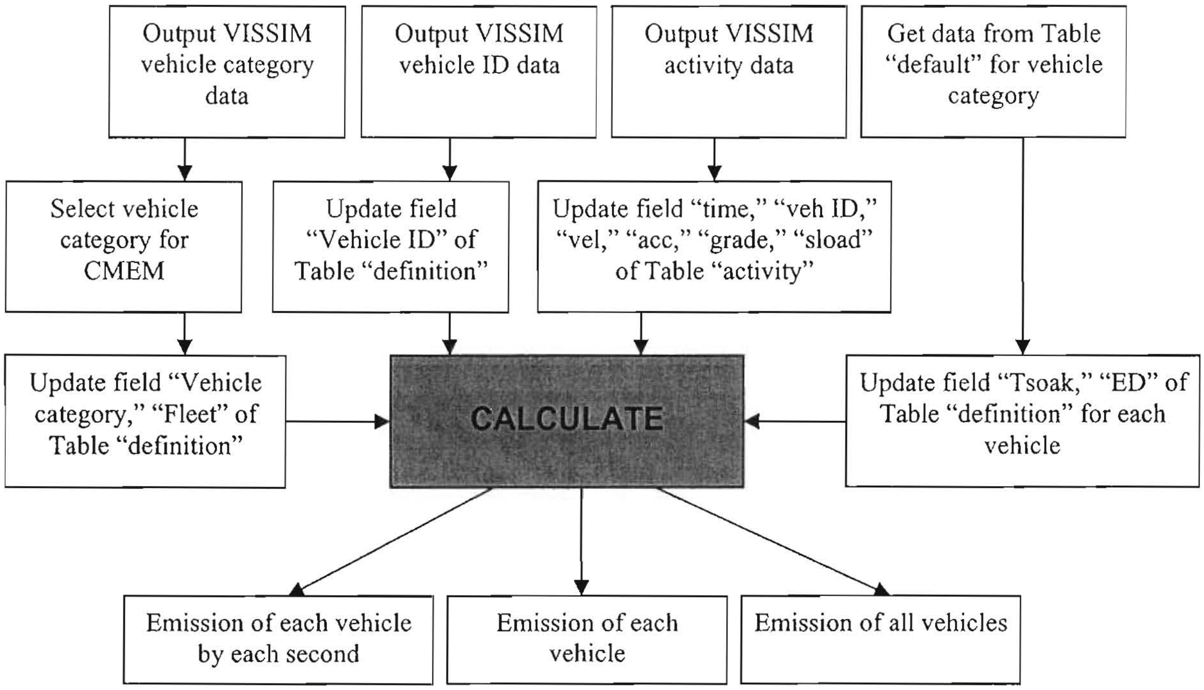


FIGURE 7 Flowchart of program for transferring data from VISSIM to CMEM.

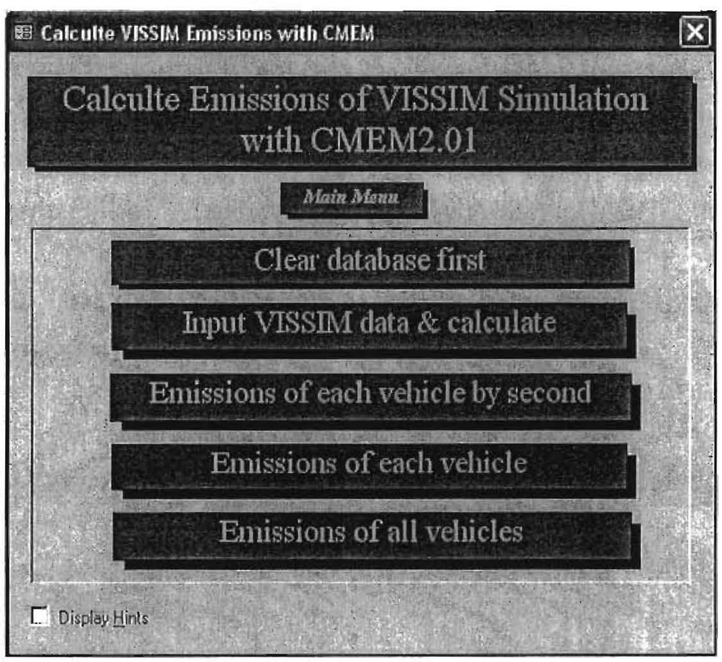


FIGURE 8 Revised CMEM-Access main menu form.

3.5 Implementation of the Framework

3.5.1 Data Needed

In order to run VISSIM, the four types of data need to be collected.

- The first type of data is the vehicle type. As mentioned earlier, various types of vehicles run around terminals that consist of a very unique and complicated traffic stream. They can be categorized into three typical types: private vehicle, truck and bus.

- The second type of data is the total amount of traffic volumes entering the airport and the traffic turning ratio at each intersection.

- The third type of data is the stop-time of vehicles in front of each terminal. Inappropriate stop time settings could induce traffic congestion in the network simulation. So the proper adjustment of the stop-time value is necessary.

- The fourth type of data is the vehicle instantaneous speed, which is the key factor for the emission estimation. It is used to validate the model calibration result in the case study.

In order to run CMEM, the following output data from VISSIM are needed:

- Vehicle type. It is the important information to calculate emissions.

- Simulation time in the unit of second.

- Vehicle number. It is the important information to calculate emissions.

- Vehicle speed in the unit of miles per hour.

- Vehicle acceleration rate in the unit of meters per squared second.

3.5.2 Computer Program Needed

There are three computer programs needed in the proposed framework: the data transfer program, the traffic simulation calibration program, and AUTOSIM program. The data transfer program is used to connect VISSIM to CMEM. The traffic simulation calibration program, developed in MATLAB, is used to provide an efficient way for the simulation model calibration. As an essential part of the traffic simulation calibration program, AUTOSIM is used to automatically call VISSIM.

CHAPTER 4

CALIBRATION APPROACH

The calibration of the traffic simulation model is to determine values of the model input parameters with an attempt to make the simulated results consistent with the field observations within an acceptable range. Although efforts have been made by researchers to develop various approaches to calibrate traffic simulation models, most of existing applications are either too simplified or too difficult to implement. Without a reliable and practical calibration framework in place, any traffic simulation endeavor may ultimately be found less useful.

A traffic simulation process always involves many input parameters that need to be calibrated simultaneously. The calibration of multiple parameters at the same time has to select the best combination of those parameters, which would require a tremendous amount of computing time in order to minimize the discrepancy between the simulated results and the field observations. This type of calibration problem is a multi-dimensional search process in nature, in which the Genetic Algorithm (GA) can be an efficient tool to apply. As it takes approximately 3 minutes to run the network simulation, given the numbers of possible parameter sets is 1.3×10^{11}, the total time required to finish the search is 3.9×10^{11} minutes, which is 7.4×10^{5} years. However, by using Genetic Algorithm, it only takes 13 hours to find out the optimal result and the whole process is an automatic searching. It saves tremendous time and labor work.

4.1 A Brief Introduction of GA

Genetic Algorithm is based on the Darwinian survival theory: more fit individuals are evolved from successive generations (Goldberg, 1989). GA is widely used in various research areas (Whitley, 1989; Unger and Moult, 1992; Gottweis, 2001; Montana and Brinn, 1998). GA has a robust ability to find acceptable solutions in complex search spaces, which adds credibility to the solutions found. Exploiting the flexibility and robustness of GA search is, however, dependent on the existence of an appropriately responsive model to evaluate the candidate solutions, the effective design of a representation for the elements of the application, and a compatible will-parameterized set of operators (Davis, 1991).

Population Representation and Initialization

GA operates on a number of potential solutions, called a population, consisting of some encoding of the parameter set simultaneously. Typically, a population is composed of 30 to 100 individuals, although, a variant called the micro GA uses very small population, ≤ 10 individuals, with a restrictive reproduction and replacement strategy in an attempt to reach real-time execution (Karr 1991).

The most commonly used representation of chromosomes ("agent" is used in this report as another term with the same meaning of "chromosome") in the GA is that of the single-level binary string. Here, each decision variable in the parameter set is encoded as a binary string, which is concatenated to form a chromosome. Having decided on the representation, the first step of using GA is to create an initial population. This is usually achieved by generating a required number of individuals using a random number generator that uniformly distributes numbers in the desired range.

More detailed example is given below to clarify the concepts mentioned above.

Objective and Fitness Functions

The objective function is used to provide a measure of how individuals have performed in the problem domain. In the case of a minimization problem, the fittest individuals will have the lowest numerical value of the associated objective function. This raw measure of fitness is usually only used as an intermediate stage in determining the relative performance of individuals in a GA. Another function, the fitness function, is normally used to transform the objective function value into a measure of relative fitness (De Jong, 1975):

$$F(x) = g(f(x)) \tag{2}$$

where f is the objective function, g transforms the value of the objective function to a non-negative number, and F is the resulting relative fitness.

This mapping is always necessary when the objective function is to be minimized as the lower objective function values correspond to fitter individuals. In many cases, the fitness function value corresponds to the number of offspring that an individual can expect to produce in the next generation.

Selection

It is a process of determining the number of times or trials that a particular individual is chosen for reproduction, and thus, the number of offspring that an individual will produce. The selection of individuals can be viewed as two separate processes: (1) determination of the number of trials an individual can expect to receive, and (2) conversion of the expected number of trials into a discrete number of offspring. The first part is concerned with the transformation of raw fitness values into a real-valued expectation of an individual's probability to reproduce, and is dealt with in the previous subsection as the fitness assignment. The second part is the probabilistic selection of individuals for reproduction based on the fitness of individuals relative to one another, and is sometimes known as sampling. The remainder of this subsection will review some of the more popular selection methods in the current application.

Crossover

The basic operator for producing new chromosomes in the GA is that of crossover. Like its counterpart in nature, crossover produces new individuals that have some parts of both parent's genetic material. The simplest form of crossover is that of single-point crossover.

Mutation

In a nature evolution, a mutation is a random process where one allele of a gene is replaced by another to produce a new genetic structure. In GAs, the mutation is randomly applied with a low probability, typically in the range 0.001 and 0.01, and modifies elements in the chromosomes. Usually considered as a background operator, the role of mutation is often seen as providing a guarantee that the probability of searching any given string will never be zero and acting as a safety net to recover good genetic material that may be lost through the action of selection and crossover (Goldberg, 1989).

Reinsertion

To maintain the size of the original population, the new individuals have to be reinserted into the old population. Similarly, if not all the new individuals are to be used at each generation or if more offspring are generated than the size of the old population, then a reinsertion scheme must be used to determine which individuals are to exist in the new population. An important feature of not creating more offspring than the current population size at each generation is that the generational computational time is reduced, most dramatically in the case of the steady-state GA, and that the memory requirements are smaller as fewer and fewer new individuals need to be stored while offspring are produced.

4.2 Calibrated Model and Parameters

4.2.1 Driving Behavior Model

A driving behavior model is the core of any traffic simulation model. It determines how the vehicles will behave within the network. Different traffic simulation models use different driving behavior models. In VISSIM, the driving behavior models contain a psychophysical car following model for the longitudinal vehicle movement and a rule-based algorithm for the lateral movement. These two models are based on the continued work of Wiedemann (VISSIM Version 3.6 Manual, 2001).

The basic idea of the Wiedemann model is the assumption that a driver can be in one of four driving modes:

- Free driving, i.e. no influence of preceding vehicle observable. In this mode the driver seeks to reach and maintain a certain speed, his individually desired speed. In reality, the speed in free driving cannot be kept constant, but oscillates around the desired speed due to the imperfect throttle control.

- Approaching, i.e. the process of adapting the driver's own speed to the lower speed of a preceding vehicle. While approaching, a driver applies a deceleration so that the speed difference of the two vehicles is zero in the moment he reaches his desired safety distance.

- Following, i.e. the driver follows the preceding car without any conscious acceleration or deceleration. He keeps the safety distance more or less constant, but again due to the imperfect throttle control and imperfect estimation, the speed difference oscillates around zero.

- Braking, i.e. the application of medium to high deceleration rates if the distance falls below the desired safety distance. This can happen if the preceding car changes speed abruptly, or if a car changes lanes in front of the observed driver.

For each mode, the acceleration is described as a result of the speed, the speed difference, the distance and the individual characteristics of a driver and a vehicle. The driver switches from one mode to another as soon as he/she reaches a certain threshold that can be expressed as a combination of the speed difference. For example, a small speed difference can only be realized in small distances, whereas large speed differences force approaching drivers to react much earlier. The ability to perceive the speed differences and to estimate the safety distances varies among the driver population. Because of the combination of psychological aspects and physiological restrictions of the driver's perception, the model is called a psycho-physical car-following model.

4.2.2 Calibrated Parameters

Many parameters work into the car following and lane change models in VISSIM. Some of the parameters, such as the vehicle desired speed and the waiting time before diffusion, may be adapted by an experienced user. As these parameters directly affect the vehicle interaction and thus can cause substantial differences in simulation results, only experienced users are able to modify any of the parameters. So, normally we need to use a scientific method to calibrate these parameters. Ten driving behavior parameters to be calibrated are classified into four categories:

1) Lane change behavior:
   - Waiting time before diffusion (x_1)
   - Minimum headway (x_2)

2) Necessary lane change (route) behavior:
   - Maximum deceleration (x_3)
   - $-1\ m/s^2$ per distance (x_4)
   - Accepted deceleration (x_5)

3) Vehicle following behavior:
   - Maximum look ahead distance (x_6)
   - Average standstill distance (x_7)
   - Additive part of desired safety distance (x_8)
   - Multiple part of desired safety distance (x_9)

4) Lateral behavior:
   - Distance of standing and at 30 mph (x_{10})

Waiting Time before Diffusion

It defines the maximum amount of time a vehicle can wait at the emergency stop position waiting for a gap to change lanes in order to stay on its route. When this time is reached the vehicle is taken out of the network (diffusion) and a warning message will be written to the error file denoting the time and location of the removal.

Minimum Headway

It defines the minimum distance to the vehicle in front that must be available for a lane change.

Maximum Deceleration

It is the fastest vehicle can slow down or stop.

Accepted Deceleration

The value of it is smaller than maximum deceleration but bigger than minimum deceleration and the vehicle can slow down safely without any dangerous with accepted deceleration.

Maximum Look Ahead Distance

It is the maximum observing distance of the driver who adjusts vehicle driving speed based on this distance. The driver may approach the front car by acceleration to reduce the distance. This value relates to human's physical observation ability.

Average Standstill Distance

It defines the average desired distance between stopped cars and also between cars and stop lines (signal heads, priority rules etc.).

Additive Part of Desired Safety Distance and Multiple Part of Desired Safety Distance

The two parameters contained with the car following model determine the saturation flow rate for VISSIM. The saturation flow rate defines the number of vehicles that can free flow through a VISSIM model during one hour.

Distance of Standing and at 30 mph

It is the safety distance between two parallel cars at both the condition of stop and moving.

The VISSIM provides a set of default values to the above parameters. It also provides a range of possible values to each of these parameters. The use of different values for these parameters will definitely affect the simulation results. However, calibrating these parameters by selecting the best values for all parameters at the same time is not an easy task. Assuming that we only search 10 steps for each parameter, a combination of all the parameters will require a total of 10^{10} steps in a tedious search, not mention that each search will require a full simulation run. Plus, to reach a reasonably optimal result, 10 steps are clearly not sufficient. Therefore, the computing time is not within any acceptable range. Using the GA-based approach, however, can considerably reduce the number of search steps needed, and thus the amount of time required to complete the search.

4.3 Proposed GA-Based Calibration Approach

4.3.1 Index of Simulation Accuracy

In order to evaluate the quality of the simulation in the calibration, we need to define an index of simulation accuracy. While there may be different ways to do this (e.g. using travel time, queue length, etc.), this research proposes to use the Sum of Squared Error (SSE) between the vehicle speeds collected and the vehicle speeds simulated at pre-defined cross-sections at a 10-meter interval along the road. The speeds of vehicles in the simulation network are a good reflection of driving behavior parameters, provided the traffic volumes are given. Further, the instantaneous speed data in the network can be easily collected using the sophisticated GPS technology. Therefore, using the variable speed to evaluate the quality of the simulation is not only appropriate, but also practical.

The objective of the calibration is to minimize the SSE, which is expressed as the following equation.

$$SSE = \sum_{i=1}^{n} (v_i^C - v_i^S)^2 \tag{3}$$

where

i : cross - section number at a 10 - meter interval along the road where the speed is collected,
n : number of cross - sections,
v_i^c : vehicle speed collected at cross - section i by GPS, and
v_i^s : vehicle speed simulated at cross - section i by VISSIM.

For VISSIM, SSE is a function of ten driving behavior parameters:

$$SSE = f(x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}) \tag{4}$$

f is a function that is difficult to be expressed in an analytical form. It cannot be solved through an analytical approach either. This research establishes a simulation procedure to indirectly express the relationship between SSE and the ten parameters.

4.3.2 GA-Based Calibration Approach

The proposed calibration approach is to use GA as the optimization tool with an objective to minimize the SSE. The complete optimization process, which combines GA and VISSIM to find the optimal values for the ten driving behavior parameters, is illustrated in Figure 9. Subroutine AUTOSIM in the figure is used to run the simulation automatically and evaluate the SSE given a set of values of the ten parameters. See Figure 10 for details of AUTOSIM.

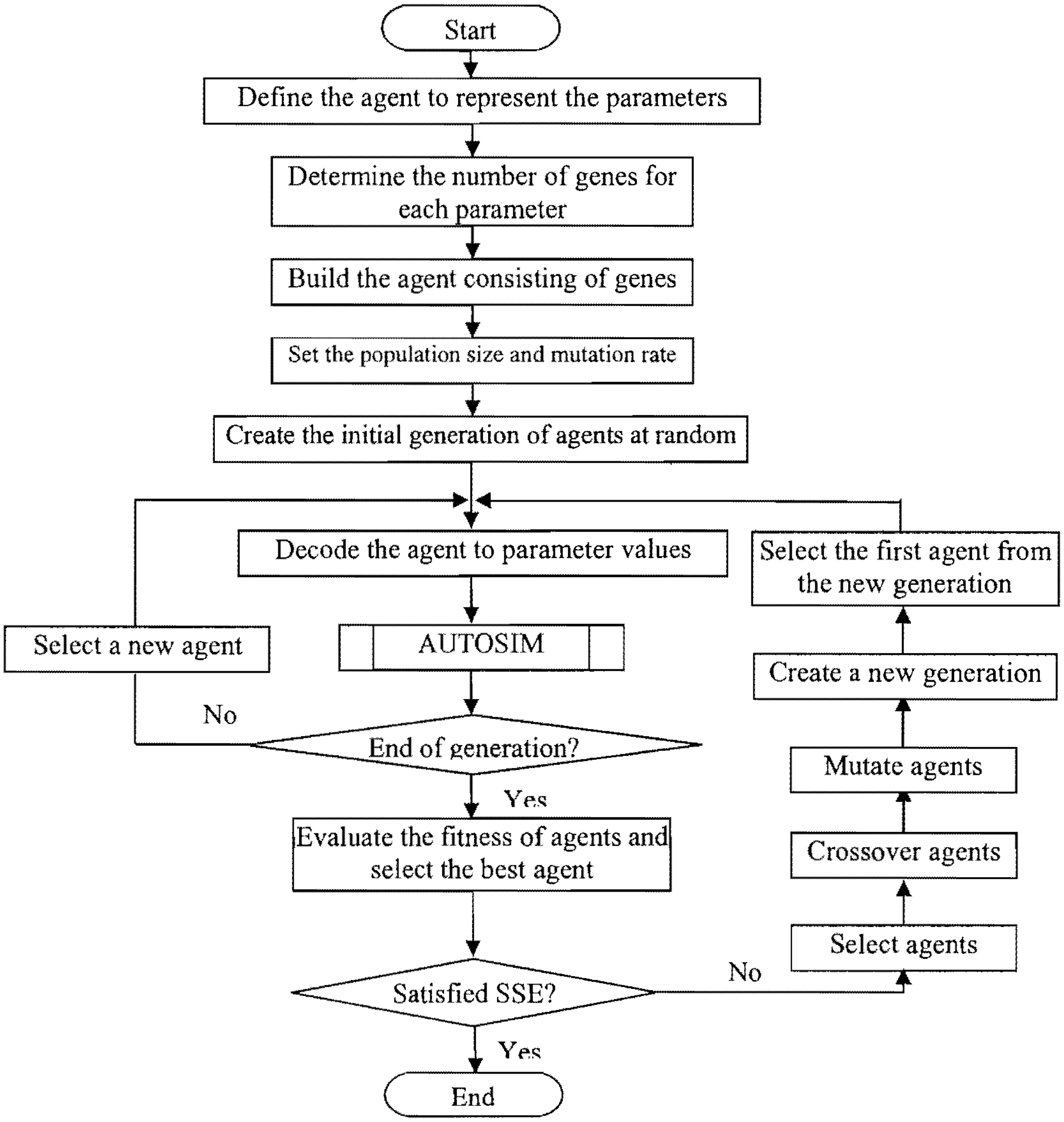


FIGURE 9 Process of the GA-based approach for calibrating driving behavior parameters in VISSIM.

Define the Agent to Represent the Parameters

For GA, the terms *agent* and *gene* are used. The term *gene* is represented by a binary digit *0* or *1*. One *agent* is defined as a group of *genes* used to represent a value of each parameter. For example, Agent *10101*, which includes five genes, represents a value of parameter x_1. Furthermore, one *generation* is defined as the specified numbers of *agents*. The *population size* is defined as the number of agents included in one *generation*.

Determine the Number of Genes for Each Parameter

For each parameter, the number of genes needed vary according to the domain of the parameter and the increment of the parameter value. Equation (5) is used to determine the number of genes n_i needed for each parameter.

$$\begin{aligned} &\max(x_i) - \min(x_i) = \alpha_i * (2^{n_i} - 1) \\ &i = 1, 2, 3, \ldots, 10 \end{aligned} \tag{5}$$

where

$\max(x_i)$: the maximum value of x_i,
$\min(x_i)$: the minimum value of x_i,
x_i : the value of ith calibrated parameter,
α_i : the increment value of x_i, and
n_i : the number of genes of the agent to represent x_i.

In Equation (5), we need to first identify $\max(x_i)$ and $\min(x_i)$, then assign an initial value to α_i based on the number of increments desired in the search process for this parameter, and finally determine n_i. After n_i is determined, it can be substituted back into Equation (5) to calculate the final precise value of α_i. The results from the calculation for all the ten driving behavior parameters are illustrated in Table 2. The values of $\max(x_i)$ and $\min(x_i)$ are given by VISSIM.

TABLE 2 Number of Genes and Increment of Each Parameter

Parameter i	Max (x_i)	Min (x_i)	# of genes (n_i)	Increment (α_i)
1. Waiting time before diffusion (second)	90	30	5	1.9
2. Minimum headway (meter)	1	0.1	4	0.06
3. Maximum deceleration (m/s^2)	-1	-5	3	0.6
4. $-1m/s^2$ per distance (meter)	80	20	5	1.9
5. Accepted deceleration (m/s^2)	-0.2	-3	4	0.2
6. Maximum look ahead distance (meter)	300	200	4	6.7
7. Average standstill distance (meter)	5	0.2	3	0.7
8. Additive part of desired safety distance (meter)	5	0.2	3	0.7
9. Multiple part of desired safety distance (meter)	6	1	4	0.34
10. Distance of standing and at 30 mph (meter)	2	0.5	4	0.1
Total number of genes			39	N/A

Build the Agent and Create the Initial Generation

Table 2 shows that a total of 39 genes are needed to represent these 10 parameters. The population size, which is the number of agents in one generation, is defined as, but not limited to 16 in this report (the number is randomly chosen, but as a sample, it should be a relatively large number so that the better individual could be found in a very short time). In the initial generation, each gene of the agent is assigned 0 or 1 randomly.

Decode the Agent to Parameter Values

Equations (6) and (7) are used to decode the agent A to the actual parameter value x_i.

$$x_i = \alpha_i * A * B + \beta_i \tag{6}$$

$$A = (a_1, a_2, a_3, \ldots, a_{n_i})$$

$$B = \begin{pmatrix} 2^{n_i - 1} \\ . \\ . \\ 2 \\ 1 \end{pmatrix} \tag{7}$$

$$i = 1, 2, 3, \ldots, 10$$

where

x_i : the value of ith calibrated parameter,

α_i : the increment value of x_i,

n_i : the number of genes of the agent to represent x_i,

β_i : min (x_i), listed in Table 2,

A: vector to represent agent,

B: coefficient vector, and

$a_1, a_2, a_3, ..., a_{n_i}$: 0 or 1.

AUTOSIM

Fitness is used to evaluate the quality of the agent. The higher the fitness, the better the agent is. In another word, the set of ten driving behavior parameters is better if the fitness resulted from the simulation is higher. In the proposed approach, *SSE* is used as the fitness function where the fitness is the highest when *SSE* is the minimum. As mentioned earlier, *f* is a function that cannot be expressed in an analytical form. As such, we design a simulation procedure, which is named AUTOSIM, to express the relationship between SSE and the 10 parameters. This procedure automatically runs VISSIM with different values of the input parameters and generates the outputs of *SSE.* The flowchart of the AUTOSIM procedure, programmed with Visual Basic 6.0, is shown in Figure 10.

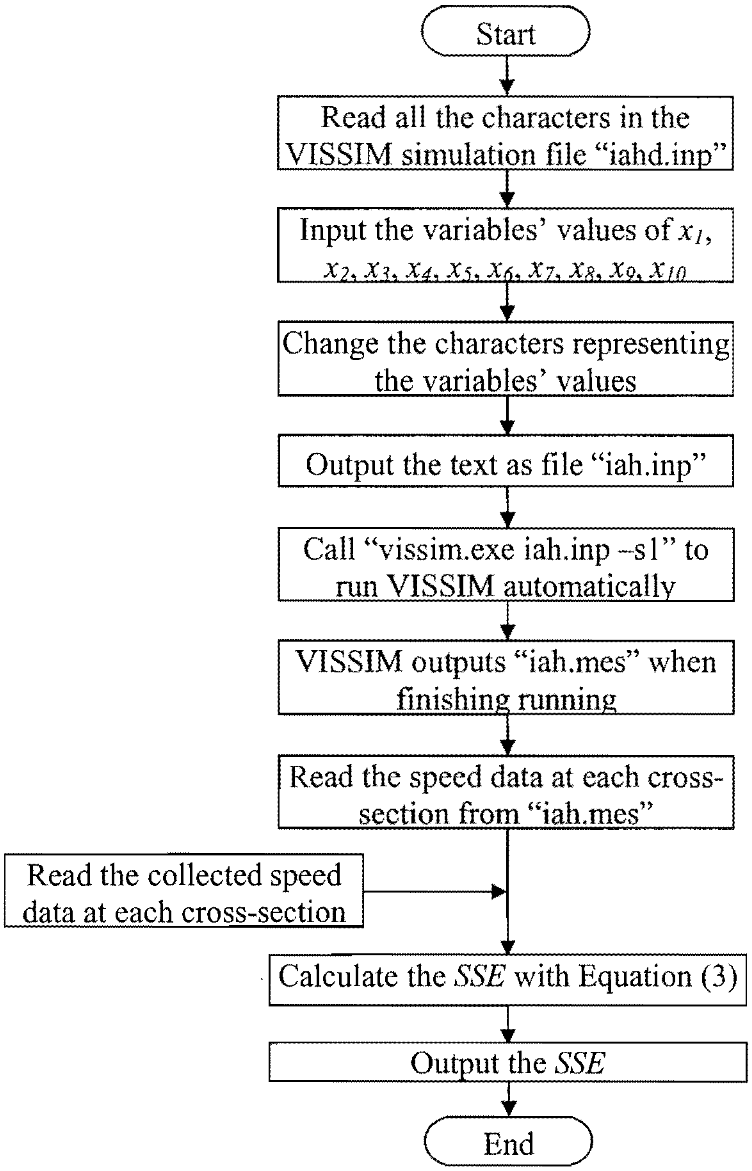


FIGURE 10 The flowchart of AUTOSIM.

Evaluate the Fitness of Agents and Select the Best Agent

Using the AUTOSIM, the evaluation of each agent in one generation can be performed. Before the AUTOSIM is entered, Equations (6) and (7) are used to decode the agent in order to derive the values of the parameters. After all agents in the current generation have gone through the AUTOSIM, the fitness of agents is evaluated based on SSE, and then the best agent is selected. If the SSE of the best agent in the current generation does not satisfy a pre-defined criterion, continue into the following step to create the next generation of agents. Otherwise, the process stops, and the optimal parameter values are derived.

Select, Crossover and Mutate Agent

In GA, select, crossover and mutate are three operators needed in creating the next generation of agents. Selection is based on the probability, and the agents with higher fitness values will most likely be selected. To crossover, two agents interchange part of their genes to create two new agents. One agent is mutated to create a new agent by changing one of its genes from 1 to 0 or from 0 to 1.

Create a New Generation

The search for the optimum values is an iterative process. After the operators of selection, crossover and mutation are carried out to the agents of the former generation, more agents will be produced to form a new generation while keeping the same population size.

4.4 Implementation of the Approach

4.4.1 GPS Data Collection

To implement the proposed GA-based approach, the instantaneous speeds at the pre-defined cross-sections at a 10-meter interval along the road need to be collected from the fields. The GPS system is used to measure the vehicle's instantaneous speeds, which has been proven to be accurate for this purpose by the previous experiment (Jiang and Li, 2002). The test vehicle equipped with GPS is driven in the network in a similar way to the floating car method (Garber and Hoel, 2002). In this method, the driver "floats" in the traffic stream, passing as many vehicles as the number of vehicles overtaking the test car, which is driven with the average speed. A number of repeated runs of the test are conducted along the same road to get reliable results.

4.4.2 Developed Computer Program for the GA-Based Calibration Approach

The MATLAB platform is used for programming to implement the proposed GA-based approach. We use the GA Toolbox developed by University of Sheffield (Chipperfield et al., 1993). This toolbox provides functions to implement the operators of selection, crossover and mutation.

The developed program can generate two kinds of results, which are saved as a text file. The first includes the minimum SSE value for each generation, and the second includes the parameter values for the final optimal SSE. According to the trend of the different SSE values between generations, the proper number of iterations can be decided.

More detailed explanations for this program are presented in the following part, which describes main functions involved.

Create an Initial Population

The first step in a GA is to create an initial population consisting of random chromosomes. *crtbp* produces a matrix, which is named *Chrom*, containing random values in its elements.

$$Chrom = crtbp\ (16,\ 39) \tag{8}$$

Function (8) creates a random binary matrix of a size 16*39, where 16 specify the number of individuals in the population and 39 is the length of the individual.

Decode the Agent to Parameter Values

After creating the initial population, we should transfer it to a real-value in a program readable format. This is relatively easy to be fulfilled by transforming the decoding function into the MATLAB readable format. According to the different numbers of genes 3, 4 and 5, we can generally achieve three results from Equation (9), which are interpreted with the following function:

$$\begin{aligned} b_1 &= [16;\ 8;\ 4;\ 2;\ 1] \\ b_2 &= [8;\ 4;\ 2;\ 1] \\ b_3 &= [4;\ 2;\ 1] \end{aligned} \tag{9}$$

In order to calculate x_i, it is necessary to separate the initial population matrix into 10 sub-matrixes and each sub-matrix represents an agent of one parameter. If one sub-matrix is from column a to column b, we should use the following function to extract the sub-matrix. Here colon ":" indicates extracting the entire row.

$$c = Chrom\ (:, [a{:}b]) \tag{10}$$

$$p = x_i = [1.9*c1*b1+30,\ \ldots,\ 0.1*c10*b2+0.5] \tag{11}$$

where p is a real-valued initial population matrix.

AUTOSIM

After finishing the real-valued initial population transforming, we need to calculate the SSE results for 16 agents respectively. AUTOSIM is developed to perform this function. In MATLAB, each agent matrix can be extracted by using Function (12)

$$pi = p\ (i, :) \tag{12}$$

where pi is an agent matrix of row i of p. The next step is to write pi to a text file, which will be read by VISSIM. The goal of this step is to change the value for each parameter in the VISSIM simulation file. The original VISSIM simulation file named iahd.inp will be changed to iah.inp after the parameter values are updated. Automatic VISSIM runs can be realized in MATLAB with the "system" function, which is a command used to run operating system and return the result. The next step is using Visual Basic program to calculate SSE by comparing the VISSIM outputs saved in iah.mes file and the collected speed data at each pre-defined cross-section. The SSE result is saved in a text file that needs to be transferred to MATLAB.

Fitness Evaluation

All of the 16 SSE results are listed randomly and the program will pick the minimum SSE among them. In the GA toolbox, the function of "ranking" ranks individuals according to their objective values, *ObjV*, and returns a column vector containing the corresponding individual fitness values, *FitnV*. This function ranks individuals for minimization.

$$FitnV = ranking\ (sse) \tag{13}$$

The algorithms for ranking sorts the objective functional values in a descending order. The least fit individual is placed in position 1 in the sorted list of objective values and the fittest individual is positioned to the end. A fitness value is then assigned to each individual depending on its position in the sorted population. The role of ranking is that the smaller the value of SSE, the larger the value of its *FitnV*. GA tends to choose the SSE with a larger *FitnV* for the next generation.

Selection

Select performs the selection of individuals from a population, *Chrom*.

$$SelCh = select\ (\text{'sus'},\ Chrom,\ FitnV,\ GGAP) \tag{14}$$

where *SelCh* is the returned selected individuals in a new population; *sus* is a string and contains the name of the low-level selection function; and *GGAP* is an optional parameter specifying the generation gap, the fraction of the population to be reproduced. *GGAP* is 0.5 (default value) in this research which means that 50 percent of the 16 populations are reproduced for the next generation.

The objective of this step is to select the number of agents to conduct crossover, mutation and so on, and finally create the new generation.

Crossover and Recombination

Recombine performs the recombination of individuals from a population, *Chrom*. Each row of *Chrom* and the new generated *Chrom* corresponds to one individual.

$$SelCh1 = recombine\ (\text{'xovsp'},\ SelCh,\ RecOpt) \tag{15}$$

where *SelCh1* is the returned recombined individuals in a new population; *xovsp* is a string and contains the name of the low-level recombination function; and *recOpt* is an optional parameter specifying the crossover rate. The value of 0.7 (default value) used in this thesis means that the crossover occurs at 70 percent of the 8 populations.

Mutation

Mut takes the representation of the current population, *SelCh2*, and mutates each element with a given probability of *Pm*.

$$SelCh2 = mut\ (SelCh1,\ Pm) \tag{16}$$

where *SelCh2* takes the current population with each row corresponding to an individual, and mutates each element with a probability *Pm*. The value of *Pm* in this research is 0.7/Lind (default value), where Lind is the length of the chromosome structure.

Create New Generation

Rep is a low-level replication function. Not normally used directly, rep is called by a number of functions in the GA-Toolbox. *Rep* performs the replication of matrixes, *SelCh* or *SelCh2*, specifically by the numbers of 1 and returns the replicated matrix, *Chrom*, which is the new generation.

$$Chrom = [rep\ (SelCh,\ [1\ 1]);\ rep\ (SelCh2,\ [1\ 1])] \tag{17}$$

The above steps will iterate continually until the satisfied SSE values are discovered. AUTOSIM is the most time-consuming part, which lasts for 2 to 3 minutes, and it usually takes 40 minutes to finish one generation's searching.

4.4.3 Developed Computer Program AUTOSIM

Figure 10 shows the flowchart of AUTOSIM, which is designed to express the relationship between SSE and the 10 driving behavior parameters. In another word, AUTOSIM inputs the 10 parameter values and outputs the SSE. More detailed explanations for this program are presented in the following part.

There are three input files for AUTOSIM: "parameter.txt," "iahd.inp" and "iah_gps_speed.txt." The file "parameter.txt" stores the input values of the 10 driving behavior parameters. The file "iahd.inp" is generated by VISSIM after coding the traffic simulation. This file stores all the information about the simulated road network, including the default values of the 10 driving behavior parameters. The file "iah_gps_speed.txt" stores the vehicle speeds collected with GPS at each pre-defined cross-section.

First, AUTOSIM reads the input values of the driving behavior parameters in the file "parameter.txt."

Second, AUTOSIM reads the file "iahd.inp" character by character and writes the character into the file "iah.inp." During this process, when reaching at the default values of the driving behavior parameters in "iahd.inp," AUTOSIM writes the input values into "iah.inp." Thus, in "iah.inp" the input values of parameters are replaced by the default values.

Third, AUTOSIM runs the traffic simulation automatically by implementing the following sentence:

```
Shell("vissim.exe iah.inp -s1", 1)
```

After running the simulation, VISSIM outputs the results into the file "iah.mes." This file contains the simulated vehicle speeds at each pre-defined cross-section.

Fourthly, AUTOSIM reads the simulated vehicle speeds at each pre-defined cross-section in "iah.mes." Then AUTOSIM reads the vehicle speeds collected with GPS at each pre-defined cross-section in "iah_gps_speed.txt."

Then AUTOSIM calculates SSE based on Equation (3).

Finally AUTOSIM outputs the SSE into the file "sse.txt."

The code of AUTOSIM is listed in Appendix D.

This computer program is developed with Visual Basic 6.0.

CHAPTER 5

CASE STUDY

5.1 Identification of the Airport Road Network

In order to implement the proposed microscopic framework, a case study is conducted. Intercontinental Airport of Houston (IAH) is identified for this case study.

The IAH consists of five terminals --- A, B, C, D and E. Terminal E has been being built since 2002 and has not been completed yet at the time of writing this report. Figure 11 shows the overall layout of the terminals excluding terminal E.

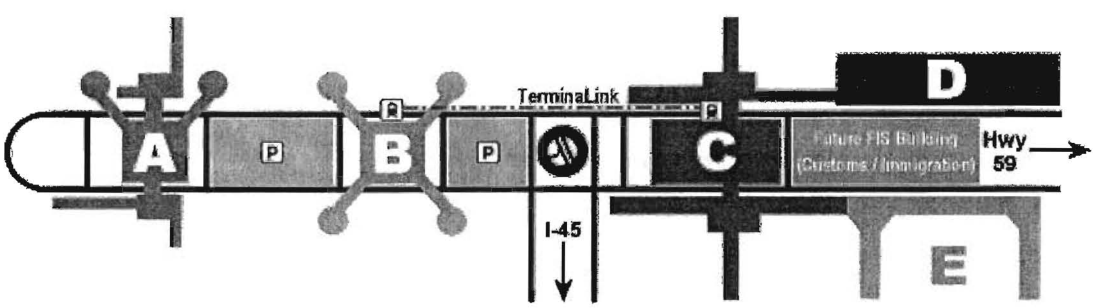


FIGURE 11 Illustration of terminals at Bush Intercontinental Airport of Houston.

The simulation area contains various facilities including one-way roads, bridges, parking-lots, a hotel, and bus stations. The roads in this network connect five terminals (Terminals A, B, C, D and E), five parking lots and a hotel at present. There are two entrances and one exit. Figure 12 shows the road network simulated in VISSIM.

5.2 Data Collection

The data collection is the first step towards analyzing the traffic behavior and emission estimations around the airport area. By means of field studies, we can expect to assemble a complete inventory of existing networks, transit facilities, and the parking structure. Passengers to the airport have a variety of transfer and transportation options available to them once they arrive at the airport. These include taxis, private limousines, scheduled buses/shuttles, courtesy vans, and even public transportation. Services can take the passengers to the nearby or downtown hotel or wherever the surrounding area. All of these are transferred into traffic volumes, which are the most important element for the simulation.

In order to meet the input requirements of VISSIM, we need to collect the data in four categories. The first is the vehicle type. As we mentioned earlier, various types of vehicles run around terminals that forming a very unique and complicated traffic stream. They are categorized into three typical types: passenger cars, trucks, and buses. The second is the total amount of traffic volumes entering the airport and the vehicle turning ratios at each intersection. The third is the length of the stop time of vehicles in front of each terminal. The fourth is the vehicle's instantaneous speed, which is the key factor for the emission estimation.

5.2.1 Traffic Volume Counting and Turning Ratio Calculation

Traffic Volume Counting

To count traffic volumes, a total of 21 intersections or points are identified, which are expressed by the letters A to N, as shown in Figure 12.

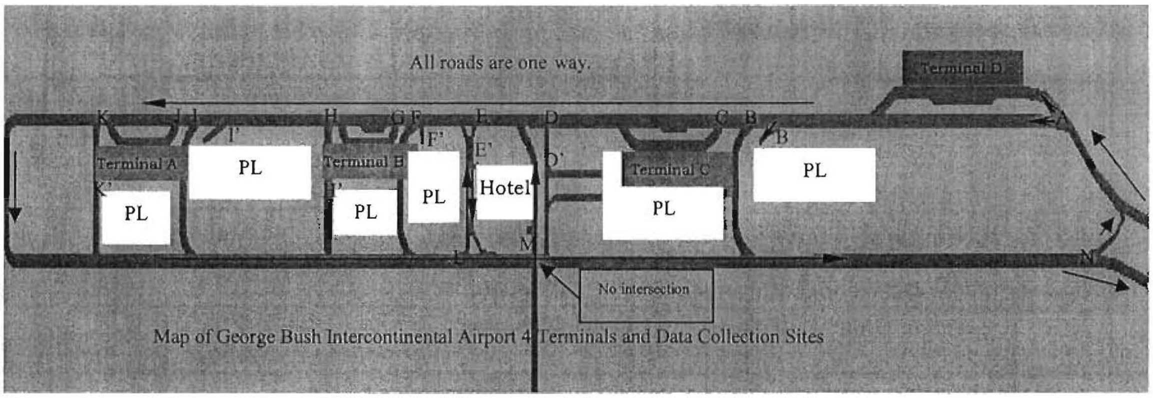


FIGURE 12 Data collection sites at IAH.

Data were collected on August 28 and 29, 2002. Table 3 provides the locations and the time periods for the data collection. A total of 8 graduate research assistants helped collect the data. They were divided into 4 groups. The data were collected in the afternoon, which was from 2:00PM to 4:00PM. It needs to be aware that for the airport entrance, the morning peak-hour data were also collected, which was from 7:00 AM to 9:00AM.

TABLE 3 Locations and Time Schedule for Data Collection

#	Site	Site Descriptions	Time	Group
1	A	Airport entrance. Traffic volumes for all types of vehicles. Traffic volumes at site A.	7:00-9:00 AM 2:00-3:00 PM (Aug 28, 2002)	1
2	B/B'	B: Traffic volumes (one goes through, and the other goes to the second floor of T-C); B': Traffic volumes in and out of the parking lot.	2:00-3:00 PM (Aug 28, 2002)	2
3	C	Traffic volumes (one goes through, the other going to T-C).	3:30-4:30 PM (Aug 28, 2002)	2
4	D/D'	D: Traffic volumes (one goes through, and the other turns); D': Traffic volumes in and out of the parking lot.	2:00-3:00 PM (Aug 28, 2002)	3
5	E/E'	E: Traffic volumes (one goes through, and the other turns); E': Traffic volumes in and out of the hotel.	3:30-4:30 PM (Aug 28, 2002)	3
6	F/F'	F: Traffic volumes (one goes through, and the other goes to the second floor of T-B); F': Traffic volumes in and out of the parking lot.	2:00-3:00 PM (Aug 28, 2002)	4
7	G	Traffic volumes (one goes through, and the other goes to T-B).	3:30-4:30 PM (Aug 28, 2002)	4
8	H/H'	H: Traffic volumes (one goes through, and the other turns); H': Traffic volumes in and out of the parking lot.	3:30-4:30 PM (Aug 29, 2002)	1
9	I/I'	I: Traffic volumes (one goes through, and the other goes to the second floor of T-A); I': Traffic volume in and out of the parking lot.	2:00-3:00 PM (Aug 29, 2002)	2
10	J	Traffic volumes (one goes through, and the other goes to T-A).	3:30-4:30 PM (Aug 29, 2002)	2
11	K/K'	K: Traffic volumes (one goes through, and the other turns); K': Traffic volumes in and out of the parking lot.	2:00-3:00 PM (Aug 29, 2002)	3
12	L	Traffic volumes (one goes through, and the other turns).	3:30-4:30 PM (Aug 29, 2002)	3
13	M	Traffic volumes include: goes through, goes into the hotel and goes out of the hotel. (There are one entrance and two exits of the hotel.)	7:00-9:00 AM 2:00-3:00 PM (Aug 29, 2002)	1
14	N	Traffic volumes (one goes out of the terminal area, and the other goes to terminal D again).	3:30-4:30 PM (Aug 28, 2002)	1

Turning Ratio Calculation

The turning ration is a very important parameter in the traffic simulation. As there is only one-way road that exists in the simulation network, it simply forms one turning movement at each intersection, which contains either left turn movement or right turn movement. Given v_g as the number of traffic going through and v_t as the number of traffic turning at the intersection, the percentage of traffic volume going through the intersection P_{V_g} is

$$P_{V_g} = \frac{v_g}{v_g + v_t} \times 100\% \tag{16}$$

The percentage of traffic volume turning at the intersection P_{V_t} is

$$P_{V_t} = \frac{v_t}{v_g + v_t} \times 100\% \tag{17}$$

Table 4 shows the collected data and calculated turning ratios.

TABLE 4 Traffic Volume and Turning Ratio at each Intersection

Sites	Through Traffic				Turning Traffic				En	Out	Total	P_{V_g}	P_{V_t}
	Car	Bus	Truck	Total	Car	Bus	Truck	Total	PL/hotel	PL/hotel			
	999	263	285	**1547**	186	340	41	**567**	N/A	N/A	**2114**	**73%**	**27%**
A	700	135	162	**997**	354	N/A	55	**610**	N/A	N/A	**1607**	**62%**	**38%**
B	471	64	36	**571**	230	31	2	**263**	N/A	N/A	**834**	**68%**	**32%**
B'	701	95	38	**834**	N/A	N/A	N/A	N/A	100	N/A	**934**	**89%**	**11%**
C	671	283	21	**975**	67	0	0	**67**	N/A	N/A	**1042**	**94%**	**6%**
D	273	135	70	**478**	799	120	143	**1062**	N/A	N/A	**1540**	**31%**	**69%**
D'	578	120	129	**827**	N/A	N/A	N/A	N/A	235	272	**1062**	**78%**	**22%**
E	542	192	85	**819**	74	16	13	**103**	N/A	N/A	**922**	**89%**	**11%**
E'	46	15	10	**71**	N/A	N/A	N/A	N/A	32	4	**103**	**69%**	**31%**
F	517	194	29	**740**	53	21	8	**82**	N/A	N/A	**822**	**90%**	**10%**
G	507	26	73	**606**	58	162	2	**222**	N/A	N/A	**828**	**73%**	**27%**
H, H', I'	461	240	99	**800**	N/A	N/A	N/A	N/A	108	126	**908**	**88%**	**12%**
I	310	173	32	**515**	125	7	1	**133**	N/A	N/A	**648**	**79%**	**21%**
J	287	179	16	**482**	223	60	3	**286**	N/A	N/A	**768**	**63%**	**37%**
K	372	14	85	**471**	38	187	2	**227**	N/A	N/A	**698**	**67%**	**33%**
K'	372	14	85	**471**	N/A	N/A	N/A	N/A	18	9	**489**	**96%**	**4%**
L	572	225	116	**913**	67	41	16	**124**	N/A	N/A	**1037**	**88%**	**12%**
	526	102	146	**774**	N/A	N/A	N/A	N/A	24	18/20	**798**	**97%**	**3%**
M	321	48	74	**443**	N/A	N/A	N/A	N/A	24	77/16	**467**	**95%**	**5%**
N	N/A	N/A	N/A	**1765**	N/A	N/A	N/A	**405**	N/A	N/A	**2170**	**81%**	**19%**

5.2.2 Projected Traffic Volume for One Week

Traffic volumes for hours other than the data collection hours, as well as other days are projected based on the forecasted travel patterns for the airport. These patterns are the hourly traffic volumes for one week in 1995, which were presented by IAH. By comparing the collected data with the historical data, we can get the traffic volume ratio for the period when the field data were collected, which is used to produce traffic volumes for other hours. In this way, the effort needed to collect the field data is minimized, while the overall travel patterns at the airport are maintained. Figure 13 to 19 illustrate the projected traffic volume distributions for a 24-hour period of each day of one week. Table 5 provides all the projected traffic volumes for one week.

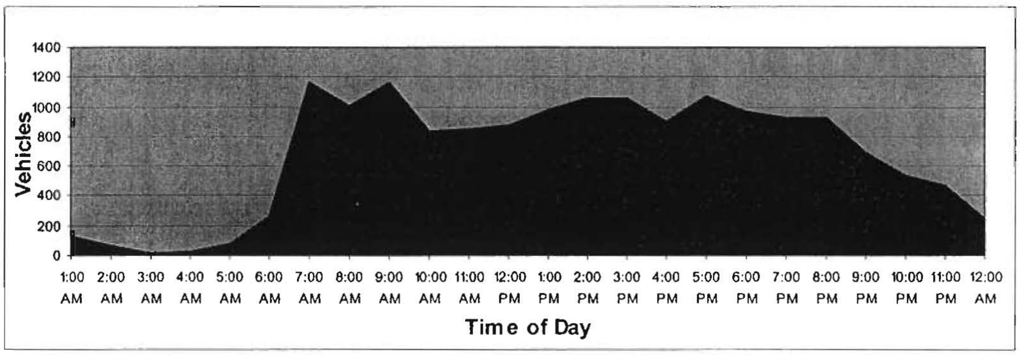


FIGURE 13 Projected hourly distributions of traffic volumes on Monday.

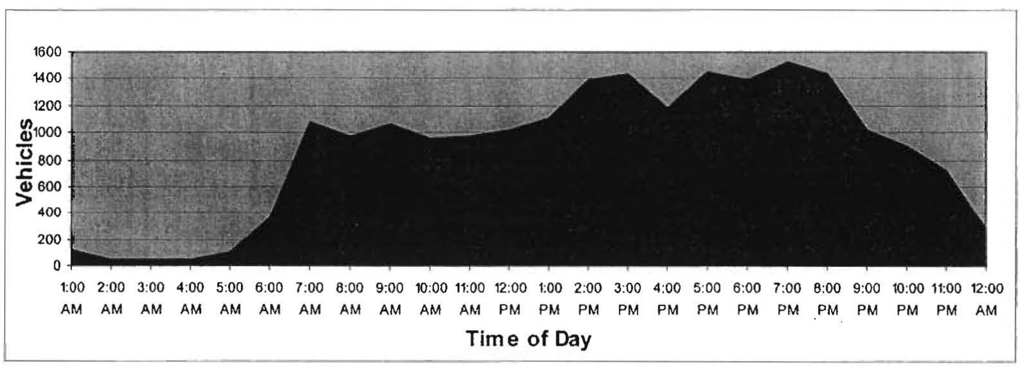


FIGURE 14 Projected hourly distributions of traffic volumes on Tuesday.

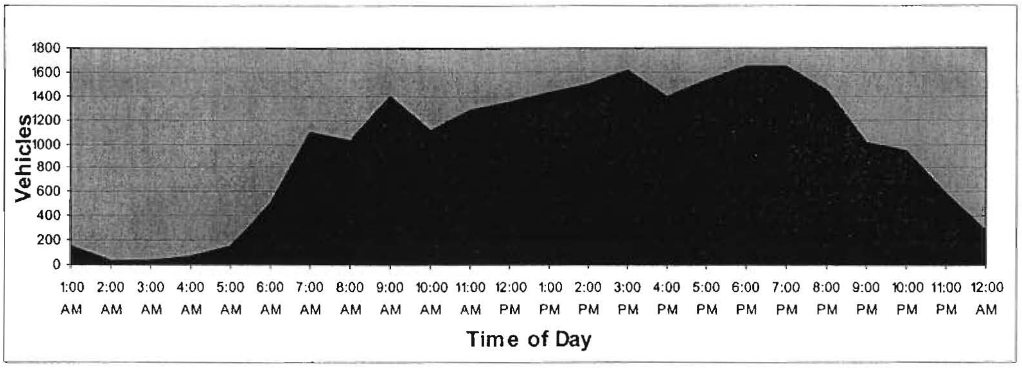


FIGURE 15 Projected hourly distributions of traffic volumes on Wednesday.

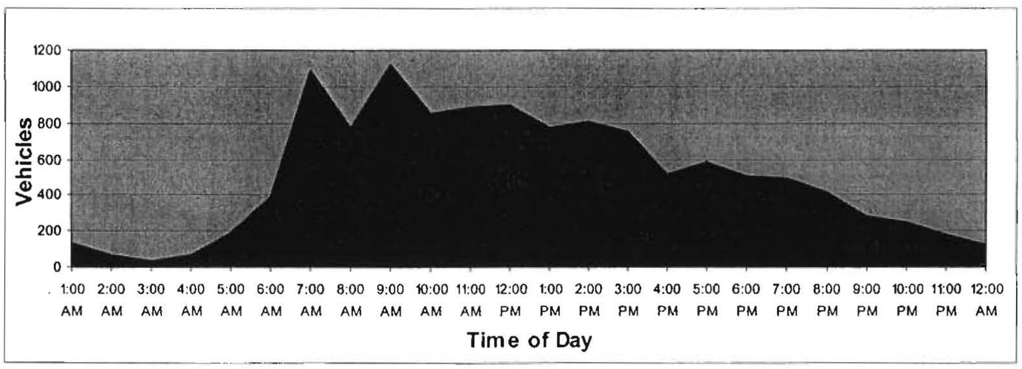


FIGURE 16 Projected hourly distributions of traffic volumes on Thursday.

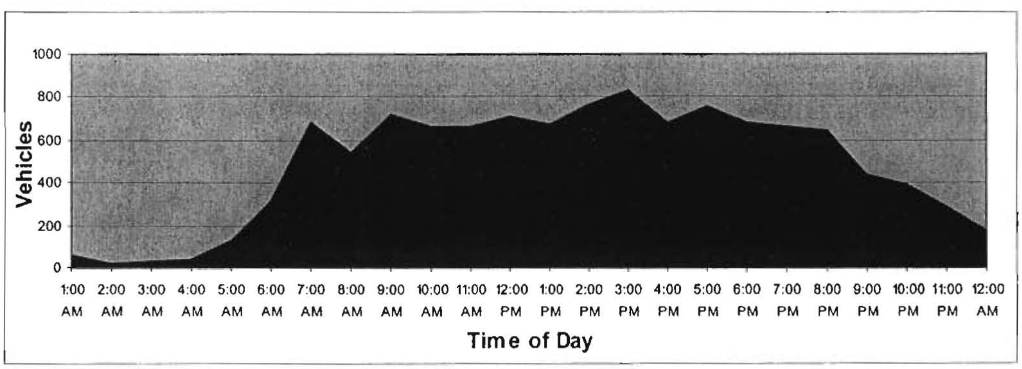


FIGURE 17 Projected hourly distributions of traffic volumes on Friday.

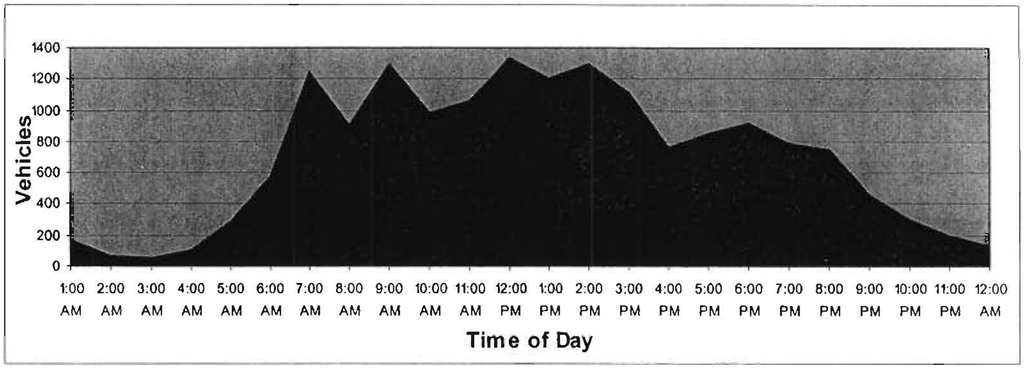


FIGURE 18 Projected hourly distributions of traffic volumes on Saturday.

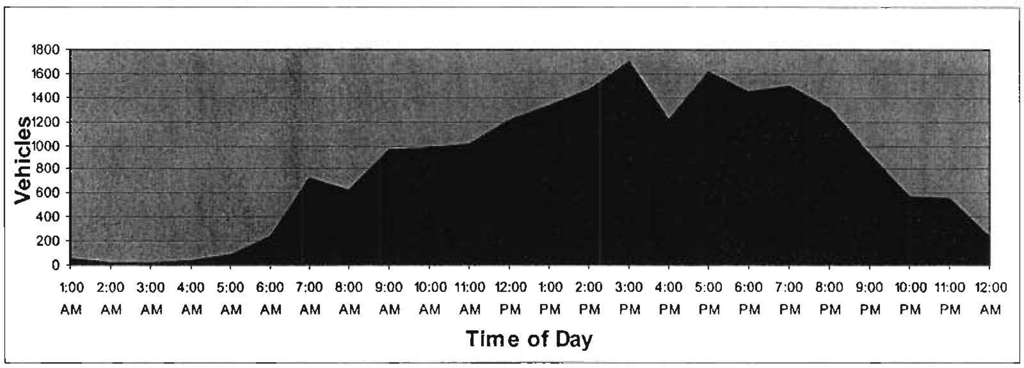


FIGURE 19 Projected hourly distributions of traffic volumes on Sunday.

TABLE 5 Hourly Traffic Volumes Projected for One Week in 2002 Based on the Forecasted Travel Patterns

Time	Monday			Tuesday			Wednesday			Thursday			Friday			Saturday			Sunday		
	Car	Truck	Bus	Car	Truck	Bus	Cark	Truck	Bus	Car	Truck	Bus	Car	Truck	Bus	Car	Truck	Bus	Car	Truck	Bus
1:00	92	23	19	79	20	16	103	26	21	96	24	20	41	10	8	120	30	24	38	10	8
2:00	41	10	8	30	8	6	26	6	5	46	12	9	19	4	3	49	12	10	17	4	4
3:00	11	3	2	29	7	6	18	4	4	21	5	4	25	5	4	32	8	7	11	3	2
4:00	20	5	4	33	8	7	42	10	8	49	12	10	35	7	6	68	17	14	20	5	4
5:00	58	14	12	76	19	15	107	27	22	144	36	29	116	23	19	196	49	40	61	15	12
6:00	184	46	37	251	63	51	347	87	71	291	73	59	270	54	44	398	99	81	167	42	34
7:00	798	199	162	738	184	150	757	189	154	803	201	163	590	118	96	856	214	174	500	125	102
8:00	689	172	140	672	168	137	709	177	144	570	143	116	463	93	75	618	154	126	431	108	88
9:00	798	199	162	730	183	149	959	240	195	831	208	169	618	124	101	892	223	181	660	165	134
10:00	574	143	117	658	164	134	764	191	156	628	157	128	570	114	93	673	168	137	677	169	138
11:00	581	145	118	671	168	137	885	221	180	655	164	133	567	113	92	732	183	149	700	175	142
12:00	605	151	123	699	175	142	931	233	189	661	165	134	614	123	100	915	229	186	835	209	170
13:00	677	169	138	764	191	155	985	246	200	573	143	117	575	115	94	830	208	169	918	230	187
14:00	733	183	149	955	239	194	1031	258	210	596	149	121	661	132	108	892	223	181	1004	251	204
15:00	733	183	149	983	246	200	1106	276	225	554	139	113	712	142	116	768	192	156	1171	293	238
16:00	621	155	126	810	202	165	964	241	196	378	95	77	590	118	96	527	132	107	831	208	169
17:00	736	184	150	995	249	202	1057	264	215	431	108	88	648	130	105	581	145	118	1109	277	226
18:00	662	166	135	957	239	195	1134	283	231	372	93	76	584	117	95	626	156	127	1000	250	204
19:00	644	161	131	1046	262	213	1134	284	231	368	92	75	571	114	93	538	135	109	1031	258	210
20:00	640	160	130	985	246	200	996	249	203	309	77	63	552	110	90	510	127	104	898	224	183
21:00	481	120	98	697	174	142	697	174	142	208	52	42	380	76	62	311	78	63	640	160	130
22:00	367	92	75	621	155	126	643	161	131	185	46	38	335	67	54	206	51	42	394	99	80
23:00	321	80	65	490	123	100	406	101	83	132	33	27	248	50	40	135	34	28	385	96	78
0:00	170	42	35	197	49	40	200	50	41	89	22	18	157	31	25	89	22	18	158	40	32

5.2.3 Vehicle Instantaneous Speed Collection

GPS Application

The GPS system made by GARMIN is used to collect the vehicle speed data. In order to collect the speed data from GPS, it is necessary to set the function of 10-meter automatic data collection. Default settings are sustained for other parameters. MAPSOURCE, which is a software provided with GPS, is used to process the collected data. Figure 20 is retrieved from MAPSOURCE, which presents the testing vehicle's running trajectory around data collection area.

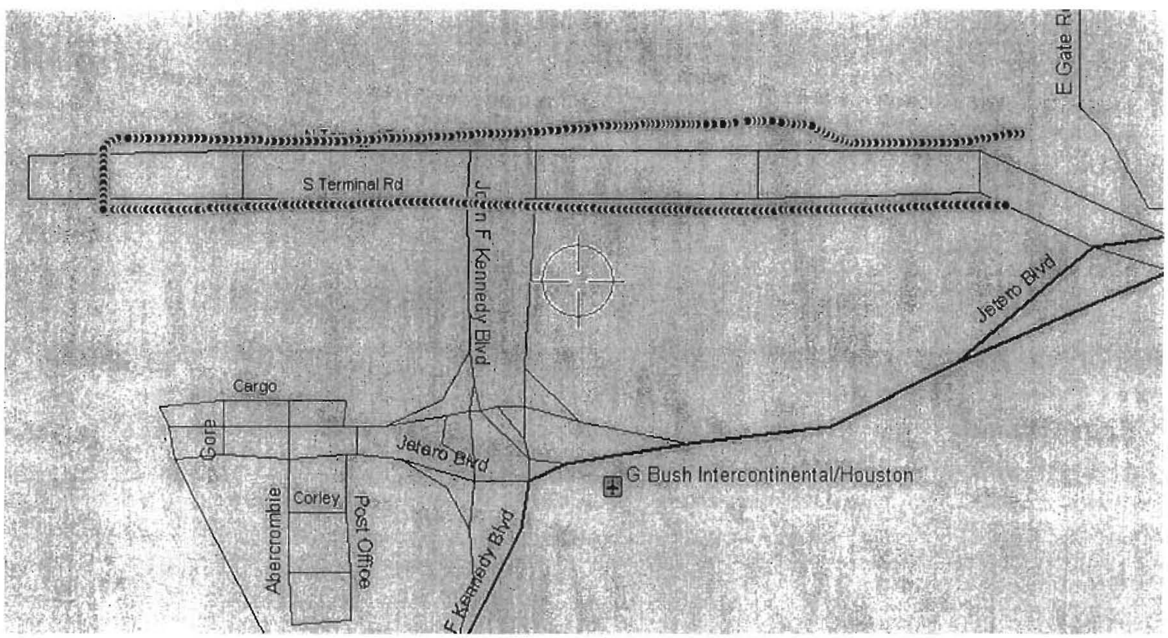


FIGURE 20 Vehicle speed collecting trajectory retrieved from MAPSOURCE.

Speed Collection

The objective of collecting the instantaneous speeds is that it will be used as a sample value that to be compared with the speed data generated from VISSIM. For this objective, six sections were defined to conduct the data collection as shown in Figure 21.

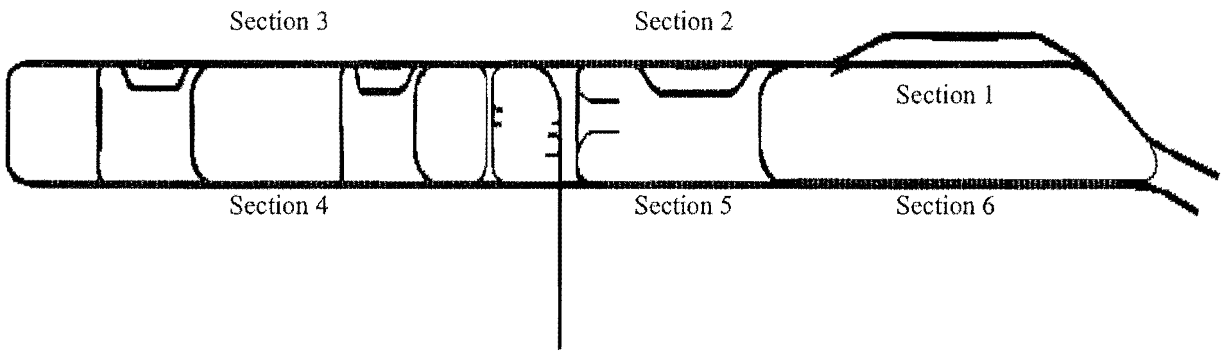


FIGURE 21 Six sections around the airport terminal loop.

The six sections are:

- Section 1 is in front of Terminal D, connecting with the airport entrance. The total length is 490 meters.
- Section 2 is in front of Terminal C and Marriot Hotel. The length is 460 meters.
- Section 3 covers the front road of Terminals A and B. The length is 750 meters.
- Section 4 covers the road behind Terminals A and B and Marriot Hotel. The length is 910 meters.
- Section 5 is behind Terminal C. It is the shortest section with a length of 320 meters.
- Section 6 is the airport exit road with a length of 590 meters.

The testing car ran 14 cycles on the airport loop. The driver complied with the floating car method.

There was 1 speed data collected on every 10 meters along the 6 sections when the testing car ran 1 cycle. The speed data from all the cycles were averaged. The results are listed in Appendix G.

5.3 Traffic Simulation and Model Calibration

5.3.1 Traffic Simulation

In the traffic simulation, the first step is to build a network with a background map (see Figure 11) with an appropriate scale. Pedestrian road has not been considered in this network because of its insignificant effect on the whole simulation results. There is no signalized intersection in the network.

The second step is to define vehicle types in VISSIM. In Figure 22, cars 1 to 6 represent different colors of passenger vehicles. Both Bus and BUS1 represent public transportation modes with different body colors. The Little truck represents the regular sized truck and the Testing car is used for the calibration.

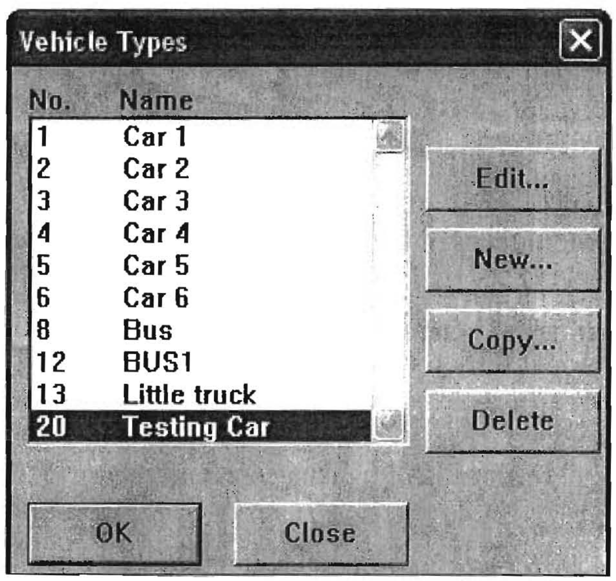


FIGURE 22 Defined vehicle types in VISSIM.

The third step is to input the traffic volumes and vehicle turn ratios at the intersections. The traffic volumes are listed in Table 5. Figure 23 shows the turning ratios assigned at a sample intersection near one of the airport entrances.

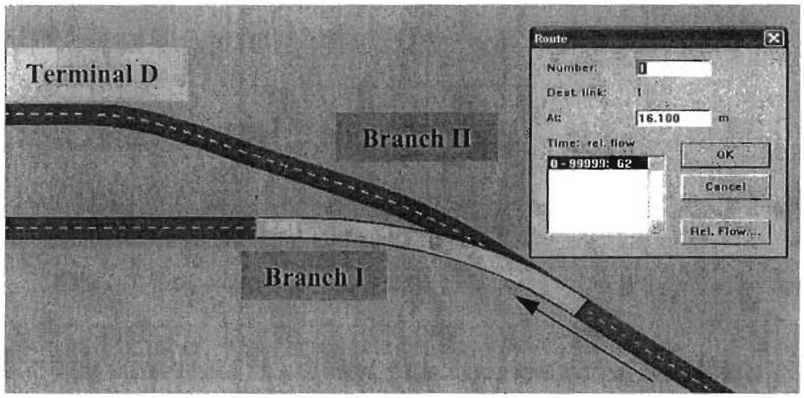


FIGURE 23 Turning ratios assigning at a sample intersection.

The fourth step is to set up the traffic signs, such as stop signs, yield signs, and the reduced speed area. Figure 24 shows one of the yield signs. The yield signs are set up on the exit of Terminal D connecting to the airport loop.

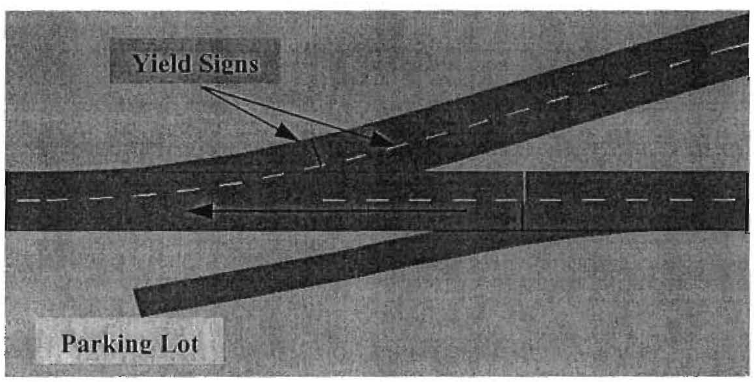


FIGURE 24 Yield signs at the exit road of Terminal D.

Figure 25 shows a reduced speed area before the curve near Terminal A. The reduced speed area here is used to reduce the vehicle speed so that the vehicle can pass the curve with an acceptable speed.

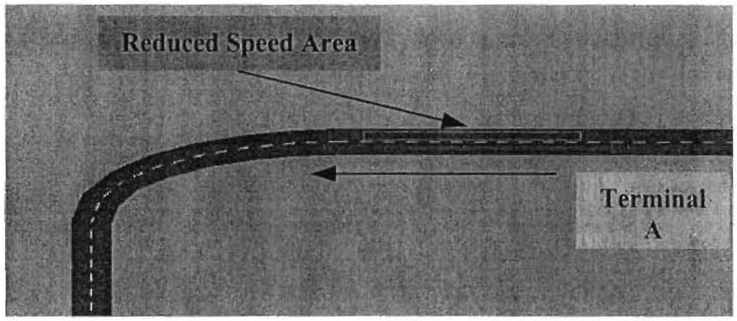


FIGURE 25 Reduced speed area near Terminal A.

The fifth step is to set up the bus routes. The bus route needs to first specify two components: the point generating buses, and the area used as a bus station. When the bus route is generated, we need to input the following data: the time when the first bus enters the network, the rate to generate bus, and the waiting time of the bus at the stations. Figure 26 shows a bus route that goes to the second floor of Terminal C.

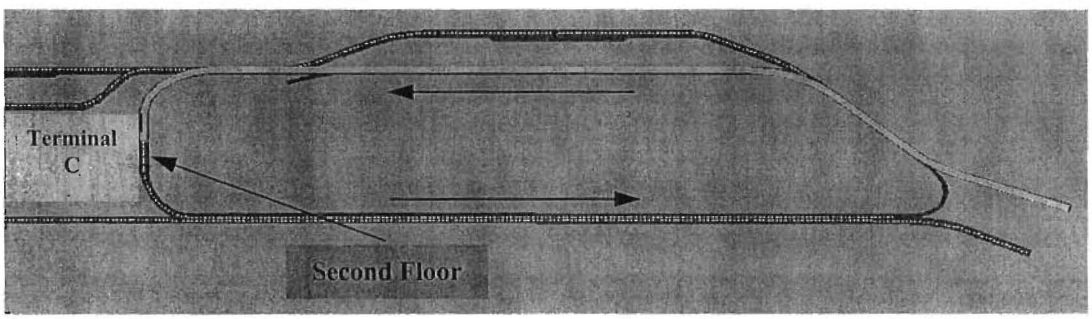


FIGURE 26 A sample bus route from the airport entrance to Terminal C.

The sixth step is to set up the cross-sections at a 10-meter interval along the loop. At each cross-section, the vehicle instantaneous speed is recorded as the vehicle passes by and the average value of all vehicles is output into a file. The GA-based approach uses the vehicle speed data simulated at the pre-defined cross-sections. A sample of these cross-sections is shown in Figure 27.

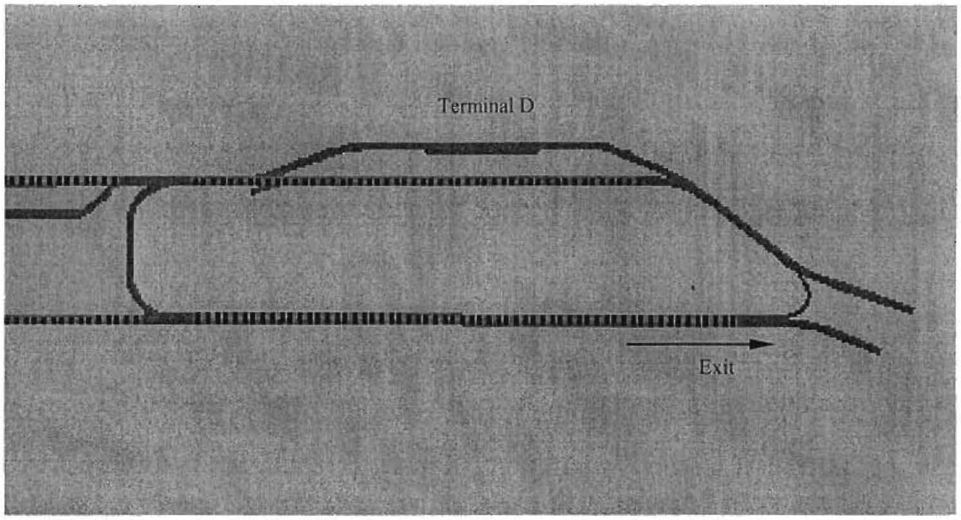


FIGURE 27 A sample of the cross-sections in the simulated network.

The seventh step is to set up the evaluation files. The "data collection" is selected to output the average vehicle speeds at the pre-defined cross-sections.

The final step is to run the network and fix any errors that may occur during the simulation. Figure 28 shows part of the three-dimensional simulation network. The road segment in the cycle is below the surface, and thus cannot appear in a 3D display.

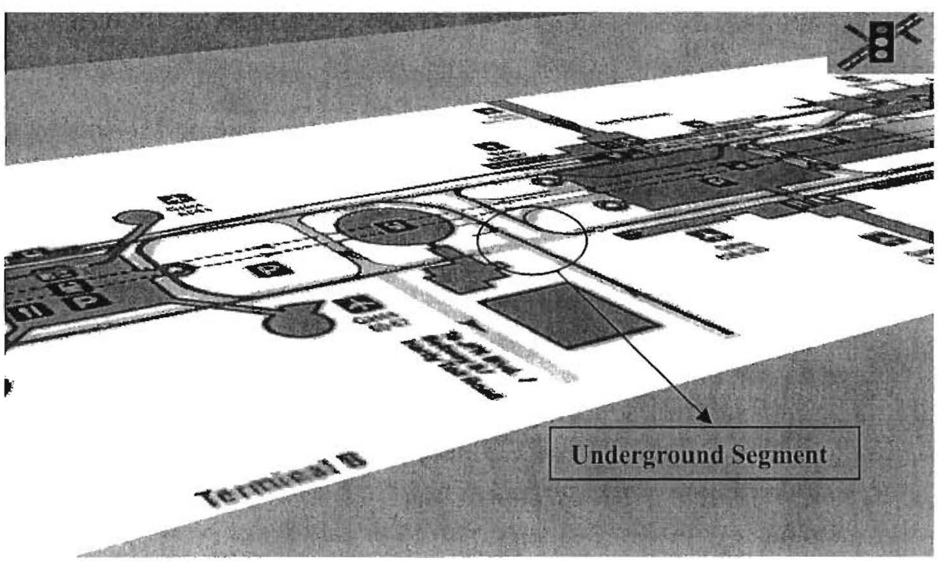


FIGURE 28 Part of simulation network with three dimensional view.

5.3.2 Model Calibration

Because of the existence of the terminal complex that generates unique traffic characteristics, the values of driving behavior parameters are expected to be different from the default values provided in VISSIM for urban streets and freeways. Here the calibration of driving behavior parameters for the IAH airport follows the proposed GA-based calibration approach.

The computer program developed to implement the proposed GA-based calibration approach is run to carry out the calibration process. One of the input files for the computer program is the prepared IAH traffic simulation file named "iahd.inp." Another input file is the one that contains the values of driving behavior parameters, in which the default values in VISSIM for urban street are used as the initial values. The third input file named "iah_gps_speed.txt" is the averaged instantaneous speeds of the testing vehicle collected by GPS on six sections. One of the output files records the calculated SSE values for the six sections. Another output file records the calibrated optimal values of the driving behavior parameters.

A criterion is specified on when the program should stop. In this case study, a criterion is specified as when either 10 consecutive generations have the same SSE, or the difference between SSEs from two consecutive runs is less than or equal to 1%. But there is an exception, which is that the program will keep running if two consecutive generations generate the same SSE. It happens because mutation cannot guarantee that the latter generation is definitely better than the former one. In other words, the program will keep the better SSE and wait for another mutation to occur, which may bring a better result. This criterion can always be changed to a different one in the practical applications. Table 6 illustrates the results from the calibration, in which the criterion is met after the program runs for 20 generations of the GA-based algorithm. Table 7 illustrates the results of SSE from the program for all 20 generations.

TABLE 6 The Default and Optimal Parameter Values

Parameter	Default Value	Optimal Value
1. Waiting time before diffusion (second)	60.00	47.10
2. Minimum headway (meter)	0.50	0.52
3. Maximum deceleration (m/s^2)	-3.00	-4.40
4. $-1m/s^2$ per distance (meter)	50.00	21.90
5. Accepted deceleration (m/s^2)	-1.00	-0.50
6. Maximum look ahead distance (meter)	250.00	226.80
7. Average standstill distance (meter)	2.00	0.90
8. Additive part of desired safety distance (meter)	2.00	0.20
9. Multiple part of desired safety distance (meter)	3.00	5.42
10.Distance of standing and at 30 mph (meter)	1.00	0.50

TABLE 7 Simulation Results of SSE from 20 Iterations

Generation #	SSE of the Best Agent	Difference of SSEs with the Previous Generation	% Difference
0	1056	N/A	N/A
1	1361		
2	1227	134	10.92
3	1195	32	2.68
4	1139	56	4.92
5	1025	114	11.12
6	979	46	4.70
7	914	65	7.11
8	901	13	1.44
9	799	102	12.77
10	694	105	15.13
11	608	86	14.14
12	608	0	0.00
13	608	0	0.00
14	608	0	0.00
15	608	0	0.00
16	608	0	0.00
17	590	18	3.05
18	549	41	7.47
19	538	11	2.04
20	533	5	0.94

With the default parameter values, which means 0 number of generation, the SSE is 1056. For the first generation, the agents are created at random, so the SSE of the best agent in this generation is 1361, greater than 1056, the default SSE.

After the computer program runs for 5, 10 and 20 generations, its values are reduced to 1025, 694 and 533 respectively. So the SSE has decreased almost 50% when the parameters are changed from the default values to the optimal ones.

For all of the six sections, the speeds collected versus simulated at the 10-meter interval pre-defined cross-sections are compared. The resulting speed profiles are shown in Figures 29 to 34.

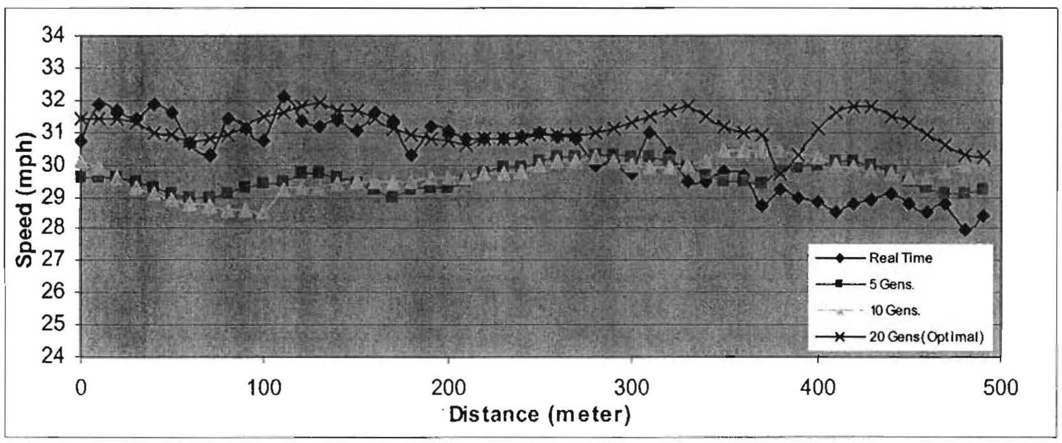


FIGURE 29 Comparison of vehicle speed profiles for Section 1.

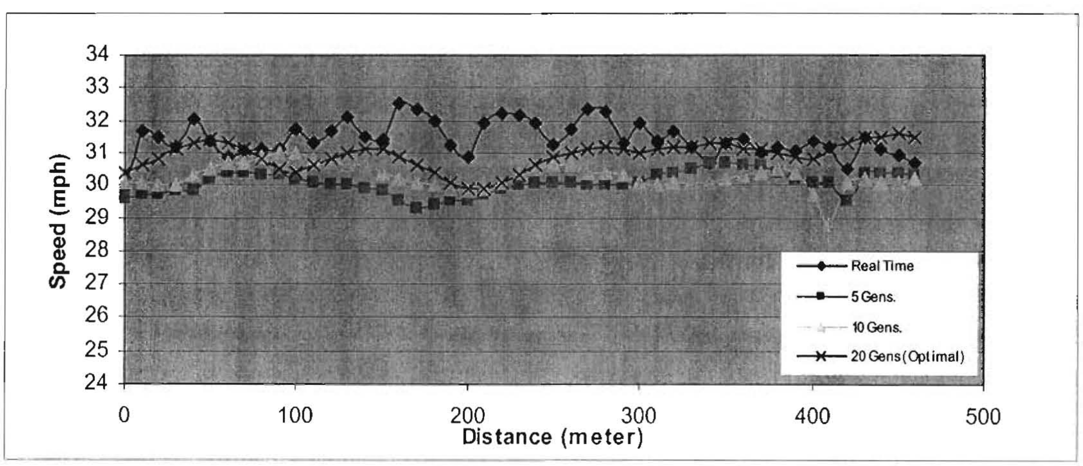


FIGURE 30 Comparison of vehicle speed profiles for Section 2.

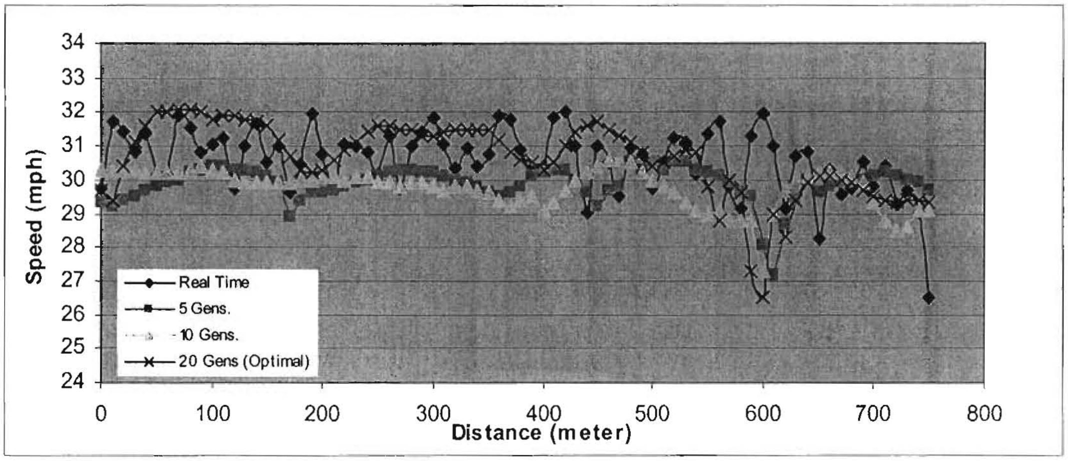


FIGURE 31 Comparison of vehicle speed profiles for Section 3.

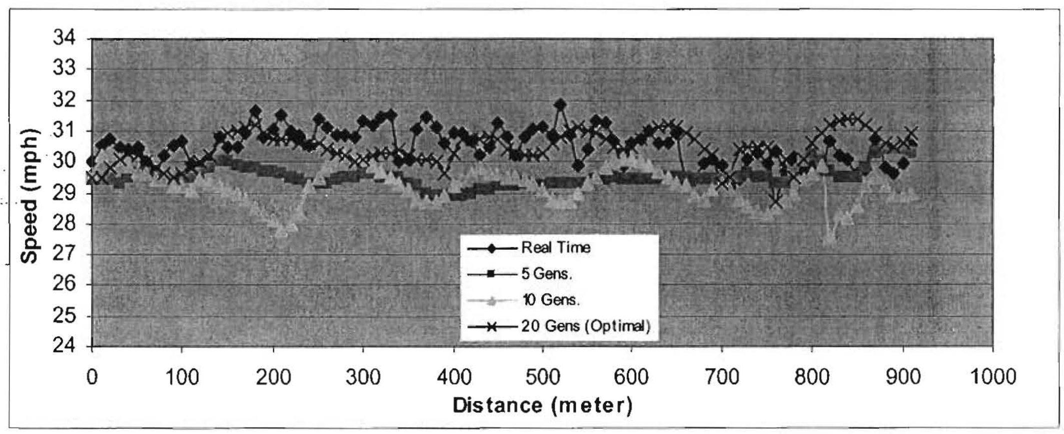


FIGURE 32 Comparison of vehicle speed profiles for Section 4.

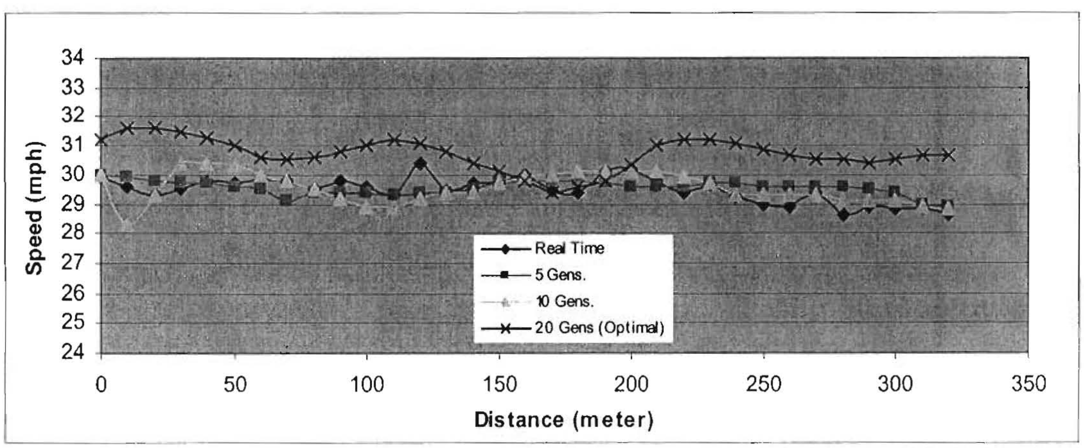


FIGURE 33 Comparison of vehicle speed profiles for Section 5.

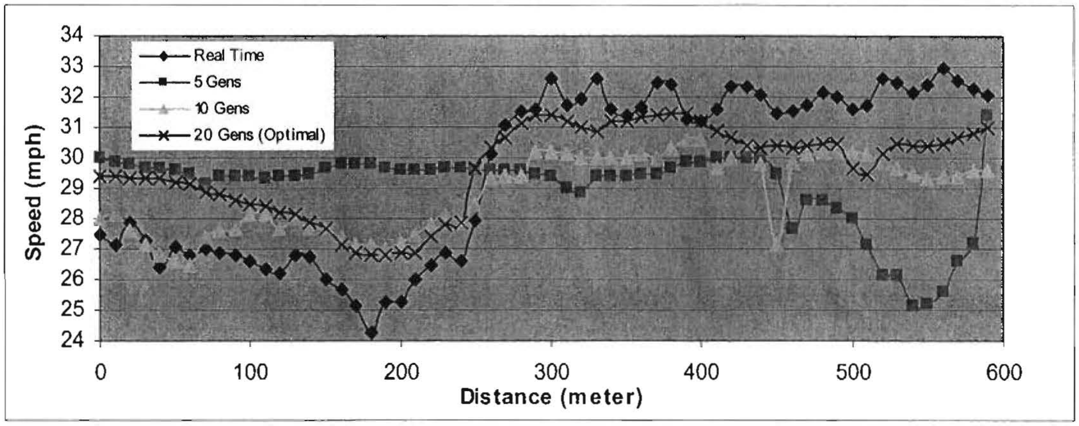


FIGURE 34 Comparison of vehicle speed profiles for Section 6.

The errors between the simulated speeds and the collected speeds at cross-sections for the particular Section 6 are computed for the comparison purpose. With the default parameter values, the errors are greater than 10% at 22 cross-sections, compared with only 2 cross-sections when the optimal parameter values are used, which are shown in Figure 35. The speed values are presented in Appendix H.

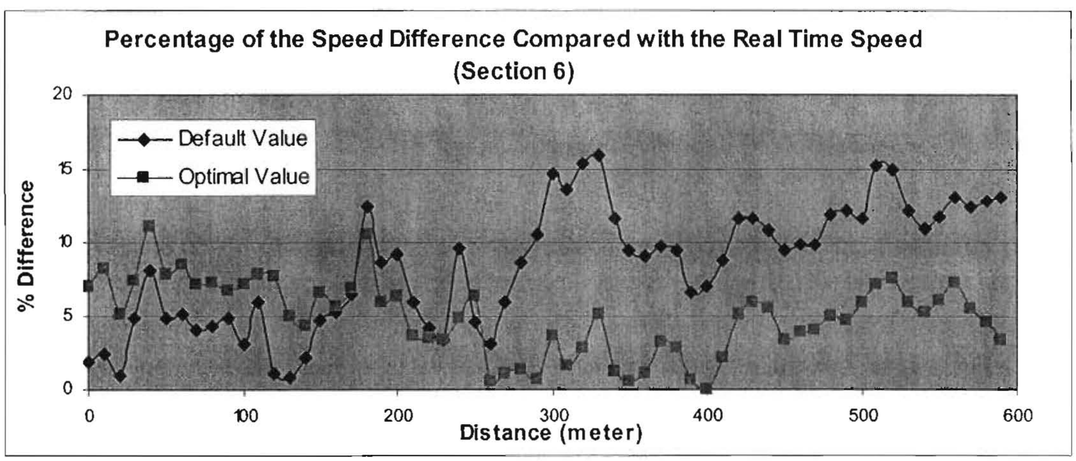


FIGURE 35 Errors of speeds at cross-sections with default values versus optimal values.

5.4 Emission Estimation

The mobile emission estimation is calculated for each hour of August 28, 2002. After inputting the calibrated driving behavior parameters, the traffic volumes by vehicle types and the turning ratios into VISSIM, the traffic simulation is run for each hour and the second-by-second vehicle activities of speed and acceleration or deceleration are derived. The output data from VISSIM are stored in a file named VISSIM.FZP, which includes the vehicle type, the simulation time in the unit of second, the vehicle number, the vehicle speed in the unit of miles per hour, and the vehicle acceleration/deceleration in the unit of meters per squared second. A computer program is developed to read and transfer all of these data from VISSIM to CMEM, and to calculate the emissions.

Considering the huge size of VISSIM.FZP file, which usually falls between 20Mb and 30Mb for only one-hour simulation, and the simulation time, usually several hours for each run, it is impossible to save the 24-hours' data in one single file. Furthermore, the calculation using CMEM generates a MS Access file with a size of several times larger than the original one. For example, the size of a new file will become 300 Mb after processing a 30 Mb FZP file. As such, a total of 24 separate FZP files are prepared in order to obtain the total amount of emissions for one single day.

After executing the CMEM, there are three kinds of files obtained for the scenario of each hour. The first includes the emissions of each vehicle on a second-by-second basis. The second includes the total emissions of each vehicle during the simulation time period. The third includes the total amount of emissions of all vehicles in one simulation hour.

Figures 36 to 38 illustrate the emission results during the consecutive 120 seconds for a selected bus during the simulation period from the 2100th second to the 2220th second, which is around 3:00 p.m. in the afternoon. Figure 36 illustrates the speed profile. In Figure 36, during the first 50 seconds, the bus runs normally along the road. The bus stops at the terminal for approximately 30 seconds, and then begins to accelerate to leave the bus station from the terminal. Figures 37 and 38 illustrate the various emission output profiles. In Figure 37, the t-X-gs represents tailpipe X emissions in grams per second.

Figures 39 to 41 illustrate the comparisons of the acceleration/deceleration profile with the profiles of CO_2, fuel and NOx respectively. Figures 39 to 41 show that the emission profiles well reflect the trends of the acceleration/deceleration profile.

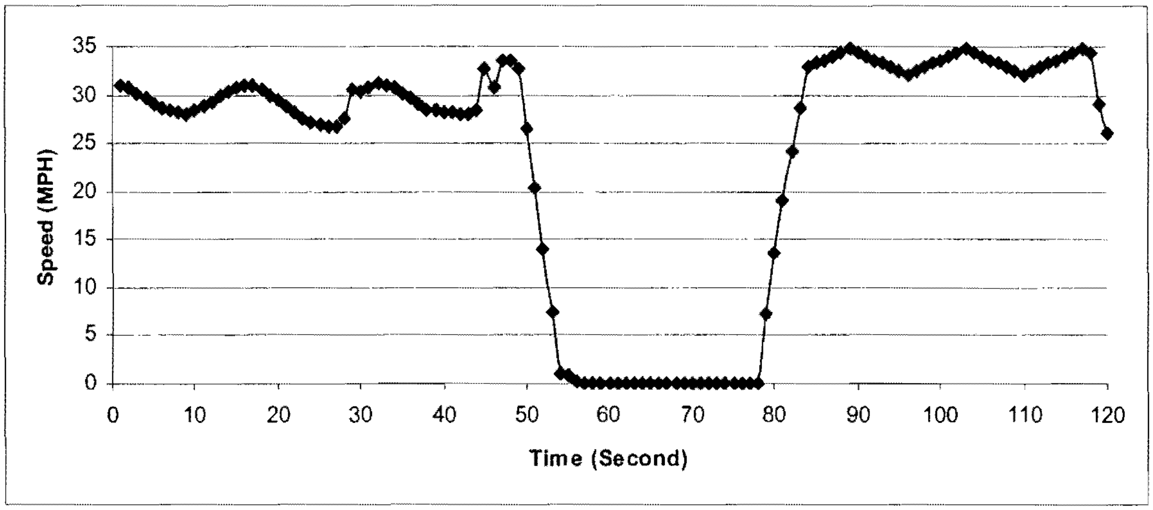


FIGURE 36 Vehicle instantaneous speeds.

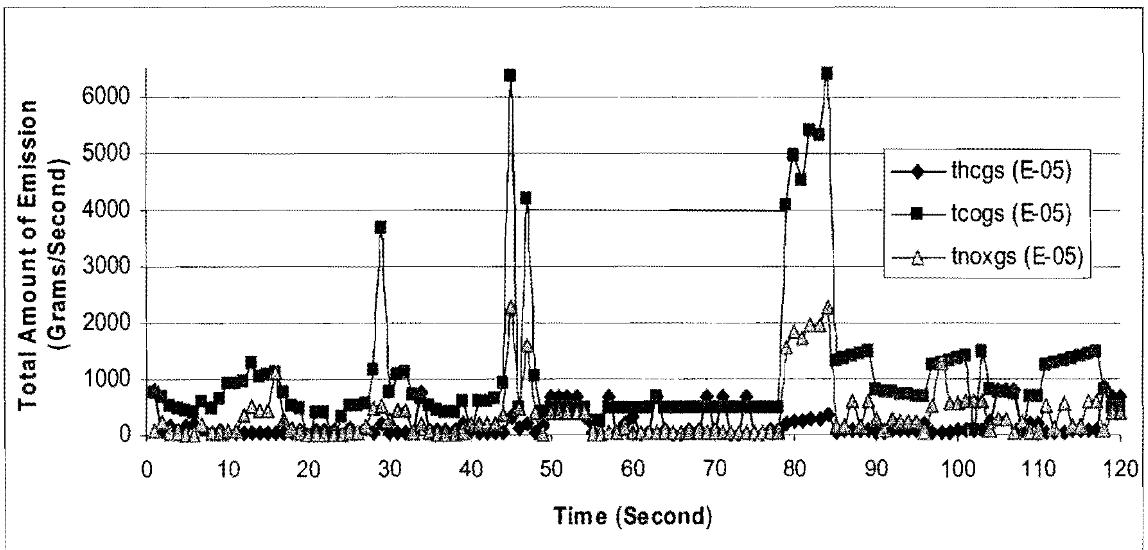


FIGURE 37 Emission amounts of a tailpipe HC, CO and NOx.

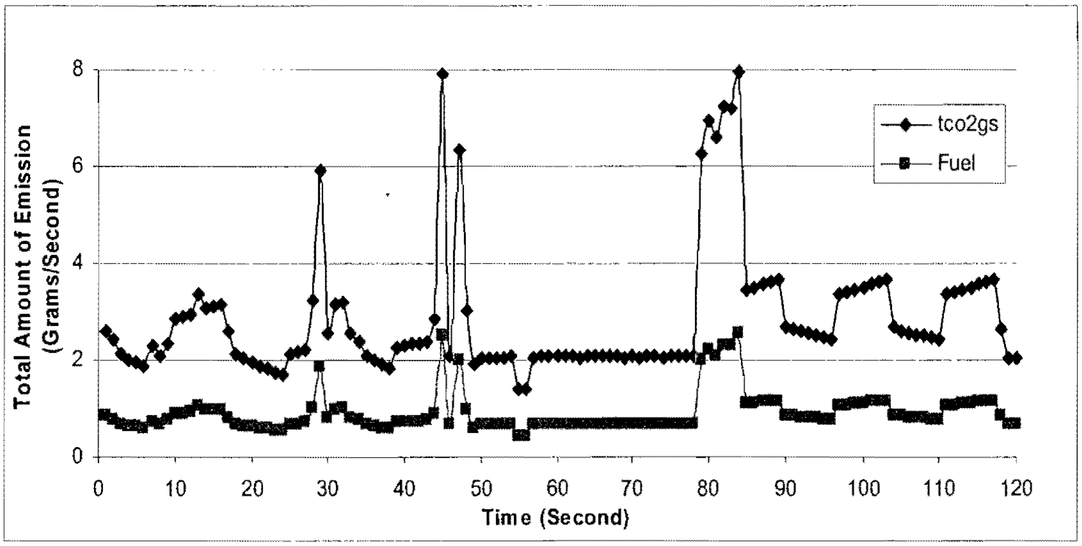


FIGURE 38 Emission amounts of tailpipe CO_2 and fuel use.

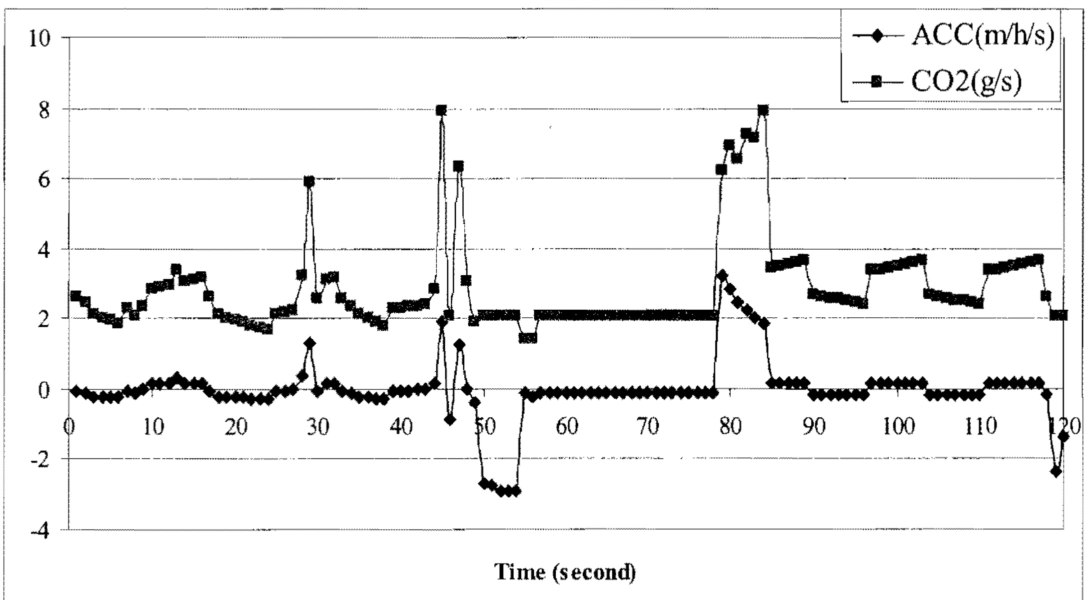


FIGURE 39 Profiles of acceleration/deceleration and CO_2.

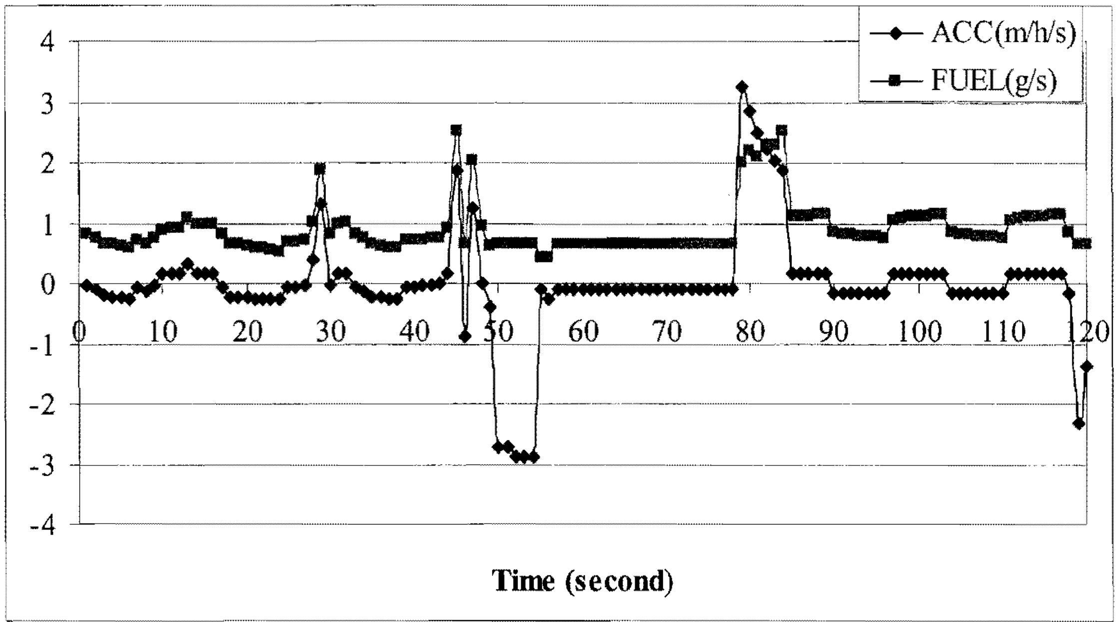


FIGURE 40 Profiles of acceleration/deceleration and Fuel.

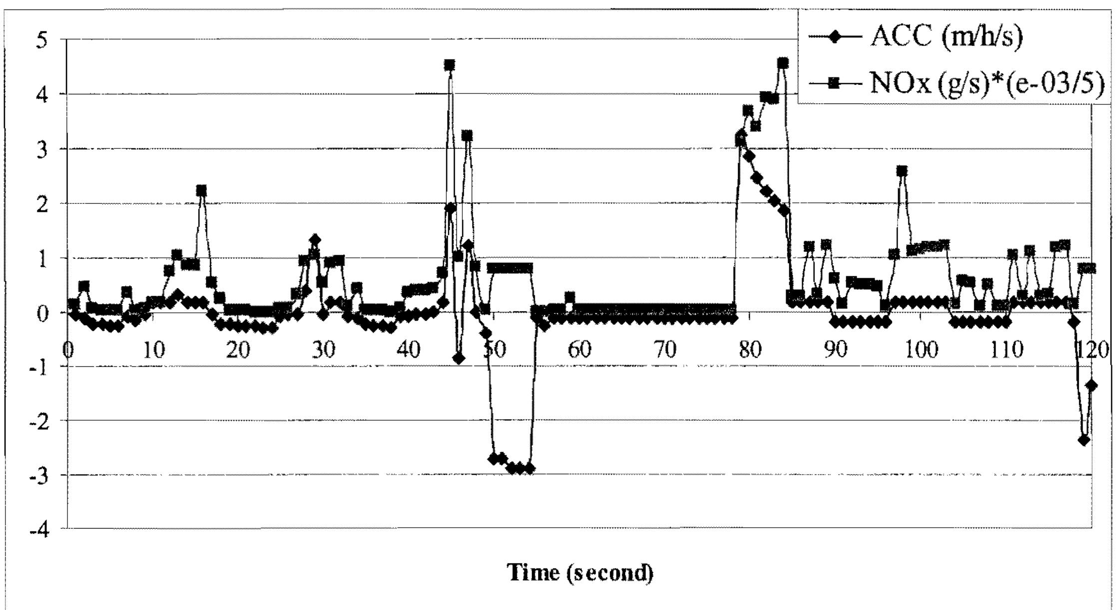


FIGURE 41 Profiles of acceleration/deceleration and NOx.

After modeling the emissions of each hour for a day by CMEM, the calculated emission results are listed in Table 8.

TABLE 8 Hourly Emission Amounts at IAH (unit: g)

Time period	CO	HC	NOx	CO_2
0:00 - 1:00	300.8	17.6	29.6	63952.7
1:00 - 2:00	211.6	12.2	20.1	43508.4
2:00 - 3:00	205.2	11.8	19.5	41800.3
3:00 - 4:00	224.4	13.2	22.5	48225.7
4:00 - 5:00	307.5	19.6	56.8	65337.8
5:00 - 6:00	655.1	39.0	92.4	140402.9
6:00 - 7:00	1206.0	71.7	170.9	253695.6
7:00 - 8:00	1125.4	73.2	208.3	237444.1
8:00 - 9:00	3722.1	395.6	885.5	855084.7
9:00 - 10:00	1278.5	87.3	242.3	274181.9
10:00 - 11:00	3542.4	379.7	847.9	828041.6
11:00 - 12:00	4150.4	437.0	988.6	935807.5
12:00 - 13:00	3815.3	405.3	914.0	876834.3
13:00 - 14:00	3894.8	415.9	942.7	893968.9
14:00 - 15:00	4066.9	428.3	972.4	924340.3
15:00 - 16:00	3685.3	392.5	877.9	856817.5
16:00 - 17:00	3951.4	416.4	940.8	899751.0
17:00 - 18:00	4150.4	437.0	988.6	935807.5
18:00 - 19:00	4229.5	444.0	1003.4	946966.4
19:00 - 20:00	3760.9	398.2	891.2	867412.3
20:00 - 21:00	1193.5	81.9	226.6	255861.7
21:00 - 22:00	1135.5	78.2	214.2	244401.2
22:00 - 23:00	801.5	56.8	156.2	178182.8
23:00 - 0:00	438.3	27.9	81.2	92407.7
Total	52052.4	5140.0	11793.5	11760234.4

Figure 42 illustrates the hourly emission distribution generated from CMEM. A majority of emissions is emitted during 9:00 a.m. to 8:00 p.m., which is reasonable, because most of vehicles enter and leave the airport during this period.

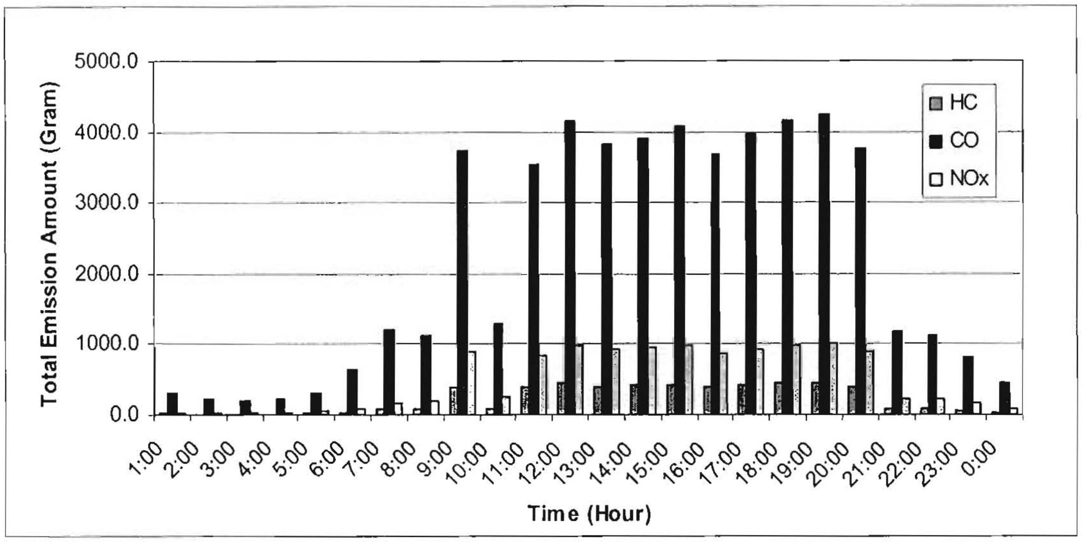


FIGURE 42 Hourly emission distributions for HC, CO and NOx at IAH.

Table 9 illustrates vehicle emissions of CO_2, HC, CO and NOx for the whole week. This result is useful as it is more specific and accurate for planning or environmental agencies to estimate or evaluate air quality in certain area that includes the airport.

TABLE 9 Weekly Emission Amounts at IAH (unit: g)

	CO	HC	NOx	CO_2
Monday	36558	3610	8283	8259505
Tuesday	46083	4551	10441	10411523
Wednesday	52052	5140	11793	11760234
Thursday	29253	2889	6628	6609201
Friday	25899	2557	5868	5851461
Saturday	37614	3714	8522	8498148
Sunday	44436	4388	10068	10039465
Total	271896	26849	61603	61429538

Based on the results in Table 9, we are able to project the emission amounts for the whole month by assuming that the emission amounts of other weeks are the same as our simulated week. Similarly, the emission amounts for the whole year of 2002 are obtained, as shown in Table 10. The emission results for the whole month and for the whole year provide an approximation of emissions, which can be improved by conducting more traffic simulations and emission calculations for other months.

TABLE 10 Projected Emissions in August and Year 2002 (unit: kg)

	CO	HC	NOx	CO_2
August of 2002	1087.58	107.40	246.41	245718.15
Year 2002	13050.98	1288.74	2956.95	2948617.82

Figure 43 is the illustration of the calculated emission results in Table 10 that represents IAH ground automobile emissions of August 2002 and the year of 2002. The total amounts of the four emissions for 2002 are 13 tons for CO, 1.3 tons for HC, 3.0 tons for NOx and 2948 tons for CO_2.

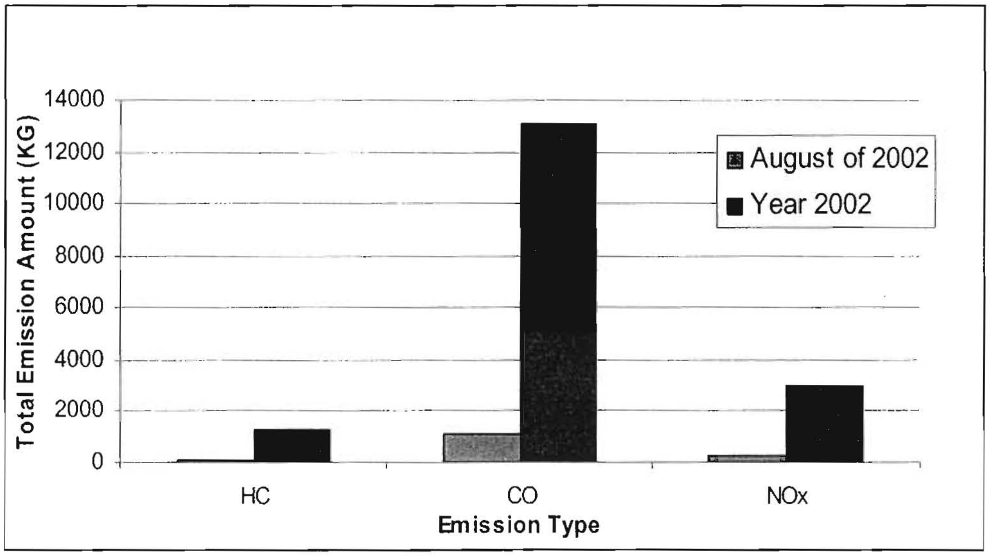


FIGURE 43 Total emissions for the August and whole year of 2002.

The above figures and tables are some examples of a variety of outputs that can be produced. In summary, the proposed framework can not only generate the total emissions for either one single vehicle or the total network, but also produce various types of emission outputs for the analysis purpose.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

In this research, a microscopic framework was constructed to evaluate airport- related traffic and mobile-source emission implications. The GA-based approach was proposed in order to calibrate the driving behavior parameters of the traffic simulation model VISSIM. The case study of IAH shows that the proposed microscopic framework and calibration approach are very efficiency and practical.

The microscopic framework integrates a microscopic traffic-simulation model and a modal-emission model. The GA-based calibration approach defines the index of simulation accuracy as the Sum of Squared Errors (SSE) between the collected speeds and the simulated speeds at the pre-defined cross-sections along the road. The program named AUTOSIM was developed to express indirectly the complex relationship between the SSE and the driving behavior parameters. The computer program implementing the GA-based approach was also developed to search for the optimal parameter values.

In the case study, IAH was modeled using the proposed microscopic framework. The field speed data were collected by using GPS. The calibrated optimal values of the VISSIM driving behavior parameters was derived for IAH loop, which resulted in almost 50% decrease of the SSE value. The number of speed errors greater than 10% at the pre-defined cross-sections had been decreased from 22 to 2 for the selected physical section. The produced emissions of each vehicle showed that the emission profiles well replicate the trends of the speed profile. The proposed framework could not only generate the total emissions for either a single vehicle or the total network, but also produce various types of emission outputs for the purpose of analysis.

The proposed microscopic framework can assist in the operational-level analysis of the mobile source emission implications around the airport. On the other hand, it also provides an efficient tool to assist in the overall airport design and planning. The GA-based calibration approach can be easily extended to networks other than airport roads. In the future research, it is suggested that more parameters can be included into the index function of simulation including travel time, queue length, etc. More simulation models other than VISSIM can also be tested in the simulation process. To increase the accuracy of the emission estimation, it is recommended the suitable on-board emission testing devices be used to detect the actual emissions of different types of vehicles, and then further calibrate the estimated emissions in the proposed framework.

REFERENCES

Airports Council International – North America (ACI-NA). Airports: The Facts. 1999. http://www.aci-na.org/facts.html. Accessed May 30, 2002.

Annual Civil Aviation Report – 1997. ICAO Journal, Vol. 53, No. 6, 1998.

Ascher, W. *Forecasting, an Appraisal for Policy-makers and Planners.* John Hopkins University Press, Baltimore, Maryland, 1978.

Bachman, W., W. Sarasua, S. Hallmark, and R. Guensler. Modeling Regional Mobile Source Emissions in a Geographic Information System Framework. *Transportation Research Part C: Emerging Technologies,* Vol. 8, No. 1-6, 2000, pp. 205-229.

Barth, M., F. An, T. Younglove, G. Scora, C. Levine, M. Ross, and T. Wenzel. *User guide: Comprehensive Modal Emissions Model (CMEM), version 2.0.* Riverside, California, 2000.

Chang, K. Y., and A. Haghani. A Simulation Model for Airport Terminal Roadway and Curbside Traffic Operations. 1992. http://www.ceeinet.umd.edu/faculty/ahaghani/Abstracts/Chang%20TR-1%20Abstract.pdf. Accessed July 26, 2003.

Chipperfield, A., P. Fleming, H. Pohlheim, and C. Fonseca. *Genetic Algorithm Tool Box for Use with MATLAB.* University of Sheffield, 1993.

CORSIM User's Guide. Federal Highway Administration (FHWA), Washington D.C., 2001.

Davis, L. A Genetic Algorithms Tutorial. *In: L. Davis (ed.) Handbook of Genetic Algorithms.* Von Nostrad Reinhold, New York, 1991.

De Jong, K. A. Analysis of the Behavior of a Class of Genetic Adaptive Systems. Ph.D. Thesis, Dept. of Computer and Communication Sciences, University of Michigan, Ann Arbor, 1975.

Newfville, D. *Airport Systems Planning: A Critical Look at the Methods and Experience.* Macmillan and MIT Press, London, England, and Cambride, Massachusetts, 1976.

Garber, N. J., and L. A. Hoel. *Traffic & Highway Engineering.* The Wadsworth Group, Pacific Grove, California, 2002.

Goldberg, D.E. *Genetic Algorithms in Search, Optimization & Machine Learning.* Addison-Wesley Publishing Company, Reading, Massachusetts, 1989.

Gottweis, J. *Pattern Recognition using Genetic Algorithms.* 2001. http://www.cg.tuwien.ac.at/studentwork/CESCG/CESCG-2001/JGottweis/. Accessed July 25, 2003.

INTEGRATION Release 2.30 for WINDOWS: User's Guide. M. Van Aerde & Assoc., Ltd, Kingston, Ontario, Canada, 2001.

Jiang, Y., and S. Li. Measuring and Analyzing Vehicle Position and Speed Data at Work Zones Using Global Positioning Systems. *ITE Journal,* Vol. 72, No. 3, 2002.

Kaemmerle, K.C. Estimating the Demand for Small Community Air Service. *Transportation Research Part A*, Vol.25, 1991, pp.101-112.

Kane, R.M. *Air Transportation*, Kendall/Hunt Publishing Company, Dubuque, Iowa, 1996.

Karlaftis, M.G. Methodological Framework for Air-Travel Demand Forecasting. *Journal of Transportation Engineering*, Vol.122, 1996, pp. 96-104.

Karr, C.L. Design of an Adaptive Fuzzy Logic Controller Using a Genetic Algorithm. *Proceeding of the 4th International Conference on Genetic Algorithm*, San Diego, California, 1991, pp. 450-457.

King County International Airport. Master Plan to Guide Development of the Airport Over the Next Twenty Years. 2002. Http://www.metrokc.gov/airport/plan/. Accessed Oct. 10, 2003.

Montana, D., M. Brinn, S. Moore, and G. Bidwell. Genetic Algorithms for Complex, Real-Time Scheduling. *IEEE Conference on Systems, Man, and Cybernetics*, 1998.

Lehrer, H., and A. Freeman. Intermodal Airport-To-City-Center Passenger Transportation at the 20 Largest U.S. Air Carrier Airports: The Past, Present, and Future. *Journal of Air Transportation World Wide*, Vol.3, No.1, 1998.

Nettey, I.R. *Enhanced Integration of Multimodal Ground Transportation with Air Transportation at Selected Major Air Carrier Airports.* Report NTIS# SWUTC 95/60037. Texas Transportation Institute, the Texas A&M University System, College Station, Texas, 1995.

Nettey, I.R. Categorical Grants as a Tool of Intergovernmental Relations: Evolution of National Airport Funding and the Airport Improvement Program. Doctoral Dissertation, University of Houston – University Park, Houston, TX, 2000.

Nygard, M. Airports Are under Growing Pressure to Change as Authorities Respond to Conflicting Demands. *ICAO Journal*, Vol. 54, No. 8, 1999.

Odoni, M.R., and R.D. Neufville. Passenger Terminal Design. *Transportation Research Part A*, Vol. 26A, 1996, pp 27-35.

Pena, F. *Department of Transportation Strategic Plan*, U.S. Department of Transportation, Washington, D.C, January 1994.

Rodrigue, J.-P. Air Transport. *Transport Geography on the Web.* 2003. http://people.hofstra.edu/geotrans/eng/ch3en/conc3en/ch3c4en.html#2. Accessed Oct. 26, 2003.

TransSolutions, LLC. *Project Report for the Construction of the New Bangkok International Airport*, Fort Worth, Texas, 1998.

Tunasar, C., G. Bender, and H. Young. Modeling Curbside Vehicular Traffic at Airports, Presented at the 1998 Winter Simulation Conference, Washington, D.C., 1998.

Unger, R., and J. Moult. Genetic Algorithms for Protein Folding Simulations. 1992. http://mie.eng.wayne.edu/faculty/chinnam/IJSESD_00_Paper.pdf. Accessed July 2, 2003.

U.S. Office of Technology Assessment. *Airport and Air Traffic Control Systems.* U.S. Congress, Washington, D.C., 1982.

U.S. Environmental Protection Agency. *User's Guide to MOBILE6.0.* EPA420-R-02-001, Ann Arbor, Michigan, 2002.

U.S. Environmental Protection Agency. MOVES (Multi-scale Motor Vehicle & Equipment Emission System). 2003. http://www.epa.gov/otaq/ngm.htm. Accessed October 18, 2003.

VISSIM Version 3.60 User Manual. PTV Planug Transport Verkehr AG, Karlsruhe, Germany, 2001.

Wells, A.T. *Airport Planning & Management.* McGraw-Hill Companies, Inc., Two Penn Plaza, New York, 1992.

Whitley, D. The GENITOR Algorithm and Selection Pressure – Why Rank-Based Allocation of Reproduction Trials is Best. Presented at the 3rd International Conference on Genetic Algorithms, Morgan Kaufmann, San Mateo, California, 1989.

Yu, L. Remote Vehicle Exhaust Emission Sensing for Traffic Simulation and Optimization Models. *Transportation Research Part D: Transport and Environment,* Vol. 3, No. 5, 1998, pp. 337-347.

Appendix A

MPO Travel Demand Model Survey Response from NCTCOG

1. What is the process and procedure used to model airport-related traffic and mobile vehicle emissions in the regional travel demand model?

For "A Description of the Multimodal Forecasting Process," the key information is as follows:

- We treat airports as Special Generators (actually, Special Attractors), for calculation of Home-Based Work, Home-Based Nonwork, and Nonhome-Based Person trip attractions; our trip rates were based on information obtained from our 1984 workplace survey.
- We use a Regional Gravity Model to perform trip distributions for each of our seven trip purposes (four HBW groups; one HNW group; one NHB group; and one OTHER group that includes trucks, taxis, and all internal-external trips).
- For DFW Airport, we adjust the HNW and NHB person trip tables so that the modeled orientations (travel patterns) for DFW Airport trips are similar to what was obtained from a 1990 DFW Airport origin-destination survey.
- Mode Choice is performed to convert the HBW, HNW, and NHB person trip tables into origin-destination vehicle trip tables and production-attraction transit passenger trip tables.
- Our traffic assignment procedures assign all Inter-Zonal vehicle trips to the coded roadway network, including the airport-related trips.
- Our post-processor programs are used to calculate vehicle miles of travel, travel speeds, and emissions on all coded roadway links, by time-of-day; we use regional vehicle mixes, rather than airport-specific vehicle mixes.

a. What is the source of these data?

Answer: Dallas-Fort Worth Regional Travel Model Publication.

b. Is the airport treated as "special attractors" and assigned a certain numbers of trip attractions? How exactly are trips calculated? Please explain.

Answer: We apply special trip rates for Basic Employee; I will send an Excel spreadsheet that shows some of the calculations, but it's a little hard to explain the process in a few sentences.

c. What methodology is used to examine ground travel choices of airport travelers?

Answer: We use our standard Mode Choice Model (see the PDF for a description of variables and coefficients used for calculation of zone-to-zone impedances).

2. What are the relevant categories used in the travel demand and emissions modeling process (i.e. time-of-day, day-of-week, vehicle classification, and trip purpose)?

   Answer: We generally consider our regional travel demand model to represent average weekday traffic during school season; airport-related trips can be found in all seven trip purposes we currently model; although our traffic assignments are usually weekday assignments, we have a post-processor program that distributes (for purposes of our emissions calculations) weekday roadway volumes to five separate time periods.

3. Are their issues or problems associated with estimating airport-related traffic?

   Answer: One has to be very careful about calculation of home-based work trips for very large airports, due to the unusual weekday travel behavior of airline pilots and stewardesses.

4. Could the current modeling process around analyzing and forecasting airport-related traffic be improved? If so, how?

   Answer: Yes. If this project is going to be of any real value, the Researchers should examine the airport-related modeling procedures used by a number of MPOs across the U.S.

5. What impact does Airport-Related Traffic have on Clean Air Act Requirements? How does this influence conformity of the Transportation Improvement Plan (TIP)?

   Answer: The travel demand model calculates traffic volumes related to DFW Airport, which (of course) have an impact on the emissions estimates.

Appendix B

MPO Travel Demand Model Survey Response from HGAC

It is important to note that the H-GAC regional travel model deals with airport trips made by residents and employees of the region, not trips made by visitors from outside the region.

1) a. The source of the data used to perform travel demand modeling for airport trips are employment and enplanement data and travel survey data for establishing employee and visitor trip rates by trip purpose.

   b. The airports are treated has special generators by the HGAC regional travel models. Trips are calculated based upon employment and enplanement data.

   c. Airport trips the same choice of modes that all other trips see in the context of the mode choice model portion of the H-GAC travel models. That is, auto and transit at the primary level and at other levels choices of shared ride or drive alone on the auto side and express, commuter and local bus choices on the transit side. The auto choices also include toll and non-toll choices.

   d. The mix of vehicles associated with airport trips is based upon the types of facilities used to access the airports.

2) The most relevant category is trip purpose.

3) Yes, airport trip present unique challenges to regional travel demand modeling. They are really a purpose unto themselves and have very different travel characteristics. Not to mention than many of the trips are made by people that do not live or work in the region.

4) Yes, by addressing some of the issues mentioned in 3), above.

5) The only specific impact that comes to mind is the fact that the trips made by people who are not residents or employees of the region are present but hard to account for.

Appendix C

GA-Based Program Code for the Calibration of Driving Behavior Parameters

```
MAXGEN=20; Maximum number of generations
gen=1; Initial Generation
aaa=100000; A large number used to compare with SSE
Small_sse_per_gen=0; Initial smallest SSE per generation
Chrom=crtbp(16,39); Create initial population with binary matrix
b1=[16;8;4;2;1]; Coefficient matrix
b2=[8;4;2;1]; Coefficient matrix
b3=[4;2;1]; Coefficient matrix
while gen<MAXGEN;
    i=1;
    se=0;
    c1=Chrom(:,[1:5]); Extracted sub-matrix representing parameter 1
    c2=Chrom(:,[6:9]);
    c3=Chrom(:,[10:12]);
    c4=Chrom(:,[13:17]);
    c5=Chrom(:,[18:21]);
    c6=Chrom(:,[22:25]);
    c7=Chrom(:,[26:28]);
    c8=Chrom(:,[29:31]);
    c9=Chrom(:,[32:35]);
    c10=Chrom(:,[36:39]);
    p=[1.9*c1*b1+30,0.06*c2*b2+0.1,0.6*c3*b3-5,1.9*c4*b1+20,0.2*c5*b2-
3.1,6.7*c6*b2+200,0.7*c7*b3+0.2,0.7*c8*b3+0.2,0.34*c9*b2+1,0.1*c10*b2+0.5];
Converted population with real-value
    while i<17;
        pi=p(i,:); Extract the ith row from matrix p
        fid=fopen('c:\vmcalib\parameter.txt','w');
```

```
        fprintf(fid,' %5.2f %4.2f %5.2f %5.2f %5.2f %6.2f %4.2f %4.2f %4.2f
%4.2f ',pi); Save pi to parameter.txt file
        fclose(fid);
        system('c:\vmcalib\vissim_a.exe'); Run VISSIM automatically
        m=1; Program waits 160 seconds to assure finish VISSIM running
        tic;
        for m=1:10000000
            presenttime=toc;
            if presenttime>160;
               break;
            end;
        end;
        presenttime;
        fid=fopen('c:\vmcalib\sse.txt');
        a=fscanf(fid,'%f'); Save calculated result SSE to sse.txt file
        fclose(fid);
        aa=a(1,1)+a(2,1)+a(3,1)+a(4,1)+a(5,1)+a(6,1); Sum of six SSE
        if aa<aaa;
           di=p(i,:);
           fid=fopen('c:\vmcalib\optimal_sse.txt','w');
           fprintf(fid,'%f ',aa,di); Save aa and di to optimal_sse.txt file
           fclose(fid);
           aaa=aa;
           if i>1;
              dii=p(i-1,:);
              fid=fopen('c:\vmcalib\optimal_sse.txt','w');
              fprintf(fid,'%f ',aa,dii);
              fclose(fid);
          end
        else
        end
        se=[se;aa];
        optv=pi
        Asse=aa
        i=i+1;
    end
    sse=se([2:17],:); Extract SSE matrix
    sm=min(sse); Extract minimum SSE
    Small_sse_per_gen=[Small_sse_per_gen,sm]; Create min SSE matrix
    fid=fopen('c:\vmcalib\Small_sse_per_gen.txt','w');
    fprintf(fid,'%f ',Small_sse_per_gen); Save min SSE matrix to
Small_sse_per_gen.txt file
    fclose(fid);
    FitnV=ranking(sse); Assign fitness value to entire SSE
SelCh=select('sus',Chrom,FitnV,0.5); Select individuals for breeding
    Chrom=SelCh;
    SelCh=recombin('xovsp',SelCh,0.7); Recombine individuals (crossover)
    SelCh=mut(SelCh); Apply mutatioin
    Chrom=[rep(Chrom,[1 1]);rep(SelCh,[1 1])]; Reinsert offspring into
population
    gen=gen+1;
end
```

Appendix D

Code of AUTOSIM

```
VERSION 5.00
Begin VB.Form main
   Caption         =   "VISSIM Calibration"
   ClientHeight    =   3165
   ClientLeft      =   60
   ClientTop       =   510
   ClientWidth     =   4890
   LinkTopic       =   "Form1"
   ScaleHeight     =   3165
   ScaleWidth      =   4890
   StartUpPosition =   3  'Windows Default
   Begin VB.Label Label1
      Caption         =   "Program is running..."
      BeginProperty Font
         Name            =   "MS Sans Serif"
         Size            =   12
         Charset         =   0
         Weight          =   700
         Underline       =   0   'False
         Italic          =   0   'False
         Strikethrough   =   0   'False
      EndProperty
      Height          =   735
      Left            =   1320
      TabIndex        =   0
      Top             =   1080
      Width           =   2535
   End
End
Attribute VB_Name = "main"
Attribute VB_GlobalNameSpace = False
Attribute VB_Creatable = False
Attribute VB_PredeclaredId = True
```

```
Attribute VB_Exposed = False

Private Sub Form_Load()

inital

Dim parameter1 As String
Dim parameter2 As String
Dim parameter3 As String
Dim parameter4 As String
Dim parameter5 As String
Dim parameter6 As String
Dim parameter7 As String
Dim parameter8 As String
Dim parameter9 As String
Dim parameter10 As String

Dim temp As Single
Dim i As Integer

Open vissim_io_folder & "parameter.txt" For Input As #11
Open vissim_io_folder & "sse.txt" For Output As #12

For i = 1 To 1
   tempstr = ""
   mychar = Input(1, #11)
   If mychar = " " Then mychar = Input(1, #11)
   tempstr = tempstr + mychar
   Do While mychar <> " "
      mychar = Input(1, #11)
      tempstr = tempstr + mychar
   Loop
   parameter1 = tempstr

   tempstr = ""
   mychar = Input(1, #11)
   tempstr = tempstr + mychar
   Do While mychar <> " "
      mychar = Input(1, #11)
      tempstr = tempstr + mychar
   Loop
   parameter2 = tempstr

   tempstr = ""
   mychar = Input(1, #11)
   tempstr = tempstr + mychar
   Do While mychar <> " "
      mychar = Input(1, #11)
      tempstr = tempstr + mychar
   Loop
   parameter3 = tempstr

   tempstr = ""
   mychar = Input(1, #11)
   tempstr = tempstr + mychar
   Do While mychar <> " "
```

```
   mychar = Input(1, #11)
   tempstr = tempstr + mychar
Loop
parameter4 = tempstr

tempstr = ""
mychar = Input(1, #11)
tempstr = tempstr + mychar
Do While mychar <> " "
   mychar = Input(1, #11)
   tempstr = tempstr + mychar
Loop
parameter5 = tempstr

tempstr = ""
mychar = Input(1, #11)
tempstr = tempstr + mychar
Do While mychar <> " "
   mychar = Input(1, #11)
   tempstr = tempstr + mychar
Loop
parameter6 = tempstr

tempstr = ""
mychar = Input(1, #11)
tempstr = tempstr + mychar
Do While mychar <> " "
   mychar = Input(1, #11)
   tempstr = tempstr + mychar
Loop
parameter7 = tempstr

tempstr = ""
mychar = Input(1, #11)
tempstr = tempstr + mychar
Do While mychar <> " "
   mychar = Input(1, #11)
   tempstr = tempstr + mychar
Loop
parameter8 = tempstr

tempstr = ""
mychar = Input(1, #11)
tempstr = tempstr + mychar
Do While mychar <> " "
   mychar = Input(1, #11)
   tempstr = tempstr + mychar
Loop
parameter9 = tempstr

tempstr = ""
mychar = Input(1, #11)
tempstr = tempstr + mychar
Do While mychar <> " "
   mychar = Input(1, #11)
   tempstr = tempstr + mychar
```

```
    Loop
    parameter10 = tempstr

    temp = vm_automation(parameter1, parameter2, parameter3, parameter4, parameter5, parameter6, parameter7,
parameter8, parameter9, parameter10)
    Print #12, sselink(1), sselink(2), sselink(3), sselink(4), sselink(5), sselink(6)

Next i

Close #11
Close #12

End

End Sub
```

```
Attribute VB_Name = "automation"
Global vissim_exe As String
Global vissim_io_folder As String
Global vissim_inp As String
Global location_num_6 As Integer
Global location_num_5 As Integer
Global location_num_2 As Integer
Global location_num_1 As Integer
Global location_num_3 As Integer
Global location_num_4 As Integer
'need re-define later
Global line_before As Integer
'need re-define later
Global sselink(6) As Single

Sub inital()
vissim_exe = "C:\Program Files\PTV_Vision\VISSIM360\Exe\vissim.exe"

vissim_io_folder = "C:\vmcalib\"

vissim_inp = "iah.inp"
'location_num = 358
'quence and number of data collections:
'link6 60, link5 33,link2 47, link1 50, link3 76, link4 92.
location_num_6 = 60
location_num_5 = 33
location_num_2 = 47
location_num_1 = 50
location_num_3 = 76
location_num_4 = 92

line_before = 545

End Sub
```

```
Function vm_automation(change1 As String, change2 As String, change3 As String, change4 As String, change5 As String, change6 As String, change7 As String, change8 As String, change9 As String, change10 As String)
Dim filename As String
Dim textline As String
Dim i As Integer
Dim mychar
Dim change As String
Dim resultstring As String

filename = Dir(vissim_io_folder & "iahd.inp", 0)
If (filename = "") Then
   MsgBox "Data file iahd.inp doesn't exist!", 48, "Find data file"
   Exit Function
Else
   Open vissim_io_folder & "iahd.inp" For Input As #5
End If

Open vissim_io_folder & "iah.inp" For Output As #6


For i = 1 To line_before
   Line Input #5, textline
   Print #6, textline
Next

mychar = Input(18, 5)
resultstring = mychar
mychar = Input(5, 5)
change = change1
resultstring = resultstring + change
mychar = Input(12, 5)
resultstring = resultstring + mychar
mychar = Input(4, 5)
change = change2
resultstring = resultstring + change
mychar = Input(14, 5)
resultstring = resultstring + mychar
mychar = Input(5, 5)
change = mychar
resultstring = resultstring + change
mychar = Input(1, 5)
resultstring = resultstring + mychar
Print #6, resultstring

mychar = Input(32, 5)
resultstring = mychar
mychar = Input(5, 5)
change = change3
resultstring = resultstring + change
mychar = Input(10, 5)
resultstring = resultstring + mychar
mychar = Input(5, 5)
change = change4
resultstring = resultstring + change
mychar = Input(5, 5)
resultstring = resultstring + mychar
```

```
mychar = Input(5, 5)
change = change5
resultstring = resultstring + change
mychar = Input(1, 5)
resultstring = resultstring + mychar
Print #6, resultstring

mychar = Input(33, 5)
resultstring = mychar
mychar = Input(5, 5)
change = change3
resultstring = resultstring + change
mychar = Input(10, 5)
resultstring = resultstring + mychar
mychar = Input(5, 5)
change = change4
resultstring = resultstring + change
mychar = Input(5, 5)
resultstring = resultstring + mychar
mychar = Input(5, 5)
change = mychar
resultstring = resultstring + mychar
Print #6, resultstring

mychar = Input(33, 5)
resultstring = mychar
Print #6, resultstring

mychar = Input(47, 5)
resultstring = mychar
mychar = Input(7, 5)
change = change6
resultstring = resultstring + change
mychar = Input(1, 5)
resultstring = resultstring + mychar
Print #6, resultstring

mychar = Input(18, 5)
resultstring = mychar
mychar = Input(4, 5)
change = change7
resultstring = resultstring + change
mychar = Input(8, 5)
resultstring = resultstring + mychar
mychar = Input(4, 5)
change = change8
resultstring = resultstring + change
mychar = Input(9, 5)
resultstring = resultstring + mychar
mychar = Input(4, 5)
change = change9
resultstring = resultstring + change
mychar = Input(1, 5)
resultstring = resultstring + mychar
Print #6, resultstring
```

```
mychar = Input(57, 5)
resultstring = mychar
mychar = Input(1, 5)
resultstring = resultstring + mychar
Print #6, resultstring

mychar = Input(56, 5)
resultstring = mychar
mychar = Input(1, 5)
resultstring = resultstring + mychar
Print #6, resultstring

mychar = Input(28, 5)
resultstring = mychar
mychar = Input(1, 5)
resultstring = resultstring + mychar
Print #6, resultstring

mychar = Input(39, 5)
resultstring = mychar
mychar = Input(1, 5)
resultstring = resultstring + mychar
Print #6, resultstring

mychar = Input(38, 5)
resultstring = mychar
mychar = Input(1, 5)
resultstring = resultstring + mychar
Print #6, resultstring

mychar = Input(37, 5)
resultstring = mychar
mychar = Input(4, 5)
change = change10
resultstring = resultstring + change
mychar = Input(10, 5)
resultstring = resultstring + mychar
mychar = Input(4, 5)
change = change10
resultstring = resultstring + change
mychar = Input(1, 5)
resultstring = resultstring + mychar
Print #6, resultstring

Do While Not EOF(5)
  Line Input #5, textline
  Print #6, textline
Loop
Close #5
Close #6


Dim runvissim As Double

filename = vissim_exe & " " & vissim_io_folder & vissim_inp & " -s1"
runvissim = Shell(filename, 1)
```

```
If runvissim = 0 Then
  MsgBox "VISSIM cannot run here!", 48, "VISSIM Run"
  Exit Function
End If
Dim ti, tj As Single
For ti = 1 To 60000
  For tj = 1 To 60000
    Debug.Print ti, tj
  Next tj
Next ti

filename = Dir(vissim_io_folder & "iah.mes", 0)
If (filename = "") Then
  Do Until filename <> ""
  Loop
  Open vissim_io_folder & "iah.mes" For Input As #1
Else
  Open vissim_io_folder & "iah.mes" For Input As #1
End If

For i = 1 To 1758
  Line Input #1, textline
Next

Dim location_vissim(3000) As Integer
Dim speed_vissim(3000) As Single
Dim time_from As Long
Dim time_to As Long

For i = 1 To location_num_6
  tempstr = ""
  mychar = Input(1, #1)
  tempstr = tempstr + mychar
  mychar = Input(1, #1)
  tempstr = tempstr + mychar
  Do While mychar <> ";"
    mychar = Input(1, #1)
    tempstr = tempstr + mychar
  Loop
  mychar = Input(1, #1)
  Do While mychar <> ";"
    mychar = Input(1, #1)
  Loop
  mychar = Input(1, #1)
  Do While mychar <> ";"
    mychar = Input(1, #1)
  Loop

  location_vissim(i) = Val(tempstr)
  Input #1, speed_vissim(i)
Next i

For i = 1 To 140
  Line Input #1, textline
Next
```

```
For i = location_num_6 + 1 To location_num_6 + location_num_5
   tempstr = ""
   mychar = Input(1, #1)
   tempstr = tempstr + mychar
   mychar = Input(1, #1)
   tempstr = tempstr + mychar
   Do While mychar <> ";"
      mychar = Input(1, #1)
      tempstr = tempstr + mychar
   Loop
   mychar = Input(1, #1)
   Do While mychar <> ";"
      mychar = Input(1, #1)
   Loop
   mychar = Input(1, #1)
   Do While mychar <> ";"
      mychar = Input(1, #1)
   Loop

   location_vissim(i) = Val(tempstr)
   Input #1, speed_vissim(i)
Next i

For i = 1 To 267
   Line Input #1, textline
Next
For i = location_num_6 + location_num_5 + 1 To location_num_6 + location_num_5 + location_num_2
   tempstr = ""
   mychar = Input(1, #1)
   tempstr = tempstr + mychar
   mychar = Input(1, #1)
   tempstr = tempstr + mychar
   Do While mychar <> ";"
      mychar = Input(1, #1)
      tempstr = tempstr + mychar
   Loop
   mychar = Input(1, #1)
   Do While mychar <> ";"
      mychar = Input(1, #1)
   Loop
   mychar = Input(1, #1)
   Do While mychar <> ";"
      mychar = Input(1, #1)
   Loop

   location_vissim(i) = Val(tempstr)
   Input #1, speed_vissim(i)
Next i

For i = 1 To 571
   Line Input #1, textline
Next
For i = location_num_6 + location_num_5 + location_num_2 + 1 To location_num_6 + location_num_5 +
location_num_2 + location_num_1
   tempstr = ""
   mychar = Input(1, #1)
```

```
    tempstr = tempstr + mychar
    mychar = Input(1, #1)
    tempstr = tempstr + mychar
    Do While mychar <> ";"
      mychar = Input(1, #1)
      tempstr = tempstr + mychar
    Loop
    mychar = Input(1, #1)
    Do While mychar <> ";"
      mychar = Input(1, #1)
    Loop
    mychar = Input(1, #1)
    Do While mychar <> ";"
      mychar = Input(1, #1)
    Loop

    location_vissim(i) = Val(tempstr)
    Input #1, speed_vissim(i)
Next i

For i = 1 To 9
    Line Input #1, textline
Next
For i = location_num_6 + location_num_5 + location_num_2 + location_num_1 + 1 To location_num_6 +
location_num_5 + location_num_2 + location_num_1 + location_num_3
    tempstr = ""
    mychar = Input(1, #1)
    tempstr = tempstr + mychar
    mychar = Input(1, #1)
    tempstr = tempstr + mychar
    Do While mychar <> ";"
      mychar = Input(1, #1)
      tempstr = tempstr + mychar
    Loop
    mychar = Input(1, #1)
    Do While mychar <> ";"
      mychar = Input(1, #1)
    Loop
    mychar = Input(1, #1)
    Do While mychar <> ";"
      mychar = Input(1, #1)
    Loop

    location_vissim(i) = Val(tempstr)
    Input #1, speed_vissim(i)
Next i

For i = location_num_6 + location_num_5 + location_num_2 + location_num_1 + location_num_3 + 1 To
location_num_6 + location_num_5 + location_num_2 + location_num_1 + location_num_3 + location_num_4
    tempstr = ""
    mychar = Input(1, #1)
    tempstr = tempstr + mychar
    mychar = Input(1, #1)
    tempstr = tempstr + mychar
    Do While mychar <> ";"
      mychar = Input(1, #1)
```

```
      tempstr = tempstr + mychar
    Loop
    mychar = Input(1, #1)
    Do While mychar <> ";"
      mychar = Input(1, #1)
    Loop
    mychar = Input(1, #1)
    Do While mychar <> ";"
      mychar = Input(1, #1)
    Loop

    location_vissim(i) = Val(tempstr)
    Input #1, speed_vissim(i)
Next i

Close #1


filename = Dir(vissim_io_folder & "iah_gps_speed.txt", 0)
If (filename = "") Then
    MsgBox "Data file iah_gps_speed.txt doesn't exist!", 48, "Find data file"
    Exit Function
Else
    Open vissim_io_folder & "iah_gps_speed.txt" For Input As #2
End If

Line Input #2, textline
Dim location_gps(3000) As Integer
Dim speed_gps(3000) As Single
For i = 1 To location_num_6 + location_num_5 + location_num_2 + location_num_1 + location_num_3 +
location_num_4
    Input #2, location_gps(i), speed_gps(i)
Next i
Close #2

Dim sse As Single

Open vissim_io_folder & "iah_sse.txt" For Output As #4

Print #4, "parameter 1=", change1
Print #4, "parameter 2=", change2
Print #4, "parameter 3=", change3
Print #4, "parameter 4=", change4
Print #4, "parameter 5=", change5
Print #4, "parameter 6=", change6
Print #4, "parameter 7=", change7
Print #4, "parameter 8=", change8
Print #4, "parameter 9=", change9
Print #4, "parameter 10=", change10

sse = 0
For i = 1 To location_num_6
    sse = sse + (speed_vissim(i) - speed_gps(i)) * (speed_vissim(i) - speed_gps(i))
Next i
Print #4, "Link6 sse=", sse
sselink(6) = sse
```

```
sse = 0
For i = location_num_6 + 1 To location_num_6 + location_num_5
   sse = sse + (speed_vissim(i) - speed_gps(i)) * (speed_vissim(i) - speed_gps(i))
Next i
Print #4, "Link5 sse=", sse
sselink(5) = sse

sse = 0
For i = location_num_6 + location_num_5 + 1 To location_num_6 + location_num_5 + location_num_2
   sse = sse + (speed_vissim(i) - speed_gps(i)) * (speed_vissim(i) - speed_gps(i))
Next i
Print #4, "Link2 sse=", sse
sselink(2) = sse

sse = 0
For i = location_num_6 + location_num_5 + location_num_2 + 1 To location_num_6 + location_num_5 +
location_num_2 + location_num_1
   sse = sse + (speed_vissim(i) - speed_gps(i)) * (speed_vissim(i) - speed_gps(i))
Next i
Print #4, "Link1 sse=", sse
sselink(1) = sse

sse = 0
For i = location_num_6 + location_num_5 + location_num_2 + location_num_1 + 1 To location_num_6 +
location_num_5 + location_num_2 + location_num_1 + location_num_3
   sse = sse + (speed_vissim(i) - speed_gps(i)) * (speed_vissim(i) - speed_gps(i))
Next i
Print #4, "Link3 sse=", sse
sselink(3) = sse

sse = 0
For i = location_num_6 + location_num_5 + location_num_2 + location_num_1 + location_num_3 + 1 To
location_num_6 + location_num_5 + location_num_2 + location_num_1 + location_num_3 + location_num_4
   sse = sse + (speed_vissim(i) - speed_gps(i)) * (speed_vissim(i) - speed_gps(i))
Next i
Print #4, "Link4 sse=", sse
sselink(4) = sse

Close #4

End Function
```

Appendix E

Program Code for Transferring Data from VISSIM to CMEM

```
Private Sub LabelVISSIM_Click()
  On Error GoTo 1000
  msg_text.Value = "Begin to transfer data and calculate..."
  Me.Repaint
    TableClass.Empty_Table "activity"
    TableClass.Empty_Table "definition"
    TableClass.Empty_Table "emissions"
    TableClass.Empty_Table "temp"
    TableClass.Empty_Table "totals"
    TableClass.Empty_Table "Before"


  Dim str As String
  Dim ss As String
  Dim i As Integer
  Dim TextLine
  str = Dir("C:\li_xiugang_new\code transfering data\vissim.fzp", 0)
  If (str = "") Then
    str = Dir("C:\vissim.fzp", 0)
    If (str = "") Then
      MsgBox "Data file c:\vissim.fzp doesn't exist!", 48, "Find data file"
      End
    Else
      Open "C:\vissim.fzp" For Input As #1
    End If
  Else
    Open "C:\li_xiugang_new\code transfering data\vissim.fzp" For Input As #1
  End If

  msg_text.Value = "Transfering VISSIM data ..."
```

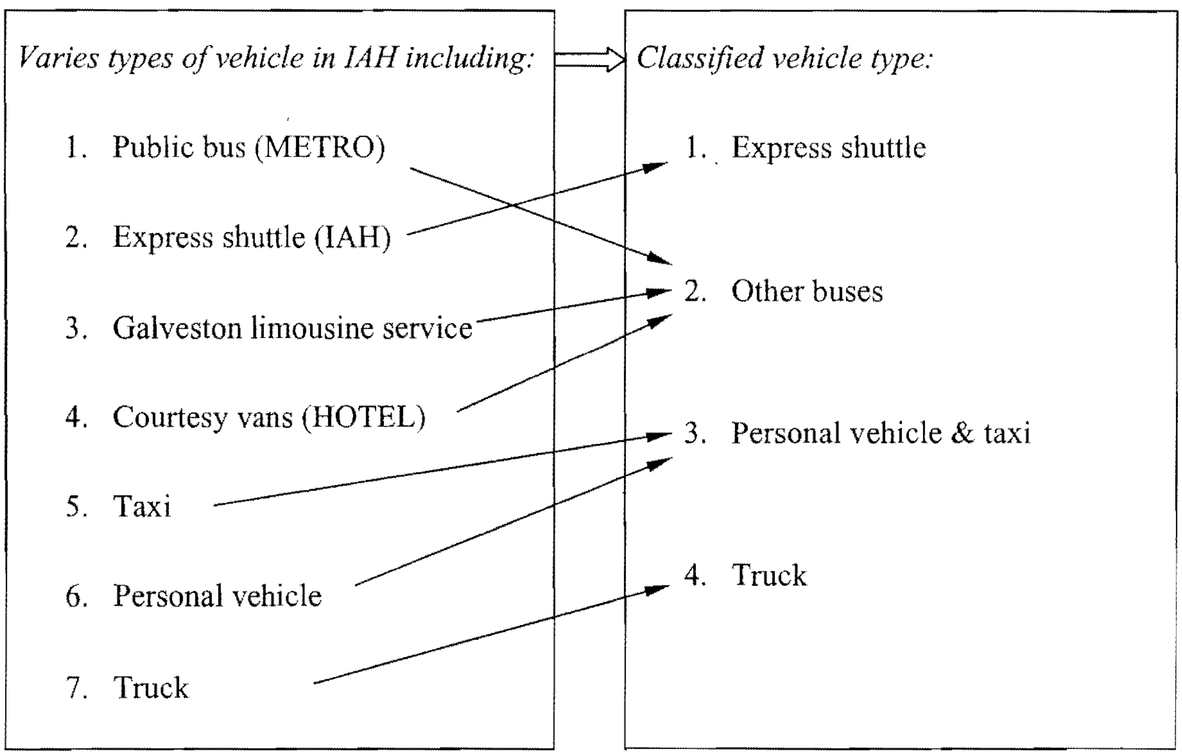
```
    Me.Repaint

'Input the text lines in file vissim.fzp
    Line Input #1, TextLine
    Line Input #1, ss
    Line Input #1, ss
    Line Input #1, ss
    Line Input #1, ss
    Line Input #1, ss
    Line Input #1, ss
    Line Input #1, ss
    Line Input #1, ss
    Line Input #1, ss
    Line Input #1, ss

'read default values of parameters in table defaults.
    Dim dbLi As Database
    Dim rsLi As Recordset
    Set dbLi = CurrentDb
    Set rsLi = dbLi.OpenRecordset("defaults", dbOpenDynaset)
    Dim vehcategory(69) As Integer
    Dim Ed(69) As Single
    Dim Nc(69) As Integer
    Dim Masslb(69) As Single
    Dim Trlhp(69) As Single
    Dim S(69) As Single
    Dim Nm(69) As Integer
    Dim Qm(69) As Single
    Dim Zmax(69) As Single
    Dim Np(69) As Integer
    Dim Mpgc(69) As Single
    Dim Idle(69) As Integer
    Dim ng(69) As Integer
    Dim sload(69) As Single
    Dim Tsoak(69) As Integer

    rsLi.MoveFirst
    For i = 1 To 69
        vehcategory(i) = rsLi(0)
        Ed(i) = rsLi(1)
        Nc(i) = rsLi(2)
        Masslb(i) = rsLi(3)
        Trlhp(i) = rsLi(4)
        S(i) = rsLi(5)
        Nm(i) = rsLi(6)
        Qm(i) = rsLi(7)
        Zmax(i) = rsLi(8)
        Np(i) = rsLi(9)
        Mpgc(i) = rsLi(10)
        Idle(i) = rsLi(11)
        ng(i) = rsLi(12)
        sload(i) = rsLi(13)
        Tsoak(i) = rsLi(14)
        rsLi.MoveNext
    Next i
    rsLi.Close
```

```
    Dim vtype As Integer
    Dim t As Double
    Dim vehnr As Double
    Dim vms As Single
    Dim a As Single
    Dim vehnr_last As Double
    vehnr_last = -1 'set vehnr_last the value different from the any possible value of vehnr

    Dim sum_car As Single   'for change vehicle type from vissim to CMEM
    Dim car5 As Single   'for change vehicle type from vissim to CMEM
    Dim car7 As Single   'for change vehicle type from vissim to CMEM
    sum_car = 0#    'for change vehicle type from vissim to CMEM
    car5 = 0#    'for change vehicle type from vissim to CMEM
    car7 = 0#    'for change vehicle type from vissim to CMEM

    Do While Not EOF(1)    ' Loop until end of file.
      Input #1, vtype, t, vehnr, vms, a
      If vtype = 0 Then
        GoTo 1000
      End If
'The following codes change the vehicle types from vissim number to CMEM number:
      If vehnr <> vehnr_last Then
        If vtype = 12 Then  'bus (vissim 12 = CMEM 16)
          vtype = 16
        Else              'car(vissim 1-6),little truck(13) and test car(20)
          If sum_car <> 0# Then
            If (car5 / sum_car) < 0.66 Then   'car5 is 66% and car7 is 34%
              vtype = 5
              car5 = car5 + 1
            Else
              vtype = 7
              car7 = car7 + 1
            End If
          Else
            vtype = 5
            car5 = car5 + 1
          End If
          sum_car = sum_car + 1
        End If
      End If
'end of changing vehicle types

'Input values of vehicle number, vehicle type, and the other values from Table default to Table definition.
      Dim rsdef As Recordset
      Dim rsact As Recordset
      Set rsdef = dbLi.OpenRecordset("definition", dbOpenDynaset)
      Set rsact = dbLi.OpenRecordset("activity", dbOpenDynaset)

      If vehnr <> vehnr_last Then
        rsdef.AddNew
        rsdef(0) = vehnr
        rsdef(1) = vtype
        rsdef(3) = Tsoak(vtype)
        rsdef(4) = Ed(vtype)
        rsdef(5) = Nc(vtype)
```

```
            rsdef(6) = Masslb(vtype)
            rsdef(7) = Masslb(vtype) / 0.4536
            rsdef(8) = Trlhp(vtype)
            rsdef(9) = S(vtype)
            rsdef(10) = Nm(vtype)
            rsdef(11) = Qm(vtype)
            rsdef(12) = Zmax(vtype)
            rsdef(13) = Np(vtype)
            rsdef(14) = Mpgc(vtype)
            rsdef(15) = Idle(vtype)
            rsdef(16) = ng(vtype)
            rsdef(17) = sload(vtype)
            rsdef.Update
        End If
        vehnr_last = vehnr

'Input activity values to Table Activity.
        rsact.AddNew
        rsact(0) = t
        rsact(1) = vehnr
        rsact(2) = vms
        rsact(3) = a
        rsact.Update

    Loop
    rsdef.Close
    rsact.Close

    Close #1
    MsgBox "Finish data transfering!", 48, "Data"


    Dim T1 As Date
    Dim T2 As Date
    DoCmd.Hourglass True
    msg_text.Value = "Deleting old output data..."
    Me.Repaint
    TableClass.Empty_Table "emissions"
    TableClass.Empty_Table "Before"
    TableClass.Empty_Table "totals"
    DoCmd.Hourglass False

    Line.Visible = True
    line_b.Visible = True
    msg_text.Value = "Processing..."
    Me.Repaint
    DoCmd.Hourglass True
    process "activity", "info", "totals", "emissions"
    DoCmd.Hourglass False
    msg_text.Value = "Calculations completed!"
    MsgBox "Calculations completed!", 48, "Calculation"
    End

1000:
    MsgBox "There is a error!Please contact the author.", 48, "Error"
End Sub
```

Appendix F

Bush Intercontinental Airport Vehicle Category



Appendix G

Testing Vehicle Instantaneous Speed Collected by Using GPS on IAH Loop

Section 1		Section 2		Section 3	
Distance (m)	Average Speed (mile/hour)	Distance (m)	Average Speed (mile/hour)	Distance (m)	Average Speed (mile/hour)
0	32.3358	0	29.893	0	29.75
10	31.86761993	10	31.6913717	10	31.75051
20	31.6763105	20	31.5075169	20	31.4227625
30	31.40381237	30	31.18888753	30	30.83855917
40	31.85497975	40	32.02468428	40	31.38762583
50	31.60439329	50	31.36849745	50	30.19637083
60	30.65116466	60	30.8757909	60	30.1826875
70	30.3190159	70	31.02698533	70	31.90245333
80	31.41426816	80	31.12628083	80	31.56328167
90	31.11173682	90	31.11768203	90	30.83271333
100	30.75729423	100	31.74766255	100	31.04915833
110	32.13342473	110	31.28645038	110	31.21836917
120	31.33857922	120	31.65253198	120	29.72277417
130	31.19868939	130	32.07653463	130	30.98001667
140	31.34810276	140	31.48273985	140	31.68619333
150	31.02222983	150	31.4536212	150	30.54701333
160	31.61563347	160	32.55400323	160	31.02573417
170	31.3854428	170	32.36800503	170	29.63406167
180	30.25979441	180	31.99691758	180	30.43729167
190	31.15770022	190	31.2283447	190	31.98976333
200	31.02589533	200	30.84228608	200	30.782755
210	30.79157295	210	31.88869468	210	29.84048667
220	30.81517912	220	32.24842468	220	31.09319667

230	30.80191882	230	32.16569918	230	31.01483
240	30.84131294	240	31.89294263	240	30.84566
250	30.95359529	250	31.21095055	250	30.18522333
260	30.85666259	260	31.75116763	260	31.27726
270	30.78325222	270	32.36566553	270	29.7498275
280	29.99168143	280	32.282486	280	31.00031
290	30.07110929	290	31.28578523	290	31.41637
300	29.7188939	300	31.92825123	300	31.83400167
310	31.01027495	310	31.35645323	310	31.05485
320	30.35282612	320	31.6812871	320	30.3434825
330	29.44568479	330	31.16640713	330	30.96338417
340	29.4872	340	30.66321143	340	30.40431167
350	29.76196428	350	31.32496148	350	30.77585333
360	29.63566234	360	31.4120047	360	31.91004
370	28.68876485	370	31.0214	370	31.79077917
380	29.21607261	380	31.19452318	380	30.87675583
390	28.94493719	390	31.07228485	390	30.25316083
400	28.85032161	400	31.33309563	400	30.398115
410	28.5347	410	31.16348855	410	31.83795167
420	28.75580718	420	30.49787428	420	32.00562167
430	28.9145	430	31.49133545	430	31.0220175
440	29.11333811	440	31.1212369	440	29.04327167
450	28.7624656	450	30.94815525	450	30.98211333
460	28.55122174	460	30.6634971	460	30.52426333
470	28.78363485			470	29.51565667
480	27.94341833			480	30.95541
490	28.40449776			490	30.76759083
				500	29.74165083
				510	30.52462167
				520	31.23914
				530	31.14382
				540	30.17051833
				550	31.35535083
				560	31.731565
				570	29.8231625
				580	29.12334
				590	31.31016
				600	31.975
				610	31.00864667
				620	29.17509583
				630	30.7327575
				640	30.84522833
				650	28.22309
				660	30.26323917
				670	29.57684417
				680	29.75003583
				690	30.50007833
				700	29.805545
				710	30.39950417
				720	29.24217
				730	29.69793
				740	29.02934417
				750	26.53663917

Section 4		Section 5		Section 6	
Distance (m)	Average Speed (mile/hour)	Distance (m)	Average Speed (mile/hour)	Distance (m)	Average Speed (mile/hour)
0	30.03545455	0	29.89914786	0	27.47115385
10	30.51004155	10	29.6115524	10	27.16035231
20	30.73418191	20	29.3036786	20	27.85969885
30	30.44151836	30	29.50847306	30	27.27551288
40	30.43037977	40	29.79237413	40	26.37658269
50	30.49921345	50	29.6892374	50	27.07921019
60	30.02957936	60	29.82117893	60	26.83049981
70	29.70304709	70	29.76619452	70	26.99150173
80	30.23654532	80	29.53829227	80	26.83352577
90	30.558171	90	29.77025717	90	26.78198558
100	30.69331691	100	29.55330804	100	26.57739673
110	29.94164264	110	29.31324273	110	26.34564077
120	29.75723745	120	30.42273541	120	26.1805625
130	30.01876673	130	29.43017615	130	26.77306885
140	30.77950014	140	29.73771852	140	26.74360308
150	30.46192586	150	29.71691237	150	25.98212827
160	30.4779305	160	29.97439087	160	25.63407846
170	30.96014877	170	29.47235944	170	25.15797558
180	31.61784027	180	29.36915842	180	24.25645288
190	30.78785609	190	30.14293783	190	25.2891925
200	31.04771673	200	30.16706161	200	25.27687673
210	31.49222164	210	29.80796092	210	25.97159788
220	31.01510345	220	29.40383436	220	26.47773019
230	30.83602091	230	29.65998982	230	26.87705923
240	30.53307082	240	29.23268028	240	26.63170385
250	31.3675815	250	28.98845214	250	27.91537942
260	31.14949791	260	28.89427408	260	30.13526269
270	30.88668518	270	29.35513602	270	31.03927096
280	30.88032323	280	28.60317821	280	31.50847885
290	30.82038359	290	28.88698105	290	31.61670212
300	31.34806277	300	28.81125582	300	32.60075712
310	31.2130435	310	28.82477867	310	33.70062077
320	31.4222275	320	28.6118726	320	33.92369654
330	31.53508909			330	34.57743115
340	30.03145109			340	33.57436558
350	30.08794686			350	33.37549981
360	31.03990955			360	33.65761135
370	31.48009691			370	34.43820423
380	31.13450186			380	34.39195538
390	30.62102823			390	33.27560577
400	30.93409864			400	33.19072481
410	30.91061968			410	33.58329212
420	30.64889677			420	34.35656173
430	30.18510295			430	34.33472827
440	30.48576664			440	34.07550058
450	31.25590664			450	33.47684019
460	30.76600464			460	33.5370025
470	30.1863905			470	33.71037962
480	30.782527			480	34.10460673
490	31.07369027			490	33.99457538
500	31.10658314			500	33.57367865

510	30.87284173			510	33.76283096
520	31.87178364			520	34.57603481
530	30.85213936			530	34.45155231
540	29.91273282			540	34.10882827
550	30.41513414			550	34.38364808
560	31.29911477			560	34.90770231
570	31.2759465			570	34.52104827
580	30.69762			580	34.27171327
590	29.87444109			590	34.09665
600	30.62455441				
610	30.72428191				
620	31.00503627				
630	30.57336041				
640	30.57352341				
650	30.93360882				
660	29.29293732				
670	29.42696289				
680	29.93334009				
690	30.07539082				
700	29.85936518				
710	29.19355377				
720	29.44297323				
730	30.06525023				
740	30.25079732				
750	29.97575445				
760	30.36584359				
770	29.68445718				
780	30.11691232				
790	29.69087459				
800	29.86405414				
810	29.73994341				
820	30.63483114				
830	30.22013064				
840	30.09509395				
850	29.64972727				
860	29.77638941				
870	30.72444709				
880	29.80247568				
890	29.61318541				
900	29.96113023				
910	30.53989645				

Appendix H

Speed Differences Generated with Using Optimal and Default Driving Parameter Values

Distance (meter)	Real Time (T_R)	Optimal (T_o)	Difference % $[(T_o - T_R)/T_R] \times 100\%$	Default (T_D)	Difference % $[(T_D - T_R)/T_R] \times 100\%$
0.0	27.5	29.4	7.0	28.0	1.9
10.0	27.2	29.4	8.2	27.8	2.4
20.0	27.9	29.3	5.2	27.6	-0.9
30.0	27.3	29.3	7.4	28.6	4.9
40.0	26.4	29.3	**11.1**	28.5	8.1
50.0	27.1	29.2	7.8	28.4	4.9
60.0	26.8	29.1	8.5	28.2	5.1
70.0	27.0	28.9	7.1	28.1	4.1
80.0	26.8	28.8	7.3	28.0	4.3
90.0	26.8	28.6	6.8	28.1	4.9
100.0	26.6	28.5	7.2	27.4	3.1
110.0	26.3	28.4	7.8	24.8	-5.9
120.0	26.2	28.2	7.7	25.9	-1.1
130.0	26.8	28.1	5.0	27.0	0.8
140.0	26.7	27.9	4.3	27.3	2.1
150.0	26.0	27.7	6.6	27.2	4.7
160.0	25.6	27.1	5.7	27.0	5.3
170.0	25.2	26.9	6.9	26.8	6.5
180.0	24.3	26.8	**10.5**	27.3	**12.5**
190.0	25.3	26.8	6.0	27.5	8.7
200.0	25.3	26.9	6.4	27.6	9.2
210.0	26.0	26.9	3.6	27.5	5.9
220.0	26.5	27.4	3.5	27.6	4.2

230.0	26.9	27.8	3.4	27.8	3.4
240.0	26.6	27.9	4.8	29.2	9.6
250.0	27.9	29.7	6.4	29.2	4.6
260.0	30.1	30.3	0.5	29.2	-3.1
270.0	31.0	30.7	-1.1	29.2	-5.9
280.0	31.5	31.1	-1.3	28.8	-8.6
290.0	31.6	31.4	-0.7	28.3	**-10.5**
300.0	32.6	31.4	-3.7	27.8	**-14.7**
310.0	31.7	31.2	-1.6	27.4	**-13.6**
320.0	31.9	31.0	-2.9	27.0	**-15.4**
330.0	32.6	30.9	-5.1	27.4	**-15.9**
340.0	31.6	31.2	-1.2	27.9	**-11.6**
350.0	31.4	31.2	-0.6	28.4	-9.5
360.0	31.7	31.3	-1.1	28.8	-9.0
370.0	32.4	31.4	-3.2	29.3	-9.7
380.0	32.4	31.5	-2.8	29.3	-9.5
390.0	31.3	31.5	0.7	29.2	-6.6
400.0	31.2	31.2	0.0	29.0	-7.0
410.0	31.6	30.9	-2.2	28.8	-8.8
420.0	32.4	30.7	-5.1	28.6	**-11.6**
430.0	32.3	30.4	-6.0	28.6	**-11.6**
440.0	32.1	30.3	-5.5	28.6	**-10.8**
450.0	31.5	30.4	-3.4	28.5	-9.5
460.0	31.5	30.3	-3.9	28.4	-9.9
470.0	31.7	30.4	-4.1	28.6	-9.8
480.0	32.1	30.5	-5.0	28.3	**-11.9**
490.0	32.0	30.5	-4.7	28.1	**-12.2**
500.0	31.6	29.7	-5.9	27.9	**-11.6**
510.0	31.8	29.5	-7.1	26.9	**-15.3**
520.0	32.6	30.1	-7.6	27.7	**-15.0**
530.0	32.5	30.5	-6.0	28.5	**-12.2**
540.0	32.1	30.4	-5.3	28.6	**-10.9**
550.0	32.4	30.4	-6.1	28.6	**-11.7**
560.0	32.9	30.5	-7.3	28.6	**-13.1**
570.0	32.5	30.7	-5.6	28.5	**-12.4**
580.0	32.3	30.8	-4.6	28.1	**-12.9**
590.0	32.1	31.0	-3.4	27.9	**-13.1**
Number of Difference Larger than 10%			**2**		**22**