A multi-factor environmental capacity model for roads

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A MULTI-FACTOR ENVIRONMENTAL CAPACITY MODEL FOR ROADS

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CERTIFICATE OF ORIGINALITY

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other defree of diploma of a university of tother institute of higher learning, except where due acknowledgement is made in the text.

I also declare that the intellectual content of this thesis is the product of my own work, even though I may have received assistance from others on style, presentation and language expression.

Doni Janarto Widiantono

ABSTRACT

Land use - transport interactions and their mathematical modeling have been extensively studied and developed by researchers and practitioners since the late 1950s. The booming of the model development occurred during the 1950s, 1960s and 1970s (Blunden and Black 1984), and critical appraisals emerged in the 1970s. Transport-land use model development in the 1980s and 1990s has been characterized by the building of computer decision support systems, which integrate the various models into interactive computer programs. On the other hand, concerns on the sustainability of the quality of environment have encouraged people to intensify the systematic identification, quantification, and evaluation of environmental impacts to be included in the modeling sequence as one of the transport system development consequences.

In order to facilitate the assessment of environmental conditions along particular road, Buchanan (1963) introduced a concept of environmental capacity that was defined as the amount of traffic and the character of the traffic permissible in a street consistent with the maintenance of good environmental conditions. From this definition he then developed a procedure for determining the environmental capacity based on pedestrian delay as a controlling factor. Several other studies were then attempted following on the work of Buchanan. Sharpe and Maxman (1972) for instance, proposed a methodology to quantify the environmental capacity of streets with different types of land-use such as commercial, institutional, or residential and different characteristics of road geometry such as number of lanes, and terrain. Other studies regarding this concept were conducted by Abeysurya (1979), Holdsworth and Singleton (1979) and by Song *et al.* (1993).

One aspect was common to the above attempts in determining the environmental capacity. They used a single controlling or determining factor to estimate the environmental capacity of roads. This has become the unattractive aspect of the concept as it produced very low values compared to physical capacity the roads (Klungbonkrong, *et.al*, 1998). Although some engineering guidelines (Australian Government, 1990; Road and Traffic Authority, 1993) have been employing the approach in determining the environmental capacity of roads as indicated by Hallam (1996), an alternative holistic approach appears worthy of being attempted.

In the present study, a Multi-Factor Environmental Capacity (MFEC) approach is put forward. Basically, the approach attempts to bring together all the environmental factors in determining the environmental capacity. This was based on the idea that people tend to experience the various environmental impacts simultaneously and therefore these impacts might be considered as a combined or simultaneous impact as implicitly indicated by Sharpe and Maxman (1979) and Song, *et.al.* (1993). The concept employs an environmental utility function that blends all the factors together into a single value. Prior to the description of the model, sensitivity analyses of several environmental prediction models were undertaken. Overall, there was a general agreement that almost all the models have similar parameters namely traffic volume, speed and road geometry parameters. This commonality may led to the suggestion that the models can be represented by single model or value namely Environmental Utility Value (EUV). This EUV can then be correlated with the road and traffic parameters to create a Multi-factor Environmental Capacity model.

Four major traffic-related environmental factors are included in the model, noise, air pollution, pedestrian delay and accident risk. An experimental design for the study was proposed, the study area selected and the required data determined. Survey instruments and methods were put forward and a sample design prepared. Bandung was chosen as the study area to represent a medium sized city in Indonesia, which is expected to suffer environmental problem in the near future. Methods employed in the study were described and the required number of samples determined. Data procedures required that around 37 sites were surveyed of which 27 were used for model calibration purposes and 9 for subsequent model validation. Traffic, road geometry and land use as well as environmental factors were also observed. At the same time community preferences were surveyed through interview and mail-back questionnaires.

After being evaluated it was decided to use DoT noise model (UK DoT, 1988) for noise prediction purposes, while General Motors line-source dispersion model (Chock, 1978) was used in predicting air pollutant concentration. For predicting pedestrian delay, model suggested by Austroads (1995) was employed, whereas for accident rate, the model as proposed by Zeeger (1984) was adopted.

Calibration as well as validation of models employed in the study has been performed using the separately collected data. Statistical tests and analyses were undertaken to justify the model performances.

Analyses of preferential data of both community and experts towards environmental factors suggested that the community preferences were different significantly (at 95% level) from those of a group of experts, particularly in determining the most annoying factors. Noise was considered as the most annoying factor according the community, while the reverse was true according to the group of experts. Other factors, such as air pollution, pedestrian delay and accidents, were not considered as important as noise according the community. The experts, on the other hand, tended to say that the three factors were almost equally more important than noise.

In terms of road class, it was found that no significant differences in responses were observed between those from residents in arterials and collectors categories, while significant differences occurred between locals and both arterials and collectors. Similar results were also found between land-uses. The analyses suggested that influences of land-use were apparent between two groups, namely commercial and residential. These outcomes led to the development and adoption of models considering two different classes of roads and two different types of land-uses.

Application of the proposed MFEC was also demonstrated. The example showed that the approach could produce higher environmental capacity compared to the traditional approach. An average improvement of environmental capacity between 485-1615 was identifiable. This fact led to a ratio between environmental capacity and road capacity (physical) of between 0.45-0.73, which was regarded as being more realistic.

Sensitivity analyses of the model showed that generally MFEC would increase by increasing road width (widening) and/or reducing speed. The MFEC would also increase by increasing EUV_L. Summary of the increasing rates of MFEC with the increase of three parameters is as presented in Table 1.

Table 1 Sensitivity of MFEC towards the Parameters (vph)

Category	Width	Speed	EUV_L
Major-Commercial	280	-24	815
Major-Residential	297	-65	444
Local-Commercial	-20	-35	278
Local-Residential	45	-8.5	222

Note: width per 1m increase, speed per 1km/h increase, EUV_L per 10 point increase

These findings indicated that the proposed model was quite promising in providing an alternative approach of determining environmental capacity that was both simple and realistic. Nevertheless, caution as to be given towards the range of applicability of the model before applying the approach in the real world cases.

"In the Name of Allah, the Merciful, the Compassionate."

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Hillsdale, October 1999.

Doni J. Widiantono

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GLOSSARY

Accident	in this study is defined as all types of traffic accidents either with fatal, casualty or damaged only level of severity and either involving single or multiple vehicles from opposite directions or of the same directions
Accident rate	number of accidents per unit of exposure, in accidents/km/yr
Air pollution	contamination of the atmosphere by the discharge of emissions of undesirable substances and gases, or the formation of these gases from the emissions by chemical reactions in the atmosphere.
Ambient	the background or surrounding parameters occurring in the environment.
Attribute	component, part or factor considered in making a decision
Bandung	capital city of West Java, Indonesia
Bandung Dalam Angka	Bandung Annual Statistical Figures
Bina Marga	Directorate General of Highways, Ministry of Public Works, Republic of Indonesia
Biro Pusat Statistik	Central Bureau of Statistics, Republic of Indonesia.
Calibration	Phase in model development, where the theoretical model is applied against empirical data
Capacity	Physical capacity of roads, maximum allowable traffic passing through any particular section of road.
Commercial	frontage land-use with predominantly commercial activities
Community	people live alongside roads concerned.
Concentration	weight per volume measurement of gas substance
Delay	delay experience by pedestrian when attempting to cross a road
Desktop Run-through	a comprehensive evaluation of study design to anticipate unwanted things by simulating various scenarios on a desktop exercise
Dinas Pekerjaan Umum	Local Government Office of Public Works
Dispersion	dispersion of air pollutant in the surrounding atmosphere
Emission	various amount of pollutants emitted by engine-powered vehicles
Environment	surrounding conditions

Environmental Factor	in the present study is defined as traffic-related environmental impacts such as noise, air pollution, delay, and accident risk
Error	difference between measured and predicted values
Eulerian	Eulerian dispersion model
Evaluation	study intended to evaluate any existing model
Experts	in the present study are defined as people who professionally deal with and presumably have sufficient understanding on environmental issues, either as consultants, government official or lecturer/educator.
Exposure	magnitude and potential conditions within which someone may encounter accidents
Gaussian	Gaussian model in predicting air pollutant dispersion
Geometry	geometry measurement of road including cross section, width and other road inventory
Gradient	Average longitudinal gradient of road section measured in % (m/m)
Indifferent Line	line where measured and predicted values are equal
Lagrangian	Lagrangian dispersion model
Land-use	type of activities or use of a particular land area
Median	element of road that separates opposing streams of traffic in order to reduce conflict and to increase safety
Microsoft Excel	Microsoft spreadsheet computer program.
Mix Land-use	frontage land-use with predominantly mix activities
Mobile Laboratory	A truck specially designed and loaded with sophisticated air pollution measuring equipment.
Multiple R-sq.	a criterion in multiple regression that merely indicates the proportion of the total variation in the dependent variable that is explained by the fitted model
Noise	unwanted sound
Over-predict	model performance evaluation that indicates the general tendency of the model to predict higher than measured/actual values.
Pairwise	observing two things at a time
Pedestrian	a person either walking, or in wheelchair, or on roller skates, or riding on 'toy vehicles' such as skate boards, or other vehicles other than a bicycle, powered by human effort or a motor in a street with a maximum speed of 7 km/h
Pilot survey	a small-scale survey used to rehearse and evaluate the study design
Pneumatic Tube	rubber tube use to detect vehicles in automatic traffic counting system

Preference	people stated inclination towards some factors
Ranking	express the level of importance of something by assigning sequential number
Rating	express the level of importance of something by assigning a nominal score
Refuge Island	raised part of a road provided for pedestrians to temporarily wait before finalize their crossing
Residential	frontage land-use with predominantly residential
Residual	error, the difference between measured or observed with predicted values
Risks	probability of having an accident or unwanted event
Road Island	see refuge island
Site	a place where data collection is undertaken
Site Code	code used to identify site
Speed	time mean speed of traffic in km/h
Spreadsheet	computer program used to manipulate and process arrays of data
Study Area	area within which the study is bound
t-test	statistical test using student-t method
Under-predict	model performance evaluation that indicates the general tendency of the model to predict lower than measured/actual values
Utility value	a value or score that measures the relative utility of something
Validation	a phase in model development intended to determine the validity of calibrated model
Volume	the number of vehicles per unit of time pass through any particular point in a section of road
Wheel meter	an apparatus composed of a stick and a wheel used to measure distance

SYMBOLS AND ABBREVIATIONS

#Lane	number of lanes
$	Australian dollar
%Delay	percentage pedestrians being delayed
°	degrees
μ	micro, 10^{-6}
±	plus-minus
/	per; divided by; and/or
:	ratio
<	less than
>	greater than
acc.	accident
ACCID	accident rate prediction module in MFEC model
AHP	Analytical Hierarchy Process
AIRPOL	air pollution prediction module in MFEC model
ATC	Automatic Traffic Counting
C	centigrade
CH_4	methane
Chi-sq.	Chi square
CI	Consistency Index
CL	Confidence Limit
Cm	centimetre
CO	carbon monoxide
CO_2	carbon dioxide
dB(A)	A-weighted decibel (a measure of sound adjusted to human hearing)
DoT	UK Department of Transport
EC	Environmental Capacity, the maximum number of allowable traffic to pass a particular road based on environmental criteria
ENVIRO	Environmental factor prediction module of MFEC model
EUV	Environmental Utility Value, an environmental score representing the general conditions of environment ranging

	between 0-1 or 0-100, arbitrarily the lower the better (relatively to the other).
EUV	EUV module of MFEC model
EUV_L	EUV at limit state, the corresponding utility of virtually acceptable conditions of environment
g	gram
Grad.	Gradient
h or hr	hour
HC	Hydro Carbon
HV	Heavy Vehicle
INPUT	input module of MFEC model
ISGLUTI	International study Group of Land-use/Transport Interaction
kg	kilogram
km	kilometre
L_{10}	noise index, noise level exceeded in 10 percent of the time
L_{eq}	equivalent noise level index (a notional steady level which would produce the same energy as the fluctuating sound)
m	metre
m^3	cubic metre
MC	motor cycle
MFEC	module in the MFEC model that determines and calculates the MFEC
MFEC	Multi-Factor Environmental Capacity
mg	milligram
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NOISE	module in MFEC model that calculate and predict noise level
NOx	Nitrogen oxides
NSW	New South Wales, Australia
OUTPUT	module in the MFEC model that display the output of the model
Pb	lead
ped.	pedestrian
PEDES	sub-module in the MFEC model that predict the pedestrian delay or proportion of delayed pedestrians
ppb	parts per billion
ppm	parts per million
RIRE	Research Institute of Road Engineering

RoadDir	Road direction
R-sq.	R square (see multiple R-sq.)
S	Speed, in km/h
SLM	Sound Level Meter
SO_2	Sulfur dioxide
SOx	Sulfur oxides
SPM	Suspended Particulate Matter
Temp.	Temperature
UK	United Kingdom
US EPA	United State Environmental Protection Agency
V	traffic volume, vph
vph	vehicle per hour
W	road width
WindDir	wind direction
WindSpd	wind speed
y or yr	year

Chapter 1

Chapter 1

INTRODUCTION

1.1 Background

Land use - transport interactions and their mathematical modeling have been extensively studied and developed by researchers and practitioners since the late 1950s. The booming of the model development occurred during the 1950s, 1960s and 1970s (Blunden and Black 1984), and critical appraisals emerged in the 1970s. Transport-land use model development in the 1980s and 1990s has been characterized by the building of computer decision support systems, which integrate the various models into interactive computer programs. There were at least nine landuse-transport models demonstrated by the International Study Group on Land Use/Transport Interaction (ISGLUTI). In general, they could be divided into two major groups, predictive models and normative models for the arrangements of land-use and activities (Webster, et.al., 1988).

On the other hand, concerns on the sustainability of the quality of environment have encouraged people to intensify the systematic identification, quantification, and evaluation of environmental impacts to be included in the modeling sequence as one of the transport system development consequences (Weiner, 1972). Attempts to include environmental aspect as externalities in the cost-benefit evaluation of infrastructure development date back to the 1960s (Prest and Turney, 1965), but mathematical models that relate traffic characteristics with environmental factors such as noise, air pollution, and accidents are more recent in origin. Number of vehicles, speed, and the distance of recipient are mostly used for predicting traffic noise level (Burgess, 1977, 1986, DoT, 1976, Delany, 1972, HRB, 1971, Lamure, 1975, Nelson, 1973, Harland, 1977, Samuels, 1982, Samuels and Fawcett, 1984). Prediction of the emission and dispersion of air pollutants such as CO, NOx, HC, particulate, and lead mainly employs traffic and meteorological parameters (Taylor and Anderson, 1982, Koh and Lim, 1985, Kot and Lai 1985, Chock, 1978, Taylor et.al, 1985; Watson, 1983; Mainwaring and Thorpe, 1983; Watkins, 1991). For predicting pedestrian delay or pedestrian risk, use of road and traffic parameters such as traffic volume, speed, headway and road width are very common (Adams, 1936; Tanner, 1951; Ashworth, 1970; Holdsworth and Singleton, 1979; Song, Black and Dunne, 1993, Guo and Black, 1998). Another aspect of road environment such as accident risk has also been attracting some people to attempt to predict by correlating the accident rate with road geometry and traffic parameters (Peltzman, 1975; Roh, *et.al*, 1999; Taylor and Lockwood, 1990; Zeeger *et.al*, 1986).

In order to facilitate the assessment of environmental conditions along particular road, Buchanan (1963) introduced a concept of environmental capacity. He defined environmental capacity as the amount of traffic and the character of the traffic permissible in a street consistent with the maintenance of good environmental conditions (Buchanan, 1963). From this definition he then developed a procedure for determining the environmental capacity based on pedestrian delay as a controlling factor. Several other studies were then attempted following on the work of Buchanan. Sharpe and Maxman (1972) for instance, proposed a methodology to quantify the environmental capacity of streets with different types of land-use such as commercial, institutional, or residential and different characteristics of road geometry such as number of lanes, and terrain. They found that the environmental capacity in most residential streets was governed by public safety, while for streets with commercial and institutional land-uses it was mostly controlled by noise and air pollution. Other studies regarding this concept were conducted by Abeysurya (1979), Holdsworth and Singleton (1979) and by Song *et al.* (1993). Abeysurya (1979) attempted to study the effect of pedestrian crossing behavior on environmental capacity while Holdsworth and Singleton (1979) tried to determine the environmental capacity based on two major factors (noise and pedestrian delay). Song *et.al.* (1993) introduced the accident risk and mean delay as the third determinant of environmental capacity.

One aspect was common to the above attempts in determining the environmental capacity. They used a single controlling or determining factor to estimate the environmental capacity of roads. The factor was usually the one that gave the minimum amount of traffic to produce the acceptable level of the impact. This has become the unattractive aspect of the concept as it produced very low values compared to physical capacity the roads (Klungbonkrong, *et.al*, 1998). Although some engineering guidelines (Australian Government, 1990; Road and Traffic Authority, 1993) have been employing the approach in determining the environmental capacity of roads as indicated by Hallam (1996), an alternative holistic approach appears worthy of being attempted.

The low values of traditional EC, which due to the approach that takes the minimum of EC values suggested by individual factor, are considered unattractive because it is very low compared to the corresponding physical capacity of the road. If this is to be adopted in practice, the road might be considered as "very expensive", which in other words would be considered as "unattractive".

In the present study, a methodology of determining environmental capacity by considering a multi-factor approach is put forward. Basically, the approach attempts to bring together all the environmental factors in determining the environmental capacity. This was based on the idea that people tend to experience the various environmental impacts simultaneously and therefore these impacts might be considered as a combined or simultaneous impact as implicitly indicated by Sharpe and Maxman (1979) and Song, *et.al.* (1993). The approach employs a multi-attribute utility theory (MAUT) to produce a representative value of environmental conditions of a particular road. The value can then be regarded as the Environmental Utility Values (EUVs) of the road. That is, the EUV is simply a blended value of all the environmental factors. Using these EUVs, environmental capacity could then be determined from their relationships with road and traffic parameters.

The concept of Multi-factor Environmental Capacity (MFEC) proposed in the thesis formulates an attempt to blend several environmental factors together into a single value (Environmental Utility Value-EUV). In order to do this, it was assumed that people tend to have different preferences towards various environmental factors. Some people may give more attention towards one factor over the other, while other people may not. It is very likely that people will have different preferences for each environmental factor, since some factors can, at times be more noticeable than others . In the model, these preferences are reflected by the weights of factors in the utility function. The more the weight the more the attention/preference the people give to the factor. These responses may also vary with different road environment; for instance people living along arterial roads may have different preferences towards environmental factors compared to people living on local roads. One objective of the surveys made of community members and of experts was to determine these weights on the basis of the survey responses.

1.2 Goals and Objectives

The goals of the present research are to review methodologies on EC and to develop an alternative method in determining environmental capacity using a multi-factor approach.

In order to achieve the goals, several objectives have been formulated. They are as follows.

- reviewing literature and identifying the state-of-the-art in the area of transport-landuse-environmental interactions;
- reviewing some background knowledge in multi-attribute utility theory and other relevant subjects;
- developing a methodology to address the problem and describing the methodology in terms of mathematical equations;
- reviewing existing environmental prediction models;
- calibrating and validating the models using a case study data;
- interpreting and evaluating the results;
- discussing the possible applications of the model.

1.3 Outline of the Thesis and Scope of the Study

Considering all the above mentioned objectives this section describes how they have been addressed in this thesis. The first chapter of the thesis introduces the nature of the problems being researched in the present study. It describes the background and sets up the goals and objectives of the study. The chapter also outlines the structure of the thesis as well as discussing the scope of matters covered in the study.

Chapter two and three provide some background knowledge in doing the research. The former mainly talks about the state-of-the-art in the subject area of transport-landuse-environmental interactions as well as the mathematical modeling of traffic related environmental impacts. The latter provides some relevant theoretical background to reinforce the ability of resolving the research problems.

Methodology adopted in conducting the research is explained in chapter four. Conceptual as well as mathematical expression of the proposed model are put forward and the sensitivity of some prediction models discussed. The chapter also provides a hypothetical case for such models to demonstrate their applicability.

Subsequent chapters, five and six, describe the data collection related activities. Chapter five describes the study design whereas chapter six covers the field data collection based on the design. Sample design and proposed methods of survey are some of the main subjects covered in chapter five, while chapter six mainly addresses such matters as survey preparation, survey procedures as well as preliminary data processing techniques.

Analyses of the data are explained in chapter seven. The chapter describes the techniques employed in the analyses and presents the summary of the calculations together with their descriptive statistics. Algorithms in calculating the predictive values of such environmental factors as noise, air pollutant concentration, pedestrian delay as well as pedestrian risk are also described in length. Some extracted results are presented while complete results of the calculations can be observed in relevant appendices in the rear part of the thesis.

Chapters eight and nine respectively focus on the calibration and validation process of the proposed models. All the models employed in the proposed methodology have been calibrated using case study data from the city of Bandung. Bandung was chosen as a case study to represent a typical medium sized city of developing countries such as Indonesia. Validation was be done using a different set of data collected from the same study area.

As the calibration and validation of the models was completed, it was desirable to see how the whole model worked together and performed. Chapter ten then provides with such a requisite. The whole structure of the model is overviewed and applications demonstrated. Sensitivity and limitations of the models are also addressed.

The last chapters of the thesis, chapters eleven and twelve, discuss the performance of the proposed methodology demonstrated in previous chapters as well as potential findings. In chapter eleven, advantages and disadvantages of the methodology are discussed in detail and potential contributions to knowledge identified. While chapter twelve simply concludes the thesis by identifying major findings as well as suggested further research in the future.

It can be summarized from the above paragraphs that the scope of the study is to develop an alternative methodology in determining the environmental capacity for roads using a multi-factor approach. The models then so developed are calibrated and validated using Bandung case study data as a representative of typical medium sized city in developing countries. Subjects covered in the background study will mainly be of transport-landuse-environmental interaction area. While the multi-attribute utility theory is the main mathematical technique adopted to facilitate the development of the model.

Chapter 2

Chapter 2

STATE-OF-THE-ART

This chapter outlines the state-of-the art within the scope of land use - transport - environmental modeling, decision support systems, and traffic related environmental impact models. In addition, the concept of environmental capacity is overviewed and progress reviewed. The last section provides the relevance of the review to the present study and suggests a researchable area within the existing technology.

2.1 Land use - Transport - Environmental Interactions

The traditional four-step transportation planning process has been proved to be an effective way of predicting the transport demand, distributing the movements between zones, classifying the mode of transport, and assigning the traffic load into road links (Blunden and Black 1984). Unfortunately, this traditional approach does not include the environmental aspect, which is nowadays becoming a critical issue. The following paragraphs give some idea about what has developments in the study of land use-transport-environment. Models that have been developed so far are overviewed. The features are compared to give an idea about what has and what has not been done in the field.

There are several land use-transport models that have been developed so far, with various features and kinds (see Table 2.1). Most of them were developed in 1970s, one in late 60s (MEP) and one in early 80s (OSAKA). Because these models were developed in the era when environmental impact had not become a critical issue, very few of them incorporated an environmental impact sub-model. Some of them like TOPAZ-URBAN in its third generation version included environmental impact as part of the model. Any other models like, CityPlan (LAND) and TRANSTAR, which were developed in the late 1980s for teaching purposes, have more comprehensive environmental impact evaluation in their systems.

TABLE 2.1 OVERVIEW OF LANDUSE-TRANSPORT-ENVIRONMENTAL MODELS

Name of Model (source)	Organization	Year Develope d	Type of Model	Basic Theory	Modeling Technique	Envi/mental Impact
AMERSFOORT (Webster et.al. 1988)	Univ. of Utrecht, Netherlands	1976	predictive	entropy-maximization	generalized gravity model	N/A
CALUTAS (Webster et.al. 1988)	Univs. of Tokyo and Nagoya, Japan	1978	predictive	microeconomics random utility, welfare economic	gravity model, choice model, linear regression	N/A
DORTMUND (Webster et.al. 1988)	Univ. of Dortmund, Germany	1977	predictive	microeconomics , entropy, random utility, time geography	gravity model, choice model, monte carlo simulation	N/A
ITLUP (Webster et.al. 1988)	Univ. of Pennsylvania, USA	1971	predictive	entropy-maximization	gravity model	N/A
LIILT (Webster et.al. 1988)	Univ. of Leeds, United Kingdom	1974	predictive	entropy maximization	gravity model, choice model, markovian model	N/A
MEP (Webster et.al. 1988)	Marcial Echenique & PartnersUnited Kingdom	1968	predictive	microeconomics, random utility, economic base	gravity model, choice model, market mechanism, input-output	N/A
OSAKA (Webster et.al. 1988)	Univ. of Kyoto, Japan	1981	predictive	microeconomics, random utility, economic base	choice model, market mech., monte carlo	N/A
SALOC (Webster et.al. 1988)	Royal Institute of Technology, Sweden	1973	normative	time geography, welfare economic	choice model, mathematical programming	N/A
TOPAZ (Brotchie et.al 1994)	Commonwealth Scientific and Industrial Research Organization, Australia	1970	predictive, normative	entropy maximization, welfare economic	gravity model, mathematical programming	energy use, greenhouse emission
MASTER (Webster et.al. 1988)	University College, United Kingdom	1971	predictive	random utility	monte carlo, choice model	N/A
TRANSTAR (Black, 1994)	Univ. of New South Wales, Australia	1980s	predictive	economic base (lowry), welfare economic	fully constrained gravity model, choice model	noise, greenhouse emission, accident
LAND/CITYPLAN (Young and Gu, 1993)	Monash Univ., Australia	1990s	predictive	random utility	gravity model, choice model	greenhouse emission, noise

Source: Adapted from Webster et.al., 1988, pp. 24-42.; Brotchie et.al., 1994; Young and Gu, 1993, Gu, 1996, Mackett, 1992..

Table 2.1 provides overview of the land-use-transport-environmental models, including the type of model (predictive, normative), basic theory employed, modeling techniques used, and whether includes environmental impact module. Almost all the models are predictive, except SALOC which was normative (optimizing) and TOPAZ which is both predictive and normative. Entropy maximization and random utility theory are the most widely used as the basis in the models. Whereas generalized gravity model, either singly or doubly constrained, and choice model are the techniques that very common in the models.

Regarding environmental impacts, it is apparent that they are only included in TOPAZ, TRANSTAR, and CityPlan. The environmental impacts covered are mostly air pollution such as in TOPAZ, CityPlan (Gu, 1993) and TRANSTAR (Black, 1994) and accident rate (TRANSTAR).

2.2 Traffic Related Environmental Impact Prediction Models

Environmental impacts resulting from infrastructure developments may be classified into categories such as road-related impacts, traffic related impacts, and administrative impacts (Lay, 1984). Road related impacts could possibly due to locating, designing, constructing, and maintaining the road physically. While traffic related impacts would include noise, air pollution, vibration and accidents caused by vehicular movements on the roads. The administrative impacts may include land acquisition, relocation of residents, community severance or other road-development-related administration procedures.

Department of Transport (1988) identifies at least eleven types of environmental impacts as a result of any road development scheme:

1. Noise;
2. Air Pollution;
3. Visual;
4. Community Severance;
5. Effects on Agriculture;
6. Heritage and conservation areas;
7. Ecological;
8. Disruption at construction stage;
9. Pedestrian and Cyclist;
10. View from the road; and
11. Driver stress.

According to Sharpe and Maxman (1972), the most dominant environmental impacts as reported by community were noise, air pollution, and child and pedestrian safety, without any intention to disregard the other impacts.

2.2.1 Noise Prediction Models

Considerable numbers of noise prediction models have been developed so far around the world. Some of them are quite simple and straightforward while the others are relatively more complicated. Simpler methods usually have restrictions on the conditions for which can be applied. For design and planning purposes simpler methods may be useful as they are easy to handle (Burgess, 1986). Some of the models that have been developed to predict traffic noise are listed in Table 2.2.

One index that is commonly used to represent the level of noise is L_{10}(18 hour), which means the arithmetic mean of noise levels which is exceeded for 10% of each hour time during 18 hours period (6am-12pm). For some particular purposes such as construction or demolition noise, it is also common to use L_{eq}, which is the equivalent continuous sound level.

Parameters that are usually encountered in noise prediction models are (Burgess, 1981):

- total vehicle flow rate (q);
- vehicle speed (s);
- percentage of heavy vehicles (p);
- gradient and surface of road;
- distance of noise resource to the recipient;
- type of ground surface;
- height of receiver;
- height and length of barrier; and
- reflection from nearby surfaces.

Since the UK Department of Transport model is a comprehensive, reliable and widely used model (Samuel and Fawcett, 1984; Wooley, 1998), it was decided to adopt this model in the present study.

TABLE 2.2 LIST OF NOISE IMPACT MODELS

Author	Model	Parameters
Burgess, M.A., (1977)	L_{10} = 56+10.7 logq+0.3p-18.5d	L_{10} = Noise level exceeded for 10% of the time, dBA q = traffic volume (veh/hour) p = percentage of heavy vehicles. D = distance from the center of traffic flow.
Burgess, M.A. (1986)	L_{10} = 60.3+11 logq + 0.3p – 23.6 logd	idem

TABLE 2.2 LIST OF NOISE IMPACT MODELS (CONT'D)

UK Department of Transport (1988)	$L_{10} = 41.2 + 10 \log q$ $L_{10(18\text{-hour})} = 28.1 + 10 \log Q$ Correction: h. s and p $33\log(s+40+500/s)+10 \log(1+5p/s)-68.8$ h. G 0.3G (for measured speed); 0.2G (for estimated speed). c. road surface with 5mm or more deep random grooving 4 – 0.03p h. d and h hard ground: $-10 \log(d'/13.5)$; grassland: $-10 \log (d'/13.5)+5.2 \log [3h/(d+3.5)]$; for $1 \le h \le (d'+3.5)/3$ $-10 \log (d'/13.5)$; for $h>(d'+3.5)/3$ (valid for $d \ge 4m$) e. barrier $-15.4-8.26x-2.787x^2-0.831x^3-0.198x^4+0.1539x^5+0.12248x^6+0.02175x^7$; for shadow zone, $-3 \le x \le 1.2$ $0.109x-0.815x^2+0.479x^3-.3284x^4+0.04385x^5$; for illuminated zone, $-4 \le x \le 0$ f. θ $10 \log(\theta/180)$ g. Y Y dBA h. φ exp.-$(0.019\phi^2)$dBA	L_{10}=basic noise level, exceeded for just 10% of the time, dBA (for s=75kph, p=0, G=0). $L_{10(18\text{-hour})}$= basic noise level exceeded for 10% of 18 hours (6am-12pm) q = total hourly volume Q = total 18-hour volume s = mean travel speed p = percentage of heavy vehicles(%) G = gradient (%) d = distance from edge of nearside carriageway (m) h = height of receiver above ground (m) $d' = ((d+3.5)^2+(h-0.5)^2)^{0.5}$ x = log δ where δ = a+b-c θ = angle of view Y = depth of cut (m) φ = angle of wall to vertical (degrees).
Delany, M.E.,(1972a)	$L_{10} = 7 \log q + 5.5 \log s - 10.7 \log d + 11$	q = volume (vph) s = speed (kph) d = distance (m)
Delany, M.E., (1972b)	$L_{10} = 26.8 + 16.2 \log(1.609s)+8.9 \log q+11.7p-10.5 \log 0.304d$	d = distance (feet) s = speed (mph)
Highway Research Board, (1971)	Auto: $L_{50} = 10\log q - 15\log d + 20\log s + 10\log(\tanh(1.19*10^{-3}qd/s))+39$ Truck: $L_{50} = 10\log q-15\log d-10\log s + 10\log(\tanh(1.19*10^{-3} qd/ s)) +95$	q = vehicles per hour d = distance from traffic stream (feet) s = speed (mph)

TABLE 2.2 LIST OF NOISE IMPACT MODELS (CONT'D)

Lamure, C. (1975)	Leq = 52+10logq/d	Leq = equivalent continuous noise level q = vehicles per hour d = distance to middle of road (m)
Nelson, P.M. (1973)	L_{10} = 8loq+20.4log s + 13 (3m from road side)	q = vehicles per hour s = speed (kph)
Nelson, P.M. (1973)	L_{10} = 8loq+20.4log s - 16log d+27.4	d = distance (m)
Samuels, S.E.(1982)	SPL = -16+30log s + 3.9 log(M^2A+Q/M)	SPL = Sound Pressure Level (dBA) s = speed (kph) M = mean macrotexture depth of the surface, mm A = contact area Q = maximum volume of air enclosed by the road surface in the tyre tread and available for pumping (mm^3).

2.2.2 Air Pollution Model

During mid 1970s a considerable amount of effort was attempted to model roadway-air-pollution dispersion (Darling, Prerau, Downey and Mengert, 1975; Noll, Miller, Rainey and May (1977); Zimmerman and Thompson, 1975). Nevertheless calibration and validation of these models has been rare due to difficulties in obtaining reliable data. In 1978 Chock of General Motors Research Laboratories attempted to develop a relatively simple model for predicting traffic related air pollution. He based his model on Gaussian line-source model, which assumed that concentration of air pollution at receptor point is the aggregate of all the infinitesimal point sources that make up a line source such as in the case of road traffic. In simplifying the model, Chock suggested disregarding the point source assumption and came up with a model as in Eqn. 2.1.

$$C(x,z) = \frac{Q}{\sqrt{2\pi}U\sigma_z}\left\{\exp\left[-\frac{1}{2}\left(\frac{z+h_0}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z-h_0}{\sigma_z}\right)^2\right]\right\} \qquad 2.1$$

where:

C(x,z) = concentration at point (x,z) relative to the line source at x=0, in g/m^3;

Q = emission rate per unit length, in g/km;

U = effective cross wind, in ms^{-1};

h_0 = plume center height at distance x from the road, in m;

σ_z = vertical dispersion parameter;

$$\sigma_z = (a + bf(\theta)x)^c \qquad 2.2$$

$$f(\theta) = 1 + \beta \left| \frac{\theta - 90°}{90°} \right|^{\gamma} \qquad 2.3$$

θ = wind angle relative to the roadway, in degrees.

a,b,c,α,β and γ are parameters determined from atmospheric stability conditions. The suggested values for stable, neutral and unstable conditions are as provided in Table 2.3. The stability was determined using a Richardson number Ri, where a Ri > 007 was sets as stable, 0.07 ≥ Ri ≥ -0.1 as neutral and Ri ≤ -0.1 as unstable conditions.

TABLE 2.3 PARAMETERS VALUES OF AIR POLLUTION MODEL

Parameters	Stable (Ri>0.07)	Neutral (0.07 ≥ Ri ≥ -0.1)	Unstable (Ri ≤ -0.1)
a	1.49	1.14	1.14
b	0.15	0.10	0.05
c	0.77	0.97	1.33
α	20.7	11.1	11.1
β	5.82	3.46	3.46
γ	3.57	3.50	3.5
U_I	0.18	0.27	0.27
U_0	0.23	0.38	0.63

Note: a in $m^{1/c}$, b in $m^{-1+1/1}$, U_1 and U_0 in ms^{-1}
Source; Chock, 1978

The model was proved to be quite simple and robust. As indicated by Watson (1983), who tried to evaluate the model using Sydney CO concentration data, the so called GM model was quite accurate in predicting the concentration of CO. Provided that the emission rate or the model in predicting emission rate was reliable, the model may be used for predicting air pollution in highway planning with some confidence (Watson, 1983). Another study conducted by Mainwaring and Thorpe (1983) supported this claim. The study compared GM model with several other models such as HIWAY (USEPA) and Detar (Detar, 1979) in predicting dispersion of particulate pollutants. They conclude that GM model was the best predictor compared to the other.

One particular study attempting to predict line-source air pollution was the one by Taylor, Simpson and Jakeman (1985). They attempt to predict concentration using a hybrid method. Some other air pollution and emission models are presented in Table 2.4.

TABLE 2.4 LIST OF AIR POLLUTION IMPACT MODELS

Author	Model	Parameters
Taylor, M.A.P. and Anderson, B.E. (1982)	CO =0.8+510/s HC = 0.6+34/s NO_x = 2.5 g/km	CO = CO emission per car, g/km HC = HC emission per car, g/km NO_x = NOx emission per car S = speed (kph)
Koh, Hock-Lye and Lim, Poh-Eng (1985)	Daytime: $CO_t = 1.49+0.68\ Co_{t-1} + 0.0016T_b + 0.00035T_c$ Night Time: $CO_t = 0.68+0.62CO_{t-1} + 0.00036T_b + 0.00027T_c$ Daytime for green lane: $CO_t = 0.26+0.41CO_{t-1} + 0.00015T_b + 0.0011T_c - 0.1W_t$	Tb,Tc,Th = hourly traffic count of motorbikes, cars and heavy veh. respectively. Wt = wind speed (m/s) CO_{t-1}=CO level at time t-1
Kot, S.C. and H.W. Lai (1985)	C = 0.0706 U + 0.0004 q +3.84 ln C = -0.178+0.232 ln q - 0.173lnU $C = 0.84\ q^{0.232U-0.204}$ $C' = 0.91\ q^{0.570U-0.204}$	Cx = concentration of ambient CO in ppm at distance x meters from kerbside measured at a height of 3m q = average veh. passing by the sampling point, vph. U = surface mean wind speed in knots C' = Cx/Cx

2.2.3 Pedestrian Delay

Child and pedestrian safety is commonly measured using the crossability level of pedestrians. This crossability level is represented by the proportion of pedestrians delayed, which depends on the average delay to all pedestrians. The average delay to pedestrians increases as the traffic volume or the carriageway width increases (Buchanan, 1963). Models for predicting pedestrian delay as presented in Table 2.5 have been extensively developed since 1930s (Adams, 1936; Tanner, 1951; Ashworth, 1971, Pillai, 1975, Goldschmidt, 1977, Cowan, 1984, Guo and Black, 1998). In terms of environmental capacity the models attempt to estimate the maximum traffic volume as the proportion of pedestrian delayed and the road width are known (Buchanan, 1963; Holdsworth and Singleton, 1979).

For urban situations, particularly those with bunching and heavy traffic, the traditional gap acceptance theory may not be applicable. These model require the traffic to be random with typically negative exponentially distributed headways (Abeisuriya, 1979). Austroads (1994) suggests using the following model in determining pedestrian delay and percentage of pedestrians delayed in urban areas.

TABLE 2.5 LIST OF SAFETY AND PEDESTRIAN DELAY MODELS

Author	Model	Parameters
Adams (1936)	$d = (e^{\alpha q}-1)/q - \alpha$	d = average pedestrian delay(sec.) q = flow rate (veh/sec) α = critical gap (sec)
Tanner (1951)	$d = (1-q\alpha_0 v^2)^{-1/v^2} - q\alpha_0 - 1)/q$	α_0 = mean critical gap v = coefficient of variation
Ashworth (1970)	$d = (e^{mq+s^2q^2/2} - mq^{-1})/q$	m = critical gap s^2 = variance q = flow rate

$$d = \frac{e^{-\lambda(t_c - t_m)}}{(1-\theta)q} - t_c - \tfrac{1}{\lambda} + \frac{(2\lambda t_m^2 - 2t_m\theta)}{2(\lambda t_m - 1 - \theta)} \qquad 2.4$$

$$p = 1 - (t_m q - 1)e^{-\lambda(t_c - t_m)} \qquad 2.5$$

$$\lambda = \frac{(1-\theta)q}{(1 - t_m q)} \qquad 2.6$$

$$\theta = 1 - e^{-2.75 t_m q} \qquad 2.7$$

where:

t_m=2/(number of lanes);

t_c =crossing time = (road width)/2.2, in second;

q = vehicles per hour.

As can be observed, the model includes the number of lanes and road width in determining delay to pedestrians. From this point of view the model is worth using in the present study as it may explain the influence of road characteristics in determining environmental capacity.

2.2.4 Accident Risks

Very few studies have been attempted to develop prediction models for accident rate/risk. Among the early attempts was Peltzman (1975) who tried to correlate accident fatality data with economic determinants such as accident costs, income per capita, alcohol consumption, vehicle speed and proportion of young drivers. He used available statistical data in US from 1946-1965. Peltzman assumed that death rate (R), in deaths per 100 million vehicle miles of travel, and the determinant factors may have relationship as per Eqn. 2.8.

$$R = D/M = aP^bY^cd^TA^eS^fK^g \qquad 2.8$$

Where:

R = death rate;

D = number of deaths;

M = 100 million vehicle miles traveled;

P = cost of accident;

Y = income per capita;

T = time

A =alcoholic inebriation;

S = vehicle speed;

K = young drivers.

The model he developed was used to evaluate automobile safety regulations introduced earlier. From his analysis he concluded that there was not enough evidence to claim that the regulations had any effect in reducing the number road fatalities. In response to his claim several studies were subsequently published, some in opposition to his claim (Joksch, 1976, Robertson, 1977) and some extending his work (Crandall and Graham, 1984 and Partyka, 1984).

Development of an accident rate model for street level was not attempted until 1986, when Zeeger, Hummer, Reinfurt, Herf, and Hunter (1986) tried to study the effect of road geometry cross section on safety. The model they developed takes the form as per Eqn. 2.9.

$$A/M/Y = 0.0076(ADT)^{0.8545}(0.8867)^{W}(0.8922)^{PA}(0.9098)^{UP}(0.9715)^{RECC}(0.8182)^{TER1}(0.2270)^{TER2} \quad 2.9$$

where:

A/M/Y = single vehicle, head-on, and sideswipe accidents per mile per year;

ADT = average daily traffic;

W = lane width (ft)

PA = average paved shoulder width (ft);

UP = average shoulder width (ft);

RECC = median recovery distance in feet;

TER = general terrain descriptor, where TER1=1 if flat, 0 otherwise; and TER2=1 if mountainous, 0 otherwise.

Other models in determining accident rates have only used the average figure of accident rate for different road facilities (SATS, 1971; Mohamedshah, 1994). In this case generalized road categories were adopted. Accident rates of some typical road categories as suggested in Mohamedshah (1994) are as presented in Table 2.6.

TABLE 2.6 ACCIDENT RATES FOR SOME ROADWAY SECTION

Roadway Type	Total Accident Rate
Urban Freeways	0.78-0.79
Urban, Two-Lane Highways	2.50-2.91
Rural Freeways	0.52-0.81
Rural, Twollane Highways	1.07-1.86

Source: Mohamedshah, 1994

From the present review it appears that there is no single model that predicts accident rate at street level. The only study that comes close to this criterion is that of Zeeger et.al (1986). Although it may not be completely appropriate for the purpose of the present study, it is probably the best model that could be applied.

2.3 Environmental Capacity Concept

Buchanan (1963) introduced the concept of environmental capacity (EC) as a measure of acceptability of traffic impacts. He developed a relationship between the proportion of delayed pedestrians with average delay to all pedestrians, road width and traffic volume. Maximum proportion of pedestrian delayed is assumed to be governed by a combination of 'level of vulnerability' (referring to the nature of pedestrian using the street) and 'level of protection' (the nature of physical condition of road and traffic). Curves were then developed representing acceptable traffic volume as a function of road width for different levels of protection and levels of vulnerability. As the study was done for residential streets, it was assumed that pedestrian safety is the only factor that controls the EC. For non-residential streets the study used the traffic noise factor to control the EC.

As some pedestrian groups such as elderly people and children are more vulnerable, Buchanan divided the street conditions into several categories. Proportions of such pedestrian groups in any particular street defined the categories. The acceptable level would therefore be lowered for a larger proportion of vulnerable pedestrians. On the other hand, as some streets may have safer physical features than others, he also differentiated the streets into several categories based on their degree of protection. Streets with continuous footpaths and better visibility for instance could be regarded as having higher protection towards pedestrians. For such a street therefore higher acceptable level of pedestrian delay is applicable.

Combinations of the two factors, pedestrian vulnerability and road protection, make up the categories of which different level of percentage of pedestrians delayed is acceptable. Table 2.7 shows the acceptable values as proposed by Buchanan (1963). In a normal situation such as a street with medium vulnerability and medium level of protection, Buchanan proposed using 50% as the acceptable level of percentage pedestrian being delayed. This level is equal to an average pedestrian delay of 2 seconds as shown in Figure 2.1. This value was corrected later on by Reynolds (1969). He indicated that the relationship does not apply to any width of road. The modified diagram between the two parameters and the corresponding traffic volume is as depicted in Figure 2.1. Accordingly the definition of EC was revised without mentioning the average pedestrian delay, that is the volume of traffic for which the proportion of pedestrians delayed is equal to *p* as in Table 2.7.

TABLE 2.7 ACCEPTABLE PERCENTAGE OF PEDESTRIAN DELAYED IN RESIDENTIAL STREETS

Level of Vulnerability	Level of Protection		
	High	Medium	Low
Low	70	60	50
Medium	60	50	40
High	40	30	20

Source: (Buchanan, 1963)

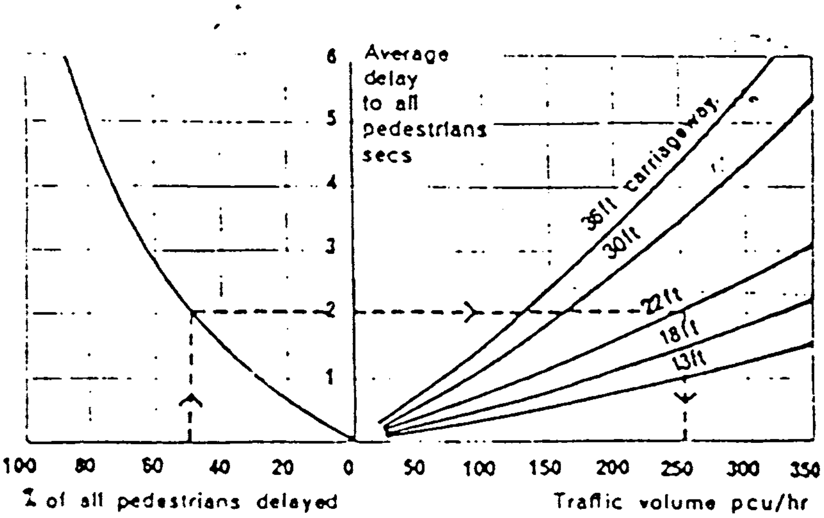

FIGURE 2.1 RELATIONSHIP BETWEEN TRAFFIC VOLUME, AVERAGE PEDESTRIAN DELAY AND THE PROPORTION OF PEDESTRIAN DELAYED

(Source: Buchanan, 1963)

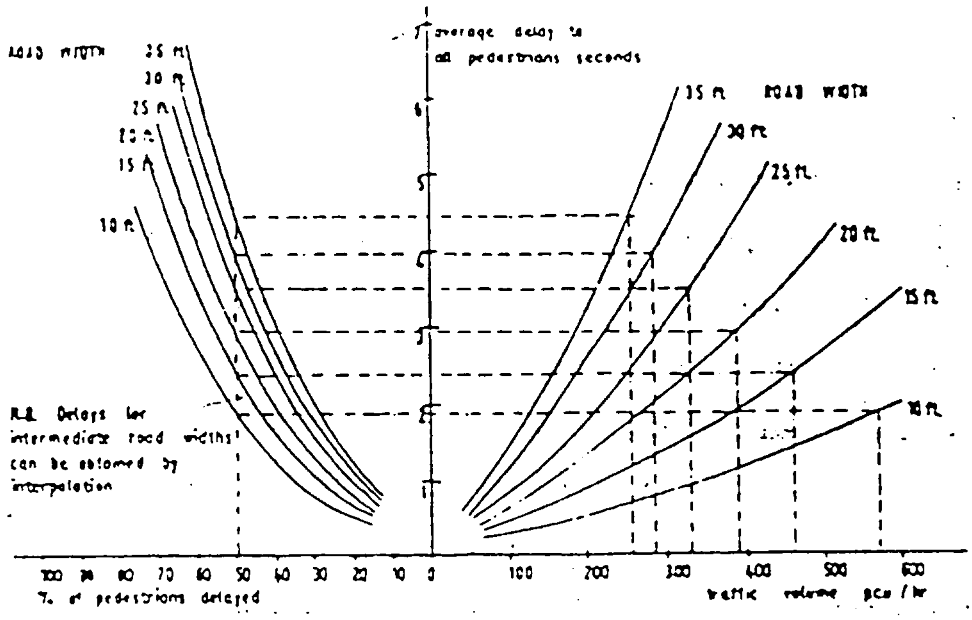

FIGURE 2.2. RELATIONSHIP BETWEEN PROPORTION PEDESTRIAN DELAYED, AVERAGE PEDESTRIAN DELAY AND TRAFFIC VOLUME FOR DIFFERENT ROAD WIDTH

(Source: Reynolds, 1969)

Following these studies, several studies regarding EC were conducted during 1970s, 1980s and 1990s. The general objective of these studies was relatively similar, that is to translate the quantification of ambient level of environmental impacts into a unit number of traffic per unit of time. Such a figure may then be interpreted as the maximum volume of traffic (capacity) of an associated road link that can be accommodated under the prevailing conditions. Table 2.8 provides an overview of the existing models and methodologies in estimating the EC of road.

In 1972, Sharpe and Maxman introduced a methodology for determining EC using an annoyance index. They tried to correlate between traffic volume (in terms of ADT) and annoyance level as responded by the people living in associated street. The analysis of their interview survey data came up with curves representing ADT as a function of annoyance index for every stratified category (environmental criteria, street type, and land use category). The curves then were used to estimate the environmental capacity of all streets in the system. One important lesson that can be learned from this study is that there is a relationship between environmental factors that dominantly control the EC with land use and roadway characteristics.

TABLE 2.8 OVERVIEW OF ENVIRONMENTAL CAPACITY STUDIES

Author	Determinant Factors	Model
Buchanan (1963)	Pedestrian delay Noise	Represented by curves road width vs. acceptable flow for various combination of level of protection and level of vulnerability; applied to residential streets only. Noise level measured and compared with recommended level
Sharpe and Maxman (1972)	Noise Air pollution Pedestrian safety	EC was estimated using curves representing annoyance index vs. ADT for different factors and land-use and road characteristics.
Holdsworth and Singleton (1979)	Noise Pedestrian delay	Noise level is estimated using CoRTN. q = -ln (1-p)/(R+L+W/1.22) p = proportion of ped. delayed R = reaction time L = time lag W = road width
Song, et.al. (1993)	Noise Pedestrian delay Pedestrian risk	idem idem $R = 1.85(1-e^{-q2\alpha}).q_2^{0.1713}.s_v^{0.733}.t_c^{0.523}x10^{-6}$ R = pedest. risk q_2 = EC (veh/sec) s_v = speed (mps) t_c = time to cross effective width (s) α = parameter

Source: Buchanan (1963), Sharpe and Maxman (1972); Holdsworth (1979); Song et.al. (1993).

Holdsworth and Singleton (1979) applied the EC approach to assess the environmental conditions of residential streets in the Melbourne suburb of Fitzroy (Australia). They found that the curves developed by Buchanan (1963) are not applicable for Australian conditions, since it only covered very limited widths of residential streets, and very low critical gaps. As a result, they modified the pedestrian delay model by incorporating perception time (R) and safe lag time (L) into the critical crossing gap (t). For estimating noise level they use the DoT model (DoT, 1988).

Song, *et. al.* (1993) conducted a recent study on EC. Their study tried to put pedestrian risk as a factor in determining the environmental capacity in addition to noise and pedestrian delay. It also put weightings onto each factor to have a combined value of EC. The combined EC was obtained from the geometric average of the environmental capacities. Their mathematical expression of the EC is as expressed in Eqn. 2.10.

$$q_c = (q_1^{n1}.q_2^{n2}.q_3^{n3})^{1/(n1+n2+n3)} \qquad 2.10$$

where

q_c = combined EC;

q_1 = delay EC;

q_2 = pedestrian risk EC;

q_3 = noise EC;

n_1, n_2, n_3 = weighting parameters for delay, pedestrian risk and noise respectively.

Pedestrian risk EC is obtained from the relationship between risk R and road and traffic parameters as per Eqn. 2.11. The parameters include traffic volume q, vehicle speed s_v, and time taken to cross effective road width t_c.

$$R = 1.85(1 - e^{-q\alpha}).q^{0.713}.s_v^{0.733}.t_c^{0.523} \times 10^{-6} \qquad 2.11$$

The pedestrian risk EC can then be determined numerically to some extent of accuracy as values of R, s_v, t_c and α are given. The relationship between EC and vehicle speed suggests that EC will decrease as vehicle speed increases. Typically, EC will decrease by 25% when vehicle speed increases by 70% (Song, *et.al*, 1993). The combined EC was demonstrated using hypothetical weights. When all weights are equal ($n_1=n_2=n_3=1$), using the same data as used by Holdsworth and Singleton (1979), the model gives an average increase of EC about 50 vph.

2.4 Summary

The state-of-the-art of relevant topics has been put forward and reviewed in this chapter. The review suggests that inclusion of environmental aspects in transportation and land-use planning processes is inevitable. Some urban/regional planning program packages such as TRANSTAR, CityPlan and TOPAZ URBAN have incorporated environmental sub-modules in their recent versions. Environmental factors covered in the models were mostly noise and air pollution. This was in line with what had been suggested by Sharpe and Maxman (1972) that the most annoying factors to the community were noise, air pollution and safety. In this regard the present study includes the four environmental factors in its model of noise, air pollution, pedestrian delay and accident risk.

Regarding the many available noise prediction models, the UK DoT (1988) model is considered amongst the most comprehensive and reliable one and is therefore recommended for the present study. The review also suggests considering the simple line-source air pollution model developed by General Motors (Chock, 1978), which was also recommended by some later studies (Watsons, 1983; Mainwaring, 1983, Taylor *etal*, 1985).

Regarding pedestrian delay, model recommended by Austroads (1994) was considered appropriate for predicting delay to pedestrians in the present study as it includes number of lanes and road width in the parameters. For accident rate/risk, there were very few prediction models available in the literature. Nevertheless it was decided to adopt the model by Zeeger (1986), although it may not be completely applicable for urban situations as those of the present study.

The review of environmental capacity studies showed that most of the approaches used a single controlling factor in determining EC. Only Song *etal* (1993) proposed a combined model of EC, but their study was inconclusive as to how the weights of the factors would be determined and the excessive effect handled.

From the review of state-of-the-art, it can be concluded that development of multi-factor approach in determining environmental capacity is worth attempting. Although there was one study that attempted to combine the resulting environmental capacities from several factors, the outcomes seems still far from conclusive. The following chapter will provide some relevant materials on background knowledge that is useful in facilitating the present study.

Chapter 3

Chapter 3

BACKGROUND KNOWLEDGE

The previous chapter has discussed the recent progress in transport-landuse-environmental interaction modeling as suggested by the literature. Various approaches and models have been discussed and their contributions identified. In the chapter, in order to provide further understanding of the main subjects in the study, some reviews of background knowledge are put forward.

First of all, theory of multi-attribute utility is described and techniques in determining weights of attribute explained. Secondly, background knowledge of some environmental factors is also discussed in length. Philosophical terms and some general aspects of each factor are to some extent explained.

3.1 Multi-attribute Utility Theory (MAUT)

Utility function concepts were initially developed for economic analysis and were usually associated with economic variables although other units could be used. This method regards pay-offs as the reflection of decision-maker's attitude towards risks (Keeney and Raifa, 1976; Chapman, 1981). The theory states that if there are two alternatives denoted by X and Y which should be chosen by a decision maker, then it is adequate to specify a scalar-valued function u, which assigns a utility index that represents worthiness of each alternative (Zeleny, 1982, pp. 415). This index may be maximized to have the best alternative. If the index comes out of a function such that:

$$u(x_1, ..., x_n) \geq u(y_1, ..., y_n) \qquad 3.1$$

whenever decision makers choose X over Y or consider them as indifferent, then u is a utility function.

The multi-attribute utility theory attempts to avoid direct assessment of $u(x_1, \ldots, x_n)$. In turn, it would rather decompose a multi-attribute utility assessment into a series of single-attribute assessments. The simplest form the decomposition functions is a simple additive function:

$$u(x_1, ..., x_n) = \lambda_1 u_1(x_1) + \ldots + \lambda_n u_n(x_n) \qquad 3.2$$

where x_i is a measure of an attribute possessed by an alternative, u_i is the one-dimensional utility function of the ith attribute, and λ_i is the measure of relative importance between attributes. The concept assumes that the attributes are independent one another, in terms of preferential and utility. The assumptions must be tested before any form of one-dimensional utility functions $u_i(x_i)$ are determined.

There are many possible forms of decomposition function. The most common ones can be observed in Table 3.1. The choice usually depends on the nature of the decision problem. In determining the decomposition form, it is necessary to ensure that there are no inseparable interactions between variables, otherwise a more complicated form such as quasi-pyramid, semi-cube, or interdependent forms must be used.

In multiplicative form, scaling factor k is involved to assure that the compound utility function u is scaled from 0 to 1. If it is assumed that $\Sigma\lambda_i = 1$, then $k=0$, otherwise $k\neq0$. The multiplicative form is a special case of quasiadditive, while both the quasiadditive and multiplicative are special cases of multi-linear decompositions.

In a broader context a utility function may represent decision maker's acceptability of the probability of possible outcomes from the proposal being evaluated, which is different from person to person and from circumstances to circumstances. Utility is therefore a tool for decision-makers to express their acceptability among alternatives (Chapman, 1981).

TABLE 3.1 COMMON UTILITY DECOMPOSITIONS

Model	Three-attribute representation
Additive	$u(x_1,x_2,x_3) = u_1(x_1) + u_2(x_2) + u_3(x_3)$
Weighted additive	$u(x_1,x_2,x_3) = \lambda_1 u_1(x_1) + \lambda_2 u_2(x_2) + \lambda_3 u_3(x_3)$
Multiplicative or log additive	$u(x_1,x_2,x_3) = \lambda_1 u_1(x_1) + \lambda_2 u_2(x_2) + \lambda_3 u_3(x_3) + k\lambda_1\lambda_2 u_1(x_1)u_2(x_2) + k\lambda_1\lambda_3 u_1(x_1)u_3(x_3) + k\lambda_2\lambda_3 u_2(x_2)u_3(x_3) + k\lambda_1\lambda_2\lambda_3 u1(x_1)u_2(x_2)u_3(x_3)$
Quasiadditive	$u(x_1,x_2,x_3) = \lambda_1 u_1(x_1) + \lambda_2 u_2(x_2) + \lambda_3 u_3(x_3) + \lambda_{12} u_1(x_1)u_2(x_2) + \lambda_{13} u_1(x_1)u_3(x_3) + \lambda_{23} u_2(x_2)u_3(x_3) + \lambda_{123} u_1(x_1)u_2(x_2)u_3(x_3)$
Bilateral	$u(x_1,x_2,x_3) = \lambda_1 u_1(x_1) + \lambda_2 u_2(x_2) + \lambda_3 u_3(x_3) + \lambda_{12} f_1(x_1)f_2(x_2) + \lambda_{13} f_1(x_1)f_3(x_3) + \lambda_{23} f_2(x_2)f_3(x_3) + \lambda_{123} f_1(x_1)f_2(x_2)f_3(x_3)$
Hybrid (a special example for particular independence conditions)	$u(x_1,x_2,x_3) = \lambda_1 u_1(x_1) + \lambda_2 u_2(x_2) + \lambda_3 u_3(x_3) + \lambda_{12} u_1(x_1)f_2(x_2) + \lambda_{13} u_1(x_1)f_3(x_3) + \lambda_{23} u_2(x_2)f_3(x_3) + \lambda_{123} u_1(x_1)f_2(x_2)f_3(x_3)$
Quasipyramid	$u(x_1,x_2,x_3) = \lambda_1 u_1(x_1) + \lambda_2 u_2(x_2) + \lambda_3 u_3(x_3) + \lambda_{12} u_{12}(x_1,x_2) + \lambda_{13} u_{13}(x_1,x_3) + \lambda_{23} u_{23}(x_2,x_3) + \lambda_{123} u_1(x_1)u_2(x_2)u_3(x_3)$
Semicube	$u(x_1,x_2,x_3) = \lambda_1 u_1(x_1) + \lambda_2 u_2(x_2) + \lambda_3 u_3(x_3) + \lambda_{12} u_{12}(x_1,x2) + \lambda_{13} u_{13}(x_1,x_3) + \lambda_{23} u_{23}(x_2,x_3) + \lambda_{123} f_1(x_1)f_2(x_2)f_3(x_3)$
Interdependent variable	$u(x_1,x_2,x_3) = \lambda_1 u_1(x_1) + \lambda_2 u_2(x_2) + \lambda_3 u_3(x_3) + \lambda_{12} u_{12}(x_1,x_2) + \lambda_{13} u_{13}(x_1,x_3) + \lambda_{23} u_{23}(x_2,x_3)$
Multilinear	$u(x_1,x_2,x_3) = \lambda_1 u_1(x_1) + \lambda_2 u_2(x_2) + \lambda_3 u_3(x_3) + \lambda_{12}\lambda_1\lambda_2 u_1(x_1)u_2(x_2) + \lambda_{13}\lambda_1\lambda_3 u_1(x_1)u_3(x_3) + \lambda_{23}\lambda_2\lambda_3 u_2(x_2)u_3(x_3) + \lambda_{123}\lambda_1\lambda_2\lambda_3 u_1(x_1)u_2(x_2)u_3(x_3))$

Source: Adopted from Zeleny, 1982, Table 12-1, p418.

3.1.1. Determination of Attributes

Attributes are considered to be measurable criteria of judgments by which a dimension of alternatives under consideration can be characterized. There are two major approaches to determine the set of attributes, a deductive and an inductive approach (Keeney and Raiffa, 1977, Nijkamp and Rietveld, 1990).

In the deductive approach, a set of attributes is obtained by identifying firstly the general aspects of the problem. The main aspects are then broken down into several criteria or variables, which are more specific in meaning. The inductive approach starts with an inventory of all possible features of the alternatives. These features are then classified into several groups, which finally construct a set of attributes.

The chosen attributes to be included in the utility function should be preferentially and utilitily independent. Zeleny (1982) defines a pair of attributes *X* and *Y* is preferentially independent of *Z* if the trade-off between *X* and *Y* is not affected by the value of *Z*. Similarly, attribute *X* is said to be utilitily independent of attribute *Y* if the decision maker's preferences among lotteries involving *X*, with *Y* fixed at a particular level, do not depend on the level of *Y*. These definition may also be applied on to set of attributes such as a given set of attribute may have to be preferentially independent of another set of complementary attributes. In general terms, preferential independence deals with the ordinal preferences while utilitily independence deals with the cardinal preferences (Zeleny, 1982, pp. 420-421).

3.1.2. Determination of Weights

Weights may be considered as relative importance of attributes in a given situation. There are many techniques available in literature to estimate the weights or coefficients of utility function, either by direct or indirect method. In the direct methods weights are estimated based on a direct questionnaire survey or interviews of decision makers, while in the indirect methods estimations are made by using past statements concerning weights of attributes such as actual choices in the past, ranking of alternatives and interactive interaction. This section will only describe some of the first methods, since they are more appropriate for the research, for some indirect methods see Nijkamp and Rietveld, 1990.

Most of the direct weighting methods are intended to address trade-offs between variables in a form of utility function. A linear form of an additive utility function may take a form as follows:

$$U(x) = \gamma_1 u_1(x_1) + \gamma_2 u_1(x_2) + \ldots + \gamma_J u_J(x_J) \qquad 3.3$$

where $u_j(x_j)$ is the j-th attribute, and γ_j its corresponding weight; $\Sigma \gamma_j = 1$; and $\gamma_j \geq 0$. The uni-dimensional utility $u_j(x_j)$ can be acquired by normalizing the original value the criteria. There are two ways in so doing, depending on whether the criteria are to be maximized or minimized (Nijkamp and Rietveld, 1990):

$A_i = (x_i - min\ x_i)/(max\ x_i - min\ x_i)$ 3.4

$B_i = (max\ x_i - x_i)/(max\ x_i - min\ x_i)$ 3.5

where:

A_i = normalized value of *i*th value of attribute x (the greater the better);

B_i = normalized value of *i*th value of attribute x (the lesser the better);

x_i = the *i*th value of attribute x;

$max\ x_i$ = the maximum value of attribute x; and

$min\ x_i$ = the minimum value of attribute x.

Rating Method

In this method, decision-makers are asked to allocate a certain value of score, say 100, among the objective criteria, which reflect their relative importance. This direct rating method can only be applied when the criteria are all in the same scale (normalized).

Ranking Method

In this method the decision-makers are asked to rank the criteria or decision variables in order of importance. The set of feasible weight can be expressed as:

$$S = \left\{ (\gamma_1, \ldots, \gamma_j) \middle| 0 \le \gamma_1 \le \gamma_2 \le \ldots \le \gamma_J ; \sum_j \gamma_j = 1 \right\} \quad 3.6$$

According to Nijkamp *et.al* (1990), if no other additional information provided, it is assumed that the weights are uniformly distributed among all values in *S*, non-negative and add up to 1.

By using the expected values of $\gamma_1, \ldots, \gamma_J$ as cardinalized values of rank numbers 1, 2.., *J*, after several integrations the following results will be obtained (see Rietveld 1982, p.44):

$E(\gamma_1) = 1/J^2$

$E(\gamma_2) = 1/J^2 + 1/J(J-1)$

...

$E(\gamma_{J-1}) = 1/J^2 + 1/J(J-1) + \ldots + 1/J.2$

$E(\gamma_J) = 1/J^2 + 1/J(J-1) + \ldots + 1/J.2 + 1/J.1$ 3.7

Results of the calculation of the expected values of the criterion weight for several selected values of J are presented in Table 3.2.

When the number of criteria to be ranked is large, respondents tend to lose the overview of the problem. Voogd (1983) then proposed a stepwise approach to overcome this problem. The approach divides the set of criteria into two subsets, the important and the less important ones. This subdivision may be repeated until the number of criteria under the subset is considered reasonable (say less than 9).

TABLE 3.2 EXPECTED VALUES OF CRITERION WEIGHT

No. of	Expected values of criterion weights								
Criteria (J)	$E(\gamma_1)$	$E(\gamma_2)$	$E(\gamma_3)$	$E(\gamma_4)$	$E(\gamma_5)$	$E(\gamma_6)$	$E(\gamma_7)$	$E(\gamma_8)$	$E(\gamma_9)$
2	.25	.75							
3	.11	.28	.61						
4	.06	.15	.27	.52					
5	.04	.09	.16	.26	.46				
6	.03	.06	.10	.16	.26	.41			
7	.02	.04	.07	.11	.16	.23	.37		
8	.02	.04	.06	.08	.11	.16	.22	.34	
9	.01	.03	.04	.06	.08	.11	.15	.20	.31

Source: Calculation based on Rietveld, 1982, p 45.

Paired Comparison

Saaty (1977,. 1982), uses verbal statements for comparing pairs of criteria. For all pairs, respondents are asked to judge the degree of difference, in a nine-point scale as presented in Table 3.3, between the two criteria. Multiple judgments are then synthesized by using their geometric mean. Results of the interview are used to construct a matrix of preferences *B* that consists of matrix element b_{jj^*} which indicate the outcomes of the comparison between all pairs of *j* and *j**.

$$\sum b_{jj^*} \gamma_{j^*} = J.\gamma_j, \text{ for all j} \qquad 3.8$$

which is read in matrix form as:

$$B\underline{\gamma} = J\underline{\gamma} \qquad 3.9$$

The vector of weights is derived as the eigen vector of preference matrix *B*, which is the geometric mean of the columns of matrix *B* (apart from a scaling factor):

$$\gamma_j = \left(\prod b_{jj^*}\right)^{1/J} \text{ for all } j \qquad 3.10$$

TABLE 3.3 SCALE OF RELATIVE PREFERENCE FOR PAIR COMPARISON

Intensity of relative importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favour one activity over another
5	Essential or strong	Experience and judgment strongly favour one activity over another
7	Very strong importance	An activity is strongly favoured and its dominance is demonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is of the highest possible order of affirmation.
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed.
Reciprocals of above non-zero numbers	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared to *i*.	

Source: Saaty, 1982, p. 56.

Trade-off method

This method is somewhat similar to the paired comparison method proposed by Saaty. In this method, respondents are asked to answer questions regarding the relative weights between pairs of variables. The relative weight between γ_1 and γ_2 is expressed by:

$$\gamma_1/\gamma_2 = c_{12} \qquad 3.11$$

By repeating the question for all pair-wise combinations of criterion 1 with respect to all criteria (j=2, ..., J), the entire weight vector $\gamma' = (\gamma_1, ..., \gamma_J)$ can be determined (apart from a scaling factor).

Consistency of the estimation can be checked by applying the triangular relationship between c_{jm}, c_{jk}, and c_{km}.:

$$c_{jm} = c_{jk} \times c_{km} \qquad 3.12$$

Experiences of using this method show that respondents tend to have difficulties in giving estimates of weights and tend to lose their consistency (Eckenrode, 1965).

3.1.3. Application of MAUT in the Proposed Model

In the present study the multi-attribute utility theory is employed to accommodate peoples' preferences towards several environmental factors. The environmental factors include noise, air pollution, pedestrian delay and accident rate (risk). The simple additive decomposition form was adopted, on the basis that the factors were independent one to another. General form of the utility function would be as per Eqn. 3.13.

$$U(i) = \gamma_1 n + \gamma_2 ap + \gamma_3 p + \gamma_4 a \qquad 3.13$$

where:

$U(x)$ = utility value of the conditions of environment at location x;

$\gamma_1\ \gamma_2\ \gamma_3\ \gamma_4$= weight coefficients of environmental factors;

n, ap, p, a = normalized values of environmental factors.

In this case pedestrian delay is considered as the level of difficulties experienced by the pedestrian in crossing the road, measured in terms of the time (delay) they have to wait until the opportunity is there to cross. Whereas the accident risk is the average probability of accidents occurring along the particular road, which is not necessarily involving pedestrian. The effect of high accident risk to its surrounding road environment may be in the form of qualitative assessment such as feeling of unsafe, discomfort, or afraid of economic loss due to material damage. In this sense pedestrian delay and accident risk can be considered as independent to each other.

The weight coefficients would be determined using the rating, ranking, and paired comparison methods. Although the ranking method was more favorable because of its simplicity, the other methods were more attractive as they were more accurate (Voogd, 1983). Therefore, in the present study, it was decided to use the three methods and to compare their results.

3.2 Environmental Impacts

In order to give a better understanding of the nature of environmental factors, the following sections describe in some extent, important aspects of the factors. Definition is given, unit of measurement is described and the modeling explained.

3.2.1. Noise

Noise is simply defined as unwanted sound (Hodges, 1973; Alexandre, 1975). It is unwanted because of its excessive intensity or pressure, which is beyond an acceptable level. But, acceptable level varies from person to person or from situation to situation. People who live near a major highway may have higher thresholds of noise than people who live away from a highway in a residential complex. Alternatively, the same noise from traffic may be considered more annoying in the night than during the day (Jansen and Gros, 1986). Very loud music can be regarded as sound to some people as well as noise to other people (Alexandre *et.al.*, 1975; Hodges, 1973).

TABLE 3.4 NOISE LEVELS

Noise Source	Noise Level (dB)	Remarks
Large rocket engine (nearby)	180	
	170	
	160	
Jet take-off (nearby)	150	
Carrier deck jet operation	140	
		Threshold of pain
Hydraulic press (1 m)	130	
Jet take-off (60 m)	120	
Automobile horn (1 m)		Maximum vocal effort possible
Construction noise (3 m)	110	
Jet take-off (600 m)		
Shout (15 cm)	100	
Subway station or train		Very annoying
Heavy truck (15 m)	90	Constant exposure endangers hearing
Inside car in city traffic		Limit for industrial exposure
Noisy office with machine	80	Annoying
Freight train (15 m)		
Freeway traffic (15 m)	70	Telephone use difficult
Conversation (1 m)		Intrusive
Accounting office	60	
Light traffic (15 m)		
Private business office	50	Quiet
Living room in home		
Bed room in home	40	
Library, soft whisper (5 m)	30	Very quiet
Broadcast studio	20	
Rustling leaves in breeze	10	Barely audible
	0	Threshold of hearing

Source: Hodges (1973) Table 7-1 pp.116.

Objectively, sound becomes more annoying as it becomes louder. The annoyance is even worse of sounds with discrete tones or irregular sounds (Hodges, 1973). Carpenter (1962) indicates that noise up to 60 dB does not interfere with conversation, and is therefore still acceptable in most situations. But, noise with a level of more than 80 dB is considered annoying and unacceptable. At this level conversation can only be made with loud shout.

Table 3.4 shows the examples of various noise levels for some typical cases from rustling leaves (10dB) to a large rocket engine (180 dB). It is shown that noise at 65 dB is already intrusive while at 80 dB it is annoying, and at about 95 dB it becomes very annoying and it can endanger hearing. If people are exposed to more intense or prolonged levels greater than acceptable limits, they may experience a gradual deterioration of hearing and, in some cases, subsequent deafness (Hodges, 1973).

Measurement of Noise

Sound is produced by vibrations and transmitted through a medium in the form of mechanical waves (Hodges, 1973). When sound travels in the air, these waves are characterized by alternate regions of compression and rarefaction and take the form of longitudinal pressure waves (see Figure 1).

Sound is usually measured by pressure level. Sound Pressure Level (SPL) has a unit of measurement of dB (decibels), where 0 dB is sound with a pressure of 20 μPa or the smallest sound to which young, good ears can respond. Practically, the SPL can be determined by the following formula (Hodges, 1973):

$$SPL = 20 \log (P_{rms}/P_0) \qquad 3.14$$

where:

SPL = sound pressure level, in decibels

P_{rms} = root mean square of $P = P/\sqrt{2}$

$P_0 = 20\ \mu Pa$

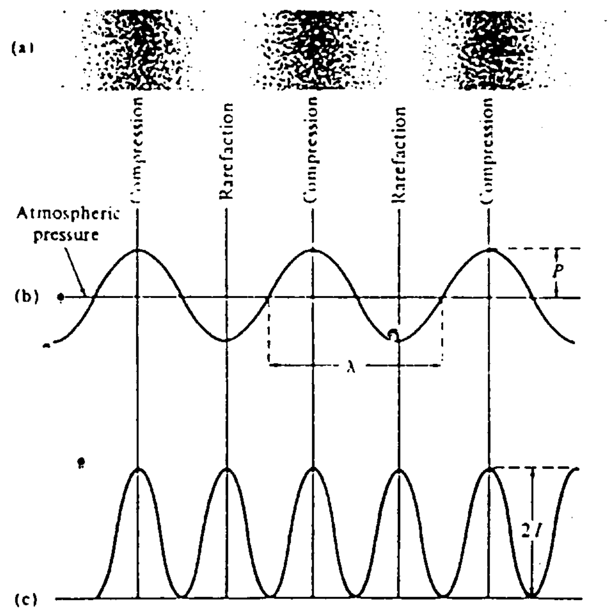

FIGURE 3.1 SOUND WAVES. (A) REGIONS OF COMPRESSION AND RAREFACTION (B)PRESSURE WAVE.
(SOURCE: HODGES, 1973 PP 113)

Threshold of Hearing

Not all sounds are perceivable to human ears, which can only hear sound with a frequency between 20 Hz (hertz, cycle per second) and 20,000 Hz. Anything less than 20 Hz or higher than 20,000 Hz can not be perceived by human ears. The sound level (decibel) at which the sound can just be perceived by human ears is called the threshold of hearing. As mentioned previously, for young good ears, this sound corresponds to a sound pressure of 20 μPa at 1000 Hz.

The threshold varies with frequency (see Figure 3.2). At a frequency of 20 Hz, threshold of hearing can be as high as 80 dB while at about 20,000 Hz it is around 70 dB. Between 20 Hz and 20,000 Hz the threshold varies from 0 dB to 50 dB. Human ears are most sensitive against sound with a frequency between 1000-5000 Hz (Hodges, 1973). Note also in Figure 3.2, that all sounds along a particular curve are rated as being equally loud. Generally, human response studies (Burgess, 1986; Samuels, 1982; Lamure, 1986) have shown that 3dB is the minimum change in SPL that good ears can detect. Furthermore, an increase of 10 dB in SPL is reported as a "doubling of sound volume".

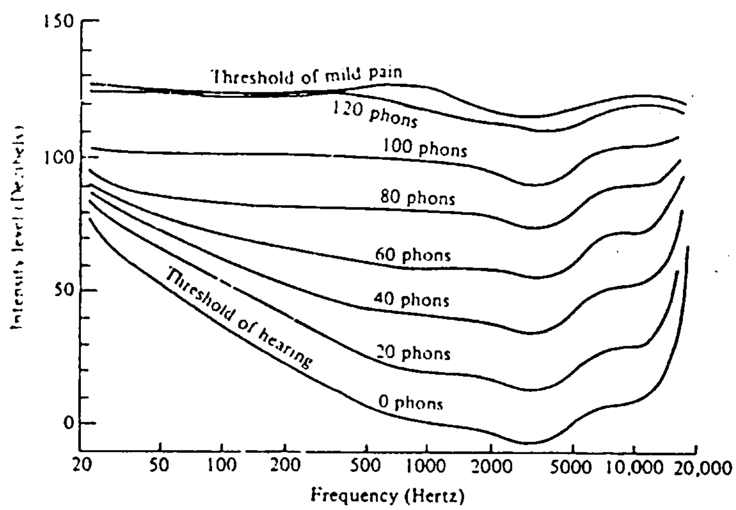

FIGURE 3.2 AUDITORY AREA BETWEEN THRESHOLD OF HEARING AND MILD PAIN (HODGES, 1973, PP. 115)

Sound Level Meter

Sound level meter (SLM) is an instrument that transforms overall pressure amplitude variations into corresponding electric signals. The signals are then being amplified and filtered before being put through into squaring and averaging processes. Typical electrical system of sound level meter includes a microphone (1), amplification sysetm (2), filter (3), squaring device (4), averaging device (5) and read-out apparatus (6) which may either be analogue or digital (see Figure 3.3) (Saenz, 1986).

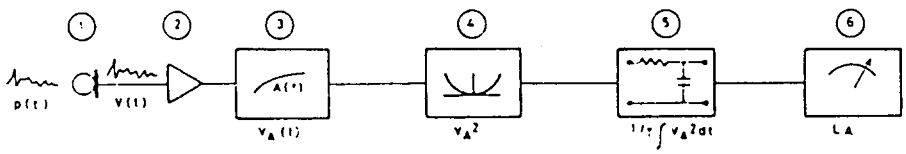

FIGURE 3.3 BLOCK DIAGRAM OF THE DIFFERENT FUNCTIONS OF A SOUND LEVEL METER: (1) MICROPHONE; (2) ELECTRICAL AMPLIFICATION; (3) FILTERING; (4) SQUARING; (5) MEAN-SQUARING; (6) LEVEL READ-OUT.

Most SLMs weight sounds at different frequencies to approximate the total loudness level. Filtering system reduces response of lower frequencies according to human sensitivity to that range. Three weighting curves A, B and C are usually found, and results of the measurements are normally indicated by dB(A), dB(B) and dB(C) respectively. The A weighting filter is based on a performance curve which is the inverse of the hearing threshold curve shown in Figure 3.2. Currently, most noise units and indexes are based on dB(A) measurement as it is believed to have the most reasonable correlation between noise level and the effects of noise on human (Hodges, 1973; Saenz, 1986). Another weighting system called D is introduced later on to measure noise involving such high frequency sounds as aircraft noise (Saenz, 1986).

Noise Measurement Indices

Modern SLMs can monitor and store both the temporal and (amplitude) level variations in noise. Percentile of noise L_n is the corresponding noise level has been exceeded for n% of the period of measurement. The most common percentiles are L_{90}, L_{50}, L_{10} and L_1. L_{90} is usually used as a reference for background level, while L_{50} is the approximate of average level and L_1 is the estimate of peak levels. L_{10} , the noise level exceeded for 10% of the measurement period is a common index used for outdoor noise such as that from road traffic. L_{eq}, which is the equivalent sound pressure level that would produce the same energy over the time period, is also a most common road traffic noise index (Burgess and McLain, 1990; Saenz, 1986).

Some other indexes are not very common used in traffic noise or they are used specifically for other purposes such as aircraft noise measurement such as Perceived Noise Level PNL and Noise Exposure Forecast NEF (Saenz, 1986).

Effects of Noise

Noise is believed to be capable of producing annoyance and hearing loss or worse still adverse physiological and psychological effects (Hodges, 1973; Griefahn, 1986; Ward, 1986; Jansen and Gros, 1986). The following paragraphs describe various effects of noise as suggested by the literature. Although noise has been considered to cause hearing damage, relationship between acoustic exposure parameters (intensity, duration, temporal pattern and spectral characteristics) and the loss of sensory capability is still not well explained (Ward, 1986).

Hearing loss or deafness as the result of prolonged exposure to noise usually begins with difficulties to hear noise at higher frequencies, but as the damage continues lower frequencies may also become difficult to hear (Hodges, 1973). In earlier stage of the noise-induced deafness, it is usually difficult to distinguish fricative consonants such as f, v, s, z, th, ch, sh. This loss of hearing is known as *presbyacusis*, which is deafness due to aging or inability to hear weak sounds.

Unfortunately, hearing damage does not only include the inability to hear sounds but also the hearing of sounds that do not exist. *Tinnitus*, as what it is usually referred to, is the ringing in the ears as a result of constant exposure to very loud noise (Ward, 1986). *Tinnitus* is usually a result of a single but very intense exposure of noise and is only temporary. Another type of hearing damage is what known as *paracusis*. In this damage, sounds are heard, but incorrectly. Unfortunately, it is difficult to detect unless the person is highly musical.

As far as occupational health is concerned, exposure of noise at a level of 80 dB for 8 hour daily is taken as the limit. US 1970 Occupational Safety and Health Act suggests that whenever noise exposure exceeds 90 dB for 8 hour a day, 95 dB for 4 hour, or 100 dB for 2 hour, administrative or engineering controls need to be applied (Hodges, 1973).

Exposure to very loud noise will produce temporary hearing loss manifested by a shift in the hearing threshold. The shift can be as high as 20 dB or more following an exposure to a pure note at 100 dB for several minutes. The shift generally varies with frequency and may be temporary or permanent. Longer and continuous exposures may result in a permanent hearing loss (Hodges, 1973).

Although effects of noise on human physiology such as alteration in the peripheral blood circulation are still questionable, Jansen and Gros (1986) suggest that people seems to respond physiologically to exposure on noise exposure. Nevertheless, they indicated that noise below the threshold value of 90 or 85 dB(A) cannot be proved to be a health hazard.

According to Jansen and Gros, noise can psychologically affect people either directly or indirectly. Direct effects may include disturbances in performances, communication, information processing, rest and relaxation. While indirectly it may result in such changes of behavior as always to have closed windows, reduce frequency of conversation, and possibly even moving home.

Sound levels higher than 90 dB(A) will lead to a drop in performance and a decrease in well being at activities of any kind. Below this level the probability depends on type of activity being done. Noise threshold is relatively lower for such activities that demands worker's intellect, demands on worker's memory or if the worker lacks of practice.

Maximum acceptable levels for different activities as adopted in Germany are as follows (Jansen and Gros, 1986):

- 55 dB(A) if the work demands intellectual exercise (creative thinking, planning, decision making etc)
- 70 dB(A) if the work involves uncomplicated things or partly mechanized
- 85 dB(A) for other activities.

Effect of noise on working performance as indicated by Jansen and Gros (1986) is as shown in Table 3.5. The figures suggest that noise below 70 dB does not give significant impact to the working performance, while substantial effects were observed if people were exposed to noise levels higher than 85 dB.

TABLE 3.5 EFFECT OF NOISE ON WORKING PERFORMANCE

Sound level in dB(A) measured during test	Effects observed
0-70	Substantial and lasting decrease in performance infrequent
70-85	Increased probability of decrease in performance with high need for achievement; compensation possible
85-100	Increased probability of substantial decrease in performance; compensation more difficult
Higher than 100	Substantial and lasting decrease in performance to be expected

Source: Jansen and Gros, 1986.

Regarding effects of noise on sleep, Griefahn (1986) suggests to divide the effects into primary and secondary (after-effects). Primary effects are the ones that directly observed after a stimulus has been given during the sleep, while after-effects may be observed during the later days.

According to the study, insignificant number people will be disturbed by noise at 60 dB(A) level in their sleeping. But, at 68 dB(A) about one-third of the population would be disturbed from which 30% would be awaken. She suggests that elderly people are more sensitive to noise disturbance in their sleep compared to younger people. People of about 70 years of age tend to react with awakening at a rate of 30% compare to only 5% of children of about 10 years. After-effects of noise-induced sleep disturbances may include alteration of mood, feeling of not having had a good sleep or even decrease to individual performance.

Sources of Vehicle Noise

Noise produced by motor vehicles may come from various sources or parts of the vehicle. The overall noise will mainly depend on how fast the vehicles are travelling. At higher speed traffic contact between tyres and road surface is believed to be the predominant source. At lower speed, noise from engine is more likely to predominate the overall noise (Lamure, 1986). Table 3.6 shows in more detail the contributions of various parts of vehicles to the overall noise it produced.

For cars and heavy vehicles in a reasonable state of maintenance, tyre/road noise is the dominant vehicle noise source at constant speeds above around 40 km/h (Samuels, 1990). Lamure (1986) and Samuels (1990) indicate that noise produced by vehicle's engine depends primarily on the engine speed. Engine capacity does not contribute as much as speed to the total noise. Noise level for different types of engine as a function of engine speed *N* and engine capacity *C*, as indicated by Lamure (1986) are as shown in Table 3.7.

TABLE 3.6 PERCENTAGE CONTRIBUTIONS FROM THE DIFFERENT BASIC SOURCES TO THE TOTAL AMOUNT OF NOISE RADIATED BY A WELL-MAINTAINED ROAD VEHICLE

Source of Noise	Light Vehicles		Heavy Vehicles	
	Town	Open Road	Town	Open Road
Air intake inlet, exhaust outlet	15 – 35			
Exhaust pipe assembly	15 – 30		15 – 60	
Engine block	20 - 30	20 - 70		40 – 80
Gear box and transmission	5 – 30		30 - 80	
Cooling fan	-		10 – 50	
Tyre-road surface contact	5 – 10	30 – 80	5	20 - 60

Source: Lamure 1986.

TABLE 3.7 TOTAL NOISE LEVEL OF VEHICLE ENGINE

Type of engine	Total noise level in dB(A)
Diesel engines	$L_A = 30 \log N + 17.5 \log C$
Supercharged diesel engines	$L_A = 40 \log N + 17.5 \log C$
Spark ignition engines	$L_A = 50 \log N + 17.5 \log C$

Source: Lamure, 1986 pp. 290; Note: L = noise level in dB(A); N= engine speed in r.p.m.; C= engine capacity.

Noise generated by tyre-road contact may be due to various effects as shown in Table 5. In general high texture level surface may generate radial excitation of the tyre and promote type I phenomenon. On the other hand, low texture level may promote type II and type III phenomena. In fact rolling noise increases rapidly when vehicle speed increases. Whenever vehicle speed is increased by 1.5 times, the noise level may increase by more than 6 dB(A). Relationship between the rolling noise L_{RA} and speed V may be expressed as in the following formula (Lamure, 1986):

$$L_{RA} = 30 \text{ to } 40 \log V + \text{constant} \quad 3.15$$

Types of tyre fitted to the car also have significant influence to rolling noise. For the same road surface, the noise generated by vehicles with different tyres may differ by up to 8 dB for cars and 12 dB in the case of heavy vehicles (Lamure, 1986).

TABLE 3.8 NOISE DUE TO TYRE-ROAD CONTACT

	Phenomenon	Road surface parameter
I	Vertical excitation and radiation of noise from the tyre casing	Longitudinal profile (macrotexture) Mechanical impedance at the point of contact (elastic properties of the road)
II	Tangential excitation as a result of stick and slip action	Physico-chemical properties and longitudinal profile
III	Suction and expulsion of air (air pumping and air picket resonance)	Geometry and porosity
IV	Aerodynamic action and air turbulence	None
V	Radiation of noise from the road itself	Elastic properties of the different layers making up the road structure
VI	Radiation of noise from the vehicle body or the liad being carried	Profile (surface evenness)

Source: Lamure, 1986 pp. 301

Modeling of Road Traffic Noise

Acoustically, road traffic can be regarded as a line-source of noise. Various parameters are used in determining the level of noise due to road traffic. In general, the noise will depend on the strength or intensity of the source, the distance and whether or not there is any excess attenuation during propagation (Brown, 1979; Lamure, 1986).

Variables influencing source strength include (DoT, 1988; Lamure, 1986; Nelson, 1991; Brown, 1979):

1. volume of vehicles
2. acoustic emission strength of individual vehicles:
   - vehicle speed
   - vehicle type and condition
3. road factors
   - gradient
   - road surface and tyre tread
   - wet or dry condition
4. traffic flow conditions (continuous or interrupted).

On top of these, some corrections may be applied in regards of noise propagation factors and ground effects. The variables may include (DoT, 1988; Lamure, 1986; Nelson, 1991; Brown, 1979):

1. distance
2. type of ground
3. height of source

4. average height of propagation
5. barriers
6. reflections
7. meteorological conditions.

The level of noise generated from road traffic varies very much with the volume of traffic. This variation can go as low as 51 dB(A) (90 percent of the time) for very light traffic, and as high as 75 dB(A) (L10) for very heavy traffic.

As an example, according to Lamure (1986), level of noise due to overall traffic in terms of Leq can be written as:

$$Leq = Lw + 10 \log Q - 10 \log Vd + 10 \log \quad /2 \qquad 3.16$$

Where:

Lw = acoustic power level of an isolated vehicle;

Q = traffic volume in vehicles/hour;

V = speed in km/h;

D = distance in metres;

= angle of view in radian.

In slightly different way, Burgess (1977) uses the following formula to estimate Leq for Sydney area::

$$Leq = 55.5 + 10.2 \log q + 0.3p - 19.3 \log d \qquad 3.17$$

Where:

q = vehicles per hour;

p = percentage of heavy vehicles;

d = distance from the roadway.

Noise Control Methods

Methods in controlling the impact of traffic noise, can be categorized into 3 major approaches (Nelson, 1987; Lamure, 1986, RTA, 1991):

1. Reducing noise at its source;
2. Limiting the spread of noise, once it has been generated;

3. Reducing noise at the reception point.

The first approach generally can be fulfilled by designing a quieter vehicles and smoother road surfaces. While the second approach may employ various types of noise attenuation techniques such as managing traffic flow, redesigning road alignment, using noise barriers. The third can be done by insulating or soundproofing dwelling and designing appropriate land-use to minimize disturbance to particular areas.

Most industrialized countries such as Federal Republic of Germany, France, Japan, Netherlands, United Kingdom, United States of America have been attempting to manufacture quieter cars (Nelson, 1987). Some countries have been conducting the project since early 1970s. Results of the projects in lowering the emission of noise varies between 3 dB(A) - 10 dB(A). Table 3.9 shows the summary outcomes of noise quietening programs of various types of vehicle.

TABLE 3.9 REDUCTION IN OVERALL NOISE LEVEL AS A RESULT OF VEHICLE QUIETENING PROGRAMMES

Vehicle Type	Reduction in Overall Noise level - dB(A)	Approximate noise level attained - dB(A)
Private Cars	6-7	74
Delivery lorries	8-9	78
Heavy Lorries	3-9	84
Rear-engined buses	9-10	80

Source: adapted from Nelson (1987), Table 8.2 pp. 8/6

It is quite obvious that traffic noise depends primarily on the number of vehicles in the traffic. Unfortunately, the level of traffic noise (Leq or L10) reaches its maximum not at its capacity level but rather at half of this volume (Lamure, 1975). So, limiting traffic in congested road links will not necessarily reduce the traffic noise.

Traffic limitation to reduce noise may be applicable for roads with relatively light traffic. In this case, traffic noise may be reduced by approximately (Lamure, 1986):

$$10 \log Q/Q_0 \quad (3.18)$$

where:

Q_0, Q = traffic volume before and after limitation.

Limiting access towards heavy vehicles is usually more effective, as typically one truck is emitting noise equal to 5-10 cars.

Speed limitation is more effective when there is no heavy vehicles in the traffic. If the traffic composed of more than 10% heavy vehicles - unless there is discriminatory limitation with low traffic limit for trucks - moderate limitation will have no significant effect to the level of noise (Lamure, 1975). Table 3.10 shows the typical reduction that can be achieved by limiting traffic speed in various conditions of traffic.

TABLE 3.10 LEQ VARIATION FOR DIFFERENT MEAN CAR SPEED LIMITS

Speed limit	Cars only	10% trucks	30% trucks	100% trucks
90 km/h for cars 80 km/h for trucks	-4	-2.5	-1.3	0
90 km/h for cars 60 km/h for trucks	-4	-4	-3	-2.4
60 km/h for cars and trucks	-9	-7	-5	-4

Source: Lamure 1975, Table 5.11 p. 171

Below 60 kph, traffic noise in terms of Leq may decrease as speed increases. For speed greater than 60 kph, Leq may vary with approximately 20 log V (Lamure, 1986). Figure 3.3 shows typical relationship between average traffic speed and Leq.

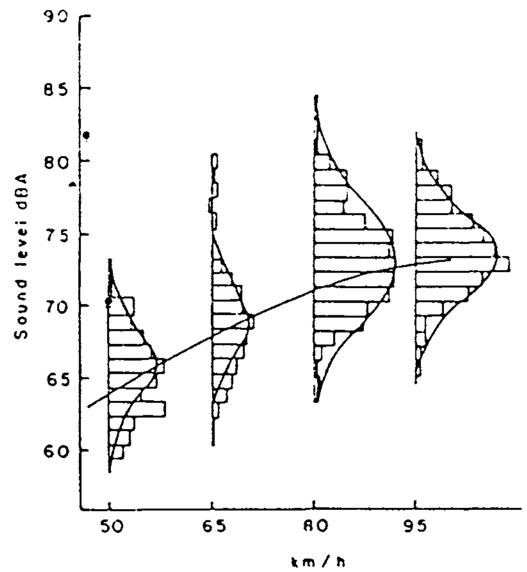

FIGURE 3.4 DISTRIBUTION OF NOISE EMISSION LEVELS AS A FUNCTION OF SPEED (SOURCE: LAMURE, 1986 P. 314)

Noise screens may include (Lamure 1986) :

- - earth mounds;
- - panel (wood or metal)
- - walls
- - combination screens
- - noise absorbing screen.

Noise barriers may reduce noise by up to 20 dB(A) depending on its height, position and material (State Pollution Control Commission, 1991; RTA, 1991). Typical noise reductions provided by noise barriers are shown in Table 3.11. Effective noise barriers can be achieved by locating the barrier so that it blocks the line of sight between source and the receiver.

TABLE 3.11 BARRIER ATTENUATION

Reduction in Sound Level	Reduction in Acoustic Energy	Degree of difficulty to attain
5 dB(A)	70%	Simple
10 dB(A)	90%	Attainable
15 dB(A)	97%	Very difficult
20 dB(A)	99%	Nearly impossible

Source: Roads and Traffic Authority of NSW, 1991

Insulating windows of houses or schools may significantly reduced noise level by 40-45 dB(A) with double windows and 25-30 dB(A) for windows equipped with thick glass panes (1cm) (Lamure in Alexandre et. al., 1975). Table 3.12 gives information on the effectiveness of various types of window glazing to reduce traffic noise.

TABLE 3.12 EFFECTS OF DIFFERENT GLAZING METHODS ON NOISE REDUCTION

Type of Window	Type and thickness of glazing	Noise Reduction Possible dB(A)
Any type of window when open (depends on size of opening)		10
Single Glazed: closed		
Openable, no seals	3 mm	Up to 20
Fixed, permanent selas	3 mm	Up to 22
Openable, weather-stripped	4 mm	Up to 23
Fixed, permanent seals	6 mm	Typically 27
Fixed, permanent seals	12 mm	Typically 30
Double Glazing:		
Closed (100 mm separation)		
Openable, weather-stripped	4 mm + 4 mm	Up to 30
Openable, weather-stripped	6 mm + 6 mm	Up to 35
Fixed, permanent seals	6 mm + 12 mm	Up to 40

Source: State Pollution Control Commission, 1991 Table 6 p. 20

3.2.2. Air Pollution

Consideration of impacts of air pollution on human and their environment began when people started to use such non-renewable sources of energy as coal (Boubel, Fox, Turner, and Stern, 1994). It was in the 14th century when coal was used in favor of wood, and since then air quality has been becoming worse and worse from day to day until recent times.

Poor and unhealthy air quality was clearly observed when industrialization was hitting Europe in the early 17^{th} century. Lethal air quality was reported in London, known as London Fog in 1952. Early in this century, when people are becoming more and more dependent on petroleum products, poor air quality is easily observed almost anywhere in the planet. The use of petroleum products as an alternative of source of energy has been responsible for creating new unwanted substances in the atmosphere. Photochemical smog for example, was one of the new substances found in Los Angeles area. Another new substance, blamed of producing acidic deposition, was sulfates (SO_4^{2-}). This actually is a secondary pollutant produced from sulfur dioxide (SO_2) which reacts with oxygen in the atmosphere and transported thousands of kilometres away from its sources by wind (Hidy and Brock, 1970).

There is also another substance that has long been neglected and only just recently people are aware of. It is carbon dioxide (CO_2). Its increasing concentration in the atmosphere has been creating a green house effect to the earth and caused an alarming increase of global temperature which simply leads to a global warming. Besides, a relatively new problem about air pollution is the reduction of stratospheric ozone layer as a result of excessive emission of chloro-fluoro-carbons (CFC) to the atmosphere. This depletion of ozone layer may reduce the efficiency of stratosphere in limiting the amount of ultra violet radiation that goes to the surface of the earth (Boubel *et.al.*, 1994).

In order to solve the problems, various attempts have been made to understand the nature, characteristics, and behavior of air pollutants in the atmosphere. These include the development of models explaining how air pollutants are emitted, transported and distributed in the atmosphere. This section describes in brief the families of air pollution models, their assumptions, parameters and constraints. At the end of this section, description is also made of the type of air pollution model that is being used in this study.

Definition

Air pollution is defined as a wide variety of gaseous and particulate materials, of which a small proportion are potentially harmful to people. The effect of air pollution on people can be either in long term health hazard such as slow reflexes and reduce in visual activity or short-term effects such as headache and *asphyxiation*. The severity of these effects depends on the length of exposure and concentration of relevant pollutant, which relate to traffic composition, traffic density, and condition of climate (Department of Transport, 1988).

Types of gaseous material that are possible to be air pollutant from vehicle emission and their common units of measurement are:

- CO (Carbon Monoxide), ppm by volume;
- NOx (Nitrogen Oxide), ppm by volume;
- HC (Hydro Carbon), ppm by volume;
- Smoke (particulate), microgram per cubic meter; and
- Lead (particulate), microgram per cubic meter.

Another definition of a pollutant is contaminant that is responsible for causing some adverse effect on the environment. While contaminant was defined by Williamson (1973) as "anything added to the environment that causes a deviation from the geo-chemical mean composition." Although in many cases both words are synonymous, it can be said that any contaminant is actually a potential pollutant. United Nations Organization simply defines pollutant as a substance that is found in an improper place at an improper time in an improper amount (Berezkin and Drugov, 1991).

Types of Air Pollutant

Air pollutant can be grouped into two forms: gases and particulate matter. In terms of their origins, gaseous pollutants can be further categorized into two categories (Boubel *etal*, 1994):

1. *Primary pollutants*: those directly emitted from sources.
2. *Secondary pollutants*: those formed by chemical interactions among primary pollutants and normal atmospheric constituents.

Gaseous pollutants can be found mainly in the form of several of major compounds such as

- Sulfur-containing compounds
- Nitrogen-containing compounds
- Carbon-containing compounds
- Oxides of carbon
- Halogen compounds

Lists of primary and secondary pollutants of these gaseous pollutants can be observed in Table 3.13.

TABLE 3.13 CLASSIFICATION OF GASEOUS AIR POLLUTANTS

Class	Primary pollutants	Secondary pollutants	Sources
Sulfur-containing compounds	SO_2, H_2S	SO_3, H_2SO_4, MSO_4	Combustion of sulfur containing fuels
Nitrogen-containing compounds	NO, NH_3	NO_2, MNO_3	Combination of N_2 and O_2 during high-temperature combustion
Carbon-containing compounds	C_1-C_5 compounds	Aldehydes, ketones, acids	Combustion of fuels; petroleum refining; solvent use
Oxides of carbon	CO, CO_2	None	Combustion
Halogen compounds	HF, HCl	None	Metallurgical operations

Note: MSO_4 and MNO_3 denote general sulfate and nitrate compounds, respectively
Source: Seinfeld (1975), pp. 6

Particulate matter can simply be defined as any substance - either liquid or solid, except pure water - other than gaseous pollutants that exists in the atmosphere. Particulate matter can be differentiated based on their sizes (Zannetti, 1990, pp. 3-4):

- coarse particles, are particles with diameter larger than 2.5 μm;
- fine particles, are particles with diameter less than 2.5 μm. Fine particles are also called as respirable particulate matter (RPM), and can be further divided into two modes, nuclei mode with diameter <0.1 μm and accumulation mode with diameter > 0.1 μm;
- inhalable particulate matter (IPM), are particles with diameter less than 10 μm.

Hidy and Brock (1970), used several terms in conjunction with particulate matter:

- dusts, are solid particles dispersed in the atmosphere as a result of mechanical disintegration of material such as rising dust from off-road transportation;
- smokes, are small particles resulting from combustion processes;
- fume, are smoke consist of particles with diameter less than 0.1 μm;

- mists, suspension of low concentration liquid droplets with diameter larger than 10 μm;
- fog, High concentration of mists which can obstruct visibility; and
- aerosol, a cloud of combination of particles such as smokes, fumes, mist or fog.

In urban areas, two typical cases of air pollution have been identified (Hidy and Brock, 1970). The first one is primitive air pollution usually characterized by high SO2, water, and particles from combustion of coal and high sulfur-contain fuel oil. It is usually found in cold climate regions where high level use of coal is found as the main source of energy for electric power and domestic heating.

The second one, which is relatively more recent in origin, is air pollution which is attributable to automobile emissions. This type of air pollution is characterized by high incidence of photochemical smog, result from series of reactions between organic gases and oxides of nitrogen when sunlight radiates into the atmosphere. Photochemical smog was usually found in such high temperatures, bright sunlight, and low humidity urban areas with heavy use of cars as Los Angeles, Tokyo, Denver and Rome.

Effect of Air Pollution

A diagram of the human respiratory system is as shown in Figure 3.5. As can be observed, it consists of three major sections (American Lung Association, 1978, mentioned in Boubel *et.al*, 1994):

- the *nasal* system which is composed of the nose, and mouth cavities and throat;
- the *tracheobronchial* which includes section between trachea up through bronchus and alveoli; and
- the *pulmonary* where the process of exchanging gas between respiratory and circulatory systems occurs.

Typical effects of some air pollutants on human health, which mostly enter through the respiratory system, are summarized in Table 3.14.

In the circulatory system such air pollutant as CO may form a very stable complex with hemoglobin (COHb). Although at low levels (0.5-2.0%) it is not causing any substantial effects, at higher levels it may lead to cardiovascular disease and reduce physical endurance (National Research Council, 1977, mentioned in Boubel *et.al*, 1994).

Olfactory system affected more by odors. The effects of inhalation of odors by human was reported as causing nausea, vomiting, headache, coughing, upsetting sleep, stomach, and appetite as well as creating annoyance and depression (National Research Council, 1979 as mentioned in Boubel *et.al*, 1994).

Such sensitive groups in the community as young children, elderly people and persons who have pre-existing diseases (e.g. asthma, emphysema and heart disease) are believed to have higher risk from exposure to air pollutants than the general population (Shy, 1979, mentioned in Boubel *et.al*, 1994).

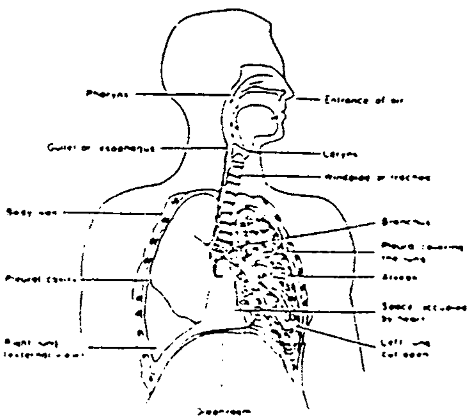

FIGURE 3.5 ANATOMY OF HUMAN RESPIRATORY SYSTEM

TABLE 3.14 SPECIFIC AIR POLLUTANTS AND ASSOCIATED HEALTH EFFECTS

Pollutant	Effects
CO	Reduction in the ability of the circulatory system to transport O_2 Impairment of performance on tasks requiring vigilance Aggravation of cardiovascular disease
NO2	Increased susceptibility to respiratory pathogens
O3	Decrement in pulmonary function Coughing, chest discomfort Increased asthma attacks
Lead	Neurocognitive and neuromotor impairment Heme synthesis and heamtologic alterations
Peroxyacyl nitrates, aldehydes	Eye irritation
SO2/particulate matter	Increased prevalence of chronic respiratory disease Increased risk of acute respiratory disease

(Source: Boubel et.al., 1994 Table 7-2, pp. 108)

Beside the above-mentioned effects, air pollution has been also believed to give some effects on vegetation, animals as well as altering the conditions of surrounding environment. The latter may include reduce in visibility, global warming and hole in the ozone layer that may directly or indirectly affect human living conditions in general (Boubel *et.al*, 1994).

Unit of Measurement

Concentration of air pollutant in the atmosphere is normally expressed in part per million by volume, or ppm. But, it is also common to use a unit of measurement based on the weight of pollutant per volume of air in micrograms per cubic meter, or $\mu g/m^3$. At standard condition (25° C and 1 atm) conversion between both units is possible using the following relationship:

$$1\ \mu g/m^3 = (24500/\text{molecular weight}) \times 10^{-6}\ ppm$$

Composition of Atmosphere

In dry air at sea level, the composition of atmosphere is as can be observed in Table 3.15. The major constituents are Nitrogen (about 78 %), Oxygen (20%), Argon (0.9%) and Carbon dioxide (0.03 %). Other species including water, ozone and gaseous air pollutants present at very low background levels. Water vapor (H_2O) for example, presents at a background level of 0 to 30,000 ppm, and Ozone (O3) at 0 to 0.07 ppm (at ground level). Typical differences between clean air and polluted air in terms of concentration of its constituents are as shown in Table 3.16.

TABLE 3.15 COMPOSITION OF DRY AIR AT SEA LEVEL

Gas	Concentration, ppm
Nitrogen N2	780,840
Oxygen 02	209,460
Argon Ar	9,340
Carbo dioxide CO2	315
Neon, Ne	18
Helium, He	5.2
Methane CH4	1.0-1.5
Krypton, Kr	1.1
Nitrous oxide, N2O	0.5
Hydrogen H2	0.5
Xenon, Xe	0.08

Source: Boubel *et.al.* (1994) p. 102

TABLE 3.16 COMPARISON OF CONCENTRATION LEVELS BETWEEN CLEAN AND POLLUTED AIR

Constituent	Clean Air	Polluted Air
SO2	0.001-0.01 ppm	0.02-2 ppm
CO2	310-330 ppm	350-700 ppm
CO	< 1 ppm	5-200 ppm
Nox	0.0001-0.01 ppm	0.01-0.5 ppm
Hydrocarbons	1 ppm	1-20 ppm
Particulate matter	10-20 μg/m^3	70-700 μg/m^3

Source: Boubel *et.al.* (1994) p. 102

Modeling of Air Pollution

The family of air pollution models can be divided into two: dispersion models and receptor models. The difference between the approaches is that the first approaches from the source side while the second from the receptor.

Two main methods in modeling the dispersion of air pollutant in the atmosphere are Eulerian, which describes the behavior of species relative to a fixed coordinate system, and Lagrangian which describes the behavior using the average atmospheric motion.

Eulerian Method

Eulerian approach employs the law of conservation mass of concentration of species within a fixed reference system. If there is a species in the atmosphere, its concentration must at any time satisfies a material balance taken over a volume element. In other words, any accumulation of material over time, must be balanced by an equivalent amount that produced from chemical reaction in the element and that added by molecular diffusion (Seinfeld, 1975).

The basic equation in Eulerian approach can then be written as (Seinfeld, 1975):

$$\frac{\delta c}{\delta t}+\frac{\delta}{\delta x}u.c = D\frac{\delta^2 c}{\delta x \delta x}+R(c,T)+S(\mathbf{x},t) \qquad 3.19$$

where:

c = concentration of the species;

D = molecular diffusivity of the species in the atmosphere;

R = the rate of generation of species by chemical reaction;

S = the rate of addition of the species at location **x** (*x,y,z*) and time t.

u = fluid (atmosphere) velocity

Concentration of any species at any time and any position in the coordinate system by various more advanced techniques can be determined by integration. In the single box model, which is the simplest form of the model, as in the slug model (Venkatram, 1978 in Zannetti, 1990) it is assumed that the concentration varies along the wind direction x and vertical direction z, but does not vary along y (cross-wind) direction. These assumptions allows the equation to be expressed in two dimension (x,z) system. The solution of the equation for the average concentration c at x and time t is (Seinfeld, 1975):

$$\bar{c}(x,t) = (x - ut)\frac{Q}{z_i(x)} \qquad \text{for } t \leq x/u \qquad 3.20$$

and

$$\bar{c}(x,t) = 0 \qquad \text{for } t > x/u \qquad 3.21$$

Lagrangian Method

Basic equation of the Lagrangian method for single pollutant species is (Seinfeld, 1975):

$$< c(\mathbf{r},t) >= \int_{-\infty}^{t}\int p(\mathbf{r},t|\mathbf{r}',t')S(\mathbf{r}',t)d\mathbf{r}'dt' \qquad 3.22$$

where:

$<c(\mathbf{r},t)>$ = average concentration at r at time t;

$S(\mathbf{r}',t')$ = source term (mass volume^{-1} time^{-1});

$p(\mathbf{r},t|\mathbf{r}',t')$ = probability density function (volume^{-1}) of an air parcel to move from **r'** at t' to **r** at t.

3.2.3. Pedestrian Delay

Definition

Pedestrian is generally defined as a person walking in a street (Hornby, 1987). In a more specific application, the walking person may include people in wheelchairs, on roller skates or riding on 'toy vehicles' such as skate boards or other vehicles, other than a bicycle, powered by human effort or a motor and with a maximum speed of 7 km/h (Austroads, 1995).

Pedestrian Characteristics

The characteristics of pedestrians are varied, depending on their age, sex and physical condition, although such factors as the purpose, time, weather and environmental conditions might affect their behavior (Austroads, 1995). Understanding the characteristics is very important particularly in providing proper facilities and requirements. The characteristics may include the typical dimension, average walking speed and range of distance covered.

Dimension

Typical dimension of space occupied by a pedestrian is as depicted in Figure 3.6. On average a body ellipse as in the figure occupies an area of about 0.21 m^2, although an adult male human body may only occupy an area of about 0.14 m^2. The difference is the space spared to accommodate such things as body sway, personal articles carried by pedestrians and some tendencies to avoid physical contact with others (Austroads, 1995).

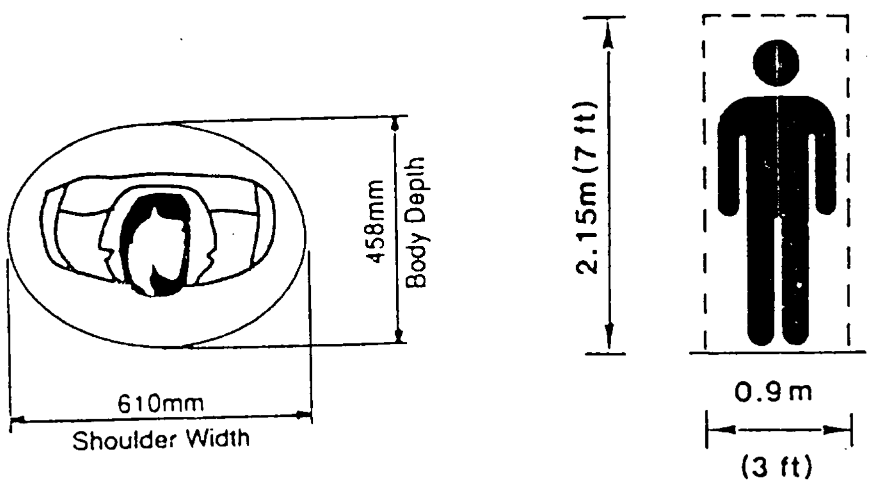

FIGURE 3.6 TYPICAL PEDESTRIAN'S BODY ELLIPSE
(Source: Austroads, 1995)

Walking Speed

Pedestrian walking speed is generally governed by their sex, age and physical condition. The typical walking speed for pedestrian is as follow (Austroads, 1995):

Minimum speed	0.74 m/s
Maximum speed	2.39 m/s
Average free-flow speed	1.35 m/s

Walking Distances

Range of pedestrian walking distance may vary due to such various factors as the purpose of trip, overall travel time, walking conditions and environment and any other personal reason. For non-recreational purposes, walking distance of about 1.5 km or about 15-minute walk is typical (Austroads, 1995). As a matter of fact, walking is considered a convenience for a distance up to about 500m (Untermann, 1984). For anything more than that, other modes of transport become more attractive. More specifically, according to Untermann (1984), 70% of people are willing to walk up to 150m, 40% willing to walk up to 300m and only 10% are willing to walk up to 800m.

Vulnerable Pedestrians

Some groups of pedestrians are vulnerable and may need special attentions. The vulnerability may be due to their physical limitation, dimension, or deterioration in reaction time and balance. These groups of pedestrians may include people with disabilities, young children, and elderly people (Austroads, 1995).

Disabled People

People with disabilities may include people in a wheelchair, people with impaired vision or hearing or people who require assistance to maintain balance and interpret direction (Austroads, 1995). People in a wheelchair have difficulties in dealing with uneven level or discontinuous surface and therefore require ramps and continuity in surface level. Similarly people with impaired vision usually have trouble with visual signs, marking or any other visual guidance. So a clear and contrasting signs and markings may be required for this sort of pedestrian. People with impaired hearing may have difficulties in recognizing the sound of incoming vehicles, therefore require a clearer view from the side of the road.

Young Pedestrian

Problems with young pedestrians are due to their immaturity, both physical and mental. According to Hoffman (1978) young children, particularly less than 12 years of age, have insufficient mental capacity to make good judgements about traffic. Therefore, to ensure and maximize their safety, this group of pedestrians generally needs continuous supervision.

Elderly Pedestrian

The physical aging of people may to some extent cause them to have relatively slower walking speed and longer reaction times. Consequently, elderly pedestrians need longer time to cross a road, due to both longer waiting time and crossing time. Kerb delays of 3-4 seconds are very common in people over 60 years (Grayson, 1975).

Pedestrians as Traffic

Pedestrian can be regarded as traffic in the fact that groups of pedestrians have such characteristic as flow, speed and density, although relationships between these variables are more difficult to explain (Austroads, 1995). Nevertheless, similar techniques as used in traffic planning can be applied in pedestrian planning. Demand of pedestrians is usually estimated by identifying some typical pedestrian generated activities. These may include office activity, retail activity, residential, and recreational activity. Each of these has typical pattern and pedestrian generation rate. For such purposes, usually 15 minute observation of pedestrian traffic peak is adequate (Austorads, 1995).

Pedestrian Capacity

Pedestrian capacity of such facilities as footways, elevated walkways, stairs, ramps, escalators, or travelators, depends on the level of service of the facilities to maintain and whether or not there is any obstruction. Fruin (1971) divides the level of service into six levels as described in Table 3.17 and illustrated by Figure 3.7. The level of service according to the concept is governed primarily by pedestrian module size M. It is imaginary buffer zones around individual pedestrian representing the degree of social context and situations, which are desirable to maintain. Module size is measured in m^2/pedestrian. Provided that the horizontal space speed S (m/minute) is known, pedestrian flow rate P can be determined using Eqn. 3.23.

$$P = S/M \qquad 3.23$$

where:

P = pedestrian flow rate (pedestrian/m/min);

S = mean horizontal space speed (m/min);

M = pedestrian module size (m^2/pedestrian).

TABLE 3.17 LEVEL OF SERVICE OF PEDESTRIAN FACILITIES

Level of Service	Module Size M (m^2/ped.)	Flow Rate (ped./m/min)	Remarks
A	>3.3	23	Public buildings or plazas without severe peaking fit this level
B	2.3 – 3.3	23 - 33	Suitable for transport terminals or buildings with recurrent but not severe peaks.
C	1.4 – 2.3	33 - 49	Recommended design level for heavily used transport terminals, public buildings or open space where severe peaking and space restrictions limit design feasibility.
D	0.9 – 1.4	49 - 66	Found in crowded public spaces where continual alteration of walking speed and direction is required to maintain reasonable forward progress.
E	0.5 – 0.9	66 - 82	To be used only where peaks are very short (eg. sports stadia or on a railway platform as passengers disembark). A need exists for holding areas for pedestrians to seek refuge from the flow.
F	0.5	Variable, up to 82	The flow becomes a moving queue, and this is not suitable for design purposes.

Source: Fruin, 1971.

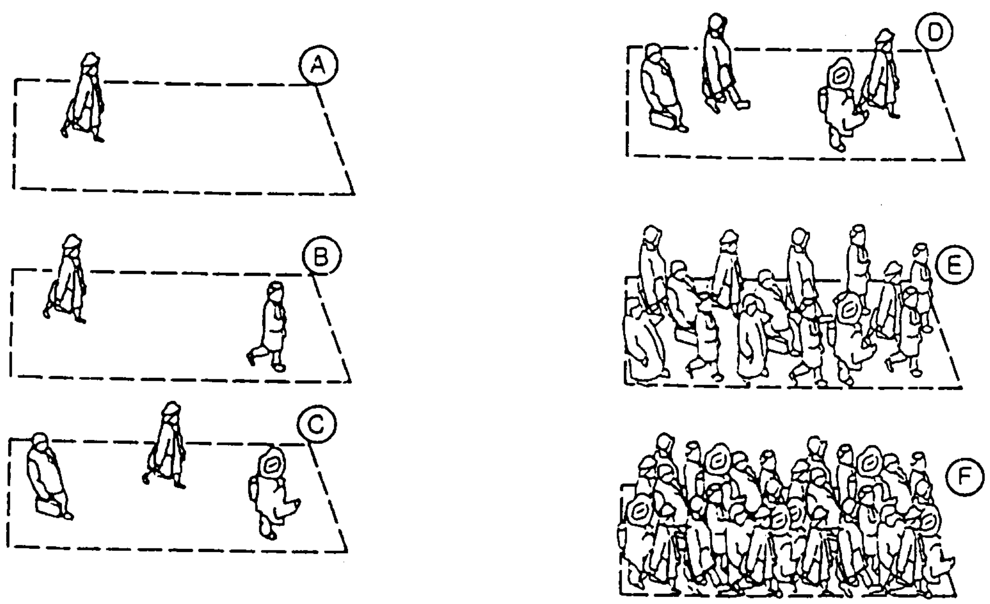

FIGURE 3.7 ILLUSTRATION OF LEVEL OF SERVICE OF PEDESTRIAN FACILITIES

(Source: Austroads, 1995)

Design of Pedestrian Facilities

Width

General pedestrian facilities such as a footpath require at least 1.2m of width. For situations where high pedestrian volumes are observable, the width may be increased up to 2.4 m. Table 3.18 provides basic width requirement for various conditions of a pedestrian facility.

TABLE 3.18 WIDTH REQUIREMENT FOR FOOTPATHS

Conditions	Width
General minimum width	1.2m
Absolute minimum	0.9m
High pedestrian volumes	2.4m or greater depending on demand
For wheelchairs to pass Absolute minimum	1.8m 1.5m
For people with disabilities	1.0m to 1.8m

Source: Austroads, 1995 p 18

Height

For vertical clearance, a minimum height of 2.0m from the surface is generally adopted (Austroads, 1995). Some specific conditions may require vertical clearance up to 2.4m (see Figure 3.8.

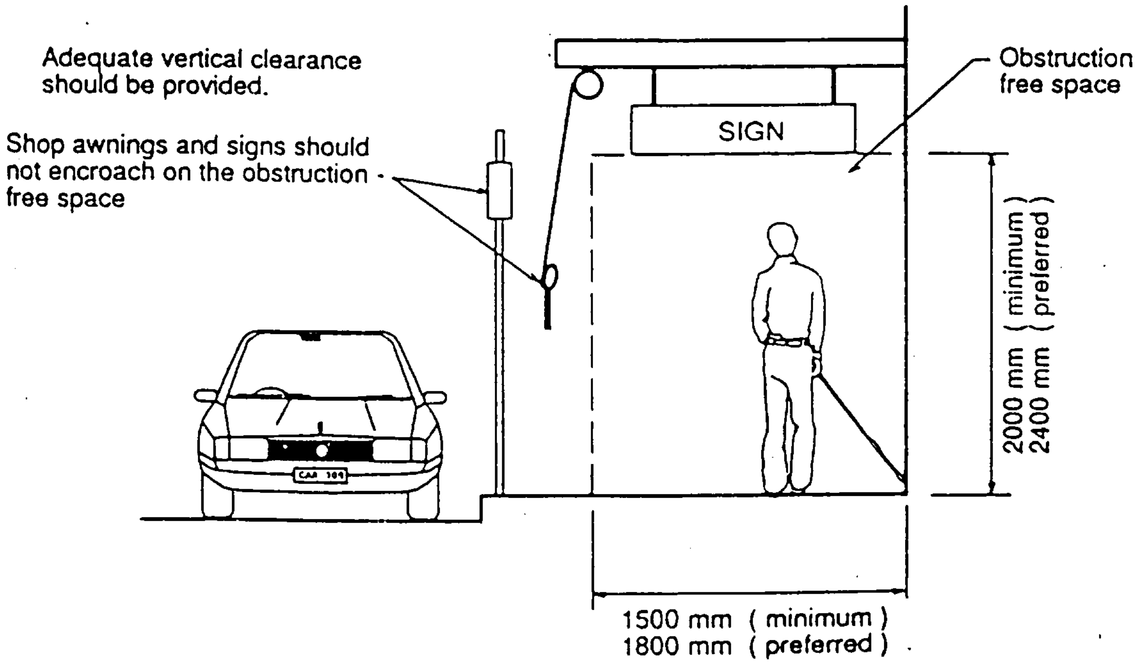

FIGURE 3.8 ENVELOPE OF WIDTH AND HEIGHT REQUIREMENTS
(Source: Austroads, 1995)

Surface Types

Surface of the pedestrian facilities should be treated so that the required conditions of a stable, firm, even and relatively smooth and slip resistant walking surface are met. Generally, hard surfaces such as concrete and asphalt are recommended for footway with gradient and possible wet condition. Unglazed paving blocks and bricks may also be used for outdoor footways. These materials should be laid properly on a firm base and sufficient joints to avoid independent movements and uneven surface. Use of such loose surface materials as exposed aggregate, gravel, soil, sand, grass for pedestrian facilities are not recommended (Austroads, 1995).

Pedestrian Crossing Facilities

Pedestrian crossing facilities can be categorized into four categories as presented in Table 3.19. General crossing treatments such as pedestrian refuge, traffic islands and medians are appropriate for roads with low to medium traffic such as local and collector roads. Whereas time separated facilities such as pelican crossing and pedestrian actuated traffic signals are more appropriate for medium to high traffic volume roads like arterial or sub-arterial or some collector roads with high pedestrian-vehicle incidence (Austroads, 1995).

TABLE 3.19 CATEGORIES OF PEDESTRIAN CROSSING FACILITIES

Categories	Objectives	Treatments
General Crossing Treatments (Physical Pedestrian aids)	TO increase the safety of pedestrians by use of physical aids within the roadway so as to reduce conflict or degree of hazard between vehicles and pedestrians and to simplify the decisions which both pedestrians and drivers have to make	Pedestrian refuge islands Traffic islands Medians Footpath (kerb) extensions Loading islands Safety zones Pedestrian fencing Speed Control Devices
Time Separated (Traffic Control) Facilities	To minimize conflict between pedestrians and vehicles by allotting short time periods for use of a section of road by pedestrians, alternating with period for use by vehicles.	Pedestrian (zebra) crossings Children crossings Pedestrian's actuated traffic signals (mid-block) Pelican crossing Signalized Intersection with pedestrian phases.
Grade (Spatially) Separated Facilities	To increase the safety of pedestrians by eliminating conflict between vehicles and pedestrians	Subways and bridges Pedestrian malls
Integrated Facilities	To provide an environment in which pedestrians and vehicles may share existing road space in a largely unsupervised manner.	Pedestrian warning signs Shared zones School zones Local Area Traffic Management Schemes Lighting

Source: AS1742.10. 1992, Table 1

General Crossing Treatments

Installation of general crossing treatments such as refuge islands is recommended in a section of road where difficulty of crossing the full width of road in one stage is obvious. Australian Standards AS1742.10-1990 suggests that such facilities should only be installed when the product of the number of pedestrians per hour and vehicles in the same hour is more than 90,000. Besides, a minimum of 60 pedestrians and 600 vehicles are observable during two separate hours of typical weekday, and 85th percentile of traffic speed is not more than 80km/h.

Typical layout of pedestrian crossing refuge is as depicted in Figure 3.9. The islands should desirably have 2.0m width to ensure safety, particularly on high-speed traffic. Or, at least 1.8m width is required to allow a person with a pram or on wheelchair to standing. For some constrained situations, 1.2m absolute minimum width of island is applicable (Austroads, 1995).

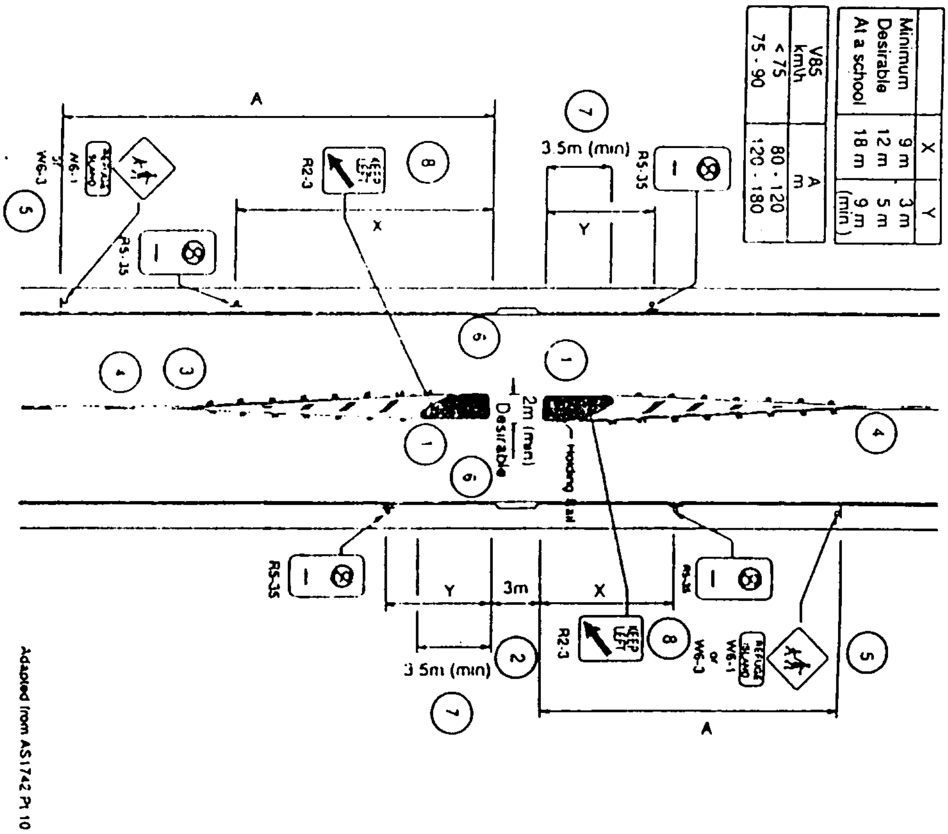

FIGURE 3.9 TYPICAL LAYOUT OF PEDESTRIAN REFUGE ISLANDS
(Source: AS1742.10-1990)

Time Separated (Controlled Traffic) Facilities

General warrants for installing such time separated pedestrian facilities as pedestrian actuated traffic signals or pelican crossing are when more than 350 pedestrians per hour are observable during 3 hours on average day (AS1742.10-1990). Besides, the volume of traffic in both directions, during the same periods of time, exceeds 600 veh/h or 1000 veh/h (where there is a refuge island).

Pelican crossing is a more sophisticated version of pedestrian actuated signals. It is more sophisticated in a way that it includes a flashing amber period to reduce delay to motorists. The standard (1990) indicates that use of pelican crossing may reduce the delay up to half that of conventional pedestrian actuated signals. For pelican crossing, which, the warrants are the same. Only that additional warrant of the 85th percentile speed of traffic should less than 80 km/h, is applicable. Figure 3.10 shows the typical layout of such facilities.

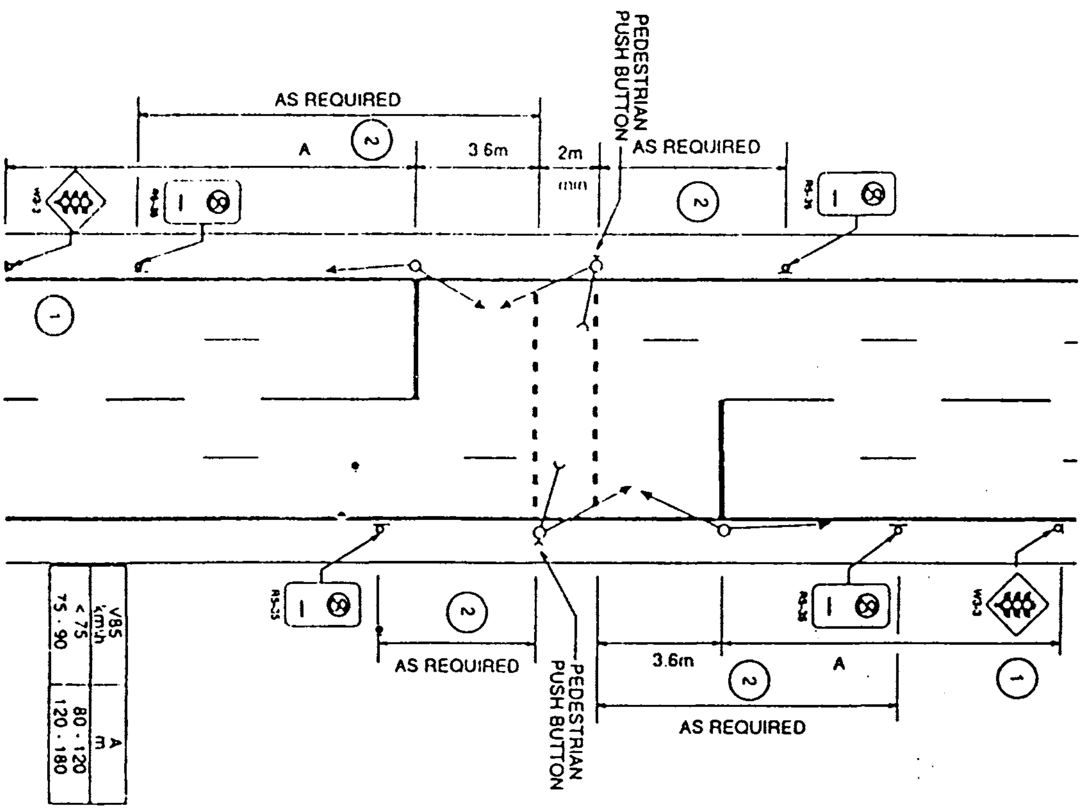

FIGURE 3.10 PEDESTRIAN ACTUATED TRAFFIC SIGNALS (MIDBLOCK)

Source: AS1472.10

Pedestrian Delay and Risk

Delay

One of the most noticeable effects of road traffic to pedestrians sharing the road is probably the delay to the pedestrians crossing a street (Buchanan, 1963). The relationship between average delay to pedestrians and the traffic characteristics is traditionally explained using gap acceptance theory. The theory, as firstly attempted by W.F. Adams, suggest relationship as expressed in Eqn. 3.24 and 3.25. The relationship is applicable for generally random series traffic with negative exponentially distributed headways (Adams, 1957).

$$d = (e^{q\alpha} - q\alpha - 1)/q \qquad 3.24$$

$$p = 1 - e^{-q\alpha} \qquad 3.25$$

where:

d = mean delay to all pedestrians crossing the road (s)

q = traffic volume (vehicles/second);

α = minimum time headway in the traffic stream that pedestrians will accept to cross (s);

p = proportion of pedestrians delayed.

There are three possible ways for pedestrians to cross roads. The first is by waiting for a sufficient gap in the combined stream and then crossing straight away. The second is by waiting for a gap in the nearest stream that followed by another gap in the far stream and make the crossing. The third is by waiting for a gap in the near stream, waiting in the centre, waiting for another gap in the far stream and finalizing the crossing.

Effects of the strategies to the average delay to pedestrians can be best explained by the graphs in Figure 3.11. The figure suggests that for a critical gap equal to 3s and 5s, the average delay to pedestrians using crossing strategy 3 is much less for the same number of traffic. This fact suggest that installing pedestrian crossing facilities that allow pedestrians to apply the strategy, such as refuge islands, will significantly reduce their delay (Wirasinghe, 1980).

Studies regarding gap acceptance or headways suggest that headway between 3.5s and 5s is generally acceptable (Adams, 1957). But, longer gaps may be required as indicated by

Robinson (1960) that 50% of pedestrians would accept 7s gap, while 95% of them would accept 12s gap.

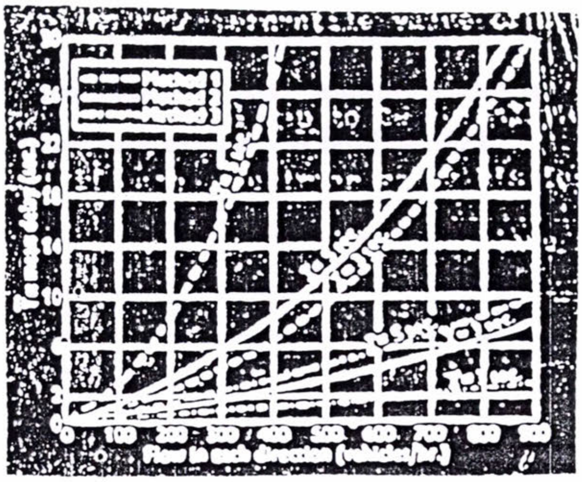

FIGURE 3.11 THEORETICAL MEAN PEDESTRIAN DELAYS WHEN CROSSING TWO STREAMS OF TRAFFIC

(SOURCE: ABEISURYA, 1979)

Risk

Pedestrians experiencing long delay are very likely to take risks by reducing his margin of safety (Abeisurya, 1979, Song *et.al*, 1993). Pedestrian risk is usually measured using ratio between accidents involving pedestrians and the corresponding total pedestrian flow. Studies suggest that the most risky areas for crossing roads are the areas within 45m of crossing facilities, while the safest place is at the facilities themselves. In terms of road types, another study suggests that streets with one-way traffic are significantly safer than two-way streets.

Male pedestrians are also reported to have a higher risk in crossing roads, due to their higher tendency in using the dangerous parts to cross. Elderly people and children under 16 years of age are also having greater chance in being involved in accidents. The risk of elderly people over 60 is about four times than normal adult people, whereas the risk of children is double.

3.2.4. Accident Risks

Traffic accidents and road safety have been the major concerns amongst road authorities since the end of World War II. Until early 1970s, considerable growth in vehicle fleet and the advance of automobile technology is believed to be major contributors to the increasing road casualties (OECD, 1986). Data from most developed countries, as shown in Figure 3.12, show that after 1973 the number of road casualties started to decrease. The figures continued to decrease and never back to their peak levels in 1973.

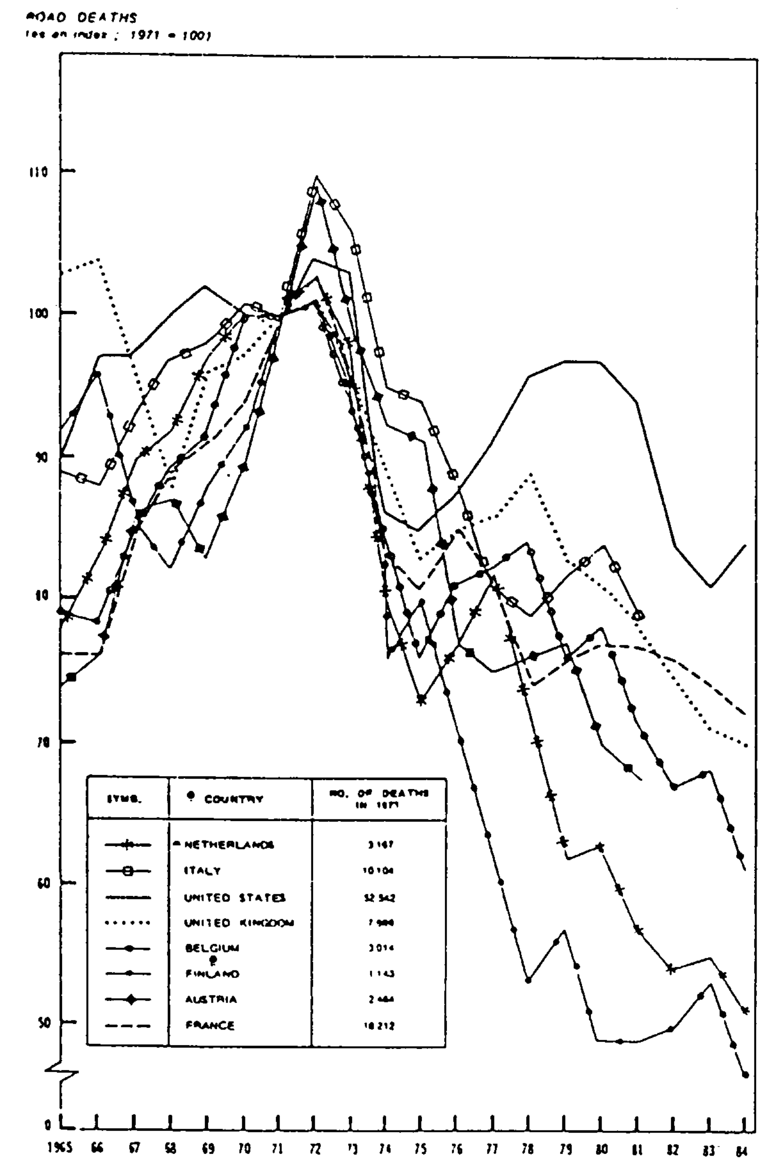

FIGURE 3.12 TRENDS IN ROAD FATALITIES IN SOME DEVELOPED COUNTRIES

Source: OECD, 1986.

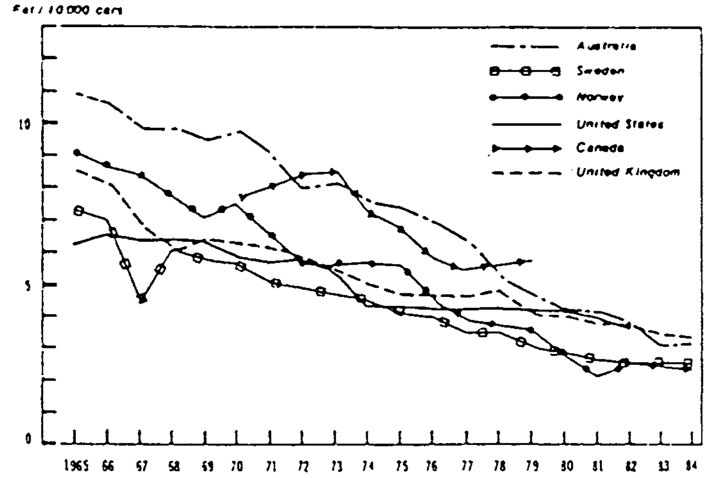

FIGURE 3.13 TRENDS IN ACCIDENT RATES (FATALITIES/10,000 CARS)
Source: OECD, 1986

Surprisingly accident rates in terms of fatalities per 10,000 cars have been constantly decreasing (see Figure 3.13). Pattern of the corresponding data show that there was no dramatic change of its trend during the 1973 peak. The fact suggest that significant drop in road casualties in the early 1970 were mainly caused by restrained traffic growth due to economic recessions, oil crisis and some road safety measures (OECD, 1986).

Comparative figures in road casualties in OECD member countries are as presented in Table 3.20. The figures suggest that although in some countries the road fatalities tend to decrease, in some other countries they have been increasing or at least stabilizing. In total, road fatalities had decrease from about 150,000 in 1971 to about 120,000 in 1984.

TABLE 3.20 NUMBER OF ROAD FATALITIES IN OECD MEMBER COUNTRIES

Country	1971	1984
Australia	3590	2810
Austria	2824	1620
Belgium	3014	1893
Canada	5573	4143
Denmark	1213	665
Finland	1143	539
France	18212	11685
Germany	18753	10199
Greece	996	1826
Iceland	-	27
Ireland	576	465
Italy	10104	7184
Japan	16278	9262

TABLE 3.20 NUMBER OF ROAD FATALITIES IN OECD MEMBER COUNTRIES (CONT'D)

Luxembourg	-	70
Netherlands	3167	1615
New Zealand	0	668
Norway	533	407
Portugal	-	2300
Spain	4247	4827
Sweden	1215	809
Switzerland	1773	1097
Turkey	-	5680
United Kingdom	7699	5424
United States	52542	44241
Total	153452	119456

Source: OECD, 1986

Major Involving Factors in Accidents

Factors contributing in most of traffic accidents may include such major components as road user, the vehicle, and the road environment. As depicted in Figure 3.14, road user or human factor is the primary cause in 95% of accidents. While vehicle and road environment involve in around 8% and 28% of the time respectively (RTA, 1991). From the 8% vehicle factor involvement, 50% are in combination with human factor. Whereas of road environment factor, only 15% that without any involvement of human factor.

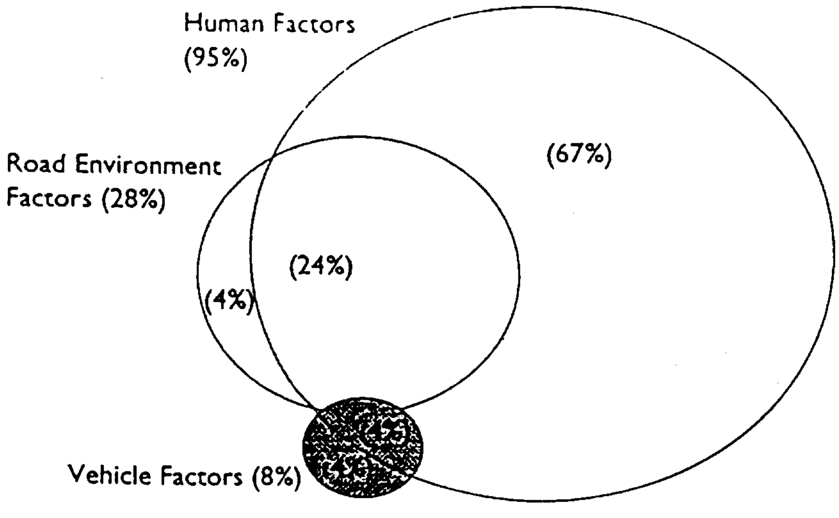

FIGURE 3.14 INVOLVEMENT OF FACTORS IN ACCIDENTS
(Source: RTA, 1991)

Accident Exposure and Risk

The most important factor in determining accident risk is the exposure, or the magnitude and potential conditions within which someone may encounter accidents. Accident exposure depends primarily on how much, where and when someone drives (DeSilva, 1942). Someone who drives more mileage would have greater probability to encounter accident hazards. Some parts of roadway may also have higher potential hazard than the other parts of the road. Accident hazards may also be higher during particular time of day or season in a year. Combinations of such factors would then determine the level of accident exposure to a road user.

Certain groups of people may be exposed to more accident hazards than any other groups. Studies conducted by OECD (1986) show that young drivers age up to 25 years have three times more likely to have an accident than the average people. People under influence of alcohol also have greater exposure to road accidents compared to non-drinking drivers. The probability can be 17 times higher for people between 30-34 year old and 39 times for drivers over 50 years of age.

Regarding the relative potential of accident hazards of some parts of roadway, rural freeway for instance, have about 1.5 times higher accident exposure than urban freeway. Accident data from New South Wales also suggest that an undivided urban road can have twice as much as divided urban roads (RTA, 1991).

Driving in such reduced visibility situation as in nighttime has substantially higher exposure to accident hazard (about twice) than those in daytime. Adverse weather conditions such as rain, snow and fog will also considerably increase the potential of accident hazards (OECD, 1986).

Measurement of Safety

There are four general ways in expressing the level of safety of any particular region or country as introduced by DeSilva (1942). The first is by using the total number of road fatalities. In this method, any region or country with larger number of population and consequently greater number of cars and vehicle usage will quite certain to have a greater road fatalities. Although it is the simplest method in identifying the level of safety, it can not be used in determining the relative safety amongst the regions or countries. The second method in presenting accident information or safety is by using the number of road fatalities per population. By using such ratio, performance between individual region or country can be compared. For such purposes, the use of road fatalities in every 100,000 population is quite common.

Another way of expressing the information is by comparing the number of fatalities with the number of registered vehicles. This method is more useful than the previous method is providing information on road safety. As vehicle ownership varies from region to region and from country to country, using fatalities per number of population may be misleading. The best way in measuring the level of safety of regions and countries is actually by comparing the number of road fatalities by the vehicles-kilometre traveled. Since vehicle-kilometre traveled can be regarded as the best representation of exposure this index is most widely used parameter in measuring the road safety (DeSilva, 1942).

Unfortunately, information on vehicle-kilometre traveled is not easily obtained. It is usually estimated from figures on total petrol consumption. From the figures, provided that the information on fuel consumption per kilometre for different types of vehicles is known, the number of kilometres traveled may be obtained.

Safety Countermeasures

As human behaviour is the major determining factor in majority of road accidents, considerable effort and research have been conducted to educate road users and promote road safety. The safety campaigns have particularly targeted high-risk user groups such as alcohol or drug-impaired drivers, inexperience or young drivers, pedestrians and cyclists, and truck drivers. Besides special attention also be given to particular age groups such as children and elderly people (OECD, 1986).

Studies regarding alcohol effect on road accidents suggest that blood alcohol concentration (BAC, in mg alcohol per 100 ml blood) of as low as 0.05% can have impaired the ability to drive. Alcohol level between 0.05-0.08% is reported to begin increasing accident risk, whereas between 0.08-0.10% the risk of accident involvement increases appreciably. Beyond 0.10% drivers are definitely impaired and accident risk is significantly increased (OECD, 1986). For these reasons OECD recommends to forbid legally driving with BAC above 0.08% (or 0.05%).

Regarding young or inexperience drivers, some studies as reported in OECD safety research (1986) suggest that young drivers are over-represented in most accident data in all situation. The report also indicates that lack in driving experience contributes about 10-15% of all accidents. One of the major suggestions in overcoming the problem is to introduce driving probationary periods after a provisional license has been granted. Evaluation is then being made after one or two years to see whether or not excessive offences have been committed.

Studies on travelling speeds show that speeding driving could be as dangerous as driving under alcohol influence (Kloeden, McLean, Moore, Ponte, 1997). Kloeden *et.al* indicate that travelling at around 65 km/h may have a comparable risk as driving with BAC of 0.05. Furthermore they indicate that the accident risk tends to double with every 5 km/h increase above 60 km/h limit as shown in Table 3.21. To overcome the problem it was suggested to reduce the 60 km/h limit down to 50 km/h in urban roads.

TABLE 3.21 TRAVELLING SPEED AND THE RISK IN 60 KM/H LIMIT ZONE

Range	No. of crashes	No. of controls	Relative Risk
33-37	0	4	0
38-42	1	5	1.41
43-47	4	30	0.94
48-52	5	57	0.62
53-57	19	133	1.01
58-62	29	205	1
63-67	36	127	2.
68-72	20	34	4.16
73-77	9	6	10.6
78-82	9	2	31.8
83-87	8	1	56.55
88+	11	0	infinite

Source: Kloeden et.al, 1997

Road Design

Safe road environment requires various safety principles to be applied. Such principles include good quality of geometry and pavement design as well as sufficient road marking and sign posting (RTA, 1991). In terms of geometry the road concerned should be sufficiently meet the following principles:

- Horizontal and vertical alignment should be well coordinated to provide a smooth and pleasing driving conditions;
- Curvature traps and adverse crossfalls should be avoided;
- Sufficient sight distance should be ensured particularly at critical road elements such as dips, crests, intersections, roundabouts, and interchanges;

- Additional lanes such as climbing or overtaking lanes should be considered in terrain and traffic conditions;
- Special attention should be given for section with unavoidable steep grades.
- Regarding pavement and carriageway design the following principles should be taken into account:
- Lanes should be wide enough to provide sufficient margins for comfortable traffic maneuvering;
- Road shoulders should be sufficiently paved to protect the pavement edge but not too wide to use as additional travel lane;
- Wherever possible, road median should be adequately provided to accommodate clear zone, auxiliary lanes at intersections or pedestrian crossing facilities. A clear area of 9-10 m outside the edge of the pavement with side slope of 6:1 or flatter is desirable for high-speed highway (Underwood, 1991).
- Pavement surface should have sufficiently good skid resistance characteristics.

From a traffic control point-of-view, the following design requirements should be maintained.

- Instruction and traffic signs should be properly located and easily understood;
- Any possible conflicts between various directions of traffic should be positively controlled;
- Some important messages should be repeated to avoid surprised to negligent driver.

Some other safety principles in road design aspect may include:

- Road should be sufficiently widened on curves to provide enough maneuvering space;
- Marking and delineation should be sufficiently visible day and night;
- Road marking should have sufficient skid resistance
- Drainage system should be properly designed to avoid any unnecessary obstructions to drivers;
- Pedestrians and bicyclists needs should be sufficiently accommodated;
- Safety fences and guardrails should be provided wherever required. Typical roadside barriers are as depicted in Figure 3.15. The barriers should be used for at least 25m and should be placed at a minimum 1.0m of the edge of shoulder wherever applicable.

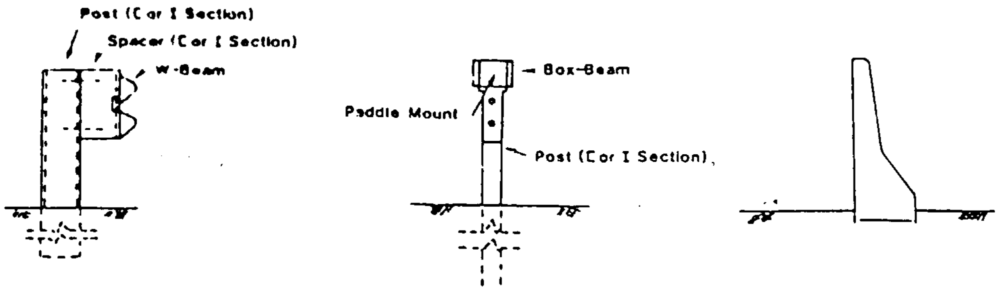

FIGURE 3.15 TYPICAL ROADSIDE BARRIERS
(Source: NAASRA, 1987)

Accident Costs

Methods in determining accidents costs are differentiated into two, ex-post and ex-ante methods. The former estimates accident costs based on data from past accidents, while the latter uses the public 'willingness to pay' for a reduced risk of injury or death as the basis of the costs estimate (Mabbott, 1998).

Cost components used in ex-post method are categorized into per-person costs and per accident costs. Per-person costs may include:

- Lost human productivity;
- Gross and net output;
- Discount rate;
- Age and gender differences;
- Loss of victim to others (family and community);
- Losses to others;
- Hospital, medical and rehabilitation;
- Legal and court proceedings;
- Pain and suffering;
- Permanent disability or impairment;
- Breakdown of costs by injury level of victims;
- Inpatient, outpatient, medical, funeral, and rehabilitation;
- Ambulance;
- Worker's compensation.

While per accident or incident costs may include:

- Vehicle repairs;
- Insurance administration costs;
- Police investigations;
- Alternative transport whilst vehicle is repaired;
- Time lost at scene and traffic delay;
- Property damage only (PDO) accidents;
- Truck, semi trailer and motorcycle accidents.

In the willingness-to-pay method estimate of accident costs are based on the results of public survey or analyses of acceptable compensation values for reduction of risk. Some countries such as United States, New Zealand, Sweden, and United Kingdom have been adopting the method in estimating accident costs (BTCE, 1996). Nevertheless, considerable difficulties have been reported practically and conceptually in using the method (Steadman and Bryan, 1988). They include the potential bias of the individual response due to their different social backgrounds and uncertainty in whether or not individuals could really distinguish between injury and death risks.

Table 3.22 presents the average accident costs for different types of injury severity as employed by various organizations in Australia and New Zealand (Mabbott, 1998). According to the figures, average fatal accident costs about AU$823,694 (1998 prices), which is much less than the estimated costs using the willingness to pay method of about $2 million (1990 prices). Average costs per accident for various types of accident are as presented in Table 3.23.

TABLE 3.22 AVERAGE ACCIDENT COSTS BY LEVEL OF SEVERITY (1998 PRICES A$)

Injury Severity	Mean	St. Deviation
Fatal	823,694	85,460
Hospitalized	150,951	21,432
Medical	21,263	5,657
No Medical	16,357	2,400
No Injury	9,815	2,646

Source: adapted from Mabbott and Swadling, 1998.
Note: Fatal = killed or died within 30 days; Hospitalized = admitted to hospital; Medical = required medical treatment; No Medical = injured, not requiring medical treatment; No Injury = not injured.

TABLE 3.23 AVERAGE ACCIDENT COSTS BY TYPE (1998 PRICES A$)

Accident Type	Urban	Rural
Intersection	39,000	90,000
Head on	90,000	175,000
Opposing vehicles, turning	42,000	82,500
Rear end	22,000	44,000
Pedestrian crossing cariageway	98,000	170,000
Off carriageway, on straight	40,000	70,000
Off carriageway, on curve	65,000	102,000
Off carriageway, on curve, hit object	84,000	121,000

Source: adapted from Mabbott and Swadling, 1998.

3.3 Acceptable Levels of Environmental Quality

3.3.1. Noise

Some industrialized countries such as European Economic Community (UK, France, West Germany, Luxembourg, Holland, Italy, Belgium, Eire, Denmark, Greece, Spain, and Portugal), Switzerland, USA, and Japan have been applying limitations to the noise emissions of individual vehicle. Table 3.24 shows the noise limit figures for various types of vehicles as applied in the countries.

TABLE 3.24 ROAD VEHICLE NOISE LIMITS OF INDUSTRIALIZED COUNTRIES - DB(A)

Vehicle	Noise Limit - dB(A)			
	EEC (1988)	Switzerland (1986)	USA (1986)	Japan (1985)
Passenger Car	77	75	75-86	78
Minibus < 3.5 ton	79			
Bus > 3.5 ton	80	80		83
Bus >147 kW	85	82		83
Light truck < 3.5 ton	79	77		81
Medium truck >3.5 ton	83		80	83
Heavy trucks > 12 ton, > 147 kW	84	84	80	86
Motor cycle , 50cc		73	70	72
50-125 cc	75	78	80	72
125-350 cc	78	80	80	75
350-500 cc		80	80	78
>500 cc	80	80	80	78

Source: Adapted from Nelson 1987, Table 9.4, 9.6, 9.7, 9.8 pp. 9/11-9/13

For Australia, through the Australian Design Rules (ADR), noise limit for various different vehicles are as presented in Table 3.25.

TABLE 3.25 ALLOWABLE NOISE LEVELS OF NEW VEHICLES IN AUSTRALIA dB(A)

Vehicle Type	Moving	Stationary	Introduction date
Car	77	90	1 January 1992
Medium Truck	83	97	1 July 1992
Large Truck	87	99	1 July 1993

Source: State Pollution Control Comission, 1991

The maximum acceptable noise levels as suggested by authorities in various countries are slightly different one another, but general guidelines as proposed by a group of researchers are as shown in Table 3.26 (Aecherli, 1986).

TABLE 3.26 GUIDELINES FOR MAXIMUM NOISE LEVELS LEQ IN DB(A)

Environment	Day	Night
Leisure or rest	55	45
Living accommodation	60	50
Living on main roads	65	55

Source: Aecherli, 1986, pp. 424

3.3.2. Air Quality Legislation

Legislation on air quality is mainly intended to reduce and control the level of air pollution to avoid undesirable impacts on either human, animals, plants, or properties. In the United States, 1963 Clean Air Act and its 1970 amendments is used as a legal basis for air pollution control. There are two types of standards in the act, the primary and secondary standards. Primary ambient air quality standards are set of standard required to protect public health with sufficient margin for safety. Secondary ambient air quality standards are required to protect public welfare such as properties, crops, vegetation, wildlife, visibility, and climate from any adverse impacts of air pollution.

Table 3.27 provides some standards on air qualities as applied in several countries.

TABLE 3.27. AIR QUALITY STANDARDS IN SEVERAL COUNTRIES, mg/m^3

Country	Carbon Monoxide	Nitrogen Oxide	Suspended Particulate	Sulfur Oxide
Australia	10/1hr	0.320/1hr	0.09/1yr	0.06/1yr
Finland	30/1hr 10/8 hr	0.300/1 hr 0.150/24 hr	0.150/24 hr 0.060/yr	0.5/1 hr 0.2/24 hr 0.04/yr
Italy		0.200/1 hr	0.150/24 hr	0.080/yr
Japan	11.1/8 hr	0.100/24 hr	0.20/1 hr 0.10/24 hr	0.3/1 hr 0.12/24 hr
The Netherlands	40/1 hr 6/8 hr	0.135/1 hr	0.150/24 hr	0.83/1 hr 0.25/24 hr

Source: Adopted from Boubel, 1994 Table 22-10, p380

In contingency plan several levels of ambient air quality standards are applied for warning, emergency and significant harm conditions. Table 3.28 shows the three different levels of ambient air quality as adopted in the United States.

TABLE 3.28 WARNING, EMERGENCY, AND SIGNIFICANT HARM LEVELS FOR AMBIENT AIR QUALITY

Pollutant	Warning levels	Emergency levels	Significant harm levels
Photochemical oxidant	800 μg/m³, 1-hr av (0.4 ppm)	1200 μg/m³, 1-hr av (0.6 ppm)	800 μg/m³, 4-hr av (0.4 ppm) 1200 μg/m³, 2-hr av (0.6 ppm) 1400 μg/m³, 1-hr av (0.7 ppm)
Carbon monoxide	34 mg/m³, 8-hr av (30 ppm)	46 mg/m³, 8-hr av (40 ppm)	57.5 mg/m³, 8-hr av (50 ppm) 86.3 mg/m³, 4-hr av (75 ppm) 144 mg/m³, 1-hr av (125 ppm)
Nitrogen dioxide	2260 μg/m³, 1-hr av (1.2 ppm) 565 μg/m³, 24-hr av (0.3 ppm)	740 μg/m³, 24-hr av (0.4 ppm)	3750 μg/m³, 1-hr av (2.0 ppm) 938 μg/m³, 24-hr av (0.5 ppm)
Sulfur dioxide	1600 μg/m³, 24-hr av (0.6 ppm)	2100 μg/m³, 24-hr av (0.8 ppm)	2620 μg/m³, 24-hr av (1.0 ppm)
Particulate matter	625 μg/m³, 24-hr av	875 μg/m³, 24-hr av	1000 μg/m³, 24-hr av
Sulfur dioxide and particulate matter combined	product of μg/m³ for both is equal to 261x10³, 24-hr av	product of μg/m³ for both is equal to 393x10³, 24-hr av	product of μg/m³ for both is equal to 490x10³, 24-hr av

Source: Boubel, *et.al* (1994)

3.3.3. Pedestrian Delay

There is no clear-cut estimate of the acceptable level of pedestrian delay. Buchanan (1963) suggested to use average delay value when 50% of pedestrians are delayed. As depicted in Figure 3.16, when 50% of all pedestrian delayed, the average delay to all pedestrians equals to 2.0 seconds. But, the delay is only applicable for road width equals to 12ft (4.0m). Reynolds (1969) then suggests the figures as summarized in Table 3.29.

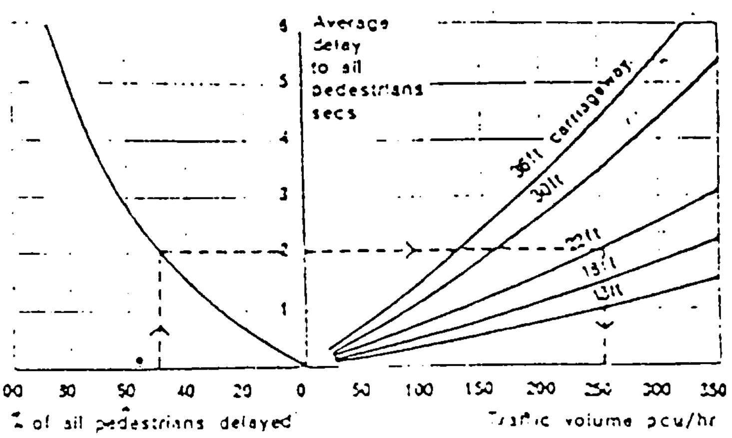

FIGURE 3.16 RELATIONSHIP BETWEEN PROPORTION OF PEDESTRIAN DELAYED, AVERAGE DELAY AND TRAFFIC VOLUME

(Source: Buchanan, 1963)

TABLE 3.29 MEAN DELAY WHEN 50% OF PEDESTRIANS ARE DELAYED

Road Width	Average Delay, (second)	Volume (pcu/hr)
10 ft.(3.05m)	1.85	570
15 ft (4.6m)	2.40	460
20 ft (6.1m)	2.95	390
25 ft (7.6m)	3.55	330
30 ft (9.2m)	3.99	285
35 ft (10.7m)	4.50	255

Source: Reynolds (1969)

3.3.4 Accident Risk

Accident risk is a stochastic or probabilistic value obtained from empirical data, and there is no such value as acceptable level of accident risk available in the literature. The only information that is close to this is the average accident rate for any specific type of road facility, which is also locally specific in its nature.

3.4 Summary

In this chapter overviews of some relevant subjects have been put forward. These include some essential background on multi-attribute utility theory as well as several major environmental factors. The background provides background information and knowledge that are relevant to the subsequent stages of the study.

Multi-attribute utility theory was described to the extent that would be required by the present study. Techniques in determining weights of attributes were also overviewed. A suggestion has been made of the possibility of employing the simple additive form of the utility decomposition function family. It was also suggested to employ such various techniques in determining weights as direct rating, direct ranking and pair-wise comparisons to see which one is practically better.

In the environmental factors department, the nature and important characteristics of such factors as noise, air pollution, pedestrian delay and accident risk were described in considerable length. Definition, units of measurement, consequences as well as basic modeling of the factors were amongst the subjects covered.

The chapter concluded by putting forward information on the acceptable ambient levels of the factors concerned. The levels quoted were either of the legal limits as in the case of noise and air pollution or of theoretical and hypothetical limits as in pedestrian delay and accident risk cases.

The subsequent chapters will discuss the methodology in conducting the research, particularly explaining how the theory could be used to facilitate the development of multi-factor environmental capacity model.

Chapter 4

Chapter 4

A NEW MODEL FOR THE MULTI-FACTOR ENVIRONMENTAL CAPACITY OF ROADS

Previous chapter has described the background knowledge relevant to the present study. This chapter describes the proposed multi-factor environmental capacity of roads. Prior to the explanation of the model, a vigorous sensitivity analyses of some environmental prediction models will be put forward. A hypothetical case is also provided to show how the suggested model will perform in determining the environmental capacity of roads.

4.1 Model Development

The approach for investigating EC proposed in the present research is graphically shown in *Fig*.4.1. Suppose there are three main categories of data that may be described as follows.

1. Environmental data (noise, delayed pedestrian, air quality and accident risk).
2. Preferential data (data on weightings of factors).
3. Road & traffic data (traffic volume, travel speed and road geometry).

By using the first and second categories of data an Environmental Utility Function may then be developed which simply calculates the relative scores of each road. Consider a road segment with Noise level (N_i), delayed pedestrian (P_i), air quality (Aq_i), and accident risk (A_i). By applying certain weighting values on each factor, the Environmental Utility Value *(EUV)* of this road may be calculated as per the form of Eqn.4.1.

$$EUV_i \approx f(n_i, p_i, aq_i, a_i) \qquad 4.1$$

where:

n_i, p_i, aq_i, and a_i = normalized values of N_i, P_i, Aq_i, and A_i respectively.

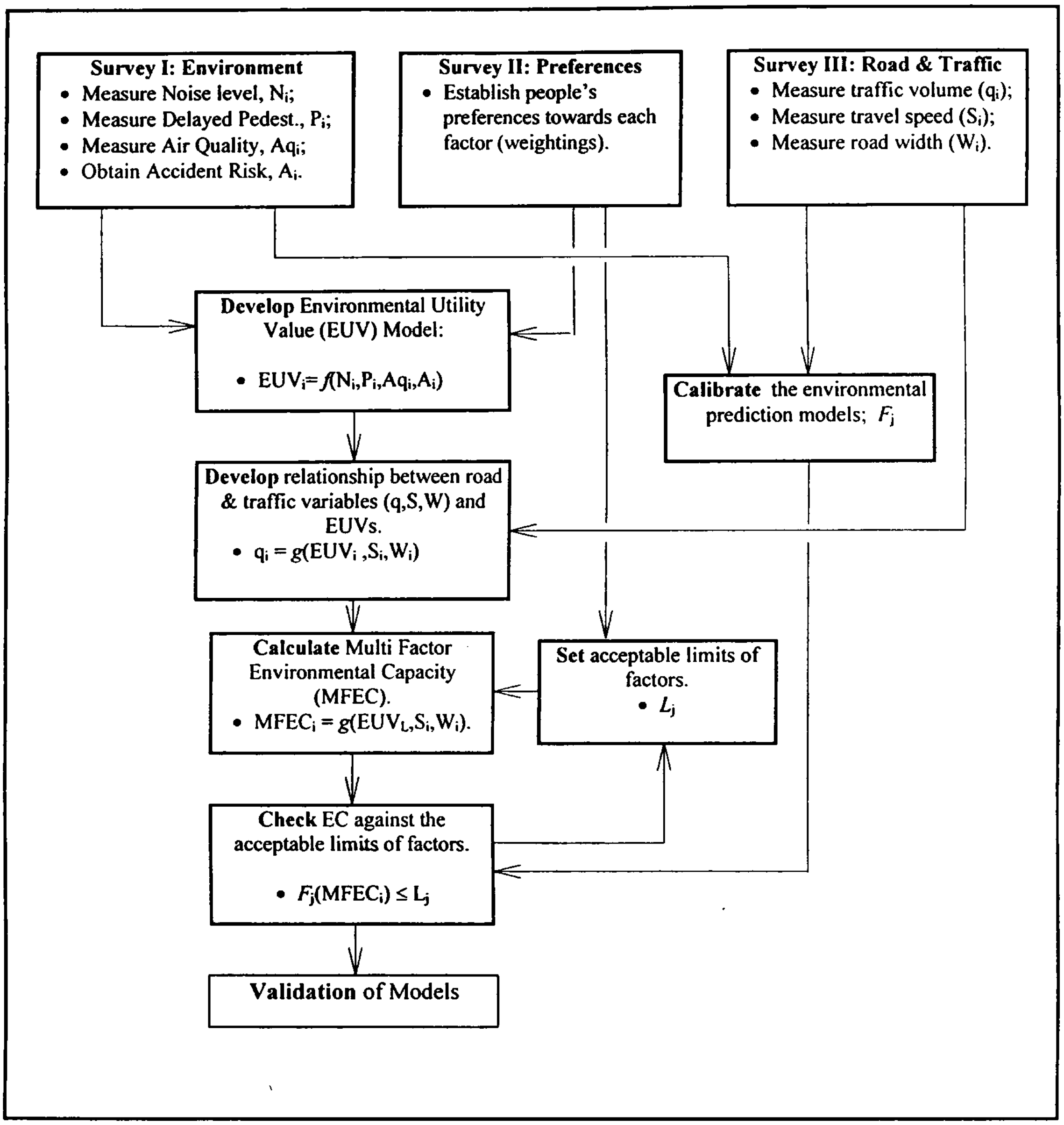

FIGURE 4.1 MULTI FACTOR ENVIRONMENTAL CAPACITY METHODOLOGY

If the quality of environment along the road depends primarily on traffic volume (q), travel speed (S), and road width (W), an attempt to develop a relationship between the EUVs and these variables may then be made. A regression analysis may probably be applied to obtain this relationship which might appear as Eqn. 4.2.

$$q_i \approx g(EUV_i, S_i, W_i) \qquad 4.2$$

So, there are two functions involving EUVs. The first one, Eqn. 4.1, is intended to determine EUV as a representative environmental value of each site, while the second, Eqn. 4.2, correlates traffic volume with its associated EUV and road/traffic characteristics.

Once the model has been developed, Multi-Factor Environmental Capacity (*MFEC*) may then be determined by substituting *EUV* with its acceptable value for that particular type of road (e.g. Local, Collector, or Arterial) as in Eqn. 4.3.

$$MFEC_i \approx h(EUV_L, S_i, W_i); \qquad 4.3$$

where:

EUV_L = acceptable level of *EUV* at a certain road type.

If the value of *MFEC* produced by the method produces any excessive impact, as calculated by the prediction models F_j, it may be altered by applying different value of EUV_L. The alteration is done by changing one or more of the previous limit levels, until no excessive impact - say not more than 10-15% of the limit - is produced. This is assuming that people have different preference towards environmental factors and common utility value is applicable, therefore trade-offs between factors could be made. The value of *MFEC* that satisfies all the limit constraints may finally then be regarded as the optimum *MFEC*.

4.2 Sensitivity Analysis of Selected Prediction Models

Developing an alternative approach in determining environmental capacity initially requires a good understanding of existing models of environmental impacts. In so doing, analyses of the sensitivity of the models are essential. The following sections provide an overview of such analyses.

Models included in the analysis are a noise prediction model, a pedestrian delay model, an air pollution model, and accident risk model. The noise model analyzed here is the Calculation of Road Traffic Noise (CoRTN) that is developed by Department of the Environment, UK (UK DoT, 1988). The pedestrian delay model as recommended by Austroads (1995) is adopted for this purpose. For the emission prediction model, use is made of model developed by Taylor and Anderson (1982) and for dispersion model the General Motors (Chock, 1978) model is used. The accident risk model to be included in the analysis is the one developed by Zeeger, *et.al.* (1986).

4.2.1 Noise Prediction Model

Techniques provided by the CORTN yield the noise level generated by traffic volume and corrected for the following factors:

- average speed;

- proportion of heavy vehicles (composition of the traffic);
- distance from the edge of the roadway to the recipient;
- gradient;
- type of ground;
- screening by barriers and the like.

For purpose of this analysis, to avoid complexity, consideration will only be made for volume, speed, composition and distance. Various noise levels (L_{10}) are calculated using the techniques for different traffic volumes (q, vph), speed (s, km/h), proportion of heavy vehicles (p, %), and distance (d, metres), and disregarding the remaining parameters.

In the techniques, noise level (L_{10}) is determined by the following formula:

$$L_{10} = 41.2 + 10 \log q \qquad 4.4$$

Where:

L_{10} = noise level exceeded in 10% of the time, in dB(A)

The correction factor of speed (s) and proportion of heavy vehicles (p) is calculated using the formula below:

$$33\log(s+40+500/s)+10\log(1+5p/s)-68.8. \qquad 4.5$$

The effect of distance from the edge of the carriageway, assuming that the ground is hard, is calculated using the following formula:

$$-10\log(d'/13.5), \qquad 4.6$$

where $d' = ((d+3.5)^2+(h-0.5)^2)^{0.5}$, and h = height of receiver above ground.

TABLE 4.1 PREDICTED L_{10} NOISE LEVELS

Flow (vph)	L_{10} (dB(A))				
	20 km/h	30 km/h	40 km/h	50 km/h	60 km/h
200	64.5	63.6	63.8	64.4	65.2
250	65.5	64.6	64.8	65.4	66.2
300	66.3	65.4	65.6	66.2	67.0
400	67.5	66.6	66.8	67.4	68.2
450	68.0	67.1	67.3	67.9	68.7
500	68.5	67.6	67.8	68.4	69.2

Note :
1. Sound Pressure Level in dB = $10\log(P/20\mu Pa)^2$.
2. Every doubling of the Sound Pressure causes an increase of 6 dB (Kryter, 1984, p.8).
3. Δ noise level of 3 dB(A) just noticed by good ears.
4. Δ noise level of 10 dB(A) considered as 'doubling' by people.

The relationship between L_{10}, q and s, based on Eqns. 4.4 and 4.5 for $p = 10$, is shown in Table 4.1 and *Fig.* 4.2. It is shown from the figure that the noise level increases with both increasing q and s. When there is no traffic at all the noise level is 41.2 dB(A). This might be regarded as background noise available from other sources. At another extreme point, say q=1000 vph. and s=100 kph., the noise level is about 75 dB(A).

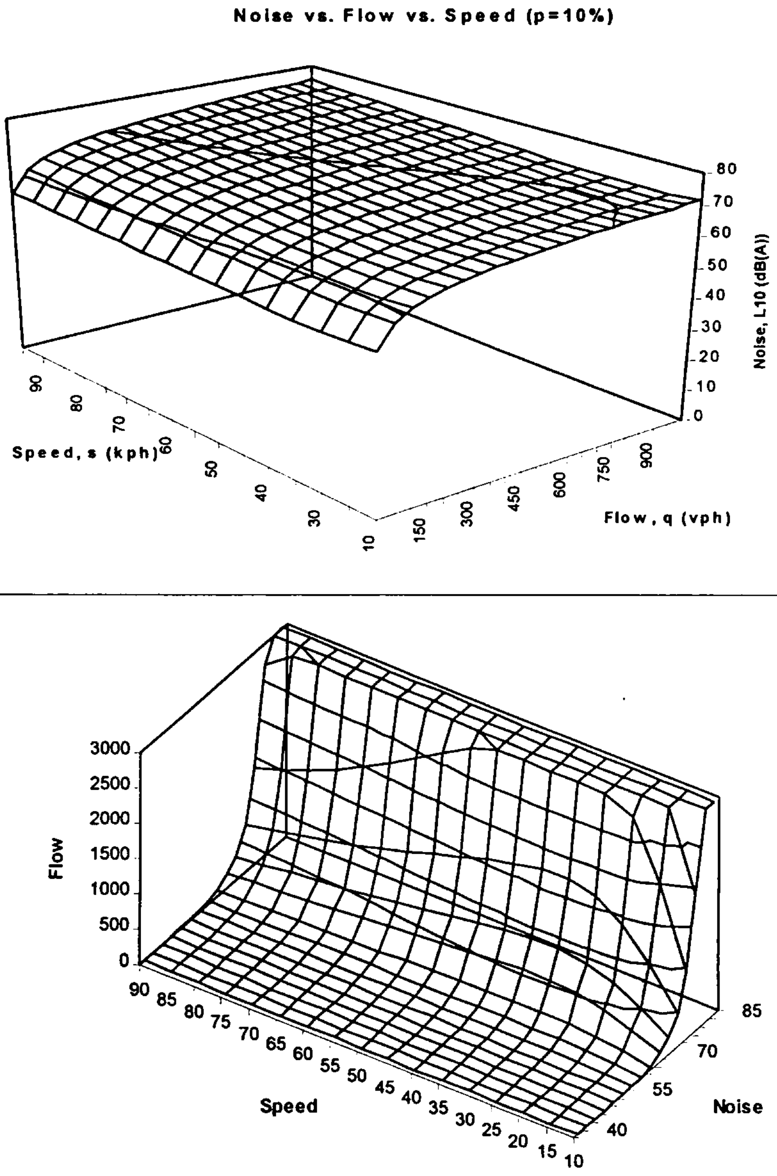

FIGURE 4.2 RELATIONSHIP BETWEEN L_{10}, q, AND S

In general, the quality of noise (L_{10}) is somewhat sensitive towards the value of q, but as they form a non-linear relationship, its degree of sensitivity is varied along their function line. When q is increased by 10%, 25%, 50% and 100%, for example, the noise level will increase by 0.4, 0.9, 1.8 and 3.0 db(A), respectively. On the other hand, as we reduce q by 10%, 20% and 50%, the noise level will reduce by 0.5, 1.7 and 3.0 dB(A), respectively. This relationship also suggests that the same additional amount of traffic does not necessarily produce the same effect to the quality of noise. Additional traffic of 50 vph, for instance, might increase the noise level by 1 dB(A) if the existing volume is 200 vph., but would only increase 0.5 dB(A) of the noise level if the previous traffic volume is 450 vph. (see Table 4.1 for detail). The relationship between noise level (L_{10}) and average traffic speed (s) for Eqn. 4.5 is shown in *Fig*.4.3. Noise level is less sensitive to changes in s than it is to changes in q.

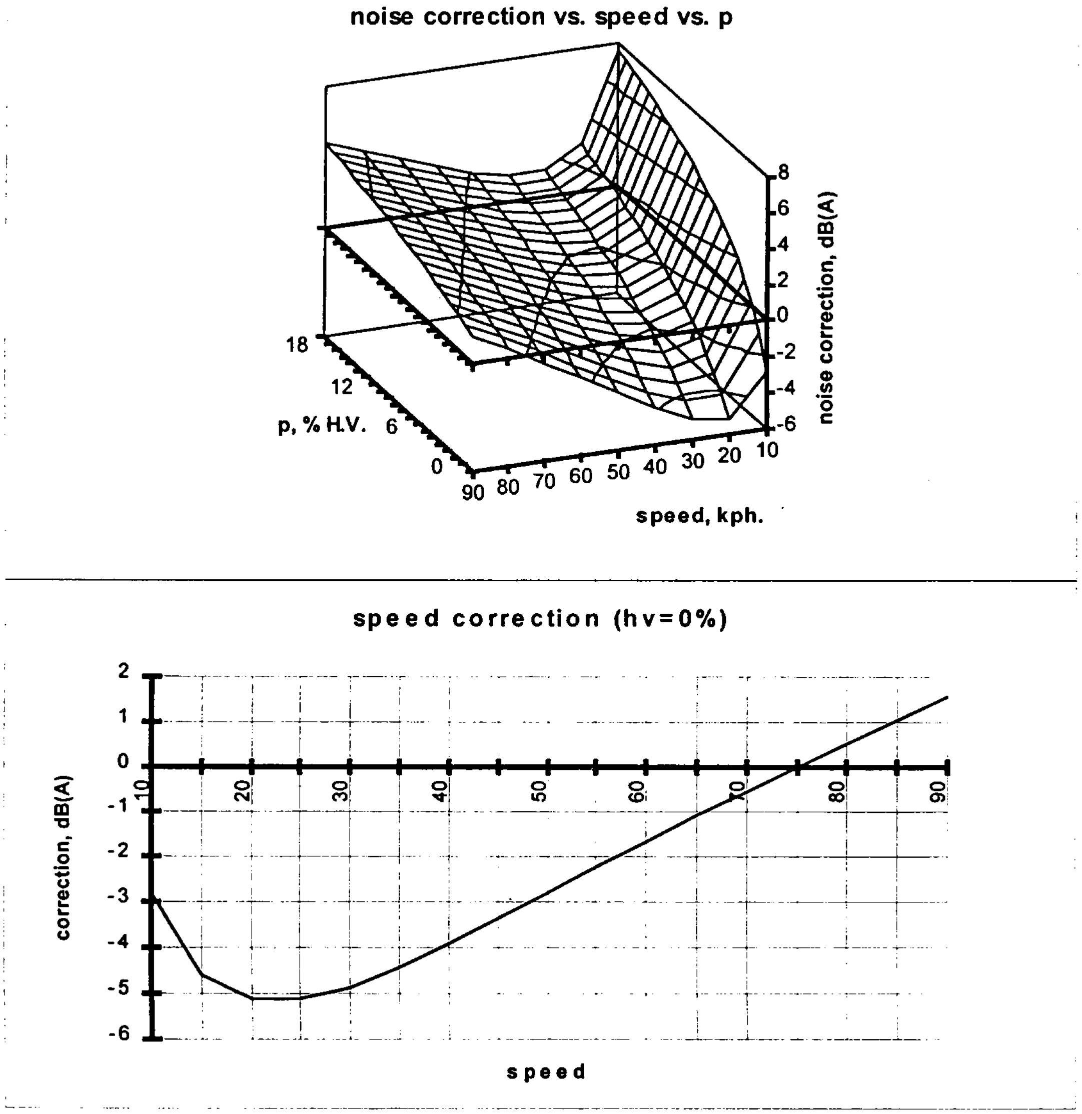

FIGURE 4.3 RELATIONSHIP AMONGST L_{10}, S AND P

Generally, the noise level will decrease linearly as s decreases, particularly when the speed value is greater than 25 kph. Below this value, their relationship becomes non-linear. When there is no heavy vehicle in the traffic (p=0), every reduction of speed by 10 kph would reduce the noise level by approximately 1.1 dB(A). This reflects the fact that q may be increased by reducing s, given the same noise level.

The relationship between L_{10} and p, as suggested in *Fig.*4.3, is relatively linear, particularly at speeds higher than 30 kph. The noise level would generally increase by around 1 dB(A), when an increase in the proportion of heavy vehicles of 5% is made.

The relationship between L_{10} and d (distance) based on Eqn. (4.6), which is graphically shown in *Fig.* 4.4, is relatively similar to relationship between L_{10} and q. The noise level would decrease almost logarithmically as the distance (d) increases. In this model, at the point of about 10m from the edge of the road, the distance has no effect to the noise level (particularly at 50cm height of recipient). This probably is the point at which the measurement of noise level is carried out during the experiment of the model.

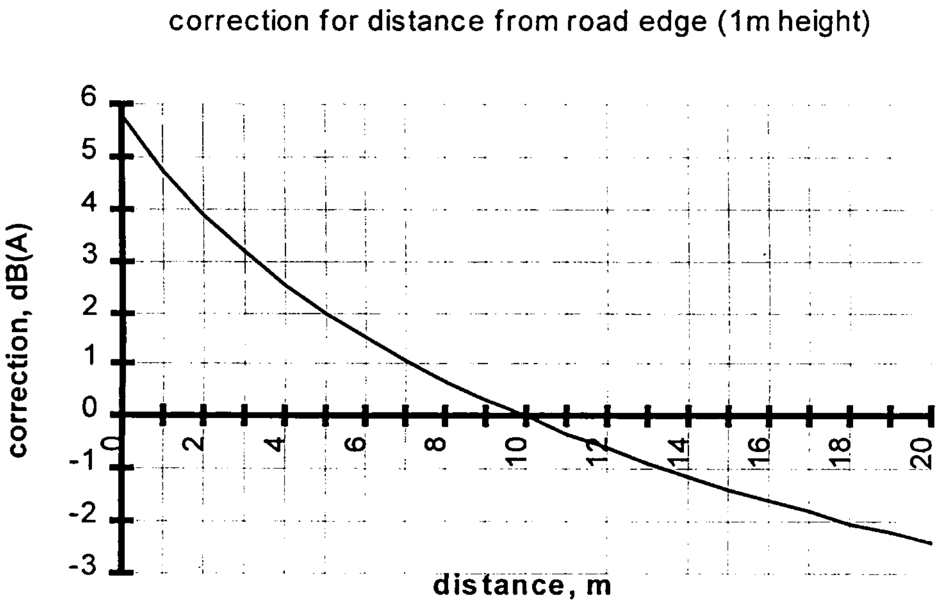

FIGURE 4.4 RELATIONSHIP BETWEEN L_{10}, AND d

4.2.2 Pedestrian Delay

Model for estimating pedestrian delay, as used in the study of EC by Holdworth and Singleton (1979), is based on Adam's delay theory using a modified critical gap value, as suggested by Underwood (1957).

$$p = 1 - e^{-q(5+L/1.22)} \qquad 4.7$$

or,

$q = -ln\,(1-p)/(5+L/1.22)$ 4.8

where:

q= traffic volume, in vehicles/second;

p = proportion of delayed pedestrian; and

L = street width, in metres.

The relationship between q, L, and p as suggested by Eqn. 4.7 is shown graphically in *Fig.* 4.5. The proportion of delayed pedestrian increases with both increasing traffic (q) and road width L. It is obvious from Table 4.2 that p is more sensitive to changes of q than to changes of L. Increases of q by 25%, 50% and 100% for example, yield an increase of p by 0.08, 0.14 and 0.25 respectively. Whereas, an increase of L by 25%, 50% and 100% would only yield an increase in p by 0.06, 0.08 and 0.14 respectively.

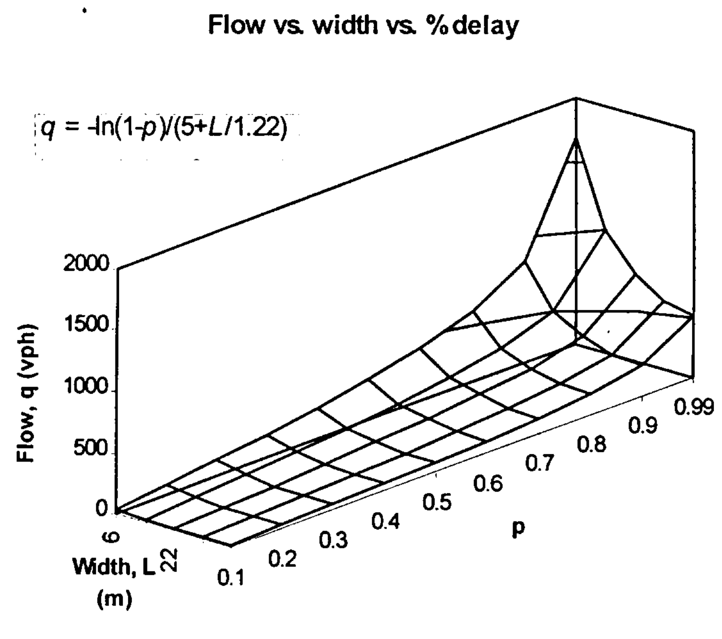

FIGURE 4.5 RELATIONSHIP BETWEEN Q, L AND P

TABLE 4.2 PROPORTION OF DELAYED PEDESTRIAN VS. FLOW AND ROAD WIDTH

Flow (vph)	Proportion of delayed pedestrian (%)			
width >	6 m	9 m	12 m	15 m
200	42	50	56	62
250	50	58	64	70
300	56	64	71	76
400	67	75	81	85
450	71	79	84	88
500	75	82	87	91

In more specific, increasing 50% of q would increase the proportion of delayed pedestrian by

12-15%, while increasing 50% of L will only increase the proportion by 7-8%. The number of vehicles that can be accommodated by the street also increases as the street width decreases. When p=0.80 for example, streets with 6m, 9m, 12m and 15m width may accommodate traffic up to 600, 475, 400 and 340 vph respectively.

4.2.3 Air Pollution

The air pollution emission models used in this research are the ones that are developed by Taylor and Anderson (1982). The quantity of pollutant produced by one car in the models is solely dependent on the speed of the vehicle. The mathematical expressions of the models are as stated in the following formula:

$$CO = 0.8 + 510/s \qquad 4.9$$

$$HC = 0.6 + 34/s \qquad 4.10$$

$$NOx = 2.5 \qquad 4.11$$

Where:

CO = Carbon monoxide emission (gr./veh.km);

HC = Hydro Carbon emission (gr./veh.km.);

NOx = Nitrogen Oxyde (gr/veh.km); and

s = vehicle speed (km/h.).

The relationship of pollutants (CO, HC and NOx) and speed (s). as expressed in Eqns. 4.9, 4.10 and 4.11 are presented graphically in Table 4.3 and *Fig.* 4.6. The amount of NOx emitted is constant at any speed. CO and HC have a hyperbolic relationship with s. As speed decreases the numbers of pollutants (CO and HC) increase. They are very sensitive to changes in speed, particularly at speed below 30 kph and 20 kph for CO and HC, respectively.

TABLE 4.3 VEHICLE EMISSIONS BY DIFFERENT VALUES OF SPEED.

Speed (vph)	Emission (gr./km/veh)		
	CO	HC	NOx
20	26.3	2.3	2.5
30	17.8	1.7	2.5
40	13.6	1.4	2.5
60	9.3	1.2	2.5
80	7.2	1.0	2.5

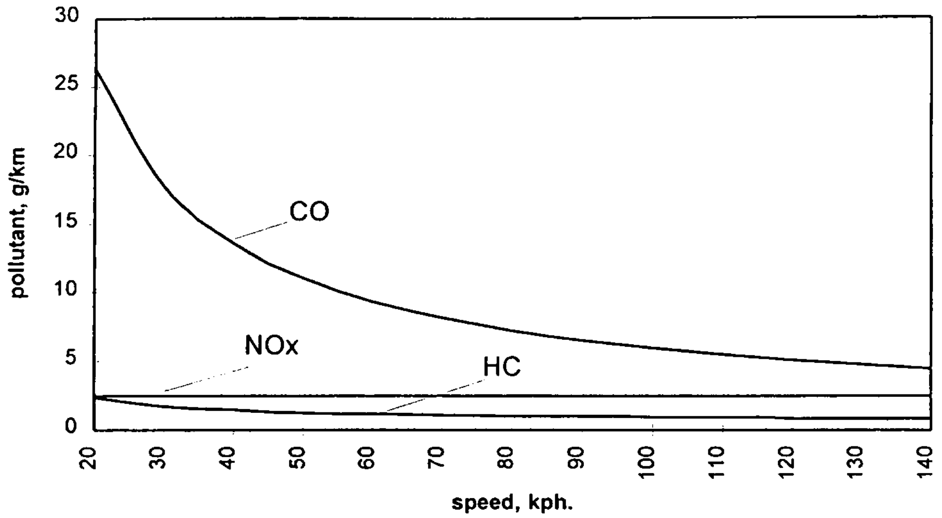

FIGURE 4.6 RELATIONSHIP BETWEEN POLLUTANTS AND S

In general, the quantity of pollutants would approximately double with reduce in 50% of speed. The fact indicates that a reduction in average speed, would significantly reduce the number of vehicles that are eligible to pass along the street given the same ambient levels of pollutants.

4.2.4 Accident Risks

An accident may generally be defined as a rare, random, unpredictable and unfortunate event. That is probably why very few attempts have been done to develop an accident prediction model. Even though, Zegeer, *et.al.*, (1986), developed the following relationship between the number of accidents per mile per year and ADT, lane width, shoulder, median, and terrain. The model after being metricated takes the following form:

$$A = 0.00472.(10.q)^{0.8545}.(0.8867)^{1.6395W}.(0.8922)^{3.279PA}.$$
$$(0.9098)^{3.279UP}.(0.9715)^{3.279R}.(0.8182)^{T1}.(0.2270)^{T2} \qquad 4.12$$

where:

A = single vehicle, head-on, and sideswipe accidents per km per year.

q = vehicle per hour (10% of ADT);

W = road width (m);

PS = average paved shoulder width (m);

UP = average shoulder width (may include gravel, stabilised earth or grass shoulder) (m.);

R = average recovery distance in ft. (measured from edge of shoulder), metre;

T1 = 1 if flat, 0 otherwise;

T2 = 1 if mountainous, 0 otherwise;

(*T1* and *T2* are both 0 for rolling terrain).

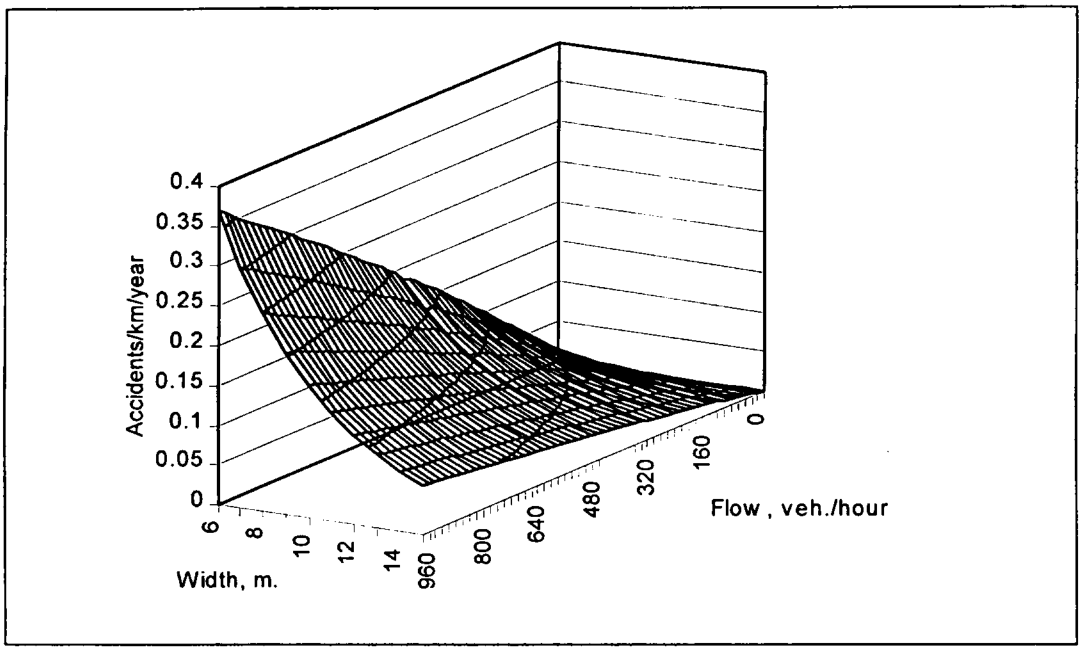

FIGURE 4.7 RELATIONSHIP BETWEEN TRAFFIC FLOW (Q), ROAD WIDTH (W) AND NUMBER OF ACCIDENTS (A).

In general, correlation between A and q is positive whereas with other parameters the correlation are negative. The greater q, and the less W, PS, UP, and R, the higher the number of accidents expected to happen per year. *Fig.* 4.7 shows the form of relationship between A, Q and W when the other variables are fixed. It can be observed that the potential accidents would be reduced by around 30%, 45% and 55% as a result of increasing lane width by 30 %, 50% and 70%, respectively. This indicates that A is relatively sensitive to W. On the other hand, the number accidents per km per year would very likely double as q is doubled. These facts suggest that we could increase the environmental capacity by simply increasing W without necessarily raising the accident risks.

Another expression that may reflect the risk is the accident rate. This figure usually represents the average number of accidents that very likely will happen per year per vehicle kilometer, or the probability of accidents to happen per unit of exposure (SATS, 1974, Mohammedshah, 1998).

TABLE 4.4 NUMBER OF ACCIDENTS VS. FLOW AND ROAD WIDTH.

Flow	Accident Risk, accidents/km/year									
Width >	6 m	7 m	8 m	9 m	10 m	11 m	12 m	13 m	14 m	15 m
200	0.09	0.08	0.06	0.05	0.04	0.03	0.03	0.02	0.02	0.02
250	0.11	0.09	0.08	0.06	0.05	0.04	0.03	0.03	0.02	0.02
300	0.13	0.11	0.09	0.07	0.06	0.05	0.04	0.03	0.03	0.02
350	0.15	0.12	0.10	0.08	0.07	0.06	0.05	0.04	0.03	0.03
400	0.17	0.14	0.11	0.09	0.08	0.06	0.05	0.04	0.03	0.03
450	0.19	0.15	0.13	0.10	0.08	0.07	0.06	0.05	0.04	0.03
500	0.20	0.17	0.14	0.11	0.09	0.08	0.06	0.05	0.04	0.03

The figure apparently suggests that the higher the exposure (number of vehicles times length of travel), the higher the number of accident would happen in a particular street corridor. The rate varied among types of accident. Accidents involving vehicle damage only, tended to have the highest rate (9.4×10^{-4} accidents/veh.km./year), whereas accidents involving casualties and fatal had lower rates, which are 4.39×10^{-4} and 10.51×10^{-6} respectively. Street with traffic intensity 800 veh-km for example, is very likely to have 0.09 accidents per year involving fatalities, 3.99 accidents involving injuries and 8.35 accidents involving vehicle damage only.

In the previous sections, sensitivity analyses of the environmental impact models proposed in this thesis have been put forward. Application of the models for different parameter values is demonstrated. The models mainly employ traffic volume (q), vehicle speed (s) as well as road width (L) as their main parameters. The results indicate that noise prediction model is very sensitive towards q, whereas air pollution model is more sensitive to s. The pedestrian delay depends primarily on q, but less sensitive to L. The vehicle accident model seems to be more sensitive towards q (ADT) and W (lane width).

Tables 4.5, 4.6 and 4.7 below, provide summary of the effect of the parameters for different environmental factors. It can be observed from Table 4.5 that almost all factors are very sensitive towards changes in traffic volume. The vehicle speed only affects significantly to the noise and air pollution factors, whereas road width influences noise as well as pedestrian delays and accidents.

TABLE 4.5 EFFECTS OF TRAFFIC VOLUME ON ENVIRONMENTAL FACTORS, V=75KPH

Volume *vph*	Noise *DB(A)*	Delay %	CO *g/h/km*	HC *g/h/km*	Nox *g/h/km*	Acc.1 *acc./y/km*	Acc.21 *Acc./y/km*	Acc.22 *acc./y/km*	Acc.23 *acc./y/km*
200.	64.2	44.9	1520	211	700	.09	.023	1.00	2.09
300.	66.0	59.1	2280	316	1050	.13	.035	1.50	3.13
400.	67.2	69.7	3040	421	1400	.17	.047	2.00	4.18
500.	68.2	77.5	3800	527	1750	.20	.058	2.49	5.22

TABLE 4.6 EFFECTS OF SPEED ON ENVIRONMENTAL FACTORS, Q=200VPH

Speed *kph*	Noise *dB(A)*	Delay %	CO *g/km/veh*	HC *g/km/veh*	Nox *g/km/veh*	Acc.1 *acc./y/km*	Acc.21 *acc./y/km*	Acc.22 *acc./y/km*	Acc.23 *acc./y/km*
20.	0.3	NA	26.3	2.0	3.5	NA	NA	NA	NA
40.	-0.4	NA	13.5	1.4	3.5	NA	NA	NA	NA
60.	1.0	NA	9.3	1.2	3.5	NA	NA	NA	NA
80.	2.6	NA	7.2	1.0	3.5	NA	NA	NA	NA

TABLE 4.7 EFFECTS OF ROAD WIDTH ON ENVIRONMENTAL FACTORS, Q=200VPH

ΔWidth *m*	Noise *dB(A)*	Delay %	CO *g/km/veh*	HC *g/km/veh*	Nox *g/km/veh*	Acc.1 *acc./y/km*	Acc.21 *acc./y/km*	Acc.22 *acc./y/km*	Acc.23 *acc./y/km*
0	0	0	NA	NA	NA	0.00	NA	NA	NA
3	-2.7	8	NA	NA	NA	-0.067	NA	NA	NA
6	-4.3	14	NA	NA	NA	-0.104	NA	NA	NA
9	-5.5	20	NA	NA	NA	-0.124	NA	NA	NA

Results of the analyses suggest that the correlation between parameters and environmental factors is not all the same. High and positive correlation is observed between traffic volume and all factors. On the other hand, increase in speed may increase the noise but decrease the air pollution and have no effect on the remaining factors. A similar observation is also made for road width. Increases in road width may decrease the noise and accidents but increase the proportion of delayed pedestrians.

In regard to environmental capacity, these facts may suggest that a general model of environmental impact could be developed using the most commonly employed parameters such as traffic flow (q), travel speed (S), and road width (W) and other related parameters.

4.3 Multi-factor Environmental Capacity

Considering the previous discussion, it is now desirable to define the variables to be included in the model. If i and j denote any nodes in the system connected by a road (route) k with road class (type) l, then q_{ijkl} can be defined as the traffic flow on road k connecting node i and node j with road type l. Similarly, S_{ijkl} can be defined as the average travel speed along the road, and W_{ijkl} as the width of the road. The level of noise of the road can also be written as N_{ijkl}, the proportion of delayed pedestrian as P_{ijkl}, the level of emission type r of the road as Aq_{ijklr}, and the expected accident risk as A_{ijkl}. Correspondingly their normalised values may be written as n_{ijkl}, p_{ijkl}, aq_{ijklr} and a_{ijkl}.

TABLE 4.8 MODEL PARAMETERS

Parameter	Definition	Units
q_{ijkl}	Traffic volume on road k connecting node i and node j with road class l.	vph
S_{ijkl}	Traffic speed on road k connecting node i and node j with road class l.	km/h
W_{ijkl}	Effective width of road k connecting node i and node j with road class l.	metres
N_{ijkl}	Noise level of road k connecting node i and node j with road class l.	dB(A)
P_{ijkl}	Proportion of delayed pedestrian on road k connecting node i and node j with road class l.	%
Aq_{ijklr}	Level of emission type r on road k connecting node i and node j with road class l.	gr/hour
A_{ijkl}	Accident risk on road k connecting node i and node j with road class l.	accidents/km/year
n_{ijkl}	Normalized value of N_{ijkl}.	dimensionless
p_{ijkl}	Normalized value of P_{ijkl}.	dimensionless
aq_{ijklr}	Normalized value of AQ_{ijklr}.	dimensionless
a_{ijkl}	Normalized value of A_{ijkl}	dimensionless
EUV_{ijkl}	Environmental utility value of road k connecting node i and node j with road class l.	dimensionless
EUV_{Ll}	EUV at the limit level for road type l.	dimensionless
$MFEC_{ijkl}$	Multi-Factor Environmental Capacity of road k connecting node i and node j with road class l.	vph
L_{ls}	Acceptable limit of environmental factor s for road class l.	
$F(s)$	Prediction model of environmental factor s.	

The environmental utility value of the road then may written as EUV_{ijkl}, which is a function of n_{ijkl}, p_{ijkl}, aq_{ijklr} and a_{ijkl}. L_{sl} may be defined as the acceptable level of environmental factor s for road type l, and $F(s)$ may represent the prediction model of the factor.

Finally, the representative value of Multi-Factor EC of road k connecting node i and node j with road type l, may be written as $MFEC_{ijkl}$. This $MFEC_{ijkl}$ may be a function of EUV_{Ll}, (EUV at the limit level for road type l), S_{ijkl}, and W_{ijkl}. In summary, the variables used in the proposed model are as shown in Table 4.8.

As a utility function, in a simple additive form, the relationship between EUV_{ijkl} and the environmental factors may be written as shown in Eqn. 4.13.

$$EUV_{ijkl} = w_{1l}{}^* n_{ijkl} + w_{2l}{}^* p_{ijkl} + w_{3l}{}^* aq_{ijklr} + w_{4l}{}^* a_{ijkl} \qquad 4.13$$

where:

$w_{1l}, w_{2l}, w_{3l}, w_{4l}$ = weightings of the factors for road class l.

And, relationship between q_{ijkl} , EUV_{ijkl} , S_{ijkl} and W_{ijkl} may be developed. Say, the relationship is linear, then regression function may be written as shown in Eqn. 4.14.

$$q_{ijkl} = a_l + b_l{}^* EUV_{ijkl} + cl^* S_{ijkl} + d_l{}^* W_{ijkl} \qquad 4.14$$

where:

b_l, c_l, d_l = coefficients of regression for road class l;

a_l = constant for road class l.

From this relationship, we can then estimate the multi-factor environmental capacity, $MFEC_{ijkl}$, which is simply the traffic volume when EUV is set at the acceptable limit. This may be done by substituting the EUV_{ijkl} in the Eqn.(5) by EUV_{Ll}, as shown in Eqn.4.15.

$$MFEC_{ijkl} = a_l + b_l{}^* EUV_{Ll} + c_l{}^* S_{ijkl} + d_l{}^* W_{ijkl} \qquad 4.15$$

This MFEC value may then be checked against the acceptable limit of each factor (Ls), by substituting $MFEC_{ijkl}$ into the prediction model F(s). Optimization of the MFEC value may be done by applying different values of Ls (EUV_{Ll}) until all the constraints are satisfied.

EUV_L or EUV for the limit-state may be estimated from either acceptable limit values or assumed percentile of sites/road sections that are expected to be under the limits. For EUV_L determined from acceptable limits, if an excessive result was obtained acceptable limits may be adjusted slightly 10-15% based on the assumption that the acceptable limit has safety margin around 25% below the ultimate limit. Therefore if the limit was adjusted by 10 or 15% it would still be acceptable as long as this did not happen all the time.

As EUV is a utility value ranging between 0 and 100 (0 is the worst and 100 is the best), EUV_L may be interpreted as percentile value, below which is the proportion of road sites with environmental conditions are worse than the acceptable limits. Therefore EUV_L may also be determined using acceptable proportion of sites or road sections expected to be greater than their environmental capacities. The percentile may be set either directly in the EUV_L figure, say 20 for 80% of sites expected to be below the acceptable limits, or by setting acceptable levels using percentiles of the environmental factors data in the population.

4.4 Hypothetical Application of the Model

For demonstration purposes, a hypothetical case study with 27 local road links has been developed as shown in Table 4.9. Suppose a survey on people's preferences in regard to the quality of the environment had been undertaken and resulted in what appears in Table 4.11. Further suppose that the outcomes of this survey may be quantified in an environmental utility function which takes form as per Eqn. 4.16. The ideal conditions of different road facilities are supposed to be as shown in Table 4.10.

TABLE 4.9 HYPOTHETICAL CONDITIONS OF LOCAL ROADS

Link	Q	S	W	Noise	Pedestrian	CO	HC	NOx	accidents
1	100	40	6	61.0	24%	1355	145	250	0.05
2	100	40	7	60.8	26%	1355	145	250	0.04
3	100	40	8	60.6	27%	1355	145	250	0.03
4	100	50	6	61.6	24%	1100	128	250	0.05
5	100	50	7	61.4	26%	1100	128	250	0.04
6	100	50	8	61.2	27%	1100	128	250	0.03
7	100	60	6	62.3	24%	930	117	250	0.05
8	100	60	7	62.2	26%	930	117	250	0.04
9	100	60	8	62.0	27%	930	117	250	0.03
10	300	40	6	65.7	56%	4065	435	750	0.13
11	300	40	7	65.6	59%	4065	435	750	0.11
12	300	40	8	65.4	62%	4065	435	750	0.09
13	300	50	6	66.3	56%	3300	384	750	0.13
14	300	50	7	66.2	59%	3300	384	750	0.11
15	300	50	8	66.0	62%	3300	384	750	0.09
16	300	60	6	67.1	56%	2790	350	750	0.13
17	300	60	7	66.9	59%	2790	350	750	0.11
18	300	60	8	66.8	62%	2790	350	750	0.09
19	600	40	6	68.7	81%	8130	870	1500	0.24
20	600	40	7	68.6	83%	8130	870	1500	0.20
21	600	40	8	68.4	85%	8130	870	1500	0.16
22	600	50	6	69.4	81%	6600	768	1500	0.24
23	600	50	7	69.2	83%	6600	768	1500	0.20
24	600	50	8	69.0	85%	6600	768	1500	0.16
25	600	60	6	70.1	81%	5580	700	1500	0.24
26	600	60	7	70.0	83%	5580	700	1500	0.20
27	600	60	8	69.8	85%	5580	700	1500	0.16

Note q in vph; S in km/h; W in metres; Noise in dB(A); Pedestrian in % delayed; CO,HC,NOx in gr/km/hr; accidents in accidents/km/year.

$$EUV_{ijkl} = 0.4^{*}n_{ijkl} + 0.3^{*}p_{ijkl} + 0.1^{*}aq_{ijklr} + 0.2^{*}a_{ijkl} \qquad 4.16$$

Subsequently by using a regression analysis, the relationship between q, EUV, S and W in this case takes form as per Eqn. (4.17).

$$q_{ijkl}\text{ (local)} = 631.99 - 5.98\, EUV_{ijkl} - 1.42\, S_{ijkl} + 10.92\, W_{ijkl} \qquad (r^2 = 0.98) \quad 4.17$$

EUV_{L1} may be calculated by substituting the normalised values of the acceptable limits into Eqn.(4.16), which is in this case equal to 46. Hence, the MFEC values may be calculated using

Eqn. (4.17) by substituting EUV_{ijkl} with EUV_{L1}. The equation may then become as per Eqn. 4.18:

$$MFEC_{ijkl} = 631.99 - 5.98\,EUV_{lL} - 1.42\,S_{ijkl} + 10.92\,W_{ijkl} \qquad 4.18$$

TABLE 4.10 IDEAL CONDITIONS OF ROAD FACILITIES

Road Type	Traffic (q), vph.	Speed (S), km/h.	Width (W), m.
Local	200	50	6.0
Collector	500	60	7.5
Arterial	1000	70	15

TABLE 4.11 ACCEPTABLE LEVEL OF ENVIRONMENTAL IMPACTS (HYPOTHETICAL)

Road Type	Noise* L_{10},dB(A)	CO kg/hr	HC kg/hr	Nox kg/hr	Delayed Ped. %	Accident Risk acc./km/year
Local	65	7.0	0.5	1.2	60	0.15
Collector	70	8.5	1.5	1.5	75	0.20
Arterial	75	10	2.0	2.0	80	0.25

*Measured 10m from road edge.

By substituting the MFEC values into the prediction models, it can be checked whether the MFEC produces any unwanted impacts. To do so, the prediction models as stated earlier may be employed. By substituting the figures from Tables 4.9, 4.10, and 4.11 into Eqns. 4.17, 4.18 and the prediction models, the results shown in Table 14.12 are obtained.

EUV is calculated based on the inverse normalized value of the factor, such that:

Minimum value = 100

Maximum value = 0

The value in between is then determined by the following formula:

$$\frac{(\text{max} - \text{the value})}{(\text{max-min})}$$

Using the above technique the-higher-the-better EUV can then be obtained, since it corresponds with lower environmental factors.

Amongst all the roads, Link 3 had an EUV of 98, which means it is environmentally the best. Correspondingly, it has MFEC of 389 vph and q/MFEC ratio of 0.26 which also indicates a good quality of environment. At the other end, Link 25 has an EUV equal to 4 and is considered as the worst link amongst all local roads. It had an MFEC equal to 339 and q/MFEC ratio equal to 1.77 that indicated poor environmental conditions. Environmental conditions of the rest of the links lay between these two extremes, with q/MFEC ratios varying between 0.26 and 1.77. It may also be observed here that although some road links had different traffic intensities, they shared the same value of MFEC. That is simply because they had the same travel speed and road geometric characteristics, which make up the MFEC values.

In the remaining six columns, the levels of impacts from every single factor are given. These values are the results of impacts that ensue from their associated MFEC. From the 9 different scenarios included in Table 4.12 (combination of 3 different travel speeds and 3 different road widths), it is apparent that in all cases the noise limit level (65 dB(A)) is exceeded by 1.5-2.6 dB(A) and the proportion of pedestrians delayed limit (60%) is exceeded by 1-11%. In one case, the accident risk limit is exceeded by 0.01 accident/km/year. In no cases are the air pollution limits exceeded.

TABLE 4.12 RESULTS OF CALCULATED MFEC FOR THE LOCAL ROADS

Link	EUV	MFEC	q/MFEC	Noise	Pedestrian	CO	HC	NOx	accidents
1	97	367	0.27	66.6	64%	4972	532	917	0.16
2	97	378	0.26	66.6	68%	5120	548	945	0.13
3	98	389	0.26	66.5	71%	5268	564	972	0.11
4	94	353	0.28	67.0	62%	3880	452	882	0.15
5	95	364	0.27	67.0	66%	4001	466	909	0.13
6	96	375	0.27	67.0	70%	4121	480	937	0.11
7	91	339	0.30	67.6	61%	3149	395	846	0.15
8	92	349	0.29	67.6	65%	3250	408	874	0.12
9	93	360	0.28	67.6	69%	3352	420	901	0.10
10	49	367	0.82	66.6	64%	4972	532	917	0.16
11	51	378	0.79	66.6	68%	5120	548	945	0.13
12	52	389	0.77	66.5	71%	5268	564	972	0.11
13	47	353	0.85	67.0	62%	3880	452	882	0.15
14	49	364	0.82	67.0	66%	4001	466	909	0.13
15	50	375	0.80	67.0	70%	4121	480	937	0.11
16	44	339	0.89	67.6	61%	3149	395	846	0.15
17	46	349	0.86	67.6	65%	3250	408	874	0.12
18	47	360	0.83	67.6	69%	3352	420	901	0.10
19	8	367	1.64	66.6	64%	4972	532	917	0.16
20	12	378	1.59	66.6	68%	5120	548	945	0.13
21	15	389	1.54	66.5	71%	5268	564	972	0.11
22	7	353	1.70	67.0	62%	3880	452	882	0.15
23	10	364	1.65	67.0	66%	4001	466	909	0.13
24	13	375	1.60	67.0	70%	4121	480	937	0.11
25	4	339	1.77	67.6	61%	3149	395	846	0.15
26	8	349	1.72	67.6	65%	3250	408	874	0.12
27	11	360	1.66	67.6	69%	3352	420	901	0.10

Note: EUV, unitless, the greater the better; MFEC in vph. Noise in dB(A); Pedestrian in % delayed; CO,HC,NOx in gr/km/hr; accidents in accidents/km/year

Using this multi-factor approach the MFEC for a road with 7m width and 50 km/h travel speed of 364 vph results in an EUV_L=46. At this value of MFEC, the noise level would be 67 dB(A) and pedestrian delay would be around 66%. To reduce this excessive impact,

EUV_L may be altered to a higher value. For instance, if the EUV_L is set to be 60 (by lowering the noise limit to 63 dB(A) and pedestrian delay to 55%), the MFEC becomes 281 vph, with associated noise level and pedestrian delay are 65.9 dB(A) and 56% respectively (see Table 4.13). In comparison, the value of EC in the similar condition when using the single approach method (with noise as control factor) is around 230 vph. Consequently, an improvement of more than 50 vph in environmental capacity has been achieved via the new approach.

Table 4.14 shows how the MFEC responds to changes in independent variables. The EUV_L simply represents the percentile of sites that would be above the limit. When EUV_L is set to be 60, that means 60% of the sites concerned would be below the acceptable environmental quality. Decision in determining the EUV_L would depend on how far it is allowed to have any impact beyond the acceptable limit when traffic is at capacity level.

TABLE 4.13 MFEC VALUES TOWARDS CHANGES OF EUV_L

EUV_L	MFEC (50 km/h, 7m)	Noise level, dB(A) at MFEC	Pedestrian delay, % at MFEC
46	364	67	66
50	340	66.7	59
60	281	65.9	56
62	267	65.7	55
68	229	65	50

In general, the model for determining MFEC utilizing the multi-factor approach is very sensitive towards both travel speed and road width. For local roads, increases in average speed alone by 20% may decrease the MFEC by 4.5%, whereas reducing speed by 20% will increase MFEC by 5.0%. On the other hand, the widening road by 15% will increase the MFEC by 6.5%, while reducing road width by 15% will reduce MFEC by also 6.5%. When changes against both variables are done simultaneously, the story is rather different. Changes both in speed by 20% and road width by 15% in positive ways will in fact increase the MFEC by only 2%. While reducing speed by 20%, but at the same time increasing road width by 15% will significantly increase MFEC by 11.5%.

Similar observations are made in the case of EUV. Generally, with the same traffic intensity, EUV will increase as travel speed decreases or as road width increases. Substantial positive changes in EUV are observed when speed is reduced by 20% while at the same time road width is widened by 15%. Furthermore, the most negative changes happened when increasing speed by 20% as well as reducing road width by 15%.

TABLE 4.14 SENSITIVITY OF THE MODEL TOWARDS CHANGES ON INDEPENDENT VARIABLES

Speed	Width	MFEC	EUV*
+20%	0%	-4.5%	---
-20%	0%	+5.0%	++
0%	+15%	+6.5%	+
0%	-15%	-6.5%	-
+20%	+15%	+2.0%	--
+20%	-15%	-11.0%	----
-20%	+15%	+11.5%	+++
-20%	-15%	-1.5%	++

* Changes in score, proportional to traffic volume; the greater the volume the greater the changes.

It is understandable that the air pollutant concentration at any particular road location such as those studied in this research might be affected by pollutants generated along other roads in the general vicinity of a given location. The model used in the thesis is a line-source air pollution model developed by General Motors (Chock, 1978). The model basically composed of two different models, firstly is the vehicle emission model to obtain the emission rate, and the dispersion model that simulates the distribution of emission to the surrounding area. While the first model depends mostly on the average vehicle speed, the second is more depending on the meteorological conditions of the road. In this case the meteorological conditions are represented by temperature, wind speed and wind direction of the surrounding atmosphere. Relationships of these parameters in the models are as shown in the formulas below.

The emission models used in the thesis are as follow:

$CO = 662*S^{-0.85}$ g/km for light vehicles (4-19)

$CO = 1220*S^{-0.85}$ g/km for heavy vehicles (4-20)

(Johnson, 1980)

$HC = 0.6+34/S$ g/km (4-21)

$NOx = 2.5$ g/km (4-22)

(Taylor and Anderson,1982)

where S is the vehicle speed in km/h.

While the GM dispersion model is:

$$C(x,z) = \frac{Q}{\sqrt{2\pi}U\sigma_z}\left\{\exp\left[-\frac{1}{2}\left(\frac{z+h_0}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z-h_0}{\sigma_z}\right)^2\right]\right\} \tag{4-23}$$

TABLE 4.14 SENSITIVITY OF THE MODEL TOWARDS CHANGES ON INDEPENDENT VARIABLES

Speed	Width	MFEC	EUV*
+20%	0%	-4.5%	---
-20%	0%	+5.0%	++
0%	+15%	+6.5%	+
0%	-15%	-6.5%	-
+20%	+15%	+2.0%	--
+20%	-15%	-11.0%	----
-20%	+15%	+11.5%	+++
-20%	-15%	-1.5%	++

* Changes in score, proportional to traffic volume; the greater the volume the greater the changes.

It is understandable that the air pollutant concentration at any particular road location such as those studied in this research might be affected by pollutants generated along other roads in the general vicinity of a given location. The model used in the thesis is a line-source air pollution model developed by General Motors (Chock, 1978). The model basically composed of two different models, firstly is the vehicle emission model to obtain the emission rate, and the dispersion model that simulates the distribution of emission to the surrounding area. While the first model depends mostly on the average vehicle speed, the second is more depending on the meteorological conditions of the road. In this case the meteorological conditions are represented by temperature, wind speed and wind direction of the surrounding atmosphere. Relationships of these parameters in the models are as shown in the formulas below.

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(Johnson, 1980)

$HC = 0.6+34/S$ g/km (4-21)

$NOx = 2.5$ g/km (4-22)

(Taylor and Anderson,1982)

where S is the vehicle speed in km/h.

While the GM dispersion model is:

$$C(x,z) = \frac{Q}{\sqrt{2\pi}U\sigma_z}\left\{\exp\left[-\frac{1}{2}\left(\frac{z+h_0}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z-h_0}{\sigma_z}\right)^2\right]\right\} \quad (4\text{-}23)$$

where:

$C(x,z)$ = concentration at point (x,z) relative to the line source at x=0, in g/m^3;

Q = emission rate per unit length, in g/km;

U = effective cross wind, in ms^{-1};

h_0 = plume center height at distance x from the road, in m;

σ_z = vertical dispersion parameter;

The relationships show that the air pollution model (Eq. 4-23) depends on the emission rate (Q) that mostly depends on the vehicle speed parameter (Eq. 4-19 to 4-22). Detailed explanation of the model is available in section 7.2.2. Further, it should be noted that an extensive empirical investigation of the model was conducted in the Bandung study described in the Thesis. This study monitored pollutant concentrations at a number of locations. It could reasonably be argued that these concentration data were comprised of the pollution generated in the measurement location road and that generated at other roads in the vicinity of the measurement location. On this basis the effects of the pollution from the other roads might be deemed to be incorporated in the outcomes of the Bandung study. This would point to the need to repeat such a study at the type of road locations in any particular city in which the model was going to be applied in the future.

4.5 Summary

A multi-factor environmental capacity concept has been proposed. The concept employs the environmental utility function that blends all the factors together into a single value. Prior to the description of the model, sensitivity analyses of several environmental prediction models incorporated in the Multi-Factor Environmental Capacity (MFEC) have been described in length. In general, it was observed that almost all the models have similar parameters namely traffic volume, speed and road geometry parameters. This commonality may lead to the suggestion that the models can be represented by single model or value namely Environmental Utility Value (EUV). This EUV can then be correlated with the road and traffic parameters to create a MFEC model.

For demonstration purposes, the model has been applied on a hypothetical case of 27 road links. The results of this process showed that the model is reasonable and can be implemented.

The next phases are the calibration and validation of the model. Chapters 5 and 6 describe the study design and data collection activities for these phases as carried out in the present study.

Chapter 5

Chapter 5

STUDY DESIGN

In an experimental research, having good and reliable data is very important. It can be obtained by maintaining a properly designed study that minimizes errors or problems. This chapter describes the design of case study and preparation necessary for data collection activities. These include description of the study area, explanation of the nature of required data, possible techniques in gathering the data as well as designing the sample itself.

5.1 Study Area

Municipality of Bandung in West Java, which is typical of a medium sized city in Indonesia, was chosen as the study area. As the capital of West Java, at the moment its economy has been steadily growing at about 11%, and population at a rate of 2.6% per annum. With a total population of around 1.8 million and area of 166.7 sq. km., it has an average density of about 108 people/ha (BPS Kotamadya Bandung, 1997).

Geographically, Bandung is located at longitude 107° East and latitude 6°55' South. The average altitude of the city is about 768 metres above sea level. Northern parts of the city are relatively higher, with a maximum of 1,050 metres while towards south it is gradually lower with a minimum of 675 metres. Average temperature as officially reported is 23.1° C, with average rainfall of 231.2 mm occurring on about 18.7 days per month (BPS Kotamadya Bandung, 1997).

Motor cycles are the most common mode of transport. The 1996 figures of vehicle ownership in Bandung suggest that of the total of 377,291 vehicles there were at least 199,964 registered motorcycles (53%) and 114,338 cars (30%). Heavy vehicle including trucks and buses comprise of only around 17% of the total or about 65,000 vehicles (BPS Kotamadya Bandung, 1997).

Total lengths of different road classes, which make up the road network, are as shown in Table 5.1. The figures suggest that 58% of paved roads serve local traffic. While collector and arterial roads comprise of about 35% and 6.5% of the total network respectively.

TABLE 5.1 LENGTH OF ROADS BY CLASSES IN BANDUNG

Road Class	1995	1996
Urban Arterial	59.770	59.770
Urban Collector	315.364	336.493
Local Roads	522.110	502.854
Other	5.121	5.121

Source: *Dinas Pekerjaan Umum Kotamadya Dati II Bandung* (1996)

Figure 5.1 shows Bandung as the study area with its major road networks.

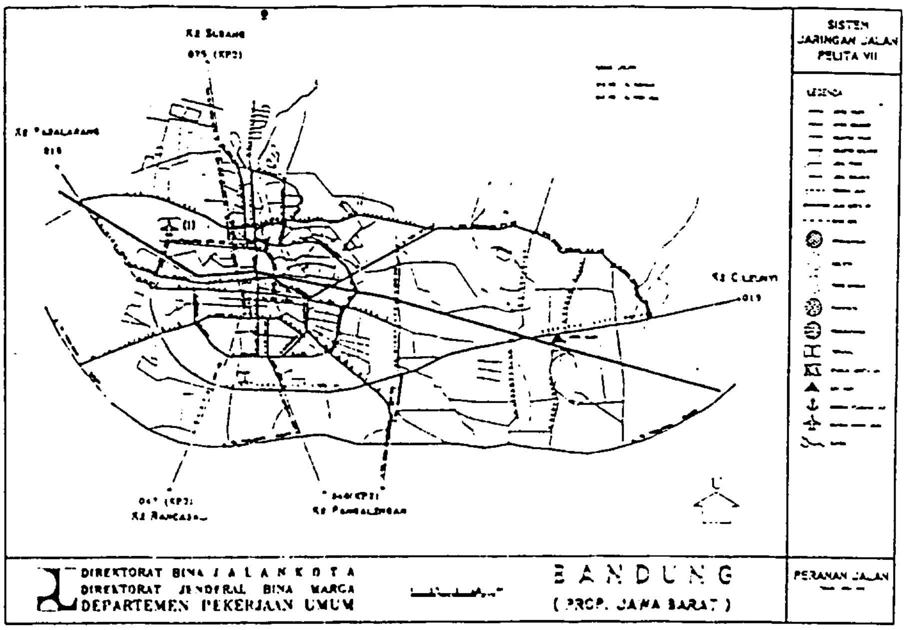


FIGURE 5.1 STUDY AREA

5.2 Required Data

5.2.1. Types of Data

Data required in this research can be broadly classified into three categories. Firstly are data on traffic, road geometry and land use, secondly data on environmental quality, and finally preferential data.

Road, traffic and land use data may include:

- Traffic movements on selected streets/corridors;

- Speed measurements on selected streets/corridors;
- Road geometry and road facilities along the streets/corridors; and
- Associated data on land use.

Data on environmental quality may include:

- Noise measurement data;
- Air pollution data (HC, NOx, CO);
- Pedestrian behavior on selected streets/corridors; and
- Accident Data.

Preferential data may include stated public preferences towards various environmental impacts (noise, air pollution, pedestrian safety, etc.).

The required observations and their related parameters required for the study are as summarized in Table 5.2. The table suggests that at least 9 observations have to be carried out simultaneously. They include community interviews, noise measurements, air pollution measurements, pedestrian observations, accident identification, traffic counting, traffic speed, along with a comprehensive inventory survey of road geometry and land use.

TABLE 5.2 LIST OF DATA TO BE OBSERVED.

Model	Parameters	Observations Required
1. Environmental Utility	Weighting values, Noise level (N), Air quality (Aq), Delayed Pedestrian (P), Accident Risk (A).	Community interview, noise level, air pollution, pedestrian behavior, accident data records, land use.
2. Noise	Traffic volume (Q), Speed (S), Road width (W), Percentage HV	Traffic counting and composition, average travel speed, road geometry, noise
3. Emission and Air Pollution	Traffic volume (Q), Speed (S), wind speed, wind direction	Traffic counting and composition, Average travel speed, air pollution level (CO, HC, NOx).
4. Pedestrian Delay	Traffic volume (Q), Road width (W).	Traffic counting, road geometry, pedestrian behavior.
5. Accident Risks	Traffic volume (Q), Road width (W), shoulder width	Traffic counting, road geometry, accident data.

For calibration and validation purposes, two different sets of data would be required. But, as time and budget were limited, collection of both data set would be carried out in parallel.

5.2.2. Possible Sources of Data

Although some of the data were possibly available, most of them had to be collected and observed directly in the field. In general, the incidences of available data were as presented in Table 5.3.

TABLE 5.3 POSSIBLE SOURCES OF DATA

Data	Availability	Possible Source
1. Preferential data	N/A	-
2. Noise	N/A	-
3. Air Pollution	N/A	-
4. Pedestrian behavior	N/A	-
5. Accident	Available	Traffic Police/RIRE
6. Traffic volume	Possibly	IHCM Project
7. Travel Speed	Possibly	IHCM Project
8. Road geometry	Possibly	IHCM Project
9. Land use	Possibly	IHCM Project/BPN

Note: IHCM is Indonesian Highway Capacity Manual Project, RIRE is Research Institute of Road Engineering MPW; BPN, National Land Body.

In addition, required data on the road network might be obtained from the following institutions:

- *Direktorat Bina Jalan Kota, PU* (Directorate of Urban Road Improvement), Jalan Pattimura 20, Jakarta.
- *Sub Direktorat Leger Jalan PU* (Sub Directorate of Road Inventory, MPW), Jalan Raya Ujung Berung, Bandung.
- *Dinas PU Kotamadya Bandung* (Bandung Regional Office for Public Works).

5.3 Survey Instruments

This section describes various survey techniques that are typically employed in transport and traffic studies and chooses some of the techniques that are suited to the present investigation. Richardson (Richardson, *et. al.*, 1995) divides the techniques into 7 major types as overviewed below.

5.3.1 Documentary Search

This type of survey is needed to collect the existing information that have been published or reported by different parties such as the Statistical Bureau, Traffic Authority, Planning Bureau, Traffic Police or any related institutions. Reports of previous studies by universities, research institutes or any other public offices are also the main targets of this documentary search (Richardson, *et. al.*, 1995).

In the present study documentary searches will be done primarily to obtain information on the collection of data for transport system inventory (road classes, road geometry, registered vehicles), accident data, and information on environmental standards that are applied in the study area.

5.3.2 Observational Survey

This type of survey is divided into two categories, direct and indirect observational surveys. Surveys on traffic such as traffic counting, speed measurements, road geometry, land use and pedestrian observations are amongst the direct observational surveys. Indirect observational surveys, which are less frequent in traffic engineering applications, include such surveys as fuel consumption, vehicle ownership, and accident trends (Richardson, *et. al.*,1995).

Direct observational surveys employed in the present study include:

- Environmental Survey: noise measurements, air pollution measurements, and pedestrian observations.
- Road and Traffic Survey: traffic counting and composition, travel speed survey, road geometry survey, and land use survey.

5.3.3. Questionnaire Surveys

This type of survey may be further classified into 2 categories: *self-completion questionnaire* and *personal interview* surveys. The difference between the two is that in a self-completion questionnaire survey, respondents are asked to respond to the questions without any presence of a facilitator or a survey officer (Richardson, *et. al.*,1995). However in a personal interview survey, such an officer is present.

There are several basic formats of self-completion questionnaire survey such as:

- mail-out/mail-back questionnaire survey;
- delivered to/mail-back questionnaire survey; and
- delivered to/collected from respondent survey.

Self-completion questionnaire survey is usually preferable than personal interview survey in some aspects such as (Richardson, *et. al.*, 1995):

- it is generally cheaper;
- it covers a relatively wider geographical area;
- it may avoid any possible bias from the interviewer;

- it provides respondents with enough time to respond to the questions;
- it allows respondents to respond to the questionnaire at their convenient time.

However, it also has some basic disadvantages such as (Richardson, *et. al.*, 1995):

- relatively low response rate (20-50%) compared to 75-85% in the personal interview surveys;
- the questions must be designed in very clear and simple manner;
- it is not possible to verify whether the questionnaire has been completed by the targeted respondents or by others;
- it is not possible to clarify the given answers, unless the detailed information of the respondent is obtained;
- it is not appropriate for attitudinal surveys;
- more literate people tend to respond more, which can lead to sampling bias;
- cross-check questions may not work very effectively, as they can scan through the questions prior to answering them.

In the present study, in order to obtain data on public preferences towards environmental factors, two different types survey would be employed.

Household Personal Interview Survey. This survey is targeting households in the surrounding areas where the observational surveys were conducted. Objectives of these surveys were to gather public opinion on how they approach various environmental factors and to quantify their preferences towards each factor.

Self-completion (mail-back) Questionnaire Survey.

The content of the questionnaire in this survey was similar to the personal interview only that it was targeted to the so called experts. The objective of this was to obtain a reliable comparison between ordinary public opinion and that from the ones who were assumed to have a professional background in environmental engineering.

5.3.4. Telephone Surveys

This type of surveys was not considered as a method of transport surveys until the early 1970s (Richardson et. al., 1995). The use of this survey in transport research was not very common. Nevertheless this type of survey has some advantages such as:

- it covers relatively wide geographical area;
- it allows the team leader to control and supervise the interviewers at any time;
- it is generally cheaper than questionnaire surveys;
- it is ideal for doing a follow-up survey;
- it is ideal for multi-lingual societies;
- it allows the operators to enter the answers directly to a computer database.

Some disadvantages of this survey may include:

- its response rate drops with a longer time of interview (usually after 10-15 minutes);
- it is difficult to have more than one respondent per household;
- some people are reluctant to respond to a telephone survey;
- sample bias is apparent as only those who have telephone connections can be included in the survey;
- it is not possible to use any visual aids in the survey such as diagram and cards.

Since the survey requires a very well established telephone network, its use in this study is not considered useful.

5.3.5. Intercept Survey

In this type of surveys, interview or questionnaire distribution is being carried out while people are in the middle of their activities. Several different variants of this survey are (Richardson, *et. al.*, 1995):

- On board distribution/mail-back
- On board distribution/on board collection
- On board distribution/combination of on board collection and mail back
- Road side distribution/mail-back
- Intercept interview
- Activity centre distribution/mail back
- Activity centre interview

This type of surveys would not be used in the present study, because there was no requirement to obtain trip distribution data.

5.3.6. Group Survey

In this type of survey, a group of selected people discusses and shares their experiences, opinions and ideas about any special subject. The discussion itself is run with the presence of a qualified facilitator. The roles of the facilitator are to guide the group discussion towards the issue and help identifying important points of the issue. Besides he/she has to be able to identify any gesture or unspoken communication between members of the group and in the end summarize the results and evaluate objectives of the discussion (Richardson, *et. al.*, 1995).

Some major advantages of the group surveys are (Richardson, *et. al.*,1995):

- under such collective environment, every member of the group tends to be more comfortable;
- an idea from any member of the group may ignite more ideas from other members;
- attitude and behavior of every group member can at the same time be observed;
- responses from different member of the group is more genuine than in an individual interview.

On the other hand there are also some disadvantages of the group surveys such as:

- success of the process depends too much on the competency of the facilitator;
- if the group does not respond quite well, the process will be stuck;
- one member of the group may dominate the others;
- the discussion may become too intense so that may lose the objectives.

In general, the group survey is not recommended in such situation as whenever statistical data are needed and wherever the subject being discussed needs a detailed level of understanding. It is also not appropriate for a situation where individual opinions are extremely varied, and when it is difficult to recruit the targeted sample of the group member. The survey is quite useful when an exploration of ideas is needed and no obvious expected outcome is available.

Application of this survey technique is not going to be considered in the present study on the basis that in this study more quantitative results were expected from preferential survey.

5.3.7. In-depth Surveys

In-depth interview survey is usually conducted to obtain a more detailed information about any particular issue when the superficial ordinary question-and-answer format is insufficient (Richardson, *et. al.*, 1995). Interviews are recorded in order to enable the interviewer to concentrate more in responses of the respondents. The interview itself usually takes more than one hour and requires a highly skilled interviewer who has to be able to conceive the questions as the discussion goes along (Richardson, *et. al.*,1995).

The technique is mainly useful in two ways. Firstly, it can be used for exploratory purposes such as to design the content and wording of a questionnaire survey, and secondly for investigative purposes when any explanation the survey results is needed. As this type of survey tends to be very long and covers limited number of respondent per unit time compares to other methods, the inclusion of this survey is not being considered in the present study.

5.4 Survey Design

5.4.1 Road and Traffic Surveys

Traffic Counting and Speed Measurement

An automatic counting system with pneumatic tubes was used for this survey. Data captured using this system included traffic volume, traffic composition, and time mean speed. Composition of traffic included cars, heavy vehicles, and motorcycles. Manual counting was done for motorcycles, just in case they were not recognized by the pneumatic tubes system. Traffic counting as carried out for 3 hours at each site.

Individual vehicle time mean speeds were measured using the same device as traffic counting. The data were then processed to obtain 15-minute aggregate and put in a summary form.

Road Geometry and Land use Survey

This survey covers the data on road type, effective road width, land use, and possible side-frictions of the street. Sketch of land use up to one hundred meter off the road edge was provided. Information gathered in the field about road geometry and conditions of carriage way and land use were recorded in a comprehensive form as shown in the Appendix. The sketch of observed area and typical cross section were also being put in the form to have a better record of the sites.

5.4.2 Environmental Survey

Noise Measurement

Noise measurements in the study were intended to collect data on actual levels of traffic noise along the roads under study. The information of noise level in this case is important in two aspects:

- It is required in order to calibrate/validate the existing traffic noise prediction model;
- It is needed to determine the quality of the general environment as to be proposed in the model (environmental utility function).

Since the observation times are limited, it is desirable to measure noise $L_{10\text{-}1\ \text{hour}}$ in dB(A) within a 15-minute sample times. These data are going to be compared with the predicted values, and adjustments are then being made of the model to be used in the study.

Measurements were carried out using a noise meter (see appendix for equipment specification) placed at the roadside (within 5 metres from road edge). The data were then transferred into forms in approximately one-hour interval. To have reliable data it is important also to ensure the following things in fields:

- Measurements are not being made unless the weather is clear/fine;
- Measurements have to be done where traffic flow are not interrupted whatsoever.

Air Pollution Measurements

Vehicle emission surveys are categorized into two groups (Taylor, 1984):

- Individual vehicle based surveys; and
- Area wide (system-wide) surveys.

Individual vehicle-based survey may be done either on-road or in a laboratory. On road emission survey is done under the assumption that there is a correlation between emission rates and fuel consumption rates. The fuel consumption data are observed using an instrumented vehicle driven in a traffic stream. Laboratory tests of individual vehicles may be done using a dynamometer where vehicle wheels are contacted with a system of flywheels. The system can be adjusted to simulate various road conditions as vehicle speed is varied. Instruments to measure fuel consumption and emission rates are attached to the vehicle engine and exhaust system. From this laboratory test, correlation between various vehicle conditions (speed, acceleration, deceleration), and fuel consumption rates and emission rates can be developed.

Area-wide air pollution measurements generally provide data on absolute levels of emission from various sources. Traffic contribution is estimated from typical shares it has of individual pollutant. EPA (1979) suggests that road traffic typically contributed 48% of HC, 78% of NOx, and 82% of CO of the overall emissions. In the present study, as it is concerned with a strategic environmental planning, a combined method was applied. The method measured the various pollutants (CO, HC and NOx) using roadside measurement devices to be correlated later on with traffic characteristics on each particular road. Relationships between traffic and various pollutants will then be expressed in the form of prediction models as suggested in the literature (Chock, 1977; Mainwaring and Thorpe, 1983, Watson, 1983, Taylor *et. al*, 1985).

A roadside air pollution apparatus was used to measure various types of air pollution (CO, HC, and NOx). The summary of measured data was filled into a survey form as attached in the Appendix. Data on recording time, and various emissions measured were recorded in 15-minute period basis.

Pedestrian Observation

Pedestrian observations in the study are intended to provide data and information particularly on pedestrian delay and the proportion of delayed pedestrians when they attempt to cross the streets under study. The information is required in order to calibrate the pedestrian delay model and to supply information on the crossability level of the streets.

The observations were carried out using a mounted camera in the roadside being studied. Data were then extracted in the laboratory (back in the office) to obtain parameters such as;

- volume counts;
- arrival time;
- delay;
- crossing time; and
- walking speed.

As the pedestrian may obstruct traffic, it is desirable to observe pedestrians far enough from the point where noise and other measurements are being carried out.

Accidents Identification

Traffic police keep data on traffic accidents. Their annual report provides the aggregate information about the accidents, but an individual accident has to be traced back from the accident files. Information on accident needed in the study includes all vehicle collisions occurred along the observed road links (mid-block) in yearly basis.

5.4.3 Community Preferences Survey

This type of survey is intended to gather information on community preferences towards environmental factors. In doing so, a carefully designed questionnaire is required.

Questionnaire Format

There are some guidelines in designing the physical format of questionnaires. For a personal interview survey the following points are considered important (Richardson *et. al.*, 1995):

- Determine whether respondent will fill in the form or not.
- Design the questions so that only minimum writing is required.
- Each form should have a unique record number.
- Questions are numbered consecutively.
- Different type of fonts may be used to differentiate between instructions and questions.

For self-completion surveys, the guidelines include:

- Questionnaire layout should be clear and concise and requires minimal writing.
- Instructions should be provided in the front page of the to include short introduction of the survey, contact numbers, and statements of confidentiality of respondents' details.
- Professionally look questionnaires printed in double-sided papers are preferable.

Question Format

There are several formats of question used for interview or questionnaire purposes (Richardson *et. al.*, 1995):

- *Open Questions.* In this format of questions respondents are asked to answer the questions in their own words. It is particularly useful for exploratory surveys where some information is needed to design a study. Use of too many open questions in an interview or questionnaire can be considered annoying to respondents.

- *Field-coded Questions.* This is actually an open questions type, which is directly coded by interviewer in the field to avoid double processing. Bias of using this type of questions may come from the interviewer in selecting the code to match the response.
- *Closed Questions.* This is the most commonly used type of questions in questionnaire surveys, particularly the self-completed ones. Questions in this type come with a list of possible answers that can be chosen by the respondents. This is particularly useful for asking factual questions, and the provision of response categories may help the respondents in understanding the topic of the question. The response categories provided in these questions should be exhaustive, mutually exclusive and unambiguous. Provision of an open category is highly recommended to avoid any inappropriate answers. Attention should be given to "yes/no" questions, as respondents tend to respond in a positive way, regardless of the question, particularly when respondents are not interested in the topic.

Types of Questions

There are several types of questions that may be employed in the questionnaire. They include (Richardson *et. al.*, 1995):

- *Classification questions.* This type of question is intended to classify respondents into different categories. This is usually used for in-depth analysis or cross checking with other questions.
- *Factual questions.* This type of question asks about the experience or knowledge of respondents on facts about any particular subject.
- *Opinion and attitude questions.* This type of question is used to obtain respondents' personal preposition towards particular issue.
- *Stated response questions.* This is similar to type of questions above, only that it deals with such multidimensional subject as assessing simultaneously different attributes of a system.

Measurements Scales

In measuring the responses different scaling system may be adopted, they include:

- *Nominal Scales.* Any value in this scale has no meaning in terms of ordering. They are usually used for assigning people or objects into different categories. Examples of this type of scale may include sex, religion, age, income rate or occupation.
- *Ordinal Scales.* In this type of scale information on orders is given, but no relative magnitude between scale is known.

- *Interval Scales.* In this scale, relative order and positions of objects are known, but there is no meaning to the absolute values of the scale. Only addition and subtraction operations are permitted towards the scales.
- *Ratio Scales.* This scale represents relative importance as well as the absolute value of objects. All mathematical operations are permitted with this type of scale.

Features of these scale types may be summarized in Table 5.4 below.

TABLE 5.4. SCALE TYPES

Scale Type	Statistics			Permissible Uses	Permissible Transformations
	central tendency	variability measure	individual position		
Ratio	geometric mean	coefficient of variation	absolute score	find ratios between	multiplication and division
Interval	arithmetic mean	variance, standard deviation	relative score	find differences between	addition and subtraction
Ordinal	median	range	rank percentile	establish rank order	any that preserve order
Nominal	mode	number of categories	belonging to category	identify and classify	Substitution within category.

SourceL adopted from Richardson *et.al*, 1995, Table 5.1 pp. 171.

Attitudinal Measurements Techniques

There are several attitudinal measurement techniques available such as (Richardson *et. al.*, 1995):

- *Paired Comparisons.* This technique set the order of objects by comparing two of them at a time. The highest rank will be the one that selected in every comparison, and the second rank will be the one that only dominated by the highest rank, and so on. In this case, the rank order does not represent the distance between two ranks.
- *Ranking Order.* In this technique, respondent is asked to directly give an ordering rank to a set of objects based on a particular attribute. This technique also produce an ordinal scales of the objects being concerned.
- *Category.* This technique may provide a nominal, an ordinal or an interval scales measures of objects, by asking respondent to categorize the objects into predefined groups.
- *Likert Scales.* In Likert scale, respondents are asked to respond against a number of attitudinal statements in a five-point dimension, such as: strongly agree, agree, undecided, disagree, strongly disagree.
- *Semantic Differential Scale.* This technique is similar to category scale, but in this case a seven-point scale is used with only two semantic differentials at their extreme points. Respondents have to indicate their preference within the intermediate points.

- *Ratio Scale.* In this technique respondents are asked to compare between alternatives using an absolute reference magnitude. It can be done either by fractionating or multiplying the reference magnitude (rating).
- *Constant Sum Allocation.* The technique asks respondents to assign constant points, say 100, between pairs of objects. The allocated points may represent the relative amount possessed by an object regarding any particular attribute.

Wording of Questions

Combination of open and closed questions may be the best way of designing a questionnaire. In constructing the questions, the following guidelines may be useful (Richardson *et.al.*, 1995):

- Use simple vocabulary.
- Use words appropriate to the audience.
- Avoid long questions involving multi-dimensional concepts.
- The topic of issue being questioned should be clearly stated.
- Avoid ambiguous questions.
- Avoid questions concerning with more than one object.
- Avoid vague words about frequency such as 'usual', 'general', 'often'.
- Avoid loaded questions that may be considered embarrassing for respondents.
- Avoid double negatives questions.
- Avoid stressful or threatening questions.
- Avoid grossly hypothetical questions.
- Avoid unwanted effect of response styles such as consent response style where some respondents consistently choose 'agree' regardless the question. Or, social desirability where respondents tend to give answers that socially most preferable. Or, position bias where some respondents tend to mark on the left, the right, or the centre of horizontal rating scale.

Design of Questionnaire in the Study

Considering the above guidelines, the questionnaire designed for the present study employs the styles that are relevant to the nature of the study. In general, a closed question format was employed, with either classification or stated response types. The three different measurement scales of ordinal, interval and ratio scales were used. Ordinal scale was used to state ranking of factors, while interval scale was employed in questions about direct rating. Ratio scale was used to facilitate pair wise comparisons between environmental factors.

Regarding attitudinal measurement techniques, the questionnaire accommodated such techniques as ranking order, constant sum allocation and paired comparison with ratio scale. From these techniques, three different types of outcomes, ranking, rating and preference ratio between pairs of factors were expected.

In general, the questions were divided into 3 parts:

- Questions about respondent's profile.
- Technical Questions: Environment, Noise, Air Pollution, Pedestrian Safety, and Accident Risks.
- Comments and Suggestion.

The technical part included questions concerning their opinions on:

- Importance of environment.
- Their preferences towards the impacts.
- The rating of their preferences in pair wise comparisons.

5.5 Sample Design

A proper sampling procedure is very important in order to obtain statistically reliable empirical data. The following sections describe the definition and determination of target population, sampling unit, sampling frame, sampling method, and the calculation of sample size adopted in the study.

5.5.1 Target Population and Sampling Unit

There were two target populations in this study, the first of was the entire road links in the urban area of Bandung where various parameters were to be measured. The second was the households residing along the roads, of which opinions towards environmental factors were to be gathered. The road links included all different classes of road (i.e. local, collector and arterial roads) except urban alleys, private roads and toll roads. The discrete unit of these roads is road link, which is defined as any section of road between two nodes or intersections. This population is classified into 3 different categories, and the total lengths for each category is as follow (Dinas Pekerjaan Umum, 1996):

- Local Roads 502.85 km (1437 links)
- Collector Roads 336.49 km (336 links)
- Arterial Roads 59.77 km (24 links)

The population of households in this study was defined as households that were directly exposed to traffic-related impacts. They comprised all the households along the sides of the above mentioned roads. The total numbers of this population in each road category were estimated as follow:

- Local Roads 25,142 households
- Collector Roads 16,824 households
- Arterial Roads 2,988 households

5.5.2 Sampling Frame

The frames used for sampling purposes were based on the road inventory data obtained from the Bandung Regional Office of Public Works, and the estimated number of houses residing along the roads. The information was available in the form of databases and maps.

5.5.3 Sampling Error and Sampling Bias

Sampling Error

Sampling error is the error that occurs when samples, instead of the entire population, are used to estimate the parameters. The error affects the variability of means and the confidence interval of parameter estimation or, the level of precision of estimate. Sampling error may not be eliminated, but may be reduced by increasing sample size.

Sampling Bias

Sampling bias is the type of measurement error that happens when samples are neither carefully designed nor randomly selected. Attention should be given more to this type of error since it affects the values of parameter means to be estimated or, the accuracy of estimate. Sampling bias may occur due to some other factors such as:

- not all the selected samples are measured/surveyed;
- non response factor;
- human pitfalls.

While increasing sample size may increase the precision of estimates (sampling error), it does not necessarily increase the accuracy (reduces the sampling bias). Sampling bias may only be eliminated or reduced if the sampling procedures are carefully applied and quality is continuously controlled throughout the entire process of survey (Statistics New Zealand, 1995; Richardson, *et. al.*, 1995).

5.5.4 Sampling Methods

There are several different methods of sampling available. The most commonly known is random sampling, which is simply done by drawing a random number of samples from the sampling frame. When additional information on the population such as groups, classification or composition that make up the population is available, some more comprehensive methods may also be applied. These methods include the stratified random sampling, variable fraction stratified random sampling, multi-stage random sampling, cluster sampling, systematic sampling, and non-random sampling (Statistics New Zealand, 1995; Richardson, *et. al.*, 1995). The following paragraphs provide an overview of the available sampling methods to give an idea of how they work.

Simple Random Sampling

This method is the basis of all other variants of random sampling method. Here the sampling is done by simply assigning number to the individual unit of population and drawing a number of samples in a random manner, either with or without replacement. The numbers obtained are considered as the sample or the representative units of the population being studied (Statistics New Zealand, 1995; Richardson, *et. al.*,1995).

Stratified Random Sampling

When any additional information regarding the nature of population is known, the simple random method is no longer sufficient as it may produce a sample with one group of population is more represented than the other. In this particular case, a stratified random sampling method may be applied. The method is different from the simple random sampling in that it ensures all different groups in the population are to be proportionally sampled. How the samples are drawn will depend on whether or not a stratified lists are available. When individual lists of stratified sample frame are available, an unrestricted random sample may be drawn from within each list. Otherwise, samples may be randomly drawn from the list of entire population. In every draw, the selected sample is put into their associated stratum and another draw is made. The draw goes along until the quota of every stratum is fulfilled (Statistics New Zealand, 1995; Richardson, *et. al.*,1995).

Variable Fraction Stratified Random Sampling

This method is similar to the stratified random sampling, only that in this case the proportion of sample assigned to each stratum is also influenced by the variability of the variable within the stratum. A stratum with higher variability may also need a higher fraction and vice versa to have a more uniform accuracy across the strata.

Multi-stage Sampling

Multi stage sampling method is used when the entire number of population is very large and individual identification of unit of population is considered difficult. The method is begun by differentiating the population into groups, groups into sub-groups, and so on until the individual unit is reached. For example, country is divided into provinces, provinces into districts, districts into towns, towns into households, and household into individuals. A random sample is then drawn at every level with stratification to ensure that higher populated groups have higher probability to be selected. Although this method may have some advantages such as lower cost and shorter time compared to a complete random sampling, the level of accuracy of parameter estimate using this method tends to be lower at the same sample size (Statistics New Zealand, 1995; Richardson, *et. al.*,1995).

Cluster Sampling

This method is very similar to multi-stage sampling. In this case, target population is divided into clusters before being sampled. The selected clusters are then either selected entirely or sampled with very high rate. In determining the clusters, it has to be considered that clusters have to be economical as far as estimation of parameters is concerned (Statistics New Zealand, 1995; Richardson, *et. al.*, 1995).

Systematic Sampling

Systematic sampling is another practical way of doing random sampling without necessarily drawing all the numbers required from sampling frame. Instead, a more systematic way is adopted using a selected number of intervals. After the first sample is randomly selected, the rest of the samples will be automatically chosen using the intervals (Statistics New Zealand, 1995; Richardson, *et. al.*, 1995).

Non Random Sampling

There are two major sampling methods that are not random in nature. The first is quota sampling, which is simply done by assigning quota of sample to every predetermined group in the population. The second method is called the expert sampling. In this method determination of sample is based entirely on expert judgment. It is particularly useful for exploratory purposes, but not appropriate for estimating parameters (Statistics New Zealand, 1995, Richardson, *et. al.*, 1995).

Sampling Method in the Study

For this particular study, a combined stratified and expert sampling was adopted, as it was desirable to include various types of land uses (residential, mix and commercial) in the sample. Some nominated road links as suggested by local experts were randomly selected to be included in each site category.

For personal interview purposes, respondents were randomly chosen from the available households in the field.

5.5.5 Sample Size Calculation

The determination of sample size is very important, particularly in relation to the expected degree of precision in estimating a parameter or testing a hypothesis. For any of the case different guidelines is applicable (Richardson, *et. al.*, 1995). The following describe the guidelines in determining sample size.

Estimation of Parameters

For parameter estimation purposes, determination of sample size depends on three major factors viz.: the size of population, the variability of parameters to be estimated, and the expected degree of estimation precision. The algorithms for both continuous and discrete variables are as described in following sections.

Continuous Variable

The formula used for determining continuous variable sample size is derived from the Central Limit Theorem (Richardson, *et. al.*, 1995). According to the theorem, standard error of means of samples taken from the population can be calculated using the following formula:

$$s.e.(m) = \sqrt{((N-n)/N)(\sigma^2/n)}$$

where:

s.e.(m) = standard error of means

N = population size;

n = sample size

σ^2 = parameter variance of the population.

For a single sample σ^2 may be given by S^2, and the formula becomes:

$$s.e.(m) = \sqrt{((N-n)/N)(S^2/n)}$$

For a relatively large population, the correction factor for finite population (N-n)/N is close to unity, and the equation may become:

$$s.e.(m) = \sqrt{(S^2/n)}$$

From this equation, it can be derived that the sample size (n) equals to:

$$n = S^2/(s.e.(m))^2$$

The value of s.e.(m) can practically be interpreted as the required level of confidence or simply the confidence limits (Richardson, *et. al.*, 1995).

confidence limits = s.e.(m)*z

where, z = critical values from unit normal distribution for the given level of confidence.

In summary, the steps for calculating the required sample size for any variable are as follows:

1. Determine the total population N;
2. Determine the expected value of standard deviation of the parameter S;
3. Determine the confidence limits either in proportion of mean or in absolute term;
4. Determine the level of confidence (usually 95% for transport survey);
5. From unit normal distribution table, determine z value;
6. Calculate the standard error of means: s.e.(m) = confidence limits/z;
7. Calculate sample size for infinite population: $n' = S^2/(s.e.(m))^2$
8. Apply the correction factor for finite population : $n = n'/(1+(n'/N))$;
9. Repeat the calculation with observed results if necessary.

Discrete Variables

For discrete variables, the central limit theorem applies to the probability of a parameter to be in a certain condition. The formula for determining the standard error of probability (p) is given by:

$$s.e.(p) = \sqrt{((N-n)/N)(p(1-p)/n)}$$

Similar with the continuous variables, procedure in determining sample size for discrete variables can be summarized as follows:

1. Determine the total population N;
2. Determine the expected value of probability of occurrence p;
3. Determine the confidence limits either in proportion of mean or in absolute term;
4. Determine the level of confidence (usually 95% for transport survey);
5. From unit normal distribution table, determine z value;
6. Calculate the standard error of probability: s.e.(p) = confidence limits/z;
7. Calculate sample size for infinite population: $n' = p(1-p)/(s.e.(p))^2$
8. Apply the correction factor for finite population : $n = n'/(1+(n'/N))$;
9. Repeat the calculation with observed results if necessary.

Hypothetical Testing

Determining sample size for hypothetical testing purposes requires different procedures. In hypothetical testing, two types of error are possibly committed. Firstly, Type I error which is an error that happens when a null hypothesis is rejected while it is actually true. Secondly, a Type II error is one that is committed when the null hypothesis is accepted while it is actually false (Richardson, *et. al.*, 1995). Attempts in minimizing these errors are expressed in the maximum probability of which the errors are still acceptable. For Type I error the probability is usually denoted by α which is also called as the significance level, while for Type II error it is usually denoted by β.

Unfortunately, both types of error are inter-related, and any attempt to reduce one of them will simply increase the other (Spiegel, 1992 in Richardson, *et. al.*,1995). Both of errors can only be reduced simultaneously by increasing the sample size *n*. For one-tailed tests *n* can be calculated using the following formula:

$$n = (z_\alpha + z_\beta)^2.\sigma^2/\delta^2$$

where:

n = sample size;

z_α and z_β = critical values from standard normal distribution at significance levels α and β;

σ^2 = parameter variance of population; and

δ = desirable difference of estimated and population values of parameter in the hypotheses.

For a two-tailed test n is given by:

$$n = (z_{\alpha/2} + z_\beta)^2.\sigma^2/\delta^2$$

Hypothetical testing can also be applied to compare results between two samples, either from the same population or different population. In this case, the required sample size for one-tailed test is:

$$n = (z_\alpha + z_\beta)^2.(\sigma_1^2+\sigma_2^2)/\delta^2$$

And, for two-tailed test the following formula is used:

$$n = (z_{\alpha/2} + z_\beta)^2.(\sigma_1^2+\sigma_2^2)/\delta^2$$

where σ_1^2 and σ_2^2 = population variances for each of the samples.

Sample Size Calculation of the Study

To obtain sufficiently reliable data, several types of field surveys were needed. The surveys were conducted at various classes of road (local, collector, arterial), with various types of land use (residential, commercial, mix), and various levels of traffic volume, travel speed and road width (low, medium, high). A stratified sampling method then was adopted to ensure that the survey included all possible combination of sites.

The sample sizes required as suggested by statistical calculation for different parameters are as shown in Table 5.5 and summarized in Table 5.6. The parameter values were obtained either from pilot surveys or from other previous studies in the area (Institute of Road Engineering, 1997; Statistical Office Bureau, 1996). The results indicate that a minimum of 132, 92 and 60 data points are required for estimation of traffic parameters of local, collector and arterial roads respectively. Besides, calculations for the questionnaire survey purposes indicated that minimum of 60 respondents would be needed for every road category to satisfy the accuracy. The sample sizes estimations were based on 95% confidence levels, with required sampling error not more than 5% of estimated mean.

TABLE 5.5 SAMPLE SIZE CALCULATIONS

Parameters	Unit	Population	Mean	S.Deviation
Locals:				
Volume	v.p.h.	1437	2422	560
Speed	km/h	1437	33.54	8.30
Noise	dB(A)	1437	76.01	2.21
NOx	ppm	1437	0.101	0.076
CO	ppm	1437	3.642	1.661
Delay	second	1437	6.28	3.96
%Delay	%	1437	0.55	0.19
Accident	acc/yr/km	1437	0.87	0.96
Collectors:				
Volume	v.p.h.	336	1552	623
Speed	km/h	336	28.84	3.82
Noise	dB(A)	336	73.55	2.86
NOx	ppm	336	0.079	0.051
CO	ppm	336	3.296	1.515
Delay	second	336	1.83	1.00
%Delay	%	336	0.38	0.26
Accident	acc/yr/km	336	0.28	0.35
Arterials				
Volume	v.p.h.	24	524	262
Speed	km/h	24	29.56	4.19
Noise	dB(A)	24	69.40	2.93
NOx	ppm	24	0.098	0.148
CO	ppm	24	2.690	1.256
Delay	second	24	0.69	0.76
%Delay	%	24	0.13	0.13
Accident	acc/yr/km	24	0.06	0.19

TABLE 5.6 SUMMARY OF THE SAMPLE SIZE CALCULATIONS

parameters	locals	collectors	arterials	total
volume	132	60	60	252
speed	60	92	34	187
noise	61	43	43	147
pedestrian	61	61	39	162
air quality	61	96	61	219
accidents	61	61	35	157
max	132	96	61	
min	60	43	34	

In order to satisfy the sampling requirements, there were 9 categories of site combinations as shown in Table 5.7. For arterial roads, 2 representative sites were assigned for each category, while 3 and 4 representative sites were required for collector and local roads respectively. To have variations on traffic characteristics a 3-hour survey period with 15-minute time samples were adopted, while a variation in road width may be obtained from the different representative sites. For validation purposes, at least one site was needed for every category. As a consequence, another 9 sites were needed to obtain validation data. So, in total there were 36 sites, which included 9 categories, with several different sites for each category (for calibration and for validation purposes) as shown in Table 5.7.

TABLE 5.7 DATA STRATIFICATION

Road Types	Landuse	Calibration Data Set	Validation Data Set	Number of sites
Arterial	Residential	2 sites	1 site	3
	Commercial	2 sites	1 site	3
	Mix	2 sites	1 site	3
Collector	Residential	3 sites	1 site	4
	Commercial	3 sites	1 site	4
	Mix	3 sites	1 site	4
Local	Residential	4 sites	1 site	5
	Commercial	4 sites	1 site	5
	Mix	4 sites	1 site	5
Total		27 sites	9 sites	36 sites

For interview survey purposes, a minimum of 61 respondents were required for each road category. Assuming that 15-20 minutes time is required for every interview, within 3 hours time in each site, 9-12 respondents were obtained from each site. In total, around 64, 94 and 126 respondents were obtained for arterial, collector and local roads respectively.

The nominated sites for each category are shown in Table 5.8. With this sample design a total 432 data points were expected, from which 324 data points were allocated for calibration purposes, while the rest 108 data points were spared for validation purposes. From data points for calibration purposes, 72, 108 and 144 data points were obtained for arterial, collector and local roads respectively.

TABLE 5.8 NOMINATED SITES

Road Types	Landuse		
	Residential	Commercial	Mix
Arterial	Jl. Dago (upstream) Jl. Raya Timur Jl. Setiabudi (upstream) Jl. Gatot Soebroto Jl. Sukajadi (upper segment)	Jl. Dago (down stream) Jl. Asia Afrika Jl. A. Yani (Cicadas) Jl. Sukajadi (mid segment) Jl. Sudirman	Jl. Dago (mid segment) Jl. Setiabudi (mid segment) Jl. Otista Jl. M. Ramdan Jl. Sukajadi (lower segment)
Collector	Jl. Cipaganti Jl. Dipati Ukur Jl. Suci	Jl. Cihampelas (upper) Jl. Suci (market) Jl. Riau	Jl. Cihampelas (lower) Jl. Suci Jl. Riau
Local	Jl. Maulana Yusuf Jl. Hasanuddin Jl. Tubagus Ismail	Jl. Gempol Jl. Cilaki Jl. Cihapit	Jl. Trunojoyo Jl. Geger Kalong Jl. Antapani

5.6 Summary

The experimental design of the study has been presented, the study area described and the required data explained. Survey instruments and methods have also been put forward. Finally a sample design has been discussed at length. Bandung was chosen as the study area to represent a medium sized city in Indonesia, which is expected to suffer environmental problem in the near future. Methods employed in the study were described and the number of samples had been determined. The next step would be applying the design to collect the required data.

Chapter 6

Chapter 6

DATA COLLECTION

This chapter describes the field data collection process from the preparation, the measurements up to the data storing and processing stages. Field surveys were carried out in Bandung, Indonesia during September and October 1997. Thirty seven sites had been observed, comprising of 10 arterial, 12 collector and 15 local roads. Observations and measurements were made of environmental factors (noise, air quality, pedestrian), road traffic, road geometry as well as frontage land-use. At the same time 159 interviews were carried on residents along the road, and, for comparison purposes, a mail-back questionnaire survey was conducted amongst a group of 100 selected experts.

6.1 Groups of Data

Data that were collected during the field survey were grouped under three major headings:

- *Traffic and Road Geometry Data.* This included data on traffic volume and its composition, time mean speed of individual vehicles, road geometry (typical cross section, surface condition, road marking condition etc.), and general information of land-use (sketch of the location, surrounding network and typical activities on the area).
- *Environmental Data.* This group of data included noise (L10, L90, Leq), air quality data (CO, HC, NOx, SOx, SPM etc.), pedestrian activities (average delay, % delayed, walking speed etc.), and accidents (number of accidents happened in particular link within particular year).
- *Community Preference Data.* Data under this heading included stated preferences of environmental impact data of community (from interviews) and stated preferences of environmental impact data of experts/planners/decision makers (by mail-back questionnaire survey).

There were also secondary data obtained that can not be included into any of the above categories, such as statistical data of Bandung municipality (Bandung 1996 Year Book), environmental standards, maps and other secondary information that were considered relevant to the study. All these relevant materials had to be identified and obtained during the data collection phase.

6.2 Preparation

Several activities had been conducted prior to the main survey. Included in such activities were pilot surveys, recruitment of survey team, training of the survey team, procurement of equipment and some paper work that is necessary to get approval to conduct this kind of survey research in Indonesia. The following sections describe these activities in more detail.

6.2.1. Pilot Studies

Pilot studies had been conducted twice. The first one was carried out in Sydney and the second one was conducted in Bandung as part of survey training. Results of these studies were used to critically evaluate the methodology and the survey design, including the designs of interview and questionnaire forms. Practical procedures of traffic and other field surveys had also been developed and revised as a result of these studies.

The first pilot survey was intended as a preliminary rehearsal in organizing a survey site and to familiarize the researcher with various types of equipment involved. This survey was conducted for about two hours at around Barker Street, Kingsford in Sydney. Equipment used in the survey included a sound level meter, a video camera, a radar-gun and hand tally counters. Involved in the survey were students and UNSW technical staff from the School of Civil and Environmental Engineering.

Results of the first pilot survey were used to evaluate the survey planning and to develop a desktop run through of the whole study design. The first attempt in measuring noise level was unsuccessful because of missing steps, such as in the procedure. The automatic traffic counting did not work, as the software to retrieve the data was not available at the time the survey was carried out. These lessons indicated the importance of having a contingency plan, having written operating procedures for survey staff and of not relying on a single data collection system.

The second pilot study was conducted as part of training of the survey team. It was also intended to familiarize the members of the team with the installation and measurement procedures and to estimate the typical time required to set up and to disassemble the equipment. The survey was carried out at Jalan Raya Cipadung, in Bandung. This was a full-scale pilot study, as all the necessary types of observations were tried out and all equipment that was going to be used in the main survey was installed. Results of the second pilot survey were used to finalize the survey program and to detect any weaknesses. The results suggested that some procedures had to be revised. Examples of these included the importance of charging batteries prior to every survey and the wording of interview scripts. Furthermore, some additional accessories had to be provided for traffic counts, such as pneumatic tube, nails and masking tape.

6.2.2. Desktop Run Through

This activity put together the plan and the assumptions in designing the study into simulated scenarios. During the simulation any required action, resources and its estimated duration were identified. By so doing, it was hoped that some unnecessary errors might be avoided and difficulties might be anticipated. As part of the simulation, a contingency plan was also prepared. The plan considered the possibility of equipment failure, accidental data loss, and practicalities of conducting the surveys according to the original plan. Alternatives were provided to anticipate even the worst scenario. In addition, some related aspects of instrumentation, logistics and operation were also discussed. Appendix A provides a complete documentation of the described desktop run through processes.

6.2.3. Team Recruitment and Training

Survey personnel was recruited based on their skill and ability to work as team. Ten members of the team were recruited to suit the available jobs. All were Research Institute of Road Engineering (RIRE), Ministry of Public Works Republic of Indonesia technicians and staff and therefore had local knowledge of Bandung. Training of the personnel was conducted on 15 September 1997. The training explained the nature of the study, the types of observations to be conducted, the techniques and methods used, and the survey operational procedures (e.g. standard site layout, set up and measurement procedures). The training was accompanied by a second pilot survey on 16 September, 1997.

This was a full-scale rehearsal intended to introduce the team members to how the real situation would be like and to provide them with the experience of handling some new equipment. After this rehearsal every team member was asked to prepare their personal notes, containing such important things as critical aspect of their job, weaknesses and possibility of committing errors. These were then incorporated into the operational procedures. In a management sense, this important set of responsibilities was divided at team building to ensure the quality and integrity of the data to be collected.

6.2.4. Equipment Procurement

Equipment used for the main survey was mainly supplied by RIRE. Only a small portion was borrowed from other sources for exmaple the Indonesian Highway Capacity Manual (IHCM) project. For practical reasons, the equipment was categorized into six categories:

- *Traffic Survey Equipment.* Including data loggers, pneumatic tubes, operating software and its various accessories such as batteries, cables, clamps, hammers etc.
- *Road Geometry and Land use Survey Equipment.* Including magnetic compass, wheel meter, band meter, and drawing equipment such as clipboard, millimeter blocks etc.
- *Noise Measuring Equipment.* Including Sound Level Meter (ONO SOKKI LA-5110), tripod and accessories.
- *Air Pollution Measuring Equipment.* Including Mobile Air Pollution Laboratory, anemometer, thermometer, sampling bags etc.
- *Pedestrian Survey Equipment.* Video camera recorder (SONY VCR EVS 550-E), Tripod, Elastic straps, umbrella and video cassettes.
- *General Purpose Equipment.* Photographic camera, operational vehicles, suitcases.

Although most of them were borrowed, some consumable materials and accessories such as masking tapes, nails, clamps, cables, cassettes and batteries had to be purchased. Detailed inventories of the equipment including the types and quantities of all categories together with their specifications are available in Appendix B.

Besides, some paper work had to be completed prior to the field survey. This included filling out equipment borrowing forms from the Warehouse Section, Traffic Engineering Division, RIRE and preparing a covering letter for the questionnaire survey. A permission letter was also lodged with the Social and Political Office of Bandung municipality for conducting the survey.

6.3 Observations and Measurements

This section describes the operational aspects of the main survey. It includes the selection of survey sites, the make up of survey schedule and the observational procedures.

6.3.1. Site Selection and Survey Schedule

Although some possible sites had been identified in the study design, revision and changes were being made to the plan. The changes were done to adjust the plan to the real conditions and limitations. The limitations might include the equipment availability and capacity, operational logistics, as well as time and funding constraints.

The sites were selected based on the following of technical criteria:

- a relatively straight section that is long enough to set up equipment;
- a relatively uninterrupted flow of traffic;
- a relatively flat terrain;
- a potential number of crossing pedestrian.

Besides, it was desirable that the sites also satisfied three additional criteria:

- having sufficient space to park the mobile laboratory for air pollution measurements;
- not too distant one to another particularly the ones scheduled on the same day; and
- distributed across the urban area of Bandung, to have a better representation of the study area.

Figure 6.1 shows the survey locations in the study area. To achieve the objectives, extensive reconnaissance surveys were conducted before hand and local experts were consulted to select the best available sites. Sites were coded according their category. Information on the survey schedule which includes site code, link name, road class, land-use type, date and day of survey, and session of survey (either a.m. or p.m.) are presented in Table 6.1.

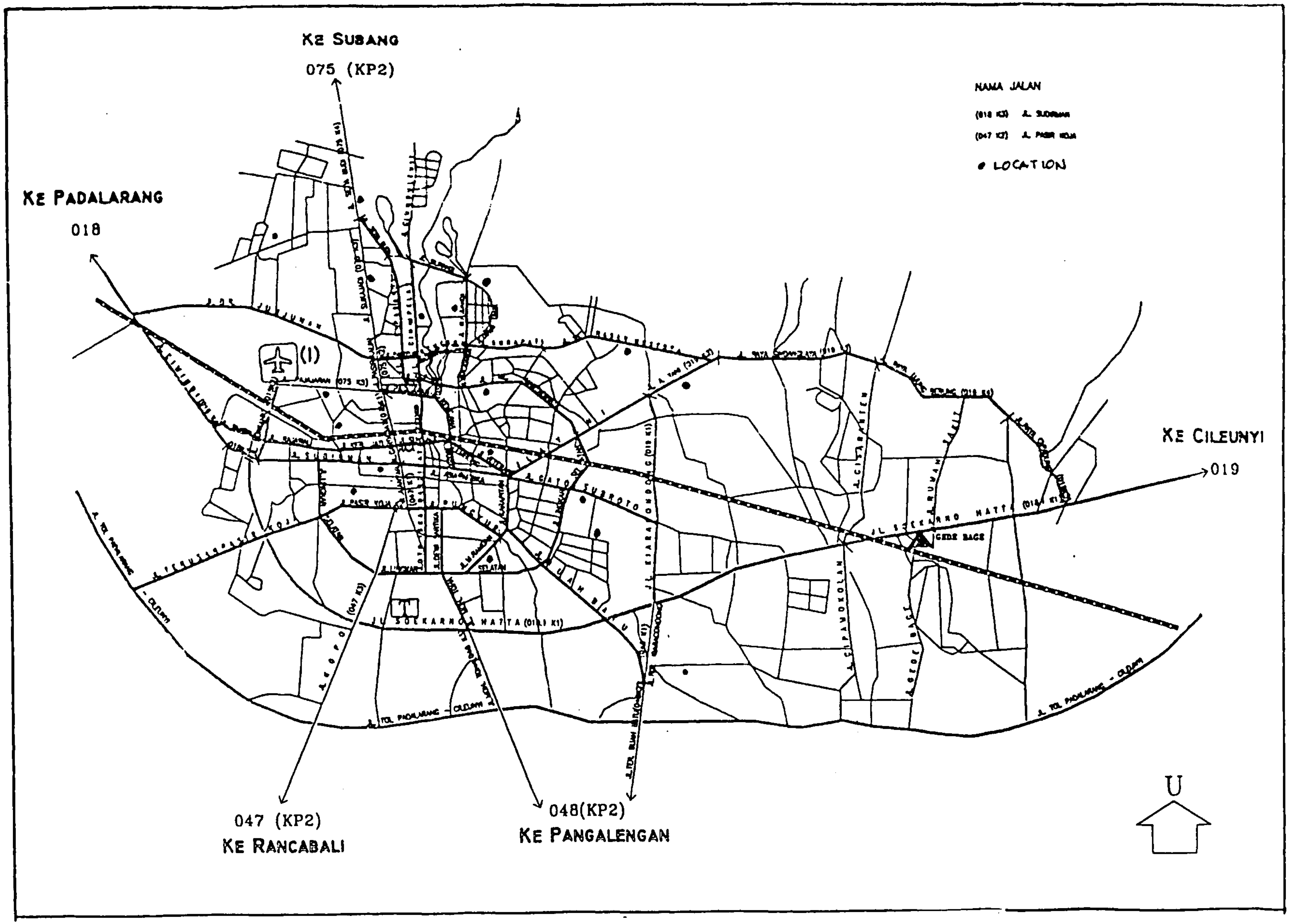


FIGURE 6.1 SURVEY LOCATIONS

TABLE 6.1 SITE CODES AND SURVEY SCHEDULE

No	Site Code	Link Name	Road Class	Land-use	Date of Survey	Session	Remarks
1.	Ac01	Jl. Setia Budi	arterial	commercial	Mon, 22/9/97	p.m.	
2.	Ac02	Jl. Asia Afrika	arterial	commercial	Fri, 26/9/97	p.m.	Data loss
2a.	Ac02a	Jl. Hasan Mustafa (Suci)	arterial	commercial	Mon, 13/10/97	a.m.	Replacement
3.	Ac03	Jl. Ahmad Yani (Cicadas)	arterial	commercial	Tue, 30/9/97	a.m.	
4.	Am01	Jl. H. Juanda (Dago)	arterial	mix	Thu, 25/9/97	a.m.	
5.	Am02	Jl. Moh. Ramdhan	arterial	mix	Mon, 29/9/97	p.m.	
6.	Am03	Jl. Martadinata (Riau)	arterial	mix	Wed, 1/10/97	p.m.	
7.	Ar01	Jl. Sukajadi	arterial	residential	Tue, 23/9/97	p.m.	
8.	Ar02	Jl. Cipaganti	arterial	residential	Wed, 24/9/97	p.m.	
9.	Ar03	Jl. Gatot Subroto	arterial	residential	Sat, 27/9/97	p.m.	
10.	Cc01	Jl. Geger Kalong Hilir	collector	commercial	Mon, 22/9/97	a.m.	
11.	Cc02	Jl. Moh. Thaha	collector	commercial	Fri, 3/10/97	p.m.	
12.	Cc03	Jl. Pagarsih	collector	commercial	Tue, 7/10/97	a.m.	
13.	Cc04	Jl. Ciwastra	collector	commercial	Thu, 9/10/97	p.m.	
14.	Cm01	Jl. Dipati Ukur	collector	mix	Thu, 25/9/97	p.m.	
15.	Cm02	Jl. Gandapura	collector	mix	Thu, 2/10/97	p.m.	
16.	Cm03	Jl. Burangrang	collector	mix	Sat, 4/10/97	p.m.	
17.	Cm04	Jl. Tubagus Ismail	collector	mix	Fri, 10/10/97	p.m.	
18.	Cr01	Jl. Karawitan	collector	residential	Mon, 6/10/97	a.m.	
19.	Cr02	Jl Reog	collector	residential	Wed, 8/10/97	p.m.	
20.	Cr03	Jl. Sriwijaya	collector	residential	Sat, 11/10/97	a.m.	
21.	Cr04	Jl. Banteng	collector	residential	Sat, 11/10/97	p.m.	
22.	Lc01	Jl. Purwakarta	local	commercial	Tue, 30/9/97	p.m.	
23.	Lc02	Jl. H. Kurdi	local	commercial	Fri, 3/10/97	a.m.	
24.	Lc03	Jl. Solontongan	local	commercial	Mon, 6/10/97	p.m.	
25.	Lc04	Jl. Suryani	local	commercial	Tue, 7/10/97	p.m.	
26.	Lc05	Jl. Sawah Kurung	local	commercial	Mon, 29/9/97	a.m.	
27.	Lm01	Jl. Jurang	local	mix	Tue, 23/9/97	a.m.	
28.	Lm02	Jl. Palasari	local	mix	Sat, 27/9/97	a.m.	
29.	Lm03	Jl. Kinanti	local	mix	Wed, 8/10/97	a.m.	
30.	Lm04	Jl. Logam	local	mix	Thu, 9/10/97	a.m.	
31.	Lm05	Jl. Imam Bonjol	local	mix	Fri, 10/10/97	a.m.	
32.	Lr01	Jl. Sejahtera	local	residential	Wed, 24/9/97	a.m.	
33.	Lr02	Jl. Vandeventer	local	residential	Fri, 26/9/97	a.m.	
34.	Lr03	Jl. Bahureksa	local	residential	Wed, 1/10/97	a.m.	
35.	Lr04	Jl. Patrakomala	local	residential	Thu, 2/10/97	a.m.	
36.	Lr05	Jl. Halimun	local	residential	Sat, 4/10/97	a.m.	

The site code was used as site identity and comprised four characters. The first character stands for road class (i.e. *a* for arterial, *c* for collector and *l* for local). The second character stands for land-use type (i.e. *c* for commercial, *m* for mix and *r* for residential), and the third and fourth characters were sequence number of the site within its category. So, the Site with code *ac01* means that the site was the first site in arterial-commercial category, while the Site with code *cc01* means a collector-commercial site number one and so on. The link name represents the street name according to the official network map. The road class could either be arterial, collector, or local. Land-use type was either commercial, mix, or residential. The date and day of survey column informs the date the site was surveyed. And the last column specifies in which session the survey was carried out.

As time and resources were limited, observations were only conducted for around three hours at each site. In so doing, two observations could be managed in one particular day, one in the morning and another in the afternoon. Data collection at the targeted 36 sites was scheduled to finish within three weeks, which could only be possible with a six-day-per-week schedule. For the same reasons, data for calibration purposes were collected at the same time as for validation purposes. From the 36 sites, 27 sites would be randomly chosen to use for calibration purposes and 9 would be reserved for validation purposes. In total 37 sites were included, with one site added to compensate a data loss (Jalan Asia-Afrika) that occurred in the early part of the survey.

6.3.2. Measurement Procedures

Typical Site Layout

Equipment at survey sites was typically laid out as shown in Figure 6.2. Traffic counting apparatus was usually located at the central position of the site. The other equipment such as air pollution laboratory and noise measurement apparatus were located not too far away from the traffic counting apparatus, while pedestrian observations were usually conducted at a location a bit further down or up the road depending on where the pedestrians tended to cross.

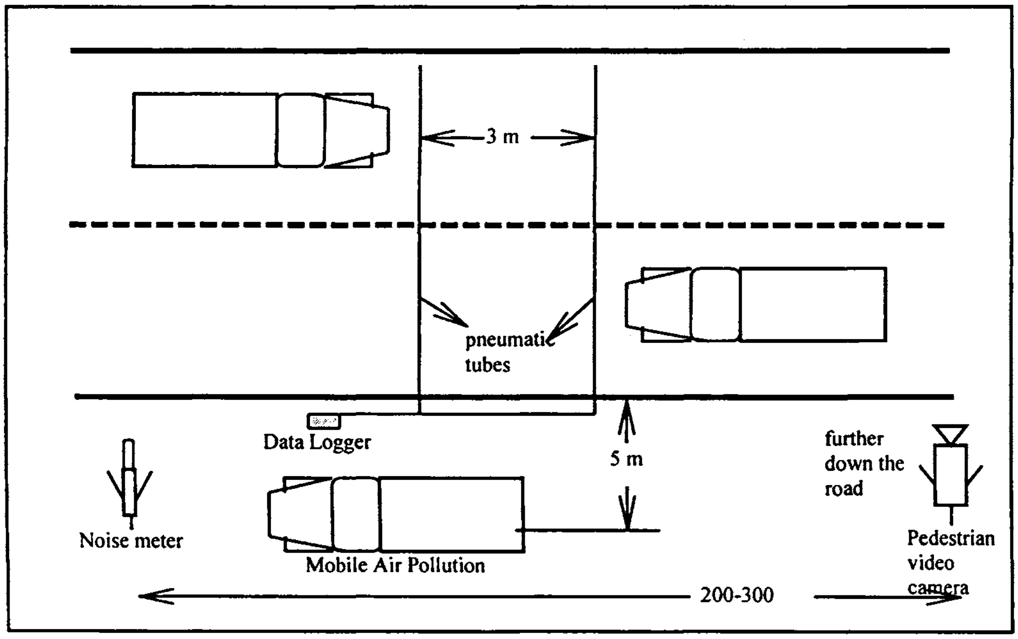


FIGURE 6.2 TYPICAL SITE LAYOUT

Traffic counting apparatus was usually the first equipment installed, as it was the most difficult and complicated equipment. It was followed by installation of the other equipment.

After all equipment was ready, time was synchronized before measurements were carried out. The preparation usually took about thirty minutes to finish, while disassembling time usually took less. Forms used in the survey are reproduced in Appendix C.

Traffic Survey

Traffic was counted using an automatic data logger with pneumatic tubes. Components of the equipment included a 32-channel data logger, a laptop PC, connector cables, pneumatic tube converters, tubes, switchboards and batteries.

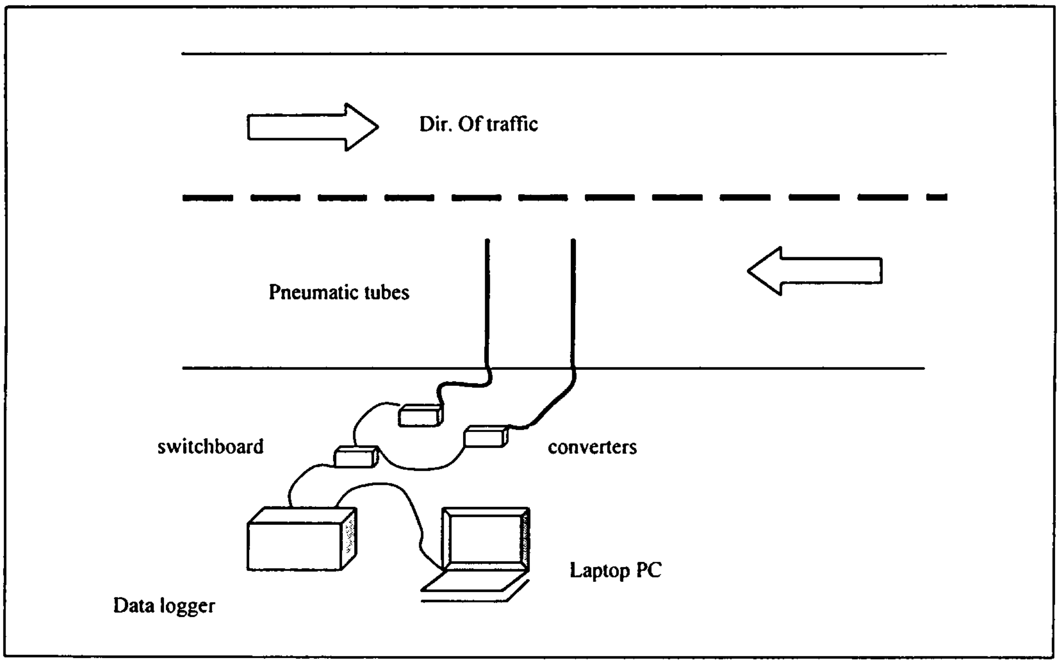


FIGURE 6.3 CONFIGURATION OF TRAFFIC COUNTING APPARATUS

When a vehicle passes over the tubes, air pressure in the tube is converted into electrical signals. The data logger then recorded the time when such signals occurred. Data were retrieved using a PC-software called TMSLOG.

In general steps taken for installing the equipment were as follows:

- Firstly pairs of tubes were laid down three metres apart for each direction of traffic;
- Secondly, tubes were connected to the converters and then through a switchboard to the data logger;
- Data logger was then connected to the batteries;
- Setting up of the system was done using TMSLOG software installed in a laptop computer. The set up procedure includes assigning channels of the data logger, setting delay time required, and setting the date and time of the measurement (see Appendix D).

Typical configuration of traffic counting apparatus is as shown in Figure 6.3 and Plate 6.1.

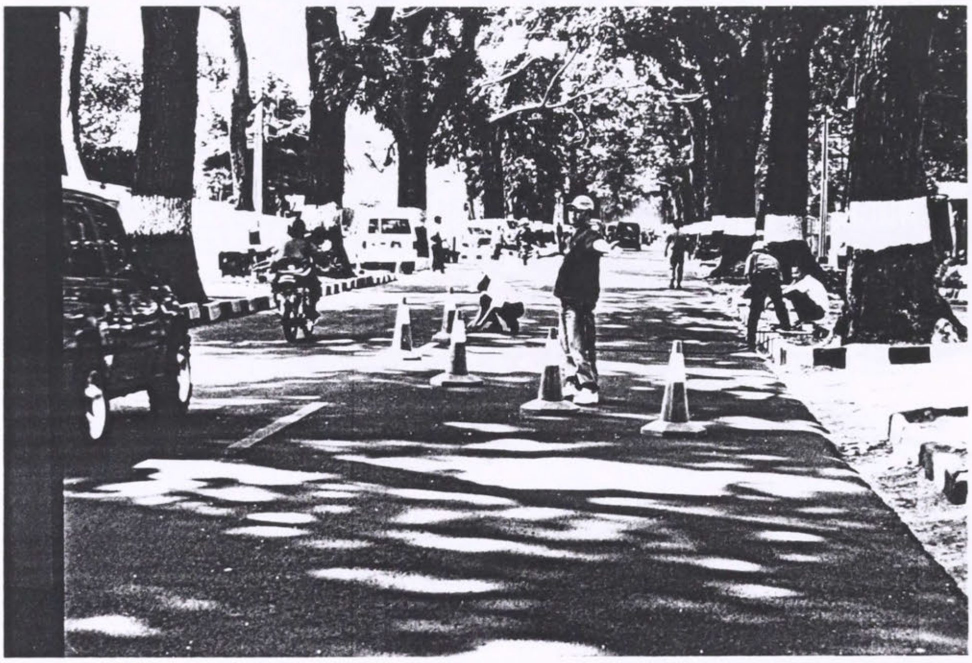


PLATE 6.1 INSTALLATION OF TRAFFIC COUNTING APPARATUS

Road Geometry and Land use

Road geometry and land use information were measured and observed manually using various apparatus such as wheel-meter and magnetic compass. The general procedure or guidelines in conducting the survey was as follow:

- Draw some sketches of the site condition;
- Draw some typical cross sections of the road;
- Measure the road geometry (i.e. road width, number of lanes, shoulder width, median);
- Determine the north direction and major icons in the site lay out sketch;
- Observe the type of land use in the surrounding area (usually within 500 m along the road);
- Write down some important information regarding land use such as streetscape, trees.

Plate 6.2 shows a typical activity during road geometry and land use observation as done by a surveyor. Form as used in the survey can be observed in Appendix C.

PLATE 6.2 MEASUREMENT OF ROAD GEOMETRY AND LAND USE

Environmental Survey

Noise

Noise levels were measured using an ONNO SOKI Sound Level Meter. The noise was fully sampled (100%) and the data were aggregated into 15-minute time slices. Three noise level indices L_{10}, L_{90} (10^{th} and 90^{th} percentiles of noise levels) and L_{eq} (equivalent steady noise level) were recorded. Procedure of noise measurement began with the set up of the SLM at about five metres from the road edge. Checking of the batteries was done right after the installation. If the battery indicator indicated low, batteries were replaced. After everything was ready, calibration of the SLM was done using the standard procedure from the manual. The SLM was then set to record noise data automatically every 15-minute period. After time synchronization was taken with the other observations, measurements were started.

Meanwhile, a survey form was filled in to record additional information such as weather, surrounding conditions, road width, and so on. After measurement time was finished (usually after 3 hours), the recorded data were recalled from the SLM memory, and necessary information was written down onto survey form. Typical situation of noise measurement was as shown in Plate 6.3.

PLATE 6.3 NOISE MEASUREMENT

Air Pollution

An integrated mobile laboratory was used to collect air quality data. The laboratory was a self-contained truck that housed various types of air pollution measuring equipment. The laboratory handled various types of air pollutant such as CO, NO, NO_2, HC, O_3, SO_2, as well as Suspended Particulate Matters (SPM). It also recorded such meteorological data as temperature, humidity, wind speed, wind direction, rain fall, and solar radiation. One problem with this laboratory was that it needed a quite large parking space, consequently it was not possible to use in many of the local roads as they usually have very narrow road and shoulder width. Another problem associated with this equipment was that it needed quite long time to warm up (2-3 hours) prior to measurements, so it could only be used on one site per one day.

To overcome these problems, the survey was arranged so that in one particular day, there would be at least one site of either a collector or an arterial (to enable the laboratory to be set up). This site was scheduled in the afternoon session to allow the warming up of the equipment. For the morning session, measurement of air quality was conducted by using sampler bags. These bags, after being filled in with air sample, were taken to the laboratory to be analyzed. Results of the analysis were then manually input into survey forms. Although the bag sampler measurements were not as accurate as direct analysis from the laboratory, this was the most practical way of doing such measurement in the field. Another method - a manual measurement and analysis of air pollutants - was tried out before hand, prior to pilot survey. But, as the equipment was so bulky and awkward, this method was not used in the main survey. The mobile laboratory was as shown in Plate 6.4.

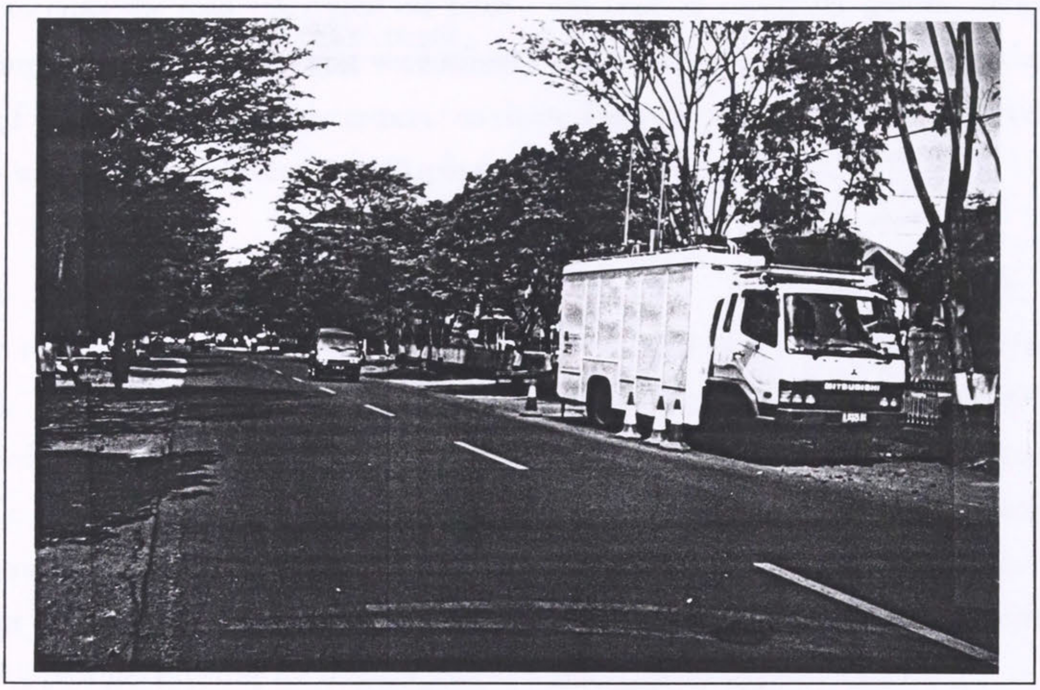


PLATE 6.4 MOBILE AIR POLLUTION LABORATORY

Pedestrian Delay

Plate 6.5 shows how observations of crossing pedestrians were carried out. A video camera was typically mounted on a fixed point such as a tree trunk or electricity pole. The camera was set up high enough so that both sides of road could be observed for about 2.5 hours at each site.

PLATE 6.5 PEDESTRIAN OBSERVATION

An 8mm video camera was used for pedestrian observation. The camera was positioned at the location between 150 to 300 m away from the other surveys, or where most pedestrians tended to cross the road. A typical car battery was used to supply the power. When everything was ready, date and time were adjusted before measurement commenced. After running for about half an hour, the camera was checked to make sure that it was running well and this step was repeated every 30 or 60 minutes.

Accident

Data on road accidents were obtained from Bandung City Police on a computer format file (ASCII). Data were analyzed using Microcomputer Accident Analysis Package (MAAP), developed by Transport Research Laboratory (TRL) UK. The program has been introduced by traffic police since the early of 1990s under an assistance program from Institute of Road Engineering (IRE), Ministry of Public Works (Institute of Road Engineering, 1991). Data on accidents are collected from the scenes and input into the program by traffic police officers, while IRE provides expertise for analyzing and maintaining the quality of the data.

Although the program has been running for about seven years, it is still difficult to have a complete record of accidents for any particular year. There are several reasons for this:

- the system has not been fully implemented by traffic police, since it is difficult to switch from a manual system into a computerized system while there was no specific funding for the project;
- traffic accidents tend to be under-reported as people generally tend to avoid police officers in their dispute after a collision happens;
- a different officer was in charge for the program every 1-2 years as a result of rotary or tour of duty system in the traffic police and this makes it more difficult to establish the project;
- MAAP was installed in stand alone PCs, and a well running mechanism is needed to have a comprehensive data.

The most reliable accident data as suggested by IRE expert that could be obtained for the purpose of the study were data of 1995 and 1996 accidents.

Preferential Survey

Data on public preferences towards environmental factors were conducted by employing a direct interview survey, which was carried out either in a household or office/commercial premise. Plate 6.6 depicted typical household interview. Besides, a mail back questionnaire survey was also adopted to gather similar data from experts/planners/decision makers. Once interview and questionnaire forms had been designed they were tried out amongst the IRE experts and researchers before being used in pilot survey. Reviews were mainly made of the wording of the questions. The final versions of the interview and questionnaire forms are as attached in Appendix C.

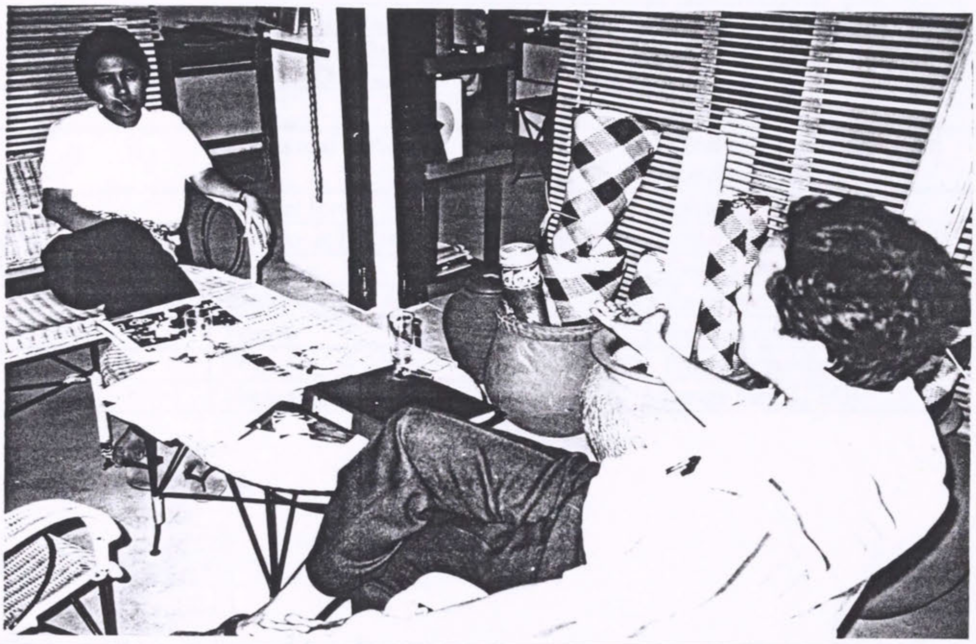


PLATE 6.6 TYPICAL SITUATION OF A HOUSEHOLD INTERVIEW

Questions in the interview and questionnaire forms were divided into 5 main sections. The first section contains general questions regarding the respondent such as age group, education level, sex, and his/her role in the household. The second section contains questions regarding their opinion on ranking towards environmental factors namely noise, air pollution, pedestrian's delay and accident risks. The third section contains questions on how they would score (give direct weighting) the environmental factors using a 100 scale scoring system. The fourth section contains questions in the format of pair wise comparisons between factors. This actually was the most difficult part of the interview. In this section, respondents were asked to compare two factors at a time, and give their opinion on how they prefer one factor to the other in an independent manner. A nine level preference scale was used as suggested by the pair wise comparison method (Saaty, 1978). The last section provides space for comments and suggestions from the respondents.

6.4 Data Processing

6.4.1. Type of Storage

Data were stored in various formats such as electronic, graphical, video, photographs, and sketches, as listed in Table 6.2. From these formats, the data were then processed to have a more useful information. The processed data were mostly stored in a Microsoft Excel files.

TABLE 6.2 TYPES OF DATA STORING FORMAT

Data	Original format	Final format
Traffic and speed	Electronic (*.dat files)	Excel spreadsheet files.
Road Geometry	Forms and Sketches	Excel spreadsheet files and sketches
Land use	Forms and sketches	Excel spreadsheet files and sketches
Noise	Manual forms	Excel spreadsheet files
Air Pollution	Electronic (*.dat files) and graphical	Excel spreadsheet files
Pedestrian delay	Video	Excel spreadsheet files
Accident	Electronic and forms	Excel spreadsheet files
Interview	Forms	Excel spreadsheet files
Questionnaire	Forms	Excel spreadsheet files
Pictures	Photographs	Image files (JPEG)

6.4.2. Processing of the Data

Road and Traffic Data

Traffic Data (Volume, Composition and Speed)

Data on traffic that were down loaded into a computer using a program called TMSLOG, were saved as text files. They were processed using another program, called PRECDIA, to convert the files into *.DAT files that contain information on type of vehicle, speed, number of axles and distance between axles of individual vehicle.

A typical format of files that contain traffic data as down loaded from a data logger using TMSLOG program was as follows.

```
1>1  15:20:30165
1>1  15:20:30185
2>1  15:20:31080
2>1  15:20:31105
```

These data simply returned the time in hh:mm:ssms when the tube was hit by the vehicle's tyres. After being run into PRECDIA program, the format of the output files became as follows:

```
11> 152030165  12  43.5  2  2.50
11> 152032105  02  52.5  2  1.80
11> 152034051  12  45.3  2  2.53
22> 152035063  12  32.0  2  2.48
```

The first two characters of the format represent traffic direction, the following nine characters represent time in hh:mm:ss:ms, and another two characters represent type of vehicles as defined in Table 6.3. The next three-digit number represents vehicle speed, followed a single digit number of axles and another three digit of distance(s) between the axles.

TABLE 6.3. CODING OF VEHICLE TYPES

No. of axles	Light Vehicle	Medium HV	Large Truck	Large Bus	Truck Combination	Motor Cycle
2	12	22		42		02
3	121		23	43	221,321,421	
4	122		24		222,231,322,331,422,431	
5					223,232,323,332,341,432	
6					224,233,242,324,333,342	
7					234,243,325,334,343	
8					244,326,335,344	

Note: 1st digit: 0 = motorcycle; 1 = light vehicle; 2 = medium heavy vehicle and large truck; 3 = truck combination; 4 = large bus. 2nd digit: axle number of tractor. 3rd digit: axle number of trailer.

To have a more handy information, the output files from PRECDIA were processed in such a way so that the data were aggregated into 15 minutes time slices, and the following information was obtained:

- number and percentage of LV;
- number and percentage of HV;
- number and percentage of MC;
- average speed of LV;
- average speed of HV;
- average speed of MC;
- total number of vehicles; and
- average speed of all vehicles.

The process was completed using an SPSS program. The program produced output files in Microsoft Excel format. Typical output of the program is as shown in Table 6.4.

TABLE 6.4 TYPICAL OUTCOME OF TRAFFIC DATA

Site: ak01 dir.: 01 (Northbound)

Time	Volume (vehicles)								Speed (km/h)			
Interval	MC	%	LV	%	HV	%	Total	VPH	MC	LV	HV	Average
14:45-15:00	54	17	231	75	25	8	310	1240	33	31	27	31
15:00-15:15	45	17	206	76	19	7	270	1080	35	30	28	31
15:15-15:30	53	21	174	70	20	8	247	988	36	32	32	33
15;30-15:45	37	14	193	75	26	10	256	1024	33	29	23	29
15:45-16:00	57	15	280	73	49	13	386	1544	30	25	22	25
16:00-16:15	54	18	210	71	31	11	295	1180	32	26	23	26
16:15-16:30	60	21	200	69	28	10	288	1152	32	27	26	28
16:30-16:45	47	15	222	71	43	14	312	1248	28	23	23	23
16:45-17:00	58	18	238	74	27	8	323	1292	33	29	26	30
17:00-17:15	53	17	236	74	31	10	320	1280	33	28	29	29
17:15-17:30	49	15	249	75	32	10	330	1320	33	27	26	28
17:30-17:45	47	15	219	71	43	14	309	1236	32	28	23	28
17:45-18:00	44	13	245	75	38	12	327	1308	34	28	26	28
18:00-18:15	47	16	220	75	26	9	293	1172	35	30	28	31
						mean		1219				29
						st. Dev		139.59				2.45

Road Geometry and Land use

Data on road geometry and land use from the field surveys were transformed into Microsoft Excel spreadsheet format back in the office. Sketches of the sites and road geometry remained in their original forms and filed in a folder.

Environmental Data

Noise

Noise data obtained from the field survey were input into spreadsheet forms in Microsoft Excel format. Typical format of the files is as shown in Table 6.5. Average values were calculated for each hour from the fifteen-minute data. The complete data for every site can be observed in Appendices D and E.

TABLE 6.5 TYPICAL NOISE DATA FORMAT

Time Interval	Memory address	L_{10}	L_{90}	L_{eq}
9.00-9.15	01	69.5	63.8	66.4
9.15-9.30	02	70.0	64.1	67.1
...	.	.	.	.

Air Pollution

Measured air pollution data were stored in the main memory of the data controller in the mobile lab. These data could be downloaded using computer software called as DNS that produces data files in ASCII format. These files were then imported to Microsoft Excel for further analysis. Manual back up of the data was also done in the field by recording the displayed results every 1 to 2 hours. Typical form used for air pollution observation is as shown below in Table 6.6. Data on air pollution of every site is provided in Appendices D and E.

TABLE 6.6 TYPICAL FORMAT OF AIR POLLUTION DATA FILE

Time interval	NO ppm	NO_2 ppm	CO ppm	NMHC ppm	CH_4 ppm	SPM μgr/m3
10.00-11.00	0.0023	0.0045	0.0014	Graphed	graphed	80
11.00-12.00	0.0024	0.0054	0.0013	Graphed	graphed	90
13.00-14.00	0.0034	0.0065	0.0017	Graphed	graphed	87
...						

Pedestrian Delay

Reduction of pedestrian data was carried out in the traffic laboratory using several video players and monitors. Observations were made of pedestrian activities such as:

- *Arrival time*, that is the time when a pedestrian enters into scene and waits at the side of the road for a gap to cross.
- *Staring time*, that is the time when the pedestrian starts to cross.
- *Stopping time*, that is the time when the pedestrian makes a stop at the centre-line to wait for traffic gap from the other direction.
- *Restarting time*, that is the time when the pedestrian continues to cross the rest of the lanes from the centerline.
- *Finishing time*, that is the time when the pedestrian arrives at the other side of the road.

Not less than 90 hours of pedestrian observations were made, which took about 120 hours of data reduction time in laboratory. The format of a typical pedestrian data file is as shown in Table 6.7.

TABLE 6.7 TYPICAL FORMAT OF PEDESTRIAN DATA FILE

Pedestrian	Arrival	Starting time	Stopping	Restarting	Finishing
1	09:00:01	09:00:10	-	-	09:00:30
2	09:01:22	09:01:22	-	-	09:01:45
3	09:10:23	09:10:23	09:10:34	09:10:37	09:10:50
4	09:13:02	09:13:32	09:13:43	09:13:48	09:13:59
...					

The data were subjected to further analysis to obtain such more useful information as:

- Individual pedestrian delay
- Average pedestrian delay
- Percentage of delayed pedestrian
- Individual walking speed, and
- Average walking speed.

This analysis was done using Microsoft Excel. Data on pedestrian delay at every site are provided in Appendices D and E.

Accident Risk

Accident data were extracted from traffic police data. The available data were accidents that occurred between 1993-1995 in Bandung urban area. Accidents were differentiated into 4 major categories: fatal, heavily injured, slightly injured and property damage only accidents. Location of an accident was identified using nodes number connected by the road link. Accident rates were then calculated from the total accidents divided by associated link length and total number of years of which the accidents were referred to. Typical information that could be produced were as shown in Table 6.8.

TABLE 6.8 ACCIDENT DATA

Link			Number of accidents between 1993-1995					Accident rate
Name	Length	Nodes	Fatal	HI	S.I.	D.O.	Total	Acc/km/year
Cimuncang-Cikutra	1.2	233-042	5	2	0	5	12	3.33
Seram-Banda	3.02	049-047	0	0	0	0	0	0.00
Turangga-Lingkar	3.45	151-038	1	0	1	2	4	0.39
...								

Note: HI=Heavily Injured, SI=Slightly Injured, DO=Damaged Only

Preferential Data

It was only possible to interview 4-5 household at each site. In general, the response from the public was very enthusiastic towards the research topic. Visual aids were used to reduce difficulties and to avoid misunderstanding of the questions by the interviewees. Use of these visual aids was found to be quite helpful in conducting the interviews, as respondents were more relaxed and thus it appeared to be easier for them to understand the questions.

The total number of respondents interviewed during the survey was 159 persons. About 25% of them (30) were people living along arterial roads, 30% (44) were of people living at collector roads, and around 45% (52) were amongst local road residents. Some of the early surveyed sites were not sampled, as interviewers were not available at the time of the survey. Additional interviews were actually planned but were not accomplished as the interviewer was engaged by another study at IRE.

The response rate of the questionnaire survey was very typical (Richardson, 1995): from 100 questionnaires sent to the respondents, whom selected from various institutions, 25 were mailed back. The questionnaires were mailed to the respondents by 11th of October 1997 and the response cut-off date was early November 1997. Unfortunately, time was did not permit to send follow up and reminding letters to increase response rate.

All of the responses from either interviews or questionnaire surveys were coded and transformed into spreadsheet files. Data from the interview surveys were keyed in into Microsoft Excel spreadsheet format, and they available in Appendix. F.

6.5 Summary

Data collection activities have been described. Measurement procedures were explained and data processing and storing discussed. Around 37 sites were surveyed of which 27 will be used for model calibration purposes and 9 for subsequent model validation. Traffic, road geometry and land use as well as environmental factors were also observed. At the same time community preferences were surveyed through interview and mail-back questionnaires. In the last part, the processing and storing of the survey results were described. By this point, data are ready to be further analyzed. The following chapter discusses the data analyzes and interpretations.

Chapter 7

Chapter 7

DATA ANALYSES

This chapter describes the methods of analyzing the data in the present study. Some of the analyses quite simple and straightforward, while others were relatively more complex. Most of them were done using Microsoft Excel program, while other supporting software was also employed.

The analyses have been consistently grouped into three major categories, of traffic, road geometry and land use data, of environmental data, and of preferential data. The following sections describe in more detail what has been done in each category.

7.1 Analysis of Traffic, Road Geometry and Land-use Data

7.1.1 Traffic

The required parameters of traffic data include traffic volume, average speed as well as proportion of heavy vehicles. Traffic volume was originally planned to be counted using an automatic counting system. But, as the system did not perform quite well in counting the traffic as compared to manual counting, a manual back-up system was used to replace the system. The manual counting was done using video recorded data, that was intended for pedestrian observation purposes.

Collection of complete traffic data can be observed in Appendix E. Summary information of the data is as shown in Table 7.1. The summary suggests that the traffic volume was ranging between 185 and 3162 with an average value of 1299 vehicles per hour (vph). The average volume on arterial roads was 2422 vph with a standard deviation of 560. Collector roads had an average of 1552 vph with a range between 455-2403 vph, and local roads had an average volume of 524 vph.

TABLE 7.1 SUMMARY OF TRAFFIC COUNTING (V.P.H.)

Data Aggregate	Average Volume	St. Deviation	Range
Arterial	2422	560	1587-3162
Collector	1552	623	455-2403
Local	524	262	185-1003
All roads	1299	897	185-3162

The complete set of traffic speed data can be observed in Appendices D and E. Traffic speed was measured using the same apparatus as automatic counting system. Processing of the raw data into more useful information has been explained in Chapter 6. As the outcomes, average values of speed for overall traffic and for individual types of vehicle were obtained. Summary of the results is as shown in Table 7.2. The figures suggest that for all road classes, the average traffic speed was 30.2 kph with standard deviation of 5.5 kph. Maximum speed was found to be 46 kph and the minimum of 19 kph. For individual road class the traffic speed was as follows. Average speed for arterial, collector and local roads were 33.5, 28.8 and 29.6 kph respectively. Arterial road had a maximum speed of 46 kph, whereas the maximum speed of collector and local roads was 34 km/h and 37 km/h respectively.

TABLE 7.2 SUMMARY OF TRAFFIC SPEED (KM/H)

Data Aggregate	Average Speed	St. Deviation	Range
Arterial	33.5	8.3	22-46
Collector	28.8	3.8	19-34
Local	29.6	4.2	24-37
All roads	30.2	5.5	19-46

7.1.2 Road Geometry and Land-use

Road geometry and land-use data were measured directly in the field as described in Chapter 6. Typically, they include such parameters as road width, number of lanes, lane width, as well as road gradient. The complete record of this data can be observed in Appendix F, while Table 7.3 provides the summary of the data for every road class. The average width of all roads under the study was 7.9 m. Arterial roads had an average of 10.3 m., the collectors of 7.9 m., and local roads of 6.7 m. The average values of lane width suggest that the arterial roads typically had wider lanes (3.9 m) compared to collectors (3.5 m) and locals (3.2 m).

As far as road gradient was concerned, arterial roads were relatively steeper than the other two classes with an average of 12.4% compared to 2.4% of collectors and 2.1% of local roads. Arterial also had relatively higher average number of lanes of 2.8 m compared to 2.3 m and 2.1 m of collector and local roads respectively.

TABLE 7.3 ROAD GEOMETRY PARAMETERS

Parameters	Road Class	Average	St. Deviation	Range
Road width, in metres	Arterial	10.3	2.2	8-13
	Collector	7.9	2.3	5-12
	Local	6.7	1.9	4-12
	All	7.9	2.5	4-13
Gradient, in %	Arterial	12.4	8.3	1.5-25
	Collector	2.4	4.5	0-15
	Local	2.1	3.9	0-14
	All	4.6	6.8	0-25
No. of lanes	Arterial	-	-	2-4
	Collector	-	-	2-4
	Local	-	-	2-3
	All	-	-	2-4
Lane width, in metres	Arterial	3.9	0.7	3.0-5.1
	Collector	3.5	0.7	2.5-5.0
	Local	3.2	0.5	2.0-4.0
	All	3.4	0.7	2.0-5.1

7.2 Analysis of Environmental Data

This section describes the analysis of various environmental factors considered in the study. The natures of the data are described and the calculation explained. Using the prediction models of the environmental factors estimated values were determined. The values were then used for subsequent calibration process by comparing measured and predicted values.

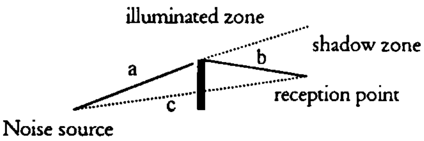
Department of Transport (1998) was used to predict the noise level, while for air pollution a model developed by Chock (1978) of General Motors (GM) was employed. For pedestrian delay, a revised Adam's delay model as proposed by Austroads (1994) was used, and for accident risk prediction, the model developed by Zeeger (1984) was adopted.

7.2.1 Noise

Noise data measured by a sound level meter were directly recorded and entered into spreadsheet files. The complete collection of the data has been documented in Appendices D and E. Further processing were simply not required for this sort of data since the raw data were already in required format of noise indices such as L_{10} and L_{eq}.

In applying the prediction model, the calculation procedure set out in Table 7.4 was utilised (DoT, 1988). Firstly, the basic noise level was calculated, and then the correction factor for speed (*s*, in kph) and proportion of heavy vehicles (*p*, in %) was applied.

TABLE 7.4 CALCULATION OF ROAD TRAFFIC NOISE (DOT, 1988)

Parameters	Equation/correction	unit
Basic noise level	$L_{10\text{-}1hour} = 41.2 + 10\log q$	q = total hourly volume in vehicles per hour
Speed and proportion of H V	$33\log(s+40+500/s)+10\log(1+5p/s)-68.8$	s= average speed, km/h p= proportion of heavy vehicles, %
Road gradient	$0.3*G$	G = road gradient, %
Distance • hard ground • grass land:	$-10\log(d'/13.5)$ $-10\log(d'/13.5)+5.2\log[3h/(d+3.5)]$ for $1 \le h \le (d'+3.5)/3$ $-10\log(d'/13.5)$ for $h > (d'+3.5)/3$. $d'=((d+0.5*W)^2+(h-0.5)^2)^{0.5}$	d = distance from road edge, m h = height of recipient from the ground, m W = total road width, in m
noise barrier	$-15.4 - 8.26x - 2.787x^2 - 0.831x^3 - 0.198x^4 + 0.1539x^5 + 0.12248x^6 + 0.02175x^7$ for recipient within the shadow zone area, or $0.109x-0.815x^2+0.479x^3-0.3284x^4+0.04385x^5$; for recipient in the illuminated zone. Where: $x = \log\delta$ where $\delta = a+b-c$	
angle of view	$10\log(\theta/180)$	θ = angle of view
Surface type	Chip Seal +3.0 Portland Cement Concrete +1.0 Dense Graded Asphaltic Concrete -1.0 Open Graded Asphaltic Concrete -5.0	dB(A)
Reflection Effects	Free field 0 1m in front of building facade +2.5 Where there is a continuous wall on opposite side of road +1.0	dB(A)

In the original the DoT model regarding the distance effect, the formula is written as:

$$-10\log(d'/13.5), \qquad 7.1$$

where $d' = ((d+3.5)^2+(h-0.5)^2)^{0.5}$, d = distance of recipient from road edge, and h = the height of recipient above the ground.

The source is assumed to be located at a line with 0.5m above the ground (probably the average centre of gravity of vehicles) and 3.5m from road edge (assumed as the distance from the road edge to the centerline or half the width). In the case that the effective road width is 7m this equals to 3.5m. Based on the assumption, the formula is then can be rewritten as:

$$d^{*}=((d+0.5*W)^2+(h\text{-}0.5)^2)^{0.5} \qquad 7.2$$

where: d = distance from the edge of near side carriage-way (m);

W = carriageway width (m);

h = height of receiver above ground (m).

Examples of the calculations to predict traffic noise level in this study are demonstrated in Table 7.5 below. Using relevant parameters as required in the model and that had been observed in the field, basic noise level can then be calculated and corrections applied. As there was no single site with noise barrier and the noise was directly measured from a point 5m from road edge, there were no noise barrier and angle correction applied. Distance correction was all applied for hard ground condition, as there was no soft ground observed. Complete calculations are available in Appendices D and E.

TABLE 7.5 EXAMPLE OF CALCULATION OF NOISE LEVEL

	Parameters	Values/Data			
Measured	SiteNo	ac01	ac02	cm02	lc04
	LinkName	Setiabudi	Suci	Gandapura	Suryani
	Road Class	arterial	arterial	collector	local
	Pavement	AC	AC	AC	CS
	Reflection	free	1m facade	1m facade	wall opp.
	Road width, m	13	8	6.5	12
	Grad, %	15	1.7	1.5	0
	Volume, vphl	2827	2880	980	354
	%HV, %	3%	2%	1%	1%
	Speed, km/h	27	22	32	31
	Measured L10-1hr	77.6	76.0	71.7	68.7
Predicted	Basic L10, dB(A)	76.7	76.8	72.1	67.7
	Correction1 (S,p)	-3.2	-3.8	-4.4	-4.2
	Correction2 (G)	4.5	0.5	0.5	0.0
	Correction3 (d)	0.7	1.7	2.1	0.9
	Correction4 (pav.)	-1.0	-1.0	-1.0	3.0
	Correction5 (refl.)	0.0	2.5	2.5	1.0
	L10-predicted	77.6	76.8	71.8	68.3
Difference	Measured-Predicted	0.0	-0.8	-0.1	0.4

Calculated $L_{10\text{-}1hour}$ noise levels were then compared with the measured values and the resulting average difference was a calibration factor subsequently applied for predicting noise levels in the study area. Statistical summary of the calculations is presented in Table 7.6. The result was used for calibrating the model as will be addressed in Chapter 8.

TABLE 7.6 SUMMARY STATISTICS OF NOISE LEVEL CALCULATIONS

	Statistics				95% Interval	
Parameters	Mean	Min	Max	St. Deviation	Lower	Upper
L10 (measured)	72.3	65.1	77.6	3.8	64.6	80.0
Leq (measured)	69.6	61.7	76.0	3.9	61.8	77.5
Basic L10	72.1	64.9	77.2	3.6	64.9	79.2
Correction1	-5.5	-7.6	-3.6	0.8	-7.2	-3.9
Correction2	1.4	0.0	7.5	2.0	-2.7	5.4
Correction3	1.8	0.7	2.8	0.6	0.6	2.9
Correction4	-0.2	-1.0	3.0	1.6	-3.4	3.0
Correction5	2.2	0.0	3.5	1.0	0.3	4.1
Predicted L10	71.7	63.8	78.4	3.8	64.0	79.4
Measured-Predicted L10	0.6	-3.1	3.8	1.5	-2.4	3.6

7.2.2 Air Pollution

Air pollution data were measured using equipment that automatically analyzed the air pollutants and provided information of their hourly average concentrations in part-per-billion (ppb). The values were then converted into mg/m³ to conform to the unit the GM model used. This was done by applying a conversion factor to each air pollutant.

TABLE 7.7 CONVERSION FACTORS BETWEEN VOLUME AND MASS UNITS OF CONCENTRATION (25°C,760 MM HG)

	To convert from	
Pollutant	ppm to	mg/m³ to ppm
Ammonia (NH_3)	0.695	1440
Carbon dioxide (CO_2)	1.800	560
Carbon monoxide (CO)	1.150	870
Chlorine	2.900	340
Ethylene	1.150	870
Hydrogen Chloride	1.490	670
Hydrogen Fluoride	0.820	1220
Hydrogen sulfide	1.390	720
Methane (carbon)	0.655	1530
Nitrogen dioxide (NO_2)	1.880	530
Nitric oxide (NO)	1.230	810
Ozone	1.960	510
Peroxyacetylnitrate	4.950	200
Sulfur dioxide	2.620	380

Source: Boubel, *et.al* (1994), Table 2-3 p.23

Beside the measured concentration, several traffic parameters such as traffic volume q, average speed S, percent heavy vehicles HV, and road direction RD were also required. Furthermore some meteorological data such as wind speed WS, wind direction WD and atmospheric temperature T were also needed.

The GM model suggests using the formula in Eqn. 7.3 for predicting concentration of any air pollutant from a line source.

$$C(x,z)=\frac{Q}{\sqrt{2\pi}U\sigma_z}\left\{\exp\left[-\frac{1}{2}\left(\frac{z+h_0}{\sigma_z}\right)^2\right]+\exp\left[-\frac{1}{2}\left(\frac{z-h_0}{\sigma_z}\right)^2\right]\right\} \quad 7.3$$

where:

$C(x,z)$ = concentration at point (x,z) relative to the line source at x=0, in g/m^3;

Q = emission rate per unit length, in g/km;

U = effective cross wind, in ms^{-1};

h_0 = plume center height at distance x from the road, in m;

σ_z = vertical dispersion parameter;

$$\sigma_z = (a+bf(\theta)x)^c \quad 7.4$$

$$f(\theta)=1+\beta\left|\frac{\theta-90°}{90°}\right|^\gamma \quad 7.5$$

θ = wind angle relative to the roadway, in degrees.

a,b,c,α,β and γ are parameters determined from atmospheric stability conditions. The suggested values for stable, neutral and unstable conditions are as provided in Table 7.8. There stability was determined using Richardson number Ri, which suggests that Ri>0.07 as stable, 0.07 ≥ Ri ≥ -0.1 as neutral and Ri ≤ -0.1 as unstable conditions.

TABLE 7.8 PARAMETERS VALUES OF AIR POLLUTION MODEL

Parameters	Stable (Ri>0.07)	Neutral (0.07 ≥ Ri ≥ -0.1)	Unstable (Ri ≤ -0.1)
a	1.49	1.14	1.14
b	0.15	0.10	0.05
c	0.77	0.97	1.33
α	20.7	11.1	11.1
β	5.82	3.46	3.46
γ	3.57	3.50	3.5
U_1	0.18	0.27	0.27
U_0	0.23	0.38	0.63

Note: a in m$^{1/c}$, b in m$^{-1+1/1}$, U_1 and U_0 in ms^{-1}
Source: Chock, 1978

The formulae in Eqns. 7.6, 7.6, 7.8 and 7.9 were used to estimate the average hourly emissions of the pollutants Q (Johnson, 1980):

$CO = 662*S^{-0.85}$ g/km for light vehicles 7.6

$CO = 1220*S^{-0.85}$ g/km for heavy vehicles 7.7

(Taylor and Anderson,1982)

HC = 0.6+34/S g/km 7.8

NOx =2.5 g/km 7.9

where S is the vehicle speed in km/h.

Consequently, an algorithm for determining the predicted concentration of air pollutant could then be summarized as depicted in Figure 7.1. In the present study concentration was typically measured at a position of about 3 metres from the road edge and 1.5 metres above the ground. So, in this case the values of x and z were typically 3 and 1.5 respectively. The wind speed was typically measured at an elevation of 10 metres above the ground. As this was different from what the GM model did at 4.5 metres, it should be corrected by a simple following power law (Stern, 1976):

$$\log(WS'/WS) = (1/N) \log (z/z_0) \quad 7.10$$

where z_0 was the height at which the wind speed WS was measured, and N was a constant which was equal to 4.5 for towns and city outskirts as suggested by Wang and Liu (1980). So, it was then possible to convert the wind speed measured at 10m into an equivalent 4.5m height magnitude.

Chock (1978) suggests using the Richardson number Ri to determine the atmospheric stability. Unfortunately, it was not possible to determine Ri as the required parameters was not available. Alternatively, the stability was determined using Pasquill Stability Categories (Boubel, 1994), based on the combination wind speed and atmospheric conditions. Table 7.9 shows the various stability classes according to the method.

TABLE 7.9 PASQUILL ATMOSPHERIC STABILITY CLASSES

Surface Speed	Day Insolation			Night	
Wind	Strong	Moderate	Slight	Thinlyovercast	<3/8 cloud
<2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

Notes: Source Boubel (1994, p. 302), Zannetti, 1990)

1. A, very unstable; B, unstable, C, slightly unstable; D, neutral; E, slightly stable; F, stable.
2. Strong insolation corresponds to sunny midday in midsummer in England, slight insolation to similar conditions in midwinter.
3. Night refers to the period from 1 hr before sunset to 1 hr after sunrise
4. The neutral category D should also be used, regardless of wind speed, for overcast conditions during day or night and for any sky conditions during the hour preceding or following night as defined above.

can then be used for calibrating the model as will be addressed in Chapter 8.

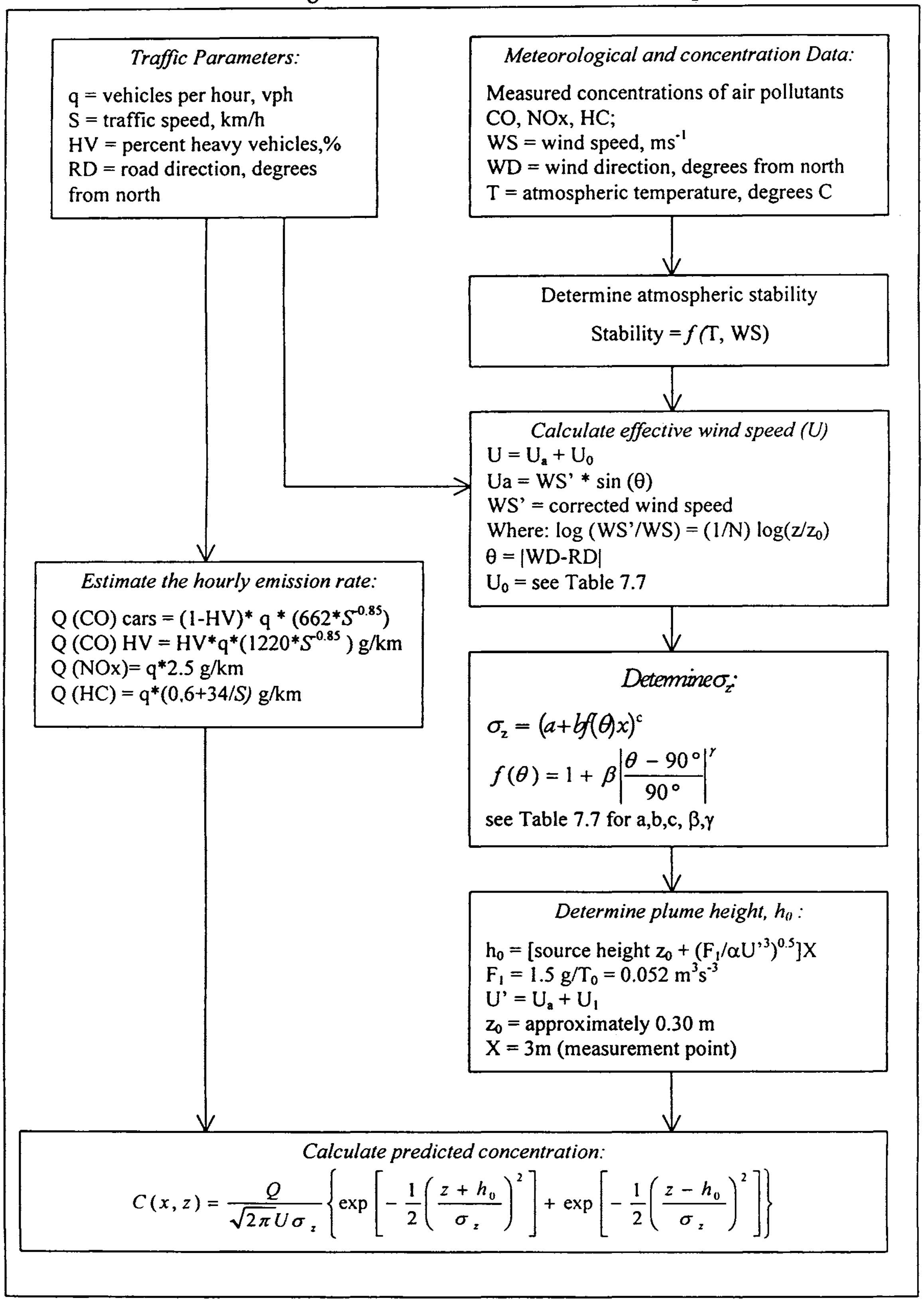


FIGURE 7.1 ALGORITHM OF PREDICTING POLLUTANT CONCENTRATION
(Source: based on Chock, 1978)

Table 7.10 provides the measured and observed values of air pollution related parameters. They include data on traffic, meteorological as well as air pollutant concentrations. From these data, as has been explained earlier, the predicted values of the concentrations could then be calculated. Results of the calculations are as shown in the subsequent Tables 7.11 and 7.12. The difference and ratio between predicted and observed values were also calculated to provide information on how well the prediction has performed. These results

TABLE 7.10 OBSERVED AIR POLLUTION RELATED PARAMETERS

	Traffic				Meteorology			Concentrations, ppm		
LinkName	Vol	%HV	Speed	RD	WS	WD	Temp	NOx	CO	HC
Setiabudi	2853	4%	26	7.0	3.0	101.2	27.0	0.111	4.041	3.630
Setiabudi	2827	3%	27	7.0	3.0	101.2	25.0	0.128	4.350	3.017
Suci	1880	1%	24	90.0	8.0	101.2	31.0	0.029	1.415	2.503
Suci	2799	2%	22	90.0	4.0	78.8	31.0	0.039	1.067	-
Ramdhan	2722	3%	34	50.0	8.0	326.2	33.0	0.074	3.228	4.435
Ramdhan	1835	3%	32	50.0	8.0	326.2	31.0	0.087	4.051	4.078
Sukajadi	1587	1%	40	177.0	2.0	191.2	30.0	0.014	3.431	4.002
Sukajadi	1858	2%	38	177.0	2.0	191.2	28.0	0.014	2.006	3.181
Cipaganti	2193	2%	40	5.0	1.0	326.2	31.0	0.249	6.300	5.069
Cipaganti	2168	2%	38	5.0	2.0	303.8	29.0	0.221	6.177	4.061
Dipati Ukur	2148	1%	32	152.0	1.0	348.8	30.0	0.124	4.646	4.130
Dipati Ukur	2403	1%	34	152.0	1.0	348.8	28.0	0.100	4.690	3.384
Gandapura	980	1%	32	14.0	1.0	326.2	32.0	0.047	2.296	-
Gandapura	901	1%	32	14.0	1.0	326.2	32.0	0.055	3.230	2.534
Burangrang	1894	1%	31	10.0	1.0	236.2	30.0	0.025	1.054	2.777
Burangrang	2028	0%	31	10.0	1.0	236.2	30.0	0.038	2.237	2.327
Reog	455	1%	26	12.5	1.0	213.8	31.0	0.044	1.268	2.651
Reog	470	1%	30	12.5	1.0	213.8	30.0	0.044	1.381	2.319
Purwakarta	917	1%	37	140.0	2.0	348.8	34.0	0.695	4.510	5.070
Purwakarta	989	1%	36	140.0	2.0	348.8	33.0	0.239	6.351	5.069
Purwakarta	868	1%	36	140.0	2.0	348.8	31.0	0.058	5.156	5.052
Selontongan	610	0%	24	20.0	2.0	101.2	31.0	0.023	1.558	3.144
Selontongan	534	0%	25	20.0	2.0	101.2	30.0	0.026	2.044	2.672
Suryani	354	1%	31	166.5	0.0	348.8	31.0	0.034	1.603	5.070
Suryani	346	1%	29	166.5	0.0	348.8	30.0	0.026	2.526	1.975
Mean	1545	1.4%	31.5	73.1	2.4	249.8	30.4	0.102	3.225	3.572
St. Deviation	863	1.0%	5.2	68.5	2.3	102.1	1.9	0.141	1.716	1.039

Note: Traffic volume in vph, %HV=percent heavy vehicles, Speed in km/h, RD=Road direction in degrees from north, WS=wind speed in ms^{-1}, WD=wind direction in degrees from north, Temperature in centigrade, - = missing data

TABLE 7.11 SUMMARY RESULTS OF THE PREDICTED NOX CONCENTRATIONS

LinkName	Stability	Volume	NOx concentrations g/m^3			
			Observed values	Predicted values	Observed-Predicted	Predicted/ Observed
Setiabudi	Unstable	2853	0.22	0.19	0.03	0.85
Setiabudi	Unstable	2827	0.26	0.20	0.05	0.79
Ramdhan	Neutral	1722	0.15	0.05	0.10	0.36
Ramdhan	Neutral	1835	0.17	0.06	0.12	0.32
Sukajadi	Unstable	1587	0.03	0.31	-0.28	11.00
Sukajadi	Unstable	1858	0.03	0.36	-0.33	12.87
Cipaganti	Unstable	2193	0.50	0.43	0.07	0.86
Cipaganti	unstable	2168	0.44	0.23	0.21	0.53
Dipati Ukur	unstable	2148	0.25	0.50	-0.25	2.02
Dipati Ukur	unstable	2403	0.20	0.56	-0.36	2.81
Gandapura	unstable	980	0.09	0.18	-0.08	1.90
Gandapura	unstable	901	0.11	0.16	-0.05	1.49
Burangrang	unstable	2028	0.08	0.37	-0.30	4.91
Reog	unstable	455	0.09	0.10	-0.01	1.17
Reog	unstable	470	0.09	0.11	-0.02	1.21
Purwakarta	unstable	917	1.39	0.14	1.25	0.10
Purwakarta	unstable	989	0.48	0.15	0.33	0.32
Purwakarta	unstable	868	0.12	0.13	-0.02	1.15
Selontongan	unstable	610	0.05	0.06	-0.01	1.31
Selontongan	unstable	534	0.05	0.05	0.00	1.02
Suryani	unstable	354	0.07	0.09	-0.02	1.30
Suryani	unstable	346	0.05	0.09	-0.03	1.67
				mean	0.02	2.27
				st. dev.	0.33	3.30
				max	1.25	12.87
				min	-0.36	0.10
				no. of observation	22	22

TABLE 7.12 SUMMARY RESULTS OF THE PREDICTED CO CONCENTRATIONS

LinkName	Stability	Volume	CO concentrations Observed values	Predicted values	Observed-Predicted	Predicted/Observed
Setiabudi	Unstable	2853	4.62	3.26	1.36	0.71
Setiabudi	Unstable	2827	4.97	3.34	1.63	0.67
Ramdhan	neutral	1722	3.69	0.74	2.94	0.20
Ramdhan	neutral	1835	4.63	0.84	3.79	0.18
Sukajadi	unstable	1587	3.92	3.58	0.34	0.91
Sukajadi	unstable	1858	2.29	4.40	-2.11	1.92
Cipaganti	unstable	2193	7.20	5.01	2.19	0.70
Cipaganti	unstable	2168	7.06	2.86	4.20	0.40
Dipati Ukur	unstable	2148	5.31	7.05	-1.74	1.33
Dipati Ukur	unstable	2403	5.36	7.49	-2.13	1.40
Gandapura	unstable	980	2.62	2.49	0.13	0.95
Gandapura	unstable	901	3.69	2.29	1.40	0.62
Burangrang	unstable	2028	2.56	5.36	-2.80	2.10
Reog	unstable	455	1.45	1.72	-0.27	1.19
Reog	unstable	470	1.58	1.57	0.00	1.00
Purwakarta	Unstable	917	5.15	1.75	3.41	0.34
Purwakarta	Unstable	989	7.26	1.93	5.33	0.27
Purwakarta	Unstable	868	5.89	1.69	4.20	0.29
Selontongan	Unstable	610	1.78	1.07	0.71	0.60
Selontongan	Unstable	534	2.34	0.91	1.43	0.39
Suryani	unstable	354	1.83	1.28	0.56	0.70
Suryani	unstable	346	2.89	1.32	1.56	0.46
				mean	1.19	0.79
				st.dev	2.23	0.53
				max	5.33	2.10
				min	-2.80	0.18
				no. of observation	22	22

7.2.3 Pedestrian Delay

A well known model for predicting pedestrian delay and percent of delayed pedestrian is basically the Adam's delay model (1936), which was the earliest attempt to relate pedestrian delay to traffic flow rate. The model proposed the following relationship between traffic volume and average delay to pedestrian:

$$d = 1/q\,(e^{q\alpha} - q\alpha - 1) \qquad 7.10$$

$$p = 1 - e^{-q\alpha} \qquad 7.11$$

where:

d = average delay to all pedestrian crossing the road, in second;

q = traffic volume, in vehicle per second;

α = the critical gap or the minimum headway of traffic that pedestrian will accept to cross, in second;

p = proportion or percent of delayed pedestrian.

In the present study, a modified model as proposed by Holdswoth and Singleton (1979) which include the road width in the model was evaluated. They simply assign the critical gap α into reaction time (R), time lag (L) and crossing time that equals road width (W) divided by walking speed. The equation would then become:

$$d = 1/q\,[e^{q(R+L+W/1.22)} - q\,(R+L+W/1.22) - 1] \qquad 7.12$$

$$p = 1 - e^{-q(R+L+W/1.22)} \qquad 7.13$$

As an alternative, another model as proposed by Austroads (1995) was employed. The model uses the following equations to predict average delay (d) and percent pedestrian delayed (p):

$$d = \frac{e^{-\lambda(t_c - t_m)}}{(1-\theta)q} - t_c - \tfrac{1}{\lambda} + \frac{(2\lambda t_m^2 - 2t_m\theta)}{2(\lambda t_m - 1 - \theta)} \qquad 7.14$$

$$p = 1 - (t_m q - 1)e^{-\lambda(t_c - t_m)} \qquad 7.15$$

$$\lambda = \frac{(1-\theta)q}{(1-t_m q)} \qquad 7.16$$

$$\theta = 1 - e^{-2.75 t_m q} \quad 7.17$$

where:

t_m=2/(number of lanes);

t_c =crossing time = (road width)/2.2, in second;

q = vehicles per hour.

So, it was desirable to compare these two models using the same data collated in this study. Table 7.13 provides summary figures of measured and predicted values of pedestrian delay for both models. The figures suggest that model2 (Austroads, 1995) outperformed model1 in predicting the percent delayed pedestrian as well as average delay. The accuracy of the prediction also shows that model2 explains pedestrian delay parameters better than model1. It was therefore decided to use the second model for conditions as in the present study.

TABLE 7.13 PEDESTRIAN DELAY MODELS PERFORMANCES

Model	Parameters	Measured	Predicted	Residual	St.dev.	Max	Min
Model1	% delayed	0.28	0.70	-0.41	0.19	-0.06	-0.95
	Ave. Delay	2.40	36.86	-34.46	41.45	-0.20	-145.93
Model2	% delayed	0.28	0.34	-0.06	0.16	0.25	-0.58
	Ave. Delay	2.40	1.93	0.47	2.42	10.16	-4.39

Note: Model1 – Holdsworth and Singleton (1979), Model2 – Austroads. (1995), average delay in second; residual – measured-predicted values

7.2.4 Accident Risks

The model for predicting accident rate was a model proposed by Zeeger et.al (1986). As described in Highway Safety (1988), the form of the model is as follows:

$$AO/M/Y = 0.0076\ (ADT)^{0.8545}\ (0.8867)^{W}\ (0.8922)^{PA}\ (0.9098)^{UP}\ (0.9715)^{RECC}\ (0.8182)^{TER1}\ (0.270)^{TER2} \quad 7.18$$

Where

AO/M/Y = single vehicle, head-on, and sideswipe accidents per mile per year

ADT = average daily traffic

W = lane width, in ft.

PA = average paved shoulder width, in ft;

UP = average shoulder width (may include gravel, stabilized earth or grass shoulder width), in ft;

RECC = median recovery distance, in ft (measured from edge of shoulder);

TER = general terrain descriptor where:

TER1 = 1 if flat, 0 if otherwise

TER2 = 1 if mountainous, 0 if otherwise

(for rolling terrain TER1=TER2=0)

The metric version of the model was as follows:

$$AO/M/Y = 0.00472\ (ADT)^{0.8545}\ (0.8867)^{W}\ (0.8922)^{PA}\ (0.9098)^{UP}\ (0.9715)^{RECC}\ (0.8182)^{TER1}\ (0.270)^{TER2} \quad 7.19$$

The model was actually designed for two-lane rural roads with an average daily traffic of 100-10000, lane width of 8-12 feet and shoulder width of 0-12 feet either paved or unpaved. Conditions in the present study might not satisfy the criteria, but it was still desirable to give the model a try. For comparison purposes, it was also desirable to develop a multivariate regression model using the data in the present study. The proposed form of the model was:

$$A = k\,L\,T\,Q^{\alpha}\,S^{\beta}\,W^{\gamma}\,Lu^{\delta}\,Lw^{\varepsilon}\,G^{\phi} \qquad 7.20$$

Where:

A = number of accidents happened during time period T years, T.≥1;

T = time period years concerned;

L = length of the associated link in km;

Q = average daily traffic ≈ 9-10 times of average hourly traffic, in vehicles per day;

S = average travel speed, in km/h;

W = carriageway width, in metres;

Lu = type of landuse, 1=commercial, 2 = residential;

Lw = lane width, in metres;

G = road gradient, in %.

k, α, β, γ, δ, ε, and ϕ are constants to be determined.

The form was chosen based on such reasons as to ensure that zero accident happens at zero traffic volume and speed. It also allows the relationship between accidents, and road geometric to be linear without necessarily forcing to be so. The model also shows that proportional relationship occurs between accident and associated time period and road length.

The linear form of the model could then be obtained by transforming the equation into logarithmic scale, which then becomes:

$$\ln A = \ln k + \ln L + \ln T + \alpha \ln Q + \beta \ln S + \gamma \ln W + \delta \ln Lu + \varepsilon \ln Lw + \phi \ln G \qquad 7.21$$

or:

$$\ln (A/L/T) = \ln k + \alpha \ln Q + \beta \ln S + \gamma \ln W + \delta \ln Lu + \varepsilon \ln Lw + \phi \ln G \qquad 7.22$$

which could be treated as a linear multivariate regression model with dependent variable ln(*A/L/T*) and independent variable lnQ, lnS, ln*Lu* and ln*Lw*. The constant and coefficients to be determined would then include lnk, $\alpha,\beta,\gamma,\delta,\varepsilon$ and ϕ.

Regression analysis applying this model on the available data suggested the following results. A multivariate regression model with R^2 value of 0.67 was obtained. The statistics also suggest that the model was significant at 71% level (see Table 7.14). The calibrated coefficients of the model are as presented in Table 7.15. By substituting the figures, the accident rate prediction model could then be written as:

$$A/L/T = 1.665\, Q^{-2.19}\, S^{4.04}\, W^{2.05}\, Lu^{-3.20}\, Lw^{2.52}\, G^{0.34} \qquad 7.23$$

Where *A/L/T* = accident rate, in accident per km per year.

TABLE 7.14 STATISTICS OF REGRESSION ANALYSIS OF ACCIDENT RATE MODEL

Regression Statistics		*ANOVA*					
Multiple R	0.82		*df*	*SS*	*MS*	*F*	*Significance F*
R^2	0.67	Regression	6	4.624	0.771	1.700	0.289
Standard Error	0.67	Residual	5	2.267	0.453		
Observations	12	Total	11	6.891			

TABLE 7.15 COEFFICIENT OF PARAMETERS

Parameters	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*95% C.I.*	
					Lower	*Upper*
ln*k*	0.51	12.67	0.04	0.97	-32.07	33.08
Q	-2.19	1.23	-1.78	0.14	-5.34	0.97
Lw	2.52	1.52	1.66	0.16	-1.39	6.42
G	0.34	0.28	1.21	0.28	-0.38	1.05
S	4.04	2.67	1.51	0.19	-2.83	10.90
W	2.05	1.36	1.51	0.19	-1.44	5.54
Lu	-3.20	1.49	-2.15	0.08	-7.04	0.63

Application of both models towards the data in this study suggests the following outcomes. The average difference between predicted and observed values (residual) for Zeeger model was 0.26 compared to 0.11 of the model developed in the present study. Variability of the residual also shows that the later (s.d. of residual = 0.62) was more accurate than the earlier model. (s.d. = 1.21). The range of values also supports this claim (see Table 7.16).

TABLE 7.16 COMPARISON BETWEEN ACCIDENT RATE PREDICTION MODELS

Author	Average values of				
	Observed accident rate, acc/km/y	Predicted accident rate, acc/km/y	Residual= pred.-obs	St.dev. of residual	Range value of residual
Zeeger, et.al, 1988	0.70	0.96	0.26	1.21	-2.50 - 2.67
Widiantono, 1999	0.70	0.81	0.11	0.62	-0.88 - 1.75

7.3 Analysis of Preferential Data

Analysis towards the preferential data was more complex than the previous ones. This was particularly because in this part there were three types of data that required different kinds of treatment. Firstly was the data on ranking that needed to be treated as ordinal data. Secondly was the data on direct rating towards the environmental factors, which was data of the interval type. Finally was the pair-wise comparison data that needed a special method called analytical hierarchy process (AHP) to analyze. All of them were expected to produce weights for environmental factors, and it was desirable to compare one another to know which one is the better method in this case.

Furthermore, at this stage the hypothesis regarding the categorization of the model that was put forward in the earlier part of the study needs to be proved. This hypothesis testing was done using relevant statistical tests according to the literature.

The following sections describe the techniques used in analyzing the data of the above methods and show the typical calculation example and its brief results. Details of the results can be observed in Appendix F.

7.3.1 Analysis of Ranking Data

One of the survey outcomes discussed in the previous chapter was the ranking of environmental factors. These rankings were set by all respondents in order to show their preferences towards the factors. A non-parametric method concerning m rankings was used to investigate the general relationship between the rankings.

Kendall (1975, pp. 94-106) provides a method of doing such an analysis. He proposed a *coefficient of concordance*, W, to measure the commonality of judgments among the m respondents. The coefficient W will equal to unity if all of the respondents agree and becomes zero if they differ very much among themselves.

If S represents the sum of squares of the actual deviations from the mean value, Kendall defines the coefficient as:

$$W=12*S/m^2(n^3-n) \qquad 7.24$$

where:
m= number of respondents; and
n = number of factors to be ranked.

As an illustration, let there were four respondents who rank six given attributes as in Table 7.17.

TABLE 7.17 RANKING DETERMINATION EXAMPLE

	Factor			
Respondent	Noise	Airpol	Pedest	Accid.
R1	3	2	1	4
R2	2	3	1	4
R3	4	1	2	3
R4	4	3	2	1
Total ranks	13	9	6	12

Average value of the sum was equal to $1/2m(n+1)$ which was equal to 10 in the above example. The deviation was 3, -1, -4, 2, for attribute Noise, Air pollution, Pedestrian, and Accident factor respectively which result in S equals to 30. The coefficient of concordance W could then be determined as:

$$(12*30) / 4^2(4^3 - 4) = 0.375 \qquad 7.25$$

As previously mentioned, this value of W only represents the community preference within a group of observers. There was no statistical tool available so far to test the significance of the difference between sets of rankings from different groups of observers (Kendall, 1975 pp.102-103). Suppose that 10 experts and 12 people in the community each rank 4 different environmental factors, and the resulting values of W were 0.5 and 0.7 for experts and the people respectively. This only shows that the community has a greater commonality in their preference than the experts.

Testing of Significance

In testing the significance of an observed value of W, Kendall suggests to use one of two methods used to approximate the distribution of W: (1) Fisher's z-distribution, (2) χ^2 distribution.

For Fisher's z-distribution,

$$z = 1/2\ln((m-1)W/(1-W)) \quad 7.26$$

$$\nu_1 = n - 1 - 2/m \quad 7.27$$

$$\nu_2 = (m - 1)\nu_1 \quad 7.28$$

The observed z may then be tested against theoretical value using tables of Fisher's distribution with 'degree of freedom' ν_1 and ν_2.

For Chi-square distribution,

$$\chi^2 = m(n - 1)W \quad 7.29$$

The observed value of χ^2 can be tested against theoretical value using tables of χ^2 with degree of freedom, $\nu = n - 1$.

Estimation of Rankings

After finding that the value of W is significant, it was interesting to know which one was the true ranking of the attributes or which ranking is the best estimate of the true ranking of factors. The best way of doing this, as suggested by Kendall, was to rank the factors according to their sums of allotted ranks. That factor with the least total was ranked first, the next lowest was ranked second, and so on. This method give smaller value of sum of squares as well as larger Spearman's ρ compared to any other possible methods (see Kendall, 1975 pp. 107-122).

Calculation Example

1. Calculate the frequency distribution of ranking for each attribute for every group of respondent.
2. Calculate the mean value of all $\Sigma x.f(x)$ of attributes.
3. Calculate the deviation $d_i = (\Sigma x.f(x))_i$ - mean.
4. Calculate the square value of $d_i - d_i^2$
5. Calculate $S = \Sigma d_i^2$
6. Calculate the Kendall W coefficient = $12 \times S/m^2(n^3-n)$,where m = number of respondent ($\Sigma f(x)$), and n = number of factor.

Factors	Σx.f(x)	d_i	d_i^2
Noise	79	-101	10201
Air Pollution	145	-35	1225
Pedestrian Delay	168	-12	144
Accident	214	34	1156
Other	294	114	12996
Mean	180	S	25722
		W	0.71
		Chi-sq	171.48

7. Test the significance of W using χ^2 value = m(n-1)W, against χ^2 for ν = n-1 = 5 -1 = 4. For α = 0.01 $\chi 2$ = 13.28.
8. From the observed value we obtain $\chi 2$ = 171.48 which is > 13.28, means that W value is significant at 0.01 level.
9. Finally determine the estimate ranking of variables by simply sorting the Σx.f(x) in ascendant order (the smaller the value the highest the ranking).

The summary result of the rest calculation is presented in Table 7.18. Note that scores can only be compared within a group of respondents, which is across rows. Comparison between groups of respondents, which is across columns, is invalid due to varying numbers of respondents in each group (See, Siegel, 1956, pp. 229-239).

TABLE 7.18 RANKING OF ENVIRONMENTAL FACTORS BY CATEGORIES

Categories	Environmental Factors					Rank	Kendall *W*	Chi-sq.
	Number of cases	Noise	Air Pollution	Pedestrian	Accident Risk			
Arterial-Commercial	7	7	14	21	28	1234	1.00	21.00
Arterial-Mix	10	10	20	30	40	1234	1.00	30.00
Arterial-Residential	11	11	29	28	42	1324	0.80	26.45
Collector-Commercial	11	14	30	27	39	1324	0.53	17.51
Collector-Mix	7	9	12	23	26	1234	0.84	17.57
Collector-Residential	11	11	29	34	36	1234	0.64	21.22
Local-Commercial	17	18	35	50	67	1234	0.91	46.34
Local-Mix	21	24	42	58	66	1234	0.47	29.57
Local-Residential	13	17	28	35	50	1234	0.68	26.45
Arterials	28	28	63	79	110	1234	0.89	74.87
Collectors	33	40	79	98	113	1234	0.55	54.35
Locals	47	53	97	129	171	1234	0.68	95.43
Commercial	35	39	79	98	134	1234	0.77	80.52
Mix	38	41	77	111	131	1234	0.65	74.08
Residential	35	41	83	97	129	1234	0.65	68.49
All community	108	121	239	306	394	1234	0.68	220.74
Experts	25	68	49	63	66	4123	0.54	553.30

Note: Chi-sq. value for v=4-1=3 and 0.05 significance level is 7.815

Comparison between categories will be addressed in the hypothetical testing section. Level of annoyance of a factor under study was indicated by the order of rank in each column. The higher the rank (lower value) indicates greatest annoyance and vice-versa.

These ranks were then converted into weights using the method explained earlier in Chapter 3. The weights of the factors as suggested by the method are as presented in Table 7.19.

TABLE 7.19 WEIGHTS OF ENVIRONMENTAL FACTORS BASED ON RANKING

Categories	Weights of Environmental Factors			
	Noise	Air Pollution	Pedestrian	Accident Risk
Arterial-Commercial	0.06	0.15	0.27	0.52
Arterial-Mix	0.06	0.15	0.27	0.52
Arterial-Residential	0.06	0.27	0.15	0.52
Collector-Commercial	0.06	0.27	0.15	0.52
Collector-Mix	0.06	0.15	0.27	0.52
Collector-Residential	0.06	0.15	0.27	0.52
Local-Commercial	0.06	0.15	0.27	0.52
Local-Mix	0.06	0.15	0.27	0.52
Local-Residential	0.06	0.15	0.27	0.52
Arterials	0.06	0.15	0.27	0.52
Collectors	0.06	0.15	0.27	0.52
Locals	0.06	0.15	0.27	0.52
Commercial	0.06	0.15	0.27	0.52
Mix	0.06	0.15	0.27	0.52
Residential	0.06	0.15	0.27	0.52
All community	0.06	0.15	0.27	0.52
Experts	0.06	0.52	0.27	0.15

7.3.2 Analysis of Rating Data

For data on direct rating, analysis was done using ordinary parametric statistical method. The calculations were very straightforward in this case. Means or average value of every factor in each category was calculated using the formula below (Spiegel, 1992):

$$\bar{X} = \frac{X_1 + X_2 + X_3 + \cdots + X_N}{N} = \frac{\sum_{j=1}^{N} X_j}{N} = \frac{\sum X}{N} \qquad 7.30$$

Standard deviation denoted by s is defined as:

$$s = \sqrt{\frac{\sum_{j=1}^{N} (X_j - \bar{X})^2}{N}} = \sqrt{\frac{\sum (X - \bar{X})^2}{N}} = \sqrt{\frac{\sum x^2}{N}} = \sqrt{\overline{(X - \bar{X})^2}} \qquad 7.31$$

where x represents the difference between X_j and the mean $\bar{X}$. For normal distribution, the confidence interval can be expressed in terms of the standard deviation as follows :

- $\overline{X} \mp s$ includes around 68.27% of the cases;
- $\overline{X} \mp 2s$ includes around 95.45% of the cases; and
- $\overline{X} \mp 3s$ includes around 99.73% of the cases.

Calculations towards the direct rating data suggest the results as presented in Table 7.20

TABLE 7.20 RATING OF ENVIRONMENTAL FACTORS

Categories	Weight of Environmental Factors							
	Noise		Air Pollution		Pedestrian		Accident Risk	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Arterial-Commercial	75.00	10.41	58.21	14.34	60.00	15.75	46.07	15.27
Arterial-Mix	45.00	10.90	40.28	17.61	35.00	10.00	31.11	20.73
Arterial-Residential	70.45	8.20	46.36	13.62	50.45	9.86	25.91	8.31
Collector-Commercial	60.50	9.85	53.00	13.37	49.50	10.66	37.00	19.03
Collector-Mix	62.05	12.59	46.82	17.65	42.27	14.89	34.09	12.21
Collector-Residential	51.36	11.85	41.82	6.81	30.00	16.28	26.82	12.10
Local-Commercial	55.00	9.52	47.94	9.20	35.00	11.99	25.15	8.12
Local-Mix	55.67	13.07	44.00	15.26	35.33	17.57	21.67	12.77
Local-Residential	53.08	11.46	39.23	15.92	27.69	15.09	21.15	13.25
Arterials	63.15	16.18	47.41	16.24	47.78	15.01	32.87	16.77
Collectors	57.89	12.17	47.03	13.73	40.31	16.01	32.50	14.81
Locals	54.67	11.15	44.11	13.66	33.00	14.98	22.83	11.28
Commercial	60.74	12.26	51.54	12.00	44.41	15.84	32.94	15.68
Mix	54.93	13.70	43.93	16.33	37.43	15.07	28.00	15.63
Residential	58.00	13.46	42.29	12.91	35.57	17.10	24.43	11.49
All community	57.86	13.25	45.87	14.33	39.09	16.32	28.41	14.67
Experts	49.40	16.30	64.80	17.14	57.00	14.98	60.10	20.91

Actual weights of the factors were obtained by normalizing the rating values using the following formula which was simply the actual rating divided by the total ratings of all factors.

$$X_i'' = \frac{X_i}{\sum_{i=1}^{N} X_i} \qquad 7.32$$

where X_i'' is the normalized rating value of factor *i*. The calculated weights of environmental factors are as presented in Table 7.21.

TABLE 7.21 WEIGHTS OF ENVIRONMENTAL FACTORS BASED ON DIRECT RATING METHOD

Categories	Weights of Environmental Factors			
	Noise	Air Pollution	Pedestrian	Accident Risk
Arterial-Commercial	0.31	0.24	0.25	0.19
Arterial-Mix	0.30	0.27	0.23	0.21
Arterial-Residential	0.36	0.24	0.26	0.13
Collector-Commercial	0.30	0.27	0.25	0.19
Collector-Mix	0.33	0.25	0.23	0.18
Collector-Residential	0.34	0.28	0.20	0.18
Local-Commercial	0.34	0.29	0.21	0.15
Local-Mix	0.36	0.28	0.23	0.14
Local-Residential	0.38	0.28	0.20	0.15
Arterials	0.33	0.25	0.25	0.17
Collectors	0.33	0.26	0.23	0.18
Locals	0.35	0.29	0.21	0.15
Commercial	0.32	0.27	0.23	0.17
Mix	0.33	0.27	0.23	0.17
Residential	0.36	0.26	0.22	0.15
All community	0.34	0.27	0.23	0.17
Experts	0.21	0.28	0.25	0.26

Note: the total weights may not equal to 1.0 due to rounding

7.3.3 Pair-wise Comparison Data Analysis

Analytical Hierarchy Process (AHP), as introduced by Saaty (1980), is a mathematical method intended to enable decision makers in determining priority amongst several decision alternatives. The priority was based on their preferences towards the alternatives, and express in terms of weights.

The method, as described in earlier Chapter 3, employs pair-wise comparison approach in determining the weights of the alternatives or attributes of the decision. The input data were obtained by asking a series of questions to individuals or experts regarding their preferences between two attributes at a time. The preference was then recorded in a 9 point intensity scale as shown in Table 3.3 in Chapter 3. The information was then treated as a square matrix $A = \{a_{ij}\}$, for which a_{ij} is the intensity scale = w_i/w_j for all decision elements and $a_{ji} = 1/a_{ij}$

$$A = \begin{bmatrix} 1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & 1 & & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & 1 \end{bmatrix}$$

The matrix has a diagonal elements equal to unity, and the upper triangle elements are simply the reciprocal of the lower ones. To determine the weights of the n decision elements, the following calculation procedure as proposed in Saaty (1982, pp. 75-85) was done:

1. Determine matrix A^h for each individual/expert.
2. Determine matrix **A** of group of individuals/experts, with element a_{ij} equal to the geometric mean of all member of the group.

   $$a_{ij} = \left[\prod_{k=1}^{K} a_{ij}^{k} \right]^{1/K}$$

3. Obtain normalized matrix **A'** by dividing a_{ij} with the associate total of the column $\sum_{j=1}^{n} a'_{ij}$.
4. Calculate the average value of each rows of the normalized matrix, and obtain a column matrix W with $w_j = \frac{\sum_{i=1}^{n} a'_{ij}}{n}$. The elements of this matrix are simply the weights of the attributes concerned.

Consistency Index (CI) as a measure of the consistency in making the judgment on preferences, was determined using the following equation:

$$CI = (\lambda_{max}-n)/(n-1) \qquad 3.33$$

Where λ_{max} was the largest eigen value of the square matrix **A** and determined from the following relationship:

$$AW = \lambda_{max} W \qquad 3.34$$

λ_{max} could then be calculated by dividing elements in column matrix **AW** with corresponding elements in matrix W. The average value of λ_{max} was then used to determine CI.

Compare CI with Random Consistency Index obtained from RCI table below, and determine the Consistency Ratio (CR). CR value of 0.10 or less indicates good judgmental consistency of the group of individuals or experts.

n	1	2	3	4	5	6	7	8	9
RCI	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45

Source: Saaty, 1982, p.84.

Results of the calculations for various categories in this study are as shown in Table 7.22.

TABLE 7.22 RESULTS OF WEIGHTS CALCULATION BASED ON AHP METHOD

Categories	Weights of environmental factors using AHP				λ_{max}	CI	CR
	Noise	Air Pollution	Pedestrian	Accident Risks			
Arterial-Commercial	0.47	0.19	0.23	0.10	4.054	0.018	0.020
Arterial-Mix	0.42	0.27	0.20	0.11	4.029	0.010	0.011
Arterial-Residential	0.55	0.17	0.20	0.08	4.103	0.034	0.038
Collector-Commercial	0.46	0.25	0.18	0.11	4.020	0.007	0.007
Collector-Mix	0.50	0.22	0.17	0.11	4.006	0.002	0.002
Collector-Residential	0.47	0.25	0.17	0.12	4.032	0.011	0.012
Local-Commercial	0.44	0.32	0.15	0.09	4.040	0.013	0.015
Local-Mix	0.43	0.27	0.19	0.12	4.006	0.002	0.002
Local-Residential	0.47	0.26	0.16	0.11	4.028	0.009	0.010
Arterials	0.49	0.21	0.21	0.10	4.039	0.013	0.014
Collectors	0.48	0.24	0.17	0.11	4.008	0.003	0.003
Locals	0.45	0.29	0.17	0.10	4.018	0.006	0.007
Commercial	0.45	0.27	0.18	0.10	4.019	0.006	0.007
Mix	0.46	0.26	0.17	0.11	4.010	0.003	0.004
Residential	0.50	0.23	0.17	0.10	4.040	0.013	0.015
All community	0.47	0.25	0.18	0.10	4.016	0.005	0.006
Experts							

7.3.4 Tests of Hypotheses

Based on the above results testing of the statistical hypotheses could then be undertaken. In the present case it was desirable to test whether the weights of environmental factors in each category were indifferent between respondent categories. In terms of statistics, it was interesting to know whether the null hypothesis, that sample means were all equal for all categories, had to be accepted or rejected.

The method in doing so depended on the type of data. Table 7.23 indicates what the literature suggests for doing such a testing for different cases (Middleton, 1998).

TABLE 7.23 SUMMARY OF METHODS FOR TESTING MEANS

Type of Data	Two Samples		Three or more samples	
	independent	related	Independent	related
Interval	Independent t-test	Paired t-test	ANOVA	Repeated measures ANOVA
Ordinal	Mann-Whitney	Wilcoxon signed-rank	Kruskal-Wallis	Friedman
Nominal	Chi-squared	McNemar	Chi-square	Cochran's Q (binary only)

Source: Middleton, 1998

For the purpose of the study, it was decided to compare 2 categories at a time and conduct the significance test. As every category was composed of different respondents, it could be treated as independent two samples test. So, the appropriate methods as suggested by the table would be independent *t*-test for interval data (direct rating). For such ranking data as in this study, as indicated earlier (Kendall, 1975), there was no method available so far to do the significance test. Similar thing was also true for pairwise comparison data (AHP). Because of these reasons, comparisons between categories for both types of the data could not be performed.

The following steps were typical for a student *t* test:

1. $H_0 : \mu_1 = \mu_2$
2. $H_1 : \mu_1 \neq \mu_2$
3. Calculate *t*:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sigma\sqrt{1/N_1 + 1/N_2}} \qquad 7.35$$

where:

$$\sigma = \sqrt{\frac{N_1 s_1^2 + N_2 s_2^2}{N_1 + N_2 - 2}} \qquad 7.36$$

where $\overline{X}$ is mean value and *s* is standard deviation.

4. Using a two-tailed test at 0.05 significance level, if *t* was outside the range $-t_{.975}$ to $t_{.975}$ H_0 could then be rejected and it could be concluded that there was significant difference between the two groups. But, if t was within the range, H_0 could not be rejected at 0.05 significance level and it should be concluded that there was no significant difference between the groups.

Selected results of the calculation are as presented in Tables 7.24. More detailed versions of the table can be observed in Appendix F. The figures show that when comparison between arterial and collector categories was carried out no single factor had been different significantly (t value > $t_{.975}$). But, when comparisons were made between arterial and local categories, they different significantly in three out of four factors (noise, pedestrian delay and accident risk). Comparison between collector and local categories suggested that they disagreed in pedestrian delay and accident risks aspects.

Similar results happened when comparisons were made towards landuse categories. There was a tendency that mix and residential categories were not significantly different in giving their preferences. On the other hand, significant differences were observable amongst both commercial-mix and commercial residential comparisons.

TABLE 7.24 STUDENT T TESTS BETWEEN PAIRS OF CATEGORIES (RATING)

Pair of categories	Student t-test for environmental factor				$t_{.975}$
	Noise	Air Pollution	Pedestrian Delay	Accident Risks	
Arterial – Collector	1.40	0.09	1.80	0.09	2.00
Arterial – Local	2.59	0.91	3.99	2.99	1.99
Collector – Local	1.19	0.91	2.02	3.21	1.99
Commercial – Mix	1.83	2.17	1.85	1.29	2.00
Commercial – Residential	0.87	3.04	2.19	2.54	2.00
Mix – Residential	-0.93	0.46	0.48	1.07	2.00

Note: difference is significant at 0.05 level if t is outside $-t_{.975}$ to $t_{.975}$ range, otherwise the difference is not significant

Typical results of regression analyses produced by commercial software (e.g. Excel, SPSS), include 3 basic tables containing regression statistics, ANOVA and regression coefficients. Descriptions of the statistical terms used in the analyses are given in the Table 7.25.

TABLE 7.25 DESCRIPTION OF STATISTICAL TERMS

Statistics	Description
Multiple R	The coefficient of multiple correlation defined as square root of explained variation divided by total variation. Ranging from 0 to 1, where the closer it is to unity the better is the linear relationship between dependent and independent variables.
R Square	The coefficient of multiple determination, which is the square of the coefficient of multiple correlation. Compares estimated and actual y-values, and ranges in value from 0 to 1. If it is 1, there is a perfect correlation in the sample and there is no difference between the estimated y-value and the actual y-value. At the other extreme, if the coefficient of determination is 0, the regression equation is not helpful in predicting a y-value.
Adjusted R Square	Adjusted value of R square according to the number of variables involved.
Standard Error	Standard Error of Estimate (*SE*), defined as the average distance between the observed y-value and the estimated value or the measure of *unexplained* variation. The standard error of estimate has similar role as standard deviation. If the number of observations is large enough, a parallel lines distance at *SE*, 2*SE* and 3*SE* from the regression line may be interpreted as 68%, 95%, and 99.7% level boundary lines respectively.
Observations	The number of observations, *N*.
Df	The degree of freedom defined as number of observations *N* minus parameters used *k*, or equals to *N-k*.

SS	Sum of Squares. The summation of squared differences either between observed and estimated values (SS Error, SSE), or between observed and average value (SS Regression, SSR), or between observed and average values (SS Total,SST). SST= SSR + SSE.
MS	Mean of Squares, which is simply *SS* divided by its degree of freedom, *df*.
F	The *F* statistic, or the *F*-observed value. Use the *F* statistic to determine whether the observed relationship between the dependent and independent variables occurs by chance.
Significance *F*	The probability value of *F* statistic. Returns the probability of corresponding *F* to occur. For 95% confidence level, a significance *F* of 0.05 or lower is desirable. This may be interpreted that the relationship between dependent and independent variables is significantly useful and linear.
Coefficient	The coefficient of variables.
Standard Error	The standard error of the coefficient of variable.
t-statistic	The *t* statistic of the coefficient of variable, which is simply the coefficient value divided by its standard error.
P-value	The probability value of corresponding t-statistic. For 95% confidence level, a *P*-value of 0.05 or lower is desirable. This may be interpreted that the coefficient of variable is significantly different from zero.

Source: Spiegel, 1992; Walpole and Myers, 1985.

The following tables show the example of information provided in such regression analysis tool. From the regression statistics table it can be observed that the regression equation had an R-square of 0.69 that indicated a good relationship.

TABLE 7.26 REGRESSION STATISTICS

Regression Statistics	
Multiple R	0.86
R Square	0.74
Adjusted R Square	0.69
Standard Error	11.17
Observations	21.00

The ANOVA table confirms that the relationship was significant, shown by the value of significance *F* of (<0.05).

TABLE 7.27 TYPICAL OF ANOVA STATISTICS

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	5909.3862	1969.7954	15.7812	0.0000
Residual	17	2121.9309	124.8195		
Total	20	8031.3171			

The table of regression coefficients shows that the regression analysis suggested the following relationships between dependent variable EUV and Volume, Width and Speed as independent variables for Major-Residential group:

EUV = 50.828 - 0.038 * Volume + 6.385 * Width + 0.326 * Speed

The t-statistics also show that the coefficients of Volume and Width variables were significant at 95%, indicated by P-value less than 0.05. Although the analysis suggested that the coefficient for the Speed variable was not significantly different from zero at 95%, for consistency purposes it was included in the equation.

TABLE 7.28 TYPICAL OF REGRESSION COEFFICIENTS AND STATISTICS

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	50.8276	20.6551	2.4608	0.0249
Volume	-0.0377	0.0073	-5.1869	0.0001
Width	6.3850	2.0337	3.1396	0.0060
Speed	0.3260	0.5934	0.5493	0.5899

7.4 Summary

In this chapter, analyses of the available data have been put forward. Various calculation techniques were explained and examples were given. Complete data and calculations are available in relevant appendices. The results are now ready to be interpreted and used as the basis for model calibration and validation purposes, which will be addressed in the subsequent chapters.

Manual traffic counting data were used to replace the unsatisfactory results of the automatic counting system as originally designed. This was done using video recorded data previously intended for observing pedestrians. Fortunately, data on traffic speed from the automatic system still could be used since it was not really affected by the inaccuracy of the system in detecting types of vehicles.

Analyses of the environmental data suggested that no major difficulties occurred. The analyses included the application of various prediction models as proposed in the methodology and study design. Nevertheless, changes to the original design were inevitable due to poor performances of some of the models. The only model that performed quite well was the DoT noise model.

In the case air pollution for example, prediction of NOx could not satisfactorily be obtained from the proposed models. This was probably due to poor performance of the emission rate model rather than the air pollution dispersion model itself. As a result attempts to include NOx in the air pollution module had to be suspended, and CO became the only air pollutant considered in the present study.

Another change was made towards the pedestrian model. As originally designed, this study intended to use the modified Adam's delay model as proposed by Holdsworth and Singleton (1978). But, the nature of the data did not seem to be appropriate for the suggested model, which was supposed to use with moderate volume of random traffic. Instead, another model by Austroads (1995) was used to predict the pedestrian delay.

For accident rate, model proposed by Zeeger did not seem to predict very well either, since this model was developed for rural road situations. In this case, a self- developed multivariate regression model was attempted to correlate accident rates and various road and traffic parameters and the result was quite promising.

In regard to the preferential data the chapter mainly described what analytical techniques were used and how they were applied in this study. Three different types of data, namely ranking, rating and pairwise comparison were treated separately using different technique of analysis. The analysis suggests that amongst the proposed methods, it was only for the direct rating that comparisons between different categories were possible. Comparisons between categories of the other methods (ranking and pair-wise comparison AHP) could not be performed due to no appropriate test available. This situation leads to the decision of employing direct rating alone for further analysis of preferential data.

The next chapter will explain the calibration of the proposed models based on results of the analyses. Description and interpretation of the results will be addressed in more detail.

Chapter 8

Chapter 8

MODEL CALIBRATION

This chapter explains the results of the calibration of all the models used in the present study. The earlier parts of the chapter describe the calibration of the Environmental Utility Functions (EUF) that yield the Environmental Utility Values for various site categories. This is followed by the calibration of the Environmental Capacity model that represents the relationship between EUVs and all relevant road and traffic parameters.

Later parts of this chapter describe the outcomes of calibration processes towards environmental factor prediction models. They include noise, air pollution, pedestrian delay and accident risks models. These altogether compose a comprehensive environmental capacity model for urban roads as proposed in Chapter 4.

8.1 Calibration of the Environmental Utility Functions

About 150 people were interviewed from 36 sites, during the survey. Of these, the responses of 104 people (from 27 sites) were randomly chosen for immediate application in calibrating the model. Data from the remaining sites (9) with 42 respondents, were obtained for subsequently validating the model. A summary of the community respondents appears in Table 8.1. From the experts, amongst the 100 questionnaires mailed out, 25 were mailed back. Of these, 20 used for model calibration purposes.

TABLE 8.1 COMMUNITY RESPONDENTS

Road Class	Number of Respondents		
	Landuse Type		
	Commercial	Mix	Residential
Arterial	15 (7)	15 (9)	16 (11)
Collector	14 (10)	15 (11)	15 (11)
Local	21 (17)	19 (15)	16 (13)
Total	50 (34)	49 (35)	47 (35)

Note: Figures in the brackets represent number of respondents used for calibration purposes.

8.1.1 Rating

Average rating values as given by the community for each environmental factor are as shown in Table 8.2 below. Statistical analyses of the data, as addressed in Chapter 7, suggest that in every category, significant differences were observed between scores given to environmental factors. In other words, it can be said that there was enough evidence (at 95% level) to conclude that different scores were given to the environmental factors. Majority of categories in the community, seemed to agree to give the highest score (the most annoying factor) to noise, the second to air pollution, the third to pedestrian delay and the lowest score to accident risk.

When a comparison was made of the same factor between different categories such as noise as perceived by people residing along collector road with either commercial, mix or residential land-use, some interesting findings were observable. In general, the community's preferences towards environmental factors seemed to be independent of type of land use. This was observable particularly within the collectors and locals categories. Within arterial roads, people who live in mixed land-use, tended to respond differently from the other two categories in giving scores to noise, air pollution and pedestrian delay (see Table 8.2).

TABLE 8.2 AVERAGE RATING OF ENVIRONMENTAL FACTORS AS GIVEN BY COMMUNITY AND EXPERTS

		Average Rating				
Group	Site Category	Noise	Air Pollution	Pedestrian Delay	Accident Risk	Order
Community	Arterial-Commercial	75.00	58.21	60.00	46.07	1324
	Arterial-Mix	45.00	40.28	35.00	31.11	1234
	Arterial-Residential	70.45	46.36	50.45	25.91	1324
	Collector-Commercial	60.50	53.00	49.50	37.00	1234
	Collector-Mix	62.05	46.82	42.27	34.09	1234
	Collector-Residential	51.36	41.82	30.00	26.82	1234
	Local-Commercial	55.00	47.94	35.00	25.15	1234
	Local-Mix	55.67	44.00	35.33	21.67	1234
	Local-Residential	53.08	39.23	27.69	21.15	1234
	Arterials	63.15	47.41	47.78	32.87	1324
	Collectors	57.89	47.03	40.31	32.50	1234
	Locals	54.67	44.11	33.00	22.83	1234
	Commercials	60.74	51.54	44.41	32.94	1234
	Mixes	54.93	43.93	37.43	28.00	1234
	Residentials	58.00	42.29	35.57	24.43	1234
	All category	55.72	44.17	27.36	37.64	1243
Experts	All	49.40	64.80	57.00	60.10	4132

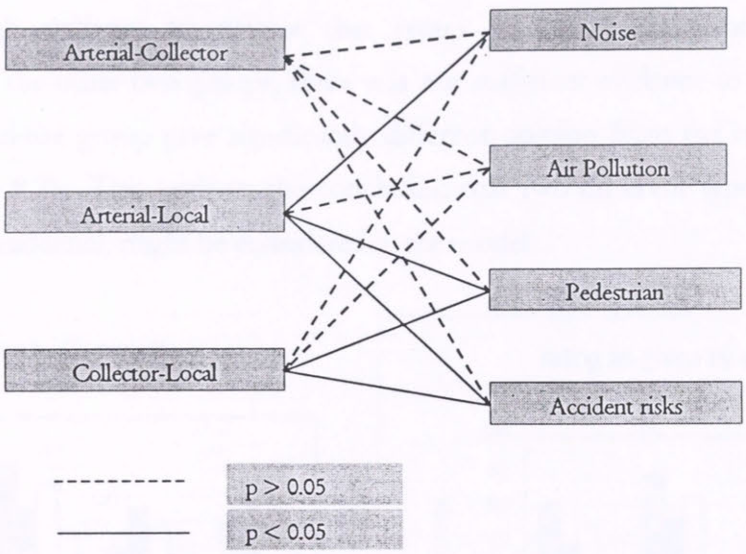


FIGURE 8.1 RESULTS OF COMPARISONS BETWEEN ROAD CLASSES

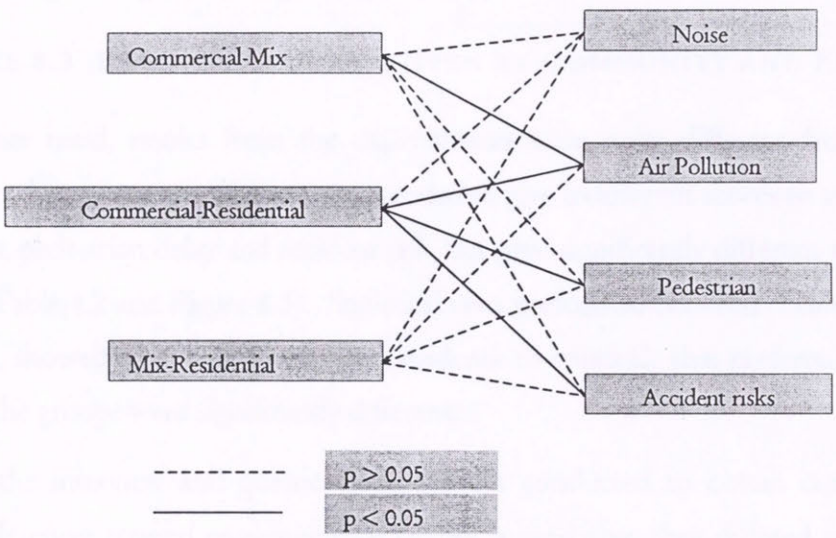


FIGURE 8.2 RESULTS OF COMPARISONS BETWEEN LAND USE TYPES

The result was somewhat different when comparisons were made between road class groups for all the data. Analyses towards these groups suggest that there were no significant differences between arterial and collector categories in giving scores to environmental factors. But, significant differences were observed between local and either arterial or collector groups (Figure 8.1). Overall therefore, it might be reasonable to propose that two different classes of roads, major and local, should be considered in the models.

Comparisons between respondents in different land-use categories suggested that people from the residential and mixed groups were not different significantly in giving scores. While there was enough evidence to suggest that group of commercial land-use differed significantly from the other two groups, there was not sufficient evidence to conclude that the residential land-use group gave significantly different opinion from the mixed land-use group (see Figure 8.2). This leads to the conclusion that two different types of land-use, commercial and residential, might be considered in the models.

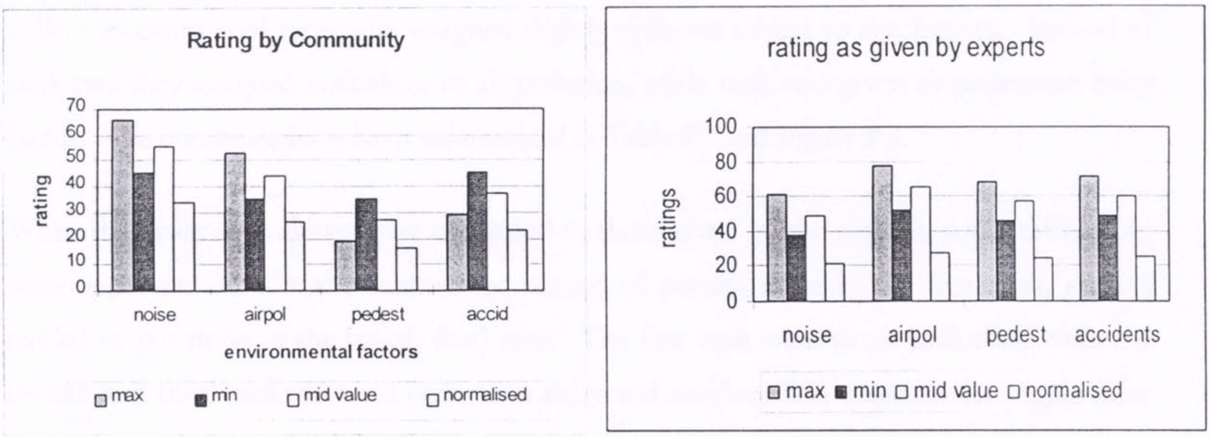


FIGURE 8.3 RATING VALUES AS GIVEN BY COMMUNITY AND EXPERTS

On the other hand, results from the experts' data were quite different from what was suggested by the community. The experts tended to give indifferent scores to such factors as air pollution, pedestrian delay and accident risk, but gave significantly different score to noise factor (see Table 8.2 and Figure 8.3). Statistical tests performed between community groups and experts, showed that there was enough evidence to conclude that preferences expressed by both of the groups were significantly different.

Results of the interview and questionnaire surveys conducted to obtain community and experts preferences toward environmental factors suggest that they differed in such a way that the community tended to give more attention towards noise factor weight (highest rating) while experts give more weight on air pollution. This difference maybe due to the different viewpoint from where the evaluation was undertaken. While community tends to evaluate based on their day-to-day experience, experts tended to make their judgements based on their scientific or engineering knowledge.

Noise is the most sensible factor amongst all, the effect of noise to people is direct and more annoying. While on the other hand other factors such as air pollution, although may cause severe impacts to human, is less sensible and the effect is rather indirect. Nevertheless, as the community is the ones who experience the impacts directly, they have more rights to say than the experts. In this respect, the environmental weights as given by the community are more eligible to use in the MFEC model.

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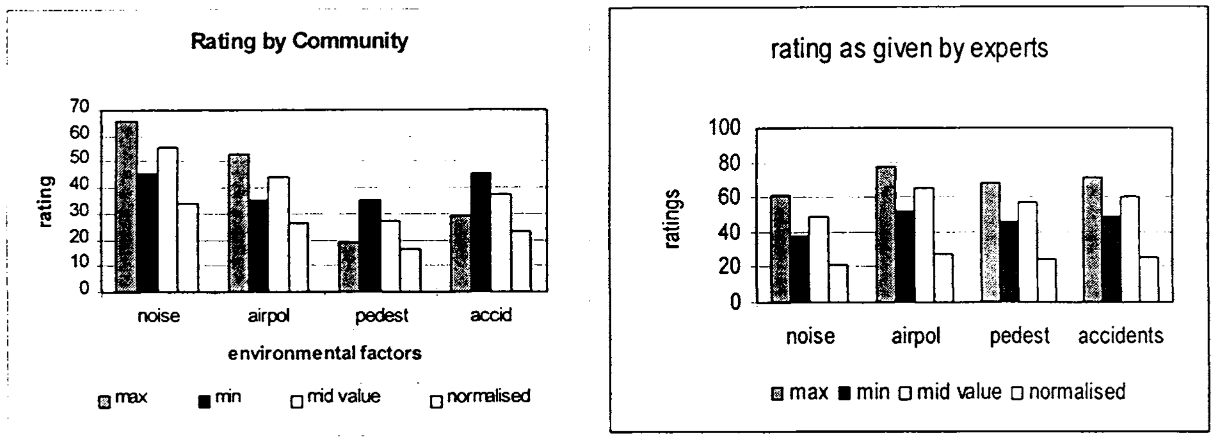

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8.1.2 Ranking

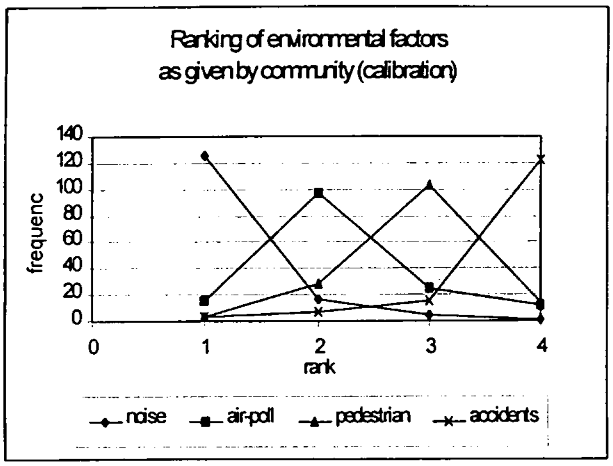
In general, results of the analyses of the ranking data were not quite different from those of the direct rating data. Initial analyses of the community surveys suggest that in terms of ranking, there were no major influences of site category in the community. At most of the categories, respondents agreed to assign rank one to noise, two to air pollution, three to pedestrian delay and four to accident risk. Only respondents from arterial residential and collector-commercial categories assigned slightly different orders to the factors. Instead of rank two they assigned rank three to air pollution, while rank two given to pedestrian delay factor. The outcomes have been summarized in Table 8.3 and Figure 8.4.

When the order of rankings were compared to those given by the experts, some differences were apparent. Unlike the community, instead of putting noise in the first rank, experts tended to put noise in the fourth (last) rank. The first rank went to air pollution, while the second and third ranks went to pedestrian delay and accident risk, respectively. Again refer to the data of Table 8.3.

Kendall (1975) provides a method of measuring the commonality of judgments among the respondents. The *coefficient of concordance* (*W*), as a measure of agreement, will equal to unity if all of the respondents agree and become zero if they differ very much among themselves. Calculated Kendall's concordant coefficients for the community categories were ranging from 0.53 to 1.0, which indicated medium-high level of agreement. While for the experts the coefficient was 0.54, which indicated only a medium level of agreement.

TABLE 8.3 RANK AND ORDER OF ENVIRONMENTAL FACTORS ACCORDING TO COMMUNITY AND EXPERTS

		Rank of Environmental Factors					
Group	Site Category	Noise	Air	Pedestrian	Accident	Kendall's	Chi sq.
Community	Arterial-Commercial	1	2	3	4	1.0	21
	Arterial-Mix	1	2	3	4	1.0	30
	Arterial-Residential	1	3	2	4	0.8	26.45
	Collector-Commercial	1	3	2	4	0.53	17.51
	Collector-Mix	1	2	3	4	0.84	17.57
	Collector-Residential	1	2	3	4	0.64	21.22
	Local-Commercial	1	2	3	4	0.91	46.34
	Local-Mix	1	2	3	4	0.57	32.68
	Local-Residential	1	2	3	4	0.68	20.45
	Arterials	1	2	3	4	0.89	74.87
	Collectors	1	2	3	4	0.58	50.26
	Locals	1	2	3	4	0.70	103.09
	Commercials	1	2	3	4	0.77	80.52
	Mixes	1	2	3	4	0.88	86.78
	Residentials	1	2	3	4	0.67	70.03
	All category	1	2	3	4	0.71	224.91
Experts	All	4	1	2	3	0.54	553



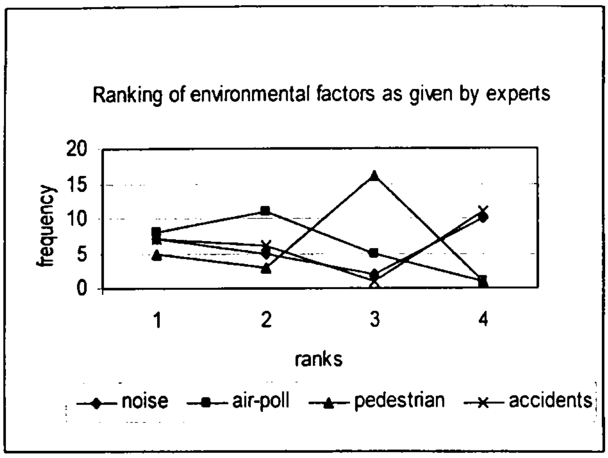


FIGURE 8.4 RANKING OF ENVIRONMENTAL FACTORS AS GIVEN BY COMMUNITY AND EXPERTS

8.1.3 Analytical Hierarchy Process (AHP)

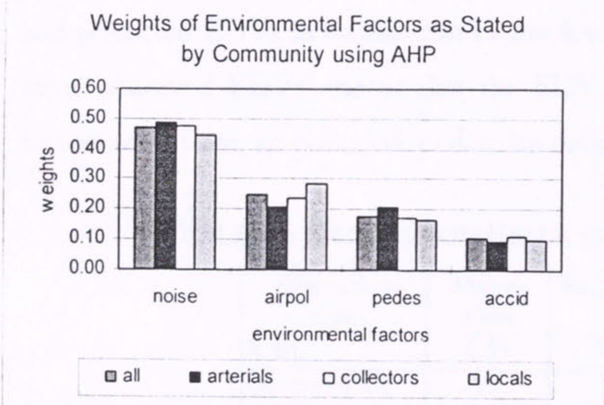
Analyses of the pair wise comparison data suggest the following results. Noise was considered as the most annoying factor, with coefficient of weighting ranging between 0.42-0.55, followed by air pollution (0.17-0.32). Pedestrian delay was considered as the third, with the coefficient ranging between 0.15 and 0.23, while accident was the least annoying with coefficient ranging from 0.08 to 0.12. The order was slightly different according to arterial-commercial and arterial-residential categories. Instead of the second most annoying, the categories put air pollution on the third place, and pedestrian delay as the second (see Table 8.4).

On the other hand, perceptions of group of experts once again differ from that of the community. In this case, they give the highest coefficient to accident risk (0.31), followed by pedestrian delay (0.28), and air pollution (0.27). Noise itself was considered as the least annoying factor by them and was given a coefficient of 0.14 - about half of the other factors (refer to Table 8.4 and Figure 8.5).

Saaty (1982) uses Consistency Index (CI) to measure the degree of consistency, and compared with Random Consistency Index (RCI) calculated from randomly generated square matrix. The ratio between CI and RCI is called the Consistency Ratio (CR), which is considered good if less than 0.10. Calculated CR of the results showed that the respondents in every categories were quite consistent in expressing their preferences. Amongst the community, CRs were ranging between 0.002 and 0.038, while amongst the experts the CI was 0.018 which indicated very good consistency (less than 0.10).

TABLE 8.4 WEIGHTING OF ENVIRONMENTAL FACTORS GIVEN BY COMMUNITY AND EXPERTS USING AHP METHOD

Group	Site Category	Noise	Air Pollution	Pedestrian Delay	Accident Risk	CR
Community	Arterial-Commercial	0.47	0.19	0.23	0.10	0.020
	Arterial-Mix	0.42	0.27	0.20	0.11	0.011
	Arterial-Residential	0.55	0.17	0.20	0.08	0.038
	Collector-Commercial	0.46	0.25	0.18	0.11	0.007
	Collector-Mix	0.50	0.22	0.17	0.11	0.002
	Collector-Residential	0.47	0.25	0.17	0.12	0.012
	Local-Commercial	0.44	0.32	0.15	0.09	0.015
	Local-Mix	0.43	0.27	0.19	0.12	0.002
	Local-Residential	0.47	0.26	0.16	0.11	0.010
	Arterials	0.49	0.21	0.21	0.10	0.014
	Collectors	0.48	0.24	0.17	0.11	0.003
	Locals	0.45	0.29	0.17	0.10	0.007
	Commercials	0.45	0.27	0.18	0.10	0.007
	Mixed	0.46	0.26	0.17	0.11	0.004
	Residentials	0.50	0.23	0.17	0.10	0.015
	All category	0.47	0.25	0.18	0.10	0.006
Experts	All	0.14	0.27	0.28	0.31	0.018



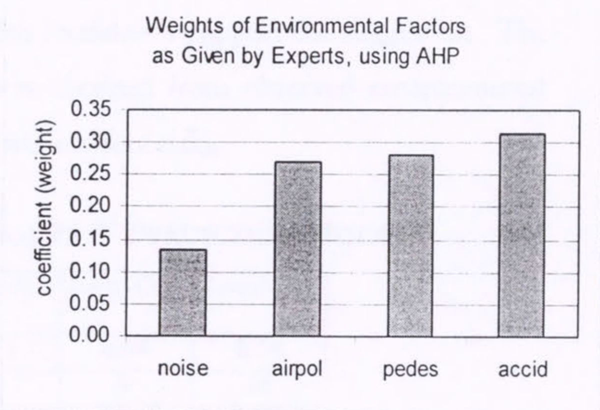


FIGURE 8.5 RESULT OF PAIRWISE COMPARISON (AHP) METHOD BY COMMUNITY AND EXPERTS

The above discussion and analyses may be summarized as follows. It suggests two distinct classes of road, namely major and local roads may be considered in the model. In terms of land -use, two different types of land-use, commercial and residential, may also be considered. Experts' preferences were significantly different from those of the community, suggesting that two models would be required - one for expert and one for community preferences. Based on the categorization, combination of weighting coefficients as shown in Table 8.5 will be employed by the proposed models.

TABLE 8.5 WEIGHTING COEFFICIENTS FOR SUGGESTED CATEGORIES

Category	Noise	Air Pollution	Pedestrian Delay	Accident Risk
MAJOR-Commercial	0.3	0.25	0.24	0.20
MAJOR-Residential	0.34	0.27	0.23	0.16
LOCAL-Commercial	0.34	0.30	0.22	0.14
LOCAL-Residential	0.38	0.26	0.20	0.16
Experts	0.21	0.28	0.25	0.26

8.1.4 EUV Prediction Model

Using the above weighting coefficients, it was desirable to calculate EUVs and develop relationships between them and the relevant road, traffic and meteorological parameters. As the relationship is developed the EUV could then be predicted using the parameters.

The relationship was developed by multivariate regression analyses and the results suggested that very close relationship observed between EUVs and the parameters. As figures in Table 8.6 suggest, an average R-square value of 0.77 was observable. Coefficients of the parameters as suggested by the analyses were as shown in Table 8.7. The scatter plot between observed and predicted EUVs as depicted in Figure 8.4 also confidently support the suggestion. The term 'observed EUVs' means that the EUV was obtained from observed environmental factors (e.g. noise, air pollution, pedestrian delay and accident risk).

TABLE 8.6 REGRESSION RESULTS FOR EUV PREDICTION MODEL

Regression Stat.	*Major-Com*	*Major-Res*	*Local-Com*	*Local-Res*
R-sq.	0.65	0.74	0.94	0.74
Observations	11	21	9	16
Significance F	0.052	0.000	0.002	0.001

TABLE 8.7 COEFFICIENT OF PARAMETERS OF THE EUV MODELS

Variables	*Coefficients*							
	Major-Com		*Major-Res*		*Local-Com*		*Local-Res*	
Intercepts	96.212	(4.17)	50.828	(2.46)	141.406	(9.77)	93.109	(5.07)
Volume	-0.010	(-1.82)	-0.038	(-5.19)	-0.063	(-1.66)	-0.047	(-5.67)
Width	-0.887	(-0.80)	6.385	(3.14)	-1.917	(-0.73)	3.994	(1.73)
Speed	-1.184	(-1.37)	0.326	(0.55)	-0.519	(-0.42)	-0.553	(-0.86)

Note: Volume in veh./hour; Width=road width in metres; and Speed = average speed in km/h. Figures in brackets are *t*-values

Generally speaking, all regression equations showed quite satisfactory goodness-of-fit as evidenced by R-sq. values greater than 0.65. Almost all of them have significant linearity, which shown by the significance F values that less than 0.05, meaning that they are linear at 95% level of confidence.

The coefficient values also showed that for Commercial type land-use, both for Major and Local roads, consistent trends were observable. All considered parameters (volume, width and speed) have negative signs, which means that greater values will yield lower utility. Besides, the figures also indicated that people living along Major roads tend to have higher sensitivity towards speed parameter (-1.184) compared to those who live along Local roads (-0.519). Whereas for other parameters (i.e. volume and width), people living along Local roads were more sensitive compared to those on Major roads.

Responses obtained from people living in residential areas both in Major and Local roads showed different results. These people tended to prefer wider roads, as indicated by the positive signs of the Width coefficients. The figures also showed that people residing in Major roads were 50% more sensitive towards road width (6.385) than those on Local roads (3.994). In regard to traffic volume both groups tended to have similar sensitivity.

Different signs were obtained for Speed parameters. Positive sign was observable for Major-Residential category, whereas Local-Residential had negative sign. This difference in parameter sign indicated that people at Major-Residential location, preferred to have higher traffic speed. This might be due to the fact that quite low average speed of traffic (33 km/h) was occurred in this road category. Higher traffic speed may result in lower air pollution levels as a consequence of the smoother traffic flow conditions.

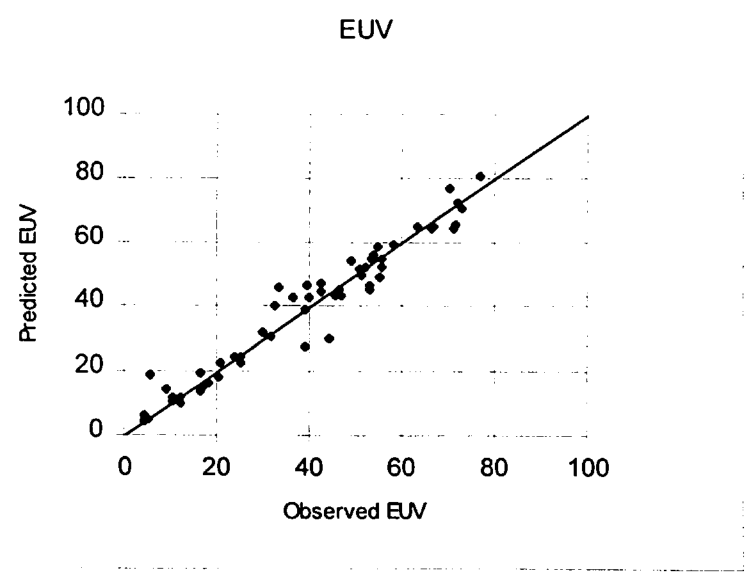


FIGURE 8.6 OBSERVED VS. PREDICTED EUVS

8.2 Calibration of the Environmental Impact Prediction Models

Prior to the adoption of the model in the study, it is necessary to have the model calibrated in order to adjust with the local conditions. Performances of the calibrated models might be measured by calculating residual d, which was simply the difference between measured value M and the value estimated by the models P (Boubel, *et.al*, 1994).

$$d = M - P \qquad 8.1$$

The first moment of the distribution of these differences or the average difference d could then be used as the measure of bias D.

$$D = 1/\mathrm{N}.\Sigma d \qquad 8.2$$

The standard deviation, which was the square root of variance S^2, was used as a measure of variability.

$$S^2 = \Sigma(d - D)^2/\mathrm{N} \qquad 8.3$$

In addition to the residuals or errors it was also desirable to determine the correlation coefficient r as the measure of degree of agreement between measured and predicted sets of values.

$$r = (\mathrm{N}\Sigma P.M - \Sigma P.\ \Sigma M)/\{[\mathrm{N}\Sigma P^2 - (\Sigma P)^2][\mathrm{N}\Sigma M^2 - (\Sigma M)^2]\}^{0.5} \qquad 8.4$$

The closer the coefficient to unity the better would be the model in representing the actual conditions. General understanding of the coefficient suggests that an r higher than 0.7 was normally considered as satisfactory

Martinez *et.al* (1980) also suggest a simple measure of accuracy of prediction model using a ratio (k) of predicted (P) to measured (M) values.

$$k = P/M \qquad 8.5$$

8.2.1 Noise Prediction Model

Values of the measured parameters are tabulated in Appendix A. Summary of the measurement statistics is as shown in Table 8.8. Traffic volumes range from 185 v.p.h. (Local) up to 3162 v.p.h. (Major) with measured L_{10} ranging between 65.1 dB(A) and 77.6 dB(A). Accordingly measured L_{eq} varies from 61.7 to 76.0 dB(A).

TABLE 8.8 MEASURED PARAMETERS FOR NOISE PREDICTION MODEL

Parameters	Mean	St. Deviation	Max. Value	Min. Value
Road Width, m	7.9	2.5	13.0	4.0
Gradient, %	4.6	6.8	25.0	0.0
No. Of lanes	-	-	4.0	2.0
Lane width	3.4	0.7	5.1	2.0
Volume, vph	1299	896	3162	185
%HV	1	1	4	0
%MC	33	8	49	21
Speed	30.2	5.5	46.0	19.0
L10-1hr, dB(A)	72.3	3.8	77.6	65.1
Leq, dB(A)	69.6	3.9	76.0	61.7

Comparison between Predicted and Measured

After the data were processed, calculations were then conducted for prediction values of noise levels according to UK DoT (1988). Summary of the results of the calculations is shown in Table 8.9 and Figure 6. It can be noted that the model tends to under-predict by an average *d* of 0.6 dB(A). The standard deviation of the difference was 1.5 dB(A), while a correlation coefficient of 0.92 was observed between the measured and the predicted L10, which was quite good.

TABLE 8.9 PERFORMANCE OF NOISE PREDICTION MODEL

Statistics	L10-measured	L10-predicted	Error (measured-predicted)
Mean	72.3	71.7	0.6
St.deviation	3.8	3.8	1.5
Maximum	77.6	78.4	3.8
Minimum	65.1	63.8	-3.1
r	0.92		

From the analysis it is therefore suggested at 95% confidence limit to use the following validated function of DoT model:

$$L_{10} = L_{10p} + 0.6$$

95% Confidence Interval (C.I.) = ± 3.0 dB(A)

Where:

L_{10} = calibrated prediction value of L_{10}-1hr in dB(A);

L_{10p} = predicted value of L_{10}-1hr using DoT formula.

Figures 8.7 shows the scatter plot between measured and predicted values that may visually support the above suggestion.

Regarding L_{eq} and L_{10}, it is also desirable to prove whether relationship between the two indexes satisfies the general relationship that L10 is between 2.5 and 3 dB greater than Leq as indicated by various sources (Lamure, 1986; Burgess, 1978). Statistical analysis of the data obtained in this study as shown in Table 7.7 Chapter 7, shows the relationship as: $L_{10} = L_{eq} + 2.7$

This undoubtedly supports the practical relationship between L_{10} and L_{eq} and indicates that the measured noise was predominantly noise of traffic from the urban or suburban areas. Figure 8.8 also shows that the data were more or less normally distributed.

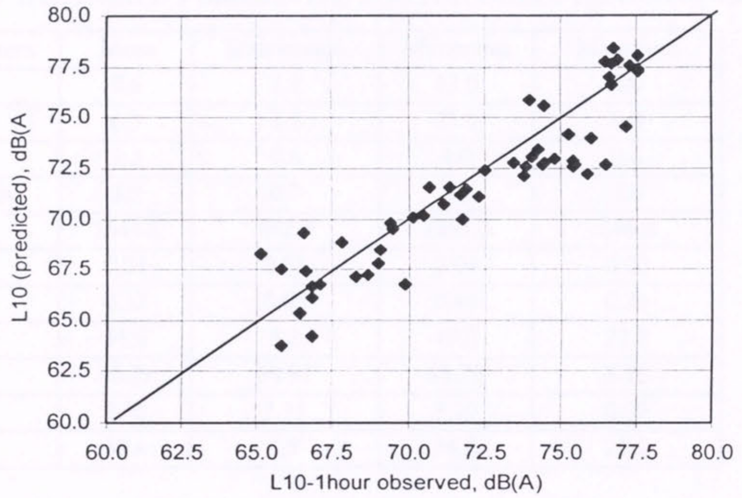


FIGURE 8.7 MEASURED VS. PREDICTED L10 USING DOT MODEL

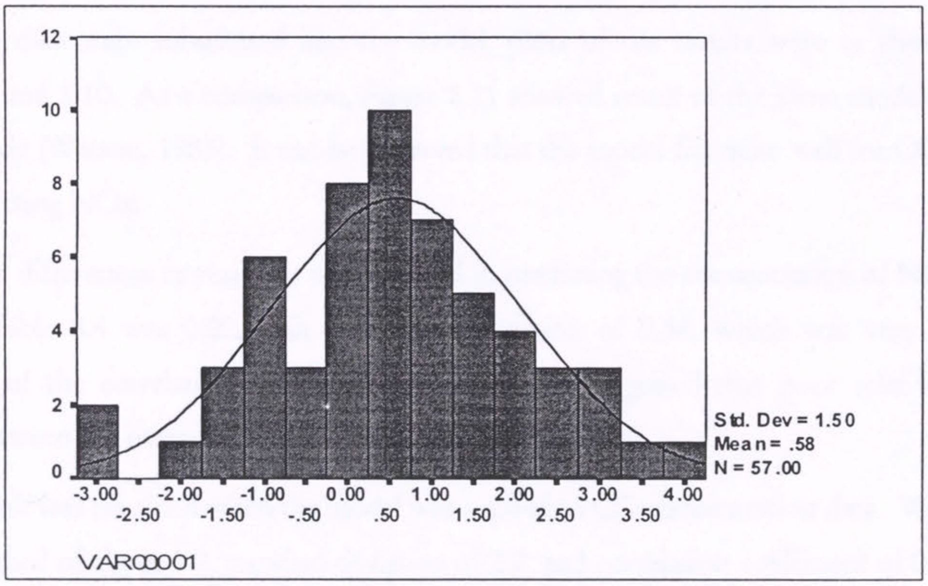


FIGURE 8.8 DISTRIBUTION OF ERROR (L10MEASURED-L10PREDICTED)

8.2.2 Air Pollution Prediction Model

The air pollution model that finally employed was the one that popularly referred to as the General Motor (GM) model (Chock, 1978). The model predicts the dispersion of concentration of pollutant from a line source such as road traffic. Measured road and traffic parameters together with some meteorological data such as wind speed and temperature are shown in Table 8.10.

TABLE 8.10 MEASURED PARAMETERS FOR AIR POLLUTION MODELS

Parameters	Mean	St.deviation	Maximum	Minimum
Width	8.6	2.2	13.0	6.0
Grad(%)	6.3	8.2	25.0	0.0
# lanes	2.2	0.6	4.0	2.0
Lane width	3.9	0.7	5.1	3.0
Vol	1544.8	862.7	2853.0	346.0
%HV	0.01	0.01	0.04	0.00
%MC	0.32	0.07	0.44	0.21
Speed	31.5	5.2	40.0	22.0
Wind Dir	40.29	28.91	85.75	2.25
WindSpd	2.36	2.31	8.00	0.00
Temp.	30.4	1.9	34.0	25.0

The measurements covered a very wide range of data. Traffic volume was observed from around 350 vph to 2850, with travelling speed of 22 km/h to the maximum of 40 km/h. In terms of meteorology the measurements covered wind speed between 0 – 8 m/s and temperature of 25 – 34 centigrade.

When these data were substituted into the model, plots of the results were as shown in Figures 8.9, and 8.10. As a comparison, Figure 8.11 showed result of the same model done by other study (Watson, 1983). It can be observed that the model fits quite well for CO, but fails in predicting NOx.

The mean of differences or residuals of the model in predicting the concentration of NOx as shown in Table 8.4 was 0.02, with a standard deviation of 0.34, which was very wide. Calculation of the correlation coefficient r of 0.06 also suggested that poor relationship occurred between the measured and predicted values.

A better result was obtained when the model was applied to CO concentration data. With an average residual of about 1.2, standard deviation of 2.2, and correlation coefficient of 0.32, it was quite close to what the other study had done. In fact, the Watson study suggests that the model tended to under-predict with average residuals (errors) 2.6, standard deviation 3.1, and correlation coefficient r of 0.88.

TABLE 8.11 PERFORMANCE OF AIR POLLUTION MODEL

	Error (measured-predicted)		
Statistics	NOx	CO	CO other study
Mean	0.02	1.2	2.6
St. Deviation.	0.34	2.2	3.1
Maximum	1.25	5.3	10.5
Minimum	-0.36	-2.8	-1.1
r	0.057	0.32	0.88
k	1.37	0.79	0.82

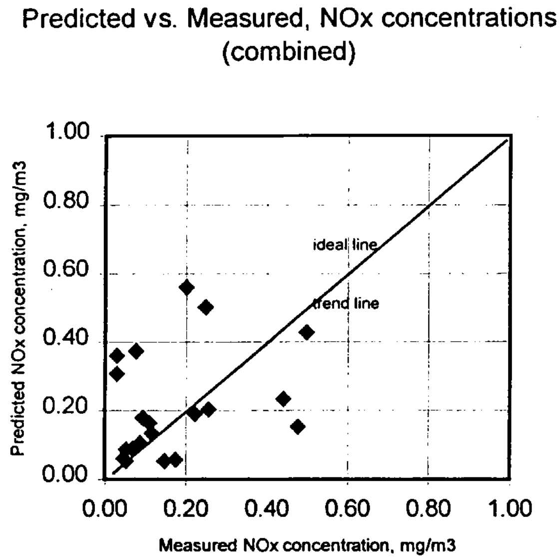


FIGURE 8.9 MEASURED VS. PREDICTED NOx CONCENTRATIONS

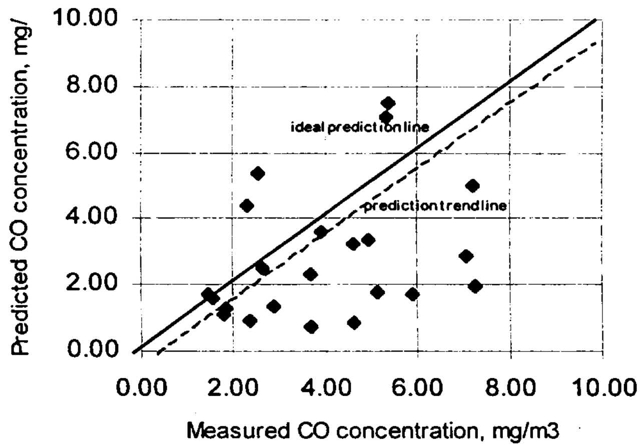


FIGURE 8.10 MEASURED VS. PREDICTED CO CONCENTRATIONS

When the performance of the model was measured using ratio between predicted and measured values *k*, similar results were occurred. The calculated *k* for NOx and CO concentrations as shown in Table 8.11 were 1.37 and 0.79 respectively compared to 0.82 of other study (Watson, 1983). These figures suggest that for NOx concentration, the model tended to over-predict by 37%, whereas for CO concentration it tended to under-predict by around 20%.

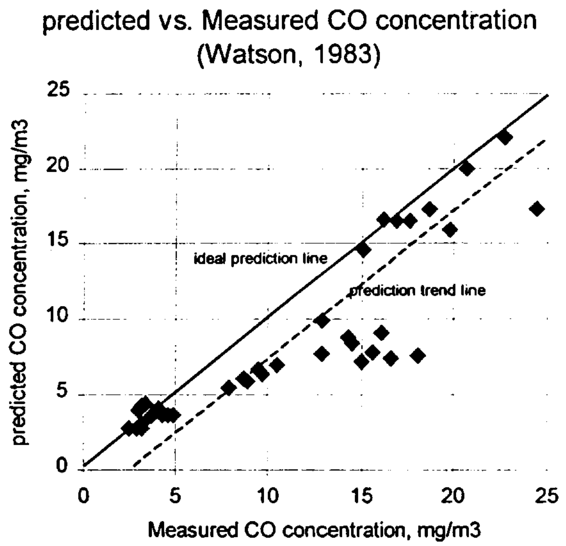


FIGURE 8.11 PERFORMANCE OF GM MODEL AS SHOWN IN OTHER STUDY

From the analysis it can be suggested that the model performed quite well in predicting CO concentration, but was very poor in predicting NOx. Regardless of the results, as the model of predicting air pollution was quite complicated, it was suggested to used the model with due precautions and conduct a further in depth study to calibrate the model using carefully designed and controlled measurements of the parameters. Air pollution model is basically composed of two models, vehicle emission model and dispersion model itself. The first usually depends on the vehicle speed while the other is more depending on meteorological conditions. Performance of air pollution model depends on the accuracy of both models.

8.2.3 Pedestrian Delay Prediction Model

As described in Chapter 7, model used to predict the pedestrian delay was the one that proposed by Austroads (1995). The range and characteristics of data used to calibrate the model are as shown in Table 8.11. On average, a pedestrian was delayed by 2.4 second every time he or she attempted to cross the road. In terms of percent delayed pedestrians, the data show that about 30% of the pedestrians were delayed on the average with a maximum as high as 90% and the minimum 0%. As far as road width is concerned, an average 7.8m width was observed, ranging from 4m to 13m.

TABLE 8.12 MEASURED PARAMETERS FOR PEDESTRIAN DELAY MODEL

Parameters	Mean	St. Deviation	Max	Min
Average Delay	2.40	3.10	13.71	0.00
% Pedestrian Delayed	0.28	0.24	0.91	0.00
Road width	7.78	2.33	13.00	4.00
Volume	1204	854	3162	185

Figures 8.12 and 8.13 show in graphical form how the model performed in predicting the average pedestrian delay and percentage of delayed pedestrians respectively. It can be observed that the model tended to over-predict the average pedestrian delay and under-predict the percentage of delayed pedestrians. Table 8.13 shows the exact figures of the model performance indicator. The figures suggest that the model performed quite well in predicting the percentage of delayed pedestrian with an average error of -0.06 (over-predict) and correlation coefficient of 0.74. Whereas in predicting the average delay, the model tended to under-predict by 0.47 seconds, with a standard deviation of 2.42 and correlation coefficient 0.63, which was quite satisfactory.

TABLE 8.13 PERFORMANCE OF CALIBRATED PEDESTRIAN DELAY MODEL

	Error (measured-predicted)	
Statistics	% Pedestrian Delayed	Average Delay
Mean	-0.06	0.47
St. Deviation	0.16	2.42
Maximum	0.58	4.39
Minimum	-0.25	-10.16
r	0.74	0.63

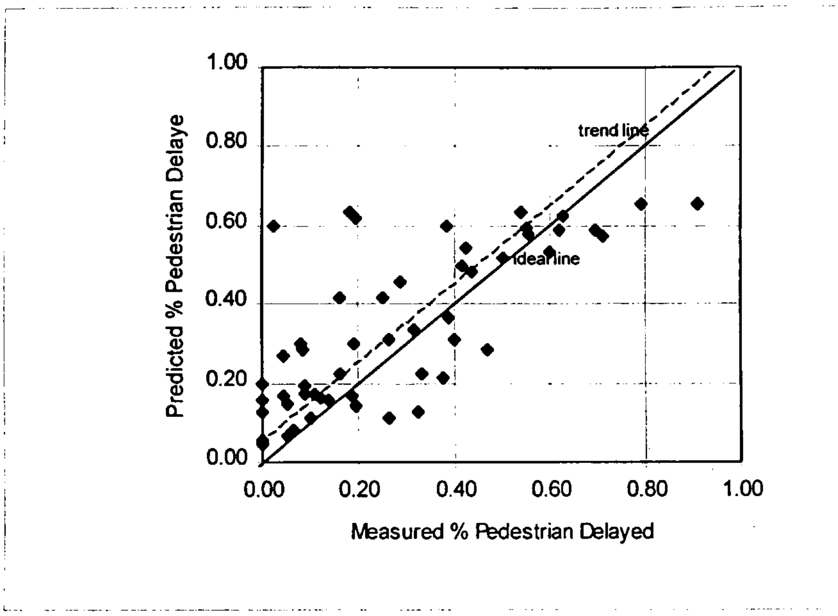


FIGURE 8.12 MEASURED VS. PREDICTED % PEDESTRIAN DELAYED

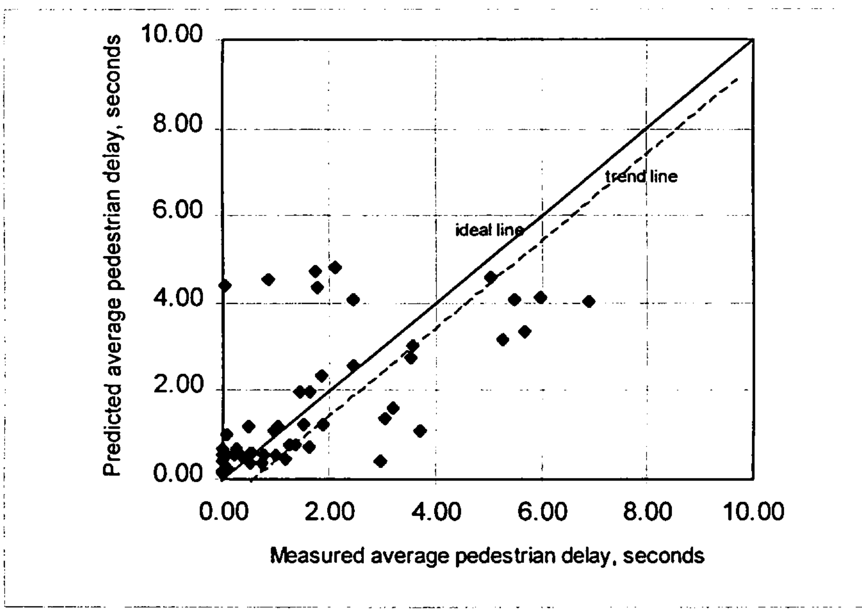


FIGURE 8.13 MEASURED VS. PREDICTED AVERAGE PEDESTRIAN DELAY

8.2.4 Accident Risks Prediction Model

For the accident risks, model developed by Zeeger (1989) was evaluated along with models developed specifically for this study. The following paragraphs compare and contrast in detail how the models had performed.

Observed parameters needed to calibrate the models are as shown in Table 8.14. The parameters include traffic volume, travel speed, link length, and various road geometry data. Accident data as extracted from the traffic police data were records of traffic accidents happened during 1993-1995 of all sorts including accident involving fatal, severely injured and vehicle damaged only. There were only 11 sites included in the calibration analysis as for the other sites the data were either not available or not complete.

TABLE 8.14 MEASURED PARAMETERS FOR ACCIDENT RISKS MODEL

Parameters	Mean	St.Deviation	Maximum	Minimum
Length	1.93	1.40	5.00	0.50
Grad(%)	7.93	8.45	25.00	1.00
Landuse	1.17	0.39	2.00	1.00
Volume	2010	670	2920	940
Speed	30.83	5.98	39.00	22.00
# lanes	2.50	0.90	4.00	2.00
Lane width	3.70	0.65	5.10	3.00
Width	8.98	2.40	13.00	6.50
acc./yr./km	0.70	0.69	2.73	0.00

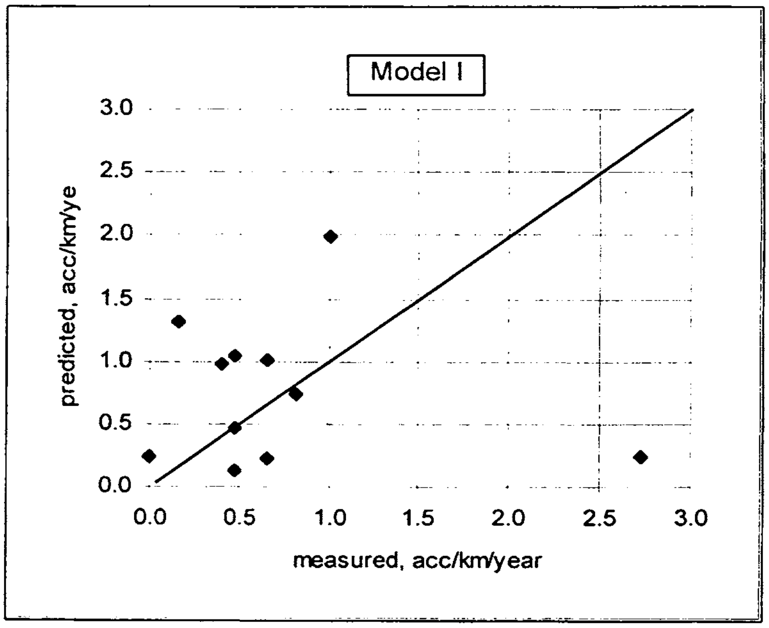


FIGURE 8.14 MEASURED VS. PREDICTED ACCIDENT RATE FOR MODEL I (ZEEGER)

As alternatives, two simple multivariate regression models had been developed in representing the data. The first one used the same dependent variable as in model I (accidents/km/year), while the second used slightly different variable excluding the link length (accident/year). Results of the analyses suggested very promising outcomes. With R-square values of 0.91 and 0.97 for Model II and Model III respectively, the models seemed to explain quite well most of the time. Figure 8.15 and 8.16 as well as Table 8.8 confirmed this conclusion.

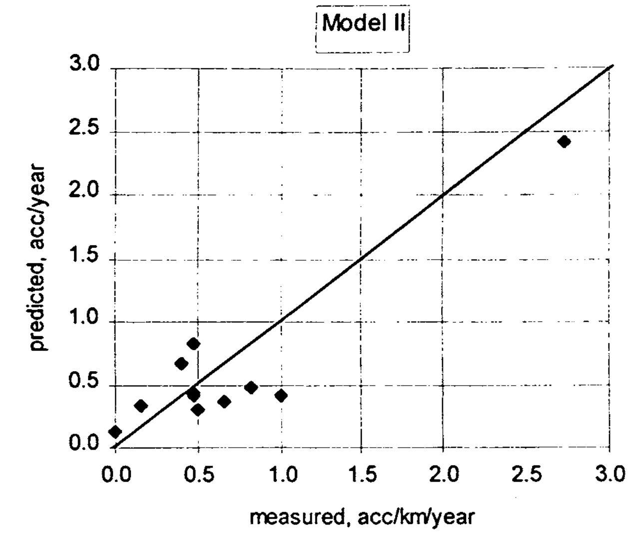


FIGURE 8.15 MEASURED VS. PREDICTED ACCIDENT RATE FOR MODEL II (REGRESSION)

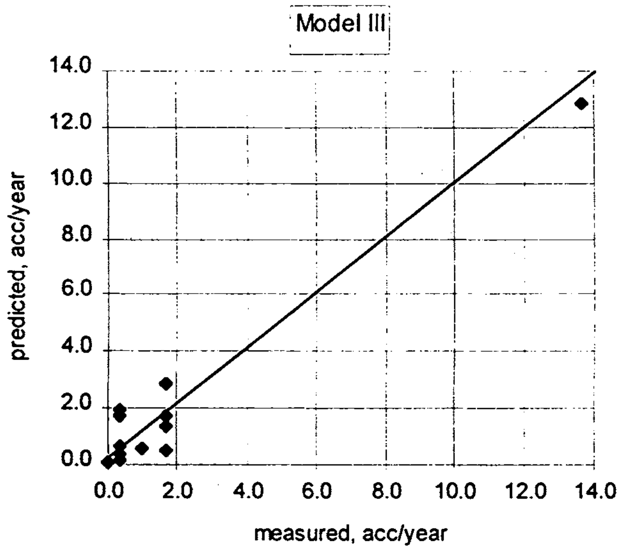


FIGURE 8.16 MEASURED VS. PREDICTED ACCIDENT RATE FOR MODEL III (REGRESSION)

Based on the statistical figures in Table 8.15, it was desirable to employ Model II in the study as the representative model in predicting the accident rate.

TABLE 8.15 PERFORMANCE OF CALIBRATED ACCIDENT RISKS MODELS

	Error (measured-predicted)		
Statistics	Model1	Model2	Model3
Mean	-0.26	0.11	-0.14
St. Deviation	1.21	0.29	0.87
max	2.50	0.59	1.17
min	-2.67	-0.35	-1.61
r	-0.15	0.91	0.97

8.3 Summary

Data on preferences of both community and experts towards environmental factors have been analysed and discussed. The results suggest that the community preferences were different significantly (at 95% level) from those of a group of experts, particularly in determining the most annoying factors. Noise was considered as the most annoying factor according the community, while the reverse was true according to the group of experts. Other factors, such as air pollution, pedestrian delay and accidents, were not considered as important as noise according the community. The experts, on the other hand, tended to say that the three factors were almost equally more important than noise.

In terms of road class, it was found that no significant difference in responses were observed between those from residents in arterials and collectors categories, while significant differences occurred between locals and both arterials and collectors. Similar results were also found between land-uses. The analyses suggested that influences of land-use were apparent between two groups, namely commercial and residential. These outcomes will lead to the development and adoption of models considering two different classes of roads and two different types of land-uses.

Calibrations of the environmental impact prediction models suggest the following. Of the noise model, method developed by Department of Transport UK (1988) performed satisfactorily and therefore was confirmed as being the adopted noise prediction model in the present study.

For predicting the concentration of air pollutant, GM model was proved to perform satisfactorily of CO concentration, but failed to predict the NOx concentration. This fact suggests to drop the model in for predicting NOx and to consider CO alone in air pollution module of the environmental capacity model.

Of pedestrian delay prediction model, adoption of modified Adam's delay model as proposed by Austroads (1995) was confirmed by satisfactory performance of the model.

On the other hand, accident risks prediction model as developed by Zeeger was not performed quite well in urban situation. Therefore, it was decided to develop a simple multivariate regression model for predicting the accident risks, which surprisingly gave very good outcome. A summary of model performance along with their correction factors is as shown in Table 8.16. All the models calibrated in this chapter are still subject to a validation process.

TABLE 8.16 SUMMARY OF MODEL CALIBRATION PERFORMANCES

Model	Author	Correction	95% C.I.	r	Remark
Noise	DoT (1988)	0.6 dB(A)	± 3.0	0.92	under-predict
Air Pollution	Chock (1979)	0.5 mg/m^3	± 6.0	0.32	under-predict
%Pedestrian Delay	Austroads (1995)	-0.06	± 0.32	0.74	over-predict
Accident	Widiantono (1999)			R^2 = 0.91	

After the models had been calibrated, it was desirable to see how the models performed against different set of data. The next chapter puts forward and describes the results of the validation undertaken in the present study using previously randomly selected set of data.

Chapter 9

Chapter 9

MODEL VALIDATION

This chapter discusses the results of the validation process. After being calibrated to the conditions of the study area, the models were then applied to the additional data that had been collected for this validation procedure. The validation was done by comparing measured (observed) with those predicted by the calibrated model. Calculations were then conducted towards the difference between the corresponding values. Furthermore, to have a better understanding of how the relationship between the values were, a simple regression analysis was established for every model. Results of the analyses were then used to determine how the models had performed.

The following sections describe one by one the results of the validation for the models. Note that the number of observations varied from model to model depending on the availability the qualified data. Complete calculations of the validation process can be observed in Appendices E and F.

9.1 Validation of the Proposed Environmental Utility Value Model

For the EUV model, validation was performed for overall categories. Model validation means checking the validity of the model using different set of data. In the case of EUV model, testing was made towards the suggested weights of environmental factors between calibration and validation data sets. Analysis towards individual categories was not possible to perform due to insufficient number of available data. Of total 17 data points, Major-Commercial made up only 4 data, Major Residential 8, Local-Commercial 2 and Local-Residential 5 data points. It was then decided to perform the validation of EUV model in predicting EUVs of overall categories.

Overall, the model had been performing satisfactorily. Calculation of the average difference between measured and predicted values (residuals) suggested that the model slightly over-predicted by 3.67 (9.5%). As the figures in Table 9.1 suggest, the average values were quite similar between measured and predicted values.

TABLE 9.1 SUMMARY STATISTICS OF EUV MODEL (VALIDATION)

EUV	*Mean*	*St. Deviation*
Measured (M)	34.75	20.89
Predicted (P)	38.42	16.64
M-P	-3.67	10.54

TABLE 9.2 REGRESSION RESULTS BETWEEN MEASURED AND PREDICTED EUV VALUES (VALIDATION)

Regression Statistics	
Multiple R	0.87
R Square	0.75
Adjusted R Square	0.73
Standard Error	10.79
Observations	17

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*	
Regression	1	5235.82	5235.82	45.00	0.00	
Residual	15	1745.09	116.34			
Total	16	6980.90				

Parameters	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-7.03	6.75	-1.04	0.31	-21.43	7.37
Predicted EUV	1.09	0.16	6.71	0.00	0.74	1.43

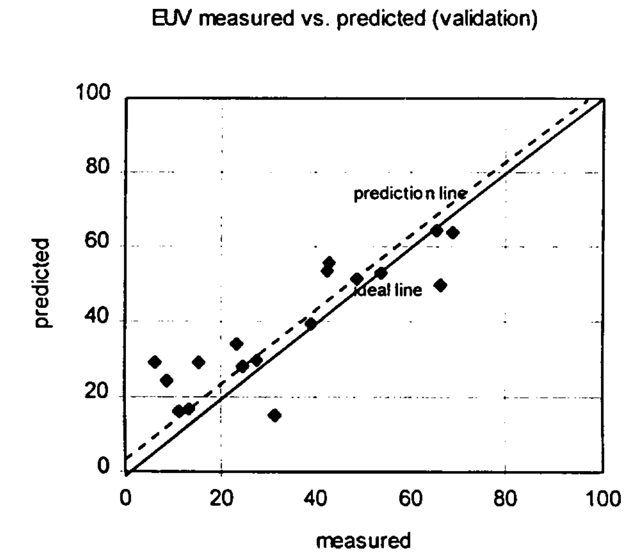


FIGURE 9.1 SCATTER DIAGRAM OF MEASURED AND PREDICTED EUVS (VALIDATION)

This claim was supported by the result of regression analysis between the measured and predicted EUV values. The result, as presented in Table 9.2, suggests R^2 value of 0.75, which could be interpreted, that there had been a good relationship between the corresponding values. The scatter diagram as depicted by Figure 9.1 shows how the position of prediction line was relative to indifferent (ideal) line. The prediction line was a line parallel to the indifferent line by a distance of average residual (3.67) value. Prediction line above indifferent line indicates a tendency of over-prediction.

9.2 Validation of the Environmental Impact Prediction Models

In this section results of validation of the environmental impact prediction models are presented. The models included noise, air pollution, pedestrian delay and accident rate prediction models.

9.2.1 Noise Prediction Model

Validation of the noise prediction model produced the following results. Generally speaking, the calibrated model performed quite well in predicting the L_{10} noise level. Comparison between measured and predicted values suggested that on average the model predicted the noise level with a difference of only 0.27 dB(A) or about 0.3% of the average value. As figures in Table 9.3 suggest, the average values as well as the standard deviations of the measured and predicted values were both quite similar.

The regression analysis of the measured and predicted values also suggested a convincing result. As Table 9.4 suggests, R^2 value of 0.98 was observed which means that the predicted values explained 98 percent of the data variability. With a significance F value of 0.00 (< 0.05), the analysis also suggests that the relationship was significant.

TABLE 9.3 SUMMARY STATISTICS OF NOISE MODEL (VALIDATION)

L10-1hour	*mean*	*s.deviation*
Measured	71.38	4.43
Predicted	71.11	4.11
Residual	0.27	0.62

Note: L10-1hr in dB(A)

TABLE 9.4 REGRESSION RESULTS BETWEEN MEASURED AND PREDICTED VALUES OF L10 (VALIDATION)

Regression Statistics	
Multiple R	0.99
R Square	0.98
Adjusted R Square	0.98
Standard Error	0.57
Observations	17

TABLE 9.4 REGRESSION RESULTS BETWEEN MEASURED AND PREDICTED VALUES OF L10 (VALIDATION) - CONT'D

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	309.15	309.15	966.36	0.00
Residual	15.00	4.80	0.32		
Total	16.00	313.94			

Parameters	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-4.73	2.45	-1.93	0.07	-9.95	0.50
L10-predicted	1.07	0.03	31.09	0.00	1.00	1.14

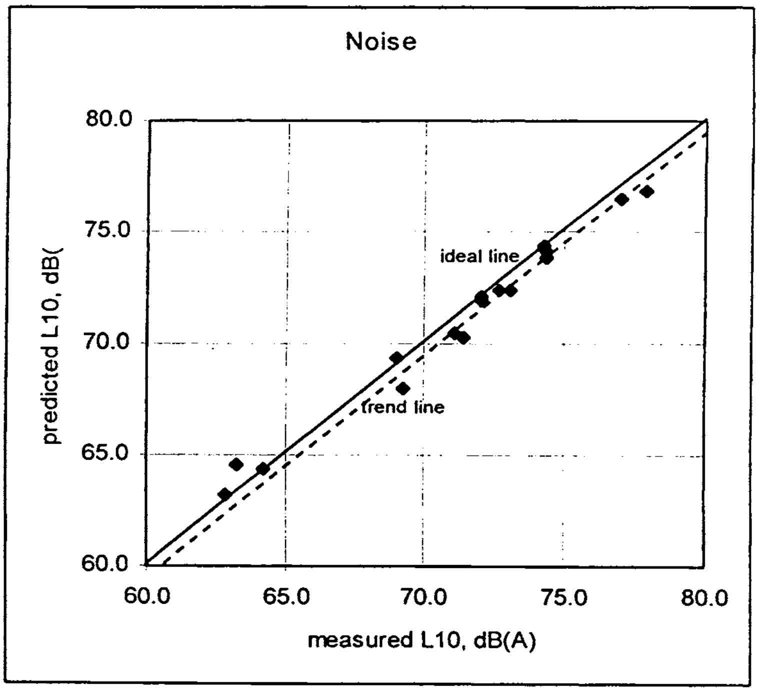


FIGURE 9.2 SCATTER DIAGRAM OF MEASURED AND PREDICTED L10 (VALIDATION)

Figure 9.2 also visually confirms this statement. Very close distance (0.27) between the ideal and the prediction line shows that the model predicted very well. Because the prediction line is slightly below the ideal line suggests a slightly under-prediction of the calibrated model.

9.2.2 Air Pollution Prediction Models

Validation of the air pollution model suggested the following outcomes. The average difference between measured and predicted values of CO concentration was about 0.37 mg/m^3 , which was around 12% of the average value. The average values of CO concentration, both measured (3.03) and predicted (3.23), were quite similar, although the predicted values had slightly greater standard deviation (see Table 9.5).

TABLE 9.5 SUMMARY STATISTICS OF AIR POLLUTION MODEL (VALIDATION)

CO concentration	*Mean*	*St.deviation*
Measured	3.03	1.65
Predicted	3.23	2.26
Residual	0.37	1.19

Note: CO concentration in mg/m³

TABLE 9.6 REGRESSION RESULTS BETWEEN PREDICTED AND MEASURED VALUES OF CO CONCENTRATIONS (VALIDATION)

Regression Statistics	
Multiple R	0.79
R Square	0.62
Adjusted R Square	0.59
Standard Error	0.71
Observations	16

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	1	11.47	11.47	22.63	0.00
Residual	14	7.09	0.51		
Total	15	18.56			

Parameters	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	1.14	0.37	3.08	0.01	0.35	1.93
Predicted CO	0.61	0.13	4.76	0.00	0.34	0.89

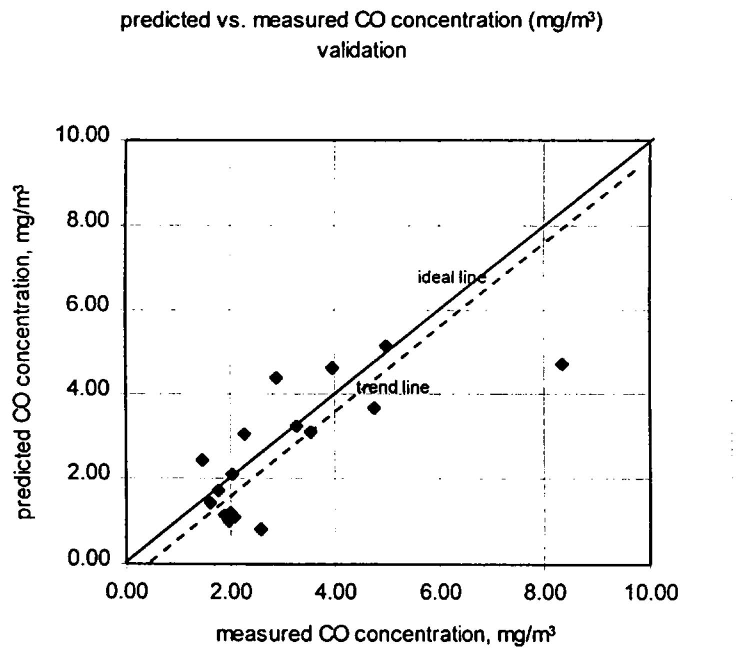


FIGURE 9.3 SCATTER DIAGRAM OF MEASURED AND PREDICTED CO CONCENTRATION (VALIDATION)

Regression analysis of these data showed that there was relatively good relationship between measured and predicted values. With R^2 of 0.62, it confirms that the model explained about

60% of the variability in the data. The analysis also suggests that the relationship was significant at 5% level (see Table 9.6).

Plotting of the data also indicates supporting result. Figure 9.3 depicts a scatter diagram between measured and predicted values of CO concentration of validation data. It can be observed from the figure that the prediction line was slightly drawn below the ideal line by a margin of about 0.40 mg/m^3, which indicates under prediction of the model.

9.2.3 Pedestrian Delay Prediction Model

Results of the validation of the pedestrian delay model were not as impressive as the previous models. As figures in Table 9.7 indicate, the average difference between measured and predicted values were quite high, 19% of percent delayed pedestrians and -0.65 seconds of average pedestrian delays. They made up about 46% and 78% of the average measured value respectively.

TABLE 9.7 SUMMARY STATISTICS OF PEDESTRIAN DELAY MODELS (VALIDATION)

Model	*Value*	*mean*	*s.deviation*
Percent delayed pedestrians	Measured	41	28
	Predicted	36	29
	Residual	19	23
Average pedestrians delay	Measured	0.83	0.64
	Predicted	1.48	0.85
	Residual	-0.65	0.60

Note: percent delayed pedestrians in %; average pedestrians delay in seconds.

TABLE 9.8 REGRESSION RESULTS BETWEEN MEASURED AND PREDICTED VALUES OF PERCENT DELAYED PEDESTRIANS (VALIDATION)

9Regression Statistics	
Multiple R	0.62
R Square	0.38
Adjusted R Square	0.32
Standard Error	0.24
Observations	13

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	0.38	0.38	6.69	0.03
Residual	11.00	0.62	0.06		
Total	12.00	0.99			

Parameters	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.17	0.10	1.68	0.12	-0.05	0.39
%delayed-pred	1.12	0.43	2.59	0.03	0.17	2.08

TABLE 9.9 REGRESSION RESULTS BETWEEN MEASURED AND PREDICTED VALUES OF AVERAGE PEDESTRIANS DELAY (VALIDATION)

Regression Statistics	
Multiple R	0.71
R Square	0.50
Adjusted R Square	0.45
Standard Error	0.47
Observations	13.00

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	2.47	2.47	10.94	0.01
Residual	11.00	2.48	0.23		
Total	12.00	4.94			

10Parameters	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.04	0.27	0.16	0.88	-0.55	0.64
Predicted ave. delay	0.53	0.16	3.31	0.01	0.18	0.89

Regression analyses of these data also suggested that the relationship between measured and predicted values were not very good. As can be observed in Table 9.8 and 9.9, R^2 of 0.38 and 0.50 were observable for percent pedestrian delayed and average delay of pedestrians respectively. These figures suggested that the models only explain about 50% or less of the data variability, which was less than satisfactory.

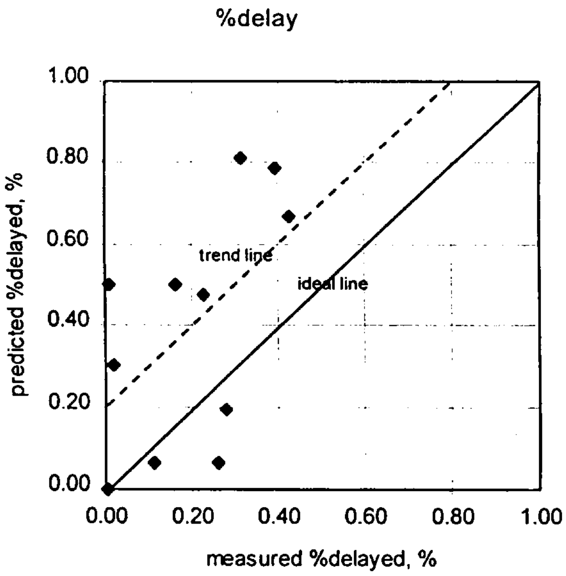


FIGURE 9.4 SCATTER DIAGRAM OF MEASURED AND PREDICTED PERCENT DELAYED PEDESTRIANS (VALIDATION)

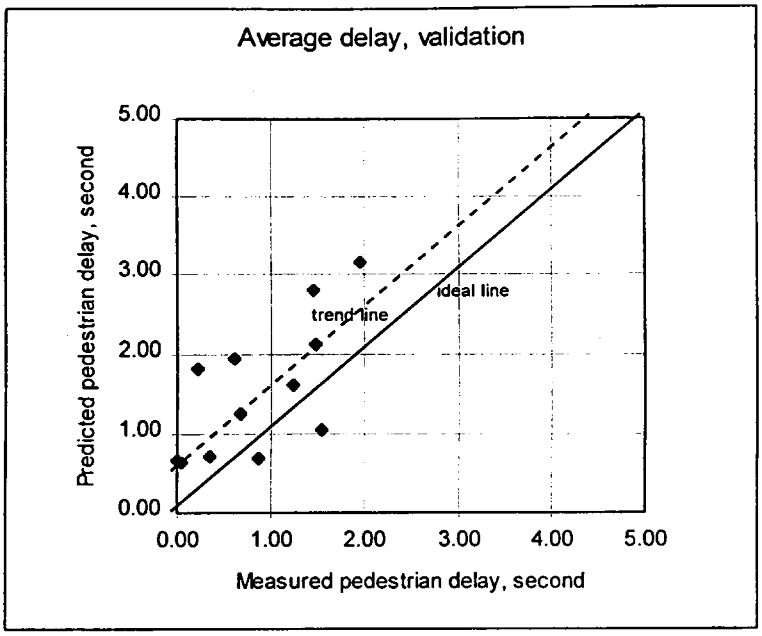


FIGURE 9.5 SCATTER DIAGRAM OF MEASURED AND PREDICTED AVERAGE PEDESTRIANS DELAY (VALIDATION)

Figures 9.4 and 9.5 graphically show the relationship between measured and predicted values of percent delay and average delay respectively. The scatter plots show how the prediction line was away from the ideal line with quite noticeable margins.

9.2.4 Accident Rate Prediction Model

For accident rate prediction model, summary result of the validation are as presented in Table 9.10. It can be noted from the table that the model predicts with an average residual of about -0.10 accidents/km/year, which makes up about 18% of the average recorded value which is satisfactory. The average predicted value (0.58) was within reasonable distance from the recorded value (0.48).

TABLE 9.10 SUMMARY STATISTICS OF ACCIDENT RATE MODEL (VALIDATION)

Accident Rate	*mean*	*s.deviation*
Recorded	0.48	0.50
Predicted	0.58	0.31
Residual	-0.10	0.36

Note: accident rate in accidents/km/year

Regression analysis of these data produced results as presented in Table 9.11. A relatively low R^2 of 0.50 was observed, indicating that the model was a reasonable predictor. This unimpressive outcome may be due to insufficient number of observation (5). Nevertheless, the model does appear reasonable when shown graphically as depicted in Figure 9.6. The diagram shows that the model tended to over-predict by about 0.10 and the data did not scatter very much from the ideal line. It was therefore concluded that the calibrated model was still acceptable.

TABLE 9.11 REGRESSION RESULTS BETWEEN MEASURED AND PREDICTED VALUES OF ACCIDENT RATE (VALIDATION)

Regression Statistics	
Multiple R	0.71
R Square	0.50
Adjusted R Square	0.33
Standard Error	0.41
Observations	5

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.51	0.51	2.97	0.18
Residual	3	0.51	0.17		
Total	4	1.02			

Parameter	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-0.20	0.43	-0.46	0.68	-1.57	1.18
Predicted accident rate	1.16	0.67	1.72	0.18	-0.98	3.30

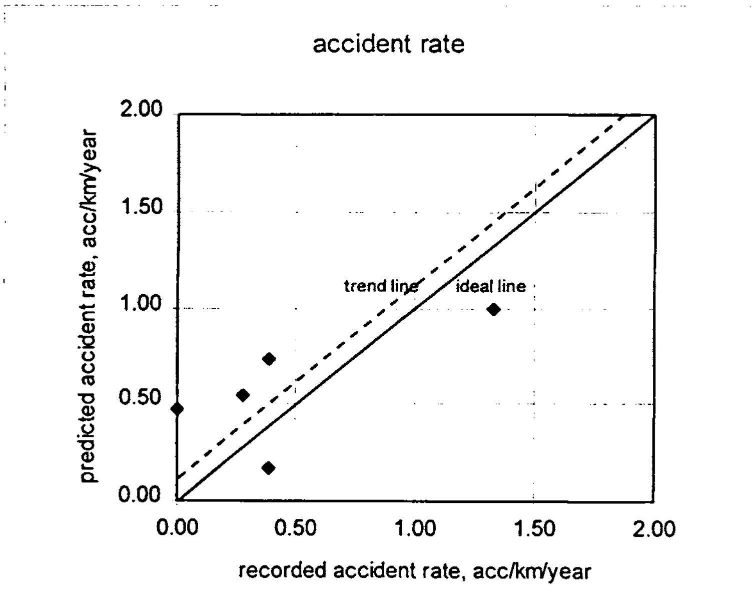


FIGURE 9.6 SCATTER DIAGRAM OF RECORDED AND PREDICTED VALUES OF ACCIDENT RATE (VALIDATION)

9.3 Summary

The calibrated models employed in the present study have been validated. Measured and predicted values were compared and regression analyses were conducted to see how the calibrated models had performed. Scatter diagrams of the measured and predicted values had also been plotted for each model.

The results suggested that basically the models performed quite satisfactorily if not very impressively. The only model that performed below the expectation was of pedestrian delay model.

The following chapter will show how these models will be working together in determining the environmental capacity of roads.

Chapter 10

Chapter 10

MODEL APPLICATION

After being calibrated and validated, it was now desirable to see how the complete model works in processing and providing some relevant information as may probably be needed by engineers or planners regarding the road related environmental problems. This chapter shows how the model might perform. Earlier part of the chapter will revisit the overall models involved in the proposed Multi-Factor Environmental Capacity (MFEC) for roads. All the models together with their required parameters and calibrated coefficients are outlined. The following section will then discuss the conditions in which the model will apply. It sets out the parameter spaces that are applicable to the models.

Later parts of the chapter will show how the model could be applied to the real world conditions. For demonstration purposes, a hypothetical set of data was generated, based on the information on the range of applicability of the model to include as much as possible of the models applicable ranges. Some possibly elaborated outputs will also be shown to give the ideas on how the model might produce some needed information. The information may include some relevant ratios and comparable figures as might have been obtained from the traditional environmental capacity approach.

10.1 The Overall Model

Basically the overall model could be divided into two groups, the general model group that consists of Environmental Utility Value (EUV) models and MFEC models, and the predicting model group that simply composed of environmental prediction models.

The models for determining EUV, which may be regarded as the relative assessment value of environmental conditions of the corresponding location (road), composed of four models one for each category. They were differentiated into two road classes (Major and Local roads) and two distinct land-uses (Commercial and Residential). The MFEC models were the models that directly estimate the MFEC using such variables as traffic speed *S*, road width *W* and the Environmental Utility Value at limit state EUV_L.

Of the predicting model group, there were also four models for predicting the environmental factors of noise, air pollution, pedestrian delay and accident rate. These models estimated the level of impact for the individual conditions as well as the level of impacts at the suggested capacity level. Variables required in so doing might include such road, traffic parameters and meteorological parameters. Road parameters would include road width *W*, number of lanes *Ln*, gradient *G* and road direction *RD*, while traffic parameters include volume *V*, speed *S*, and proportion of heavy vehicles *HV*. Meteorological data, which are mainly used for predicting air pollution, might include wind speed *WS*, wind direction *WD* and temperature *T*.

10.2 Range of Applicability of the Models

Table 10.1 presents the (rounded) maximum and minimum values of the relevant variables in the overall data and in the classified categories. It also gives the proportion of data in each category. The information provides a useful guide to the areas in which the model is particularly robust.

Although the table shows the maximum and minimum values for every variable, it does not mean that all combinations within the range is applicable. Some combinations between extreme values may not be appropriate to the model. Therefore, some caution should be exercised in applying these values, particularly in a hypothetical case.

10.3 Model Mechanism

Basically the overall models could be divided into five modules: the INPUT, MFEC, EUV, ENVIRO, and the OUTPUT. The ENVIRO module was further divided into four sub modules namely NOISE, AIRPOL, DELAY and ACCID. The flow of mechanism and interconnection between all the modules may well be understood by Figure 10.1.

Using data from the INPUT module, the EUV module could calculate the required EUV_L, which together with other variables could estimate MFEC and the approximate physical capacity of the roads concerned. INPUT also supplies required variables to the ENVIRO module to estimate the relevant environmental factors. Outcomes from this module could then be used to determine the EUVs of the roads concerned. Using the information from MFEC, the module might also produce the corresponding values at MFEC level. If there was any excessive impact at this level, the MFEC might be re-calculated by applying different EUV_L depending on the assumed scenario. OUTPUT module simply summarizes and compiles the outcomes together to provide some useful information.

TABLE 10.1 THE PARAMETER SPACES OF THE MODEL

Variables	Overall		Major-Com		Major-Res		Local-Com		Local-Res	
	max	min	max	min	max	min	Max	min	max	min
W, metres	13.0	4.0	13.0	5.0	12.6	5.0	12.0	5.0	7.0	4.0
Ln	4.0	2.0	4.0	2.0	4.0	2.0	3.0	2.0	2.0	2.0
Lw, metres	5.1	2.0	4.0	2.5	5.1	2.5	4.0	2.5	3.5	2.0
G, %	15.0	1.0	15.0	1.5	15.0	1.0	2.0	1.0	14.0	1.0
RD, degrees	177.0	0.0	110.0	5.0	177.0	0.0	166.5	0.0	104.0	0.0
WS, ms^{-1}	6.7	0.0	6.7	0.0	6.7	0.25	1.67	0.0	2.0	0.3
WD, degrees	348.7	11.2	213.7	11.2	348.7	11.2	348.7	11.2	168.7	56.2
T, centigrade	34.0	21.0	32.0	22.5	34.0	23.0	34.0	23.0	27.0	21.0
V, vph	3162	185	2880	1370	3162	455	989	346	1003	185
HV, %	4.0	0.00	4.0	1.0	3.4	0.5	3.1	0.2	2.7	0.0
S, km/h	46.0	23.0	31.0	19.0	46.0	24.0	37.0	24.0	36.0	23.0
$L_{10\text{-}1hr}$, dB(A)	77.9	62.9	77.9	72.7	77.6	67.1	73.9	66.8	74.1	62.9
Leq, dB(A)	76.0	58.4	76.0	70.1	74.5	64.8	72.1	63.2	71.2	58.4
NOx, ppm	0.70	0.01	0.21	0.03	0.25	0.01	0.70	0.02	0.26	0.02
CO, ppm	7.30	1.05	6.05	1.07	7.30	1.05	6.35	1.26	3.42	1.20
HC, ppm	5.07	1.68	4.89	2.50	5.07	2.07	5.07	1.98	3.91	1.68
Delay, seconds	13.71	0.00	7.81	0.22	13.71	0.02	3.71	0.00	2.95	0.00
% Delayed, %	0.95	0.00	0.78	0.06	0.95	0.02	0.29	0.00	0.50	0.00
acc./km/yr.	3.33	0.00	3.33	0.06	0.82	0.00	0.98	0.00	0.67	0.00

Note: *W*= road width; *Lw*=lane width; *Ln*=number of lanes; *G*=gradient; *RD*= road direction, measured clockwise from North; *WS*=equivalent wind speed at 4.5 m height, *WD*, wind direction, measured clockwise from North; *T*= temperature; *V*=traffic volume; *HV*=proportion of heavy vehicles; *S*=average traffic speed.

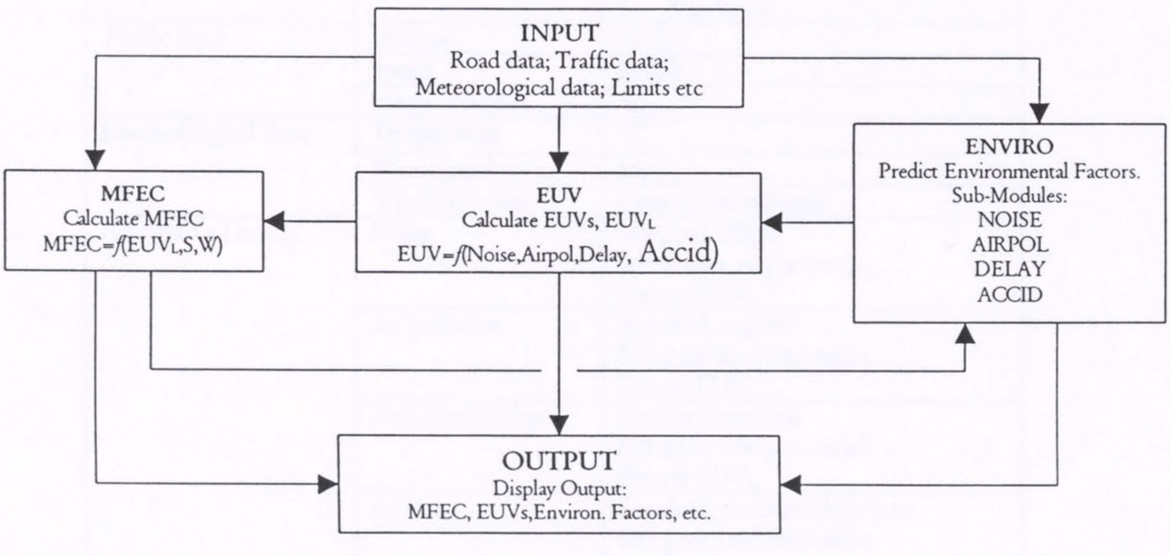


FIGURE 10.1 MODEL MECHANISM

10.4 INPUT Module

Input module is the opening module of the model. It provides data input interface to be used in the model. Although the input parameters for meteorological conditions seem to be too detail and precise, it's not really the case. As the MFEC model itself is intended for facilitating the brief evaluation of environmental conditions or to provide basic information for decision making, the model does not require accurate and precise prediction of the factor. Therefore the input parameters for meteorological data may be simplified with more practical values such as the average temperature and wind speed, while perpendicular wind direction may be assumed to obtain maximum concentration of air pollutants along the roadside. Basically, the input data were organized as presented in Table 10.2.

TABLE 10.2 DATA INPUT MODULE

Data Category	Data Item	Unit or Options
Road ID:	Road Name	User specified
	Road Code	User specified
Road data:	Class	1. Major – arterial or collector; 2. Local
	Pavement	1. Chip Seal; 2. PC Concrete; 3. Dense Graded AC; 4. Open Graded AC
	Width	Metres
	Number of lanes	User nominated
	Lane Width	Metres
	Gradient	%
	Road Direction	Degrees from North
	Shoulder type	1. Soft; 2. Hard
Landuse Data:	Type	1. Commercial; 2. Residential
Traffic data:	Volume	v.p.h.
	Speed	Km/h
	Heavy Vehicles	%
Meteorological data:	Temperature	°C
	Wind Speed	Ms^{-1}
	Wind Direction	Degrees from North
Acceptable Limits:	Noise	Standard, dB(A) Self generated percentile; Pre-set EUV_L
	Air pollution	Standard, mg/m^3 Self generated percentile; Pre-set EUV_L
	Pedestrian Delay	Standard, seconds Self generated percentile; Pre-set EUV_L
	Accident	Standard, accidents/km/year Self generated percentile; Pre-set EUV_L
Other	Noise reflection	1. Free field; 2. 1m in front of building facade; 3. Continuous wall opposite

10.4.1 ENVIRO Module

This module estimates the environmental impact of roads using the available information from the INPUT module. The module is further divided into four sub-modules, each of which specifically handles the calculation of an individual factor. Outcomes of this module can be either forwarded to the EUV module or the OUTPUT module.

NOISE Prediction Sub-Module

Noise module predicts the noise level based on the given conditions of each individual road as obtained from the INPUT module. Variables required for this purpose are:

- Traffic Volume
- Traffic Speed;
- Percent Heavy Vehicles;
- Road width;
- Gradient;
- Shoulder type; and
- Reflection.

Besides, the sub-module may also produce additional information such as environmental capacity based on noise factor alone (NoiseEC), and noise level when traffic volume was equal to MFEC (MFECNoise).

AIRPOL Prediction Sub-Module

AIRPOL sub-module predicts the concentration of CO at the given conditions. Variables need in so doing include:

- Traffic Volume
- Traffic Speed;
- Percent Heavy Vehicles;
- Road Direction;
- Wind Direction
- Wind Speed;
- Temperature

As with the NOISE sub-module, AIRPOL also produce additional information on environmental capacity based on air pollution factor alone (AirpolEC) and the CO concentration at MFEC level.

DELAY Prediction Sub-Module

This sub-module predicts the average pedestrian delay based on the available information. Variables used in this sub-module include:

- Traffic Volume
- Road width; and
- Number of lanes

It also produces estimated delay to pedestrians at MFEC level and suggests the environmental capacity based on delay alone (DelayEC).

ACCID Prediction Sub-Module

ACCID sub-module estimates the accident rate of each individual site using the following variables obtained from the INPUT module:

- Traffic Volume
- Traffic Speed;
- Road Width
- Lane width; and
- Land-use type.

The sub-module also provides information on environmental capacity based on accident alone (AccidEC) and the accident rate at MFEC level.

10.4.2 EUV Module

This module calculates the Environmental Utility Value using the information from either INPUT module or ENVIRO module. Information from the INPUT module required to estimate the EUV_L, include:

- Noise acceptable limit
- Air pollution acceptable limit
- Pedestrian delay acceptable limit; and

- Accident rate acceptable limit

EUV_L might also be determined using self-generated percentiles of the parameters. The percentiles are calculated from the data input into the model. In this case, the user had to provide information on what percentile was going to be used to calculate the EUV_L. From this information, the program calculates the percentile values from the available data and considers these values as the acceptable limits. Another option in determining the EUV_L is through pre-determined value as desired by the user. As EUV is a utility value ranging between 0 to 100, where 0 was the best and 100 was the worst conditions of environment, any EUV_L between both values might to some extent be interpreted as the percentile of the sites with environmental conditions better than the acceptable standards. Thus, if it is desirable to have 60% of sites better than the environmental limits – which might be indicated by Volume/MFEC ratio less than one - it is recommended to set the EUV_L equal to 60.

Besides the EUV_L, this module also calculates the individual EUV of each site based on information from the ENVIRO module. Information of this individual EUV might be used to obtain such information as the worst site, the best site or list of 10 worst or best sites or any other information regarding sorting sites based on environmental conditions.

10.4.3 MFEC Module

The MFEC module calculate the multi-factor environmental capacity using the following variables:

- EUV_L or EUV for the limit state conditions, obtained from EUV module;
- Traffic speed S, from INPUT module; and
- Road width W, from INPUT module.

In the option where EUVL is determined from acceptable standards, the MFEC module would forward the result of the calculated MFEC to the ENVIRO module and ENVIRO would check whether or not the MFEC produced any excessive impact (>10-15% of acceptable limit). If there were an excessive impact, the ENVIRO would forward the information to the EUV module and the module would then changes the values of the factors, and forwarded the information to the MFEC module. This loop would continue until acceptable conditions were obtained.

The same process occurs for the option using self-generated percentile. But, for the pre-determined EUV_L the module works in slightly different way. As the value was pre-determined, there was no available information regarding the individual limits of each of the factors. Therefore, the MFEC result is accepted without further modification.

10.4.4 OUTPUT Module

The OUTPUT module simply compiles the available information and displays the information to the user. Possible typical information produced by the model might include the following:

- Road name;
- Road code;
- Category;
- Noise level;
- CO concentration;
- Average delay to pedestrians;
- Accidents/km/year;
- Environmental Utility Value (EUV);
- Multi-Factor Environmental Capacity (MFEC);
- Other useful information:
    - Physical Capacity (approximated);
    - Volume/MFEC ratio;
    - MFEC/Capacity ratio;
    - MFEC – NoiseEC;
    - MFEC - AirpolEC
    - MFEC – DelayEC;
    - MFEC – AccidEC;
    - MFEC – traditional EC
    - The best site
    - The worst site
    - The best 10;
    - The worst 10.

10.5 Hypothetical Application

This section demonstrates the application of the model using a hypothetical set of data based on values within the acceptable range of the model. In this case 32 sites as presented in Table 10.3 were generated, composed of 8 hypothetical sites within each category. The data were designed to include as wide range of parameter spaces as possible, with every attempt being made to ensure they were realistically based.

10.5.1 Scenario

As described previously, there are three different ways of determining EUV_L, which are firstly by using self-generated percentiles, secondly by using acceptable standards, and thirdly by using pre-determined values. In this demonstration, the program was run three times, once for each scenario. The assumed acceptable standards were as presented in Table 10.3. Self-generated limits were determined using the 70th percentile of the input data, while a value of 60 was used for the pre-determined EUV_L.

TABLE 10.3 ACCEPTABLE LIMITS OF FACTORS

	Acceptable Limit			
Category	L10-1hr, dB(A)	CO mg/m^3	Ave. Delay sec	Accident rate acc./km/yr.
MajorCom	76.9	3.65	2.03	1.36
MajorRes	74.4	3.51	2.17	0.95
LocalCom	70.3	3.04	1.24	0.76
LocalRes	70.2	1.01	1.18	0.69
Standards	68	10	4	0.9
Note: figures other than standards are the 70th percentile values of the data.				

Tables 10.4 and 10.5 show how the program adjusted the standard limits by lowering the air pollution and delay limits to obtain EUV_L values that could reduce the MFEC so that the new value did not produce any excessive impact. Table 10.6 presents the changes over the average ratios between the MFEC level impact and the standard values. The first row presents the values before the optimization occurred and the second row the values after the adjustments were made. The adjustments reduced the average accident ratio from 1.69 to 1.09 and the noise ratio from 1.09 to 1.06, which may be regarded as acceptable.

TABLE 10.4 ACCEPTABLE LIMITS ADJUSTMENTS

	Acceptable Limits	
Factor	Standard	Adjusted
Noise, dB(A)	68	68
Airpol, mg/m^3	10	5
Delay, seconds	5	3
Accid, accidents/km/year	0.9	0.9

TABLE 10.5 STANDARD AND ADJUSTED EUV_L

	EUV_L	
Category	Standard	Adjusted
MC	52	35
MR	53	36
LC	55	36
LR	52	36

TABLE 10.6 RATIOS BETWEEN MFEC-LEVEL IMPACTS AND STANDARD VALUES (BEFORE AND AFTER ADJUSTMENT)

Limits	MFECNoise/limit	MFECAirpol/limit	MFECDelay/limit	MFECAccid/limit
Standard	1.09	0.42	0.62	1.66
Adjusted	1.06	0.51	0.55	1.09

10.5.2 Results

Results of the calculations by the models are presented in Tables 10.8, 10.9 and 10.10 for the first, second and third scenario respectively. The average MFEC as calculated by the model for the first, second and third scenario was 1306, 1731, and 2011 vph respectively. For comparison, the average of traditionally calculated EC was 821, 396 and 396 respectively (see the fourth column from the right of the tables). These indicated that an average increase of environmental capacity between 485 and 1615 vph was identifiable in these cases.

In terms of the ratio between MFEC and the corresponding physical capacity of the road, on average MFECs made up of around 0.45 of the physical capacity in the first scenario. The ratio was higher in the second (0.63) and the third (0.73) scenarios (see the last column of the tables). This could be regarded as a significant improvement from the traditional way, in which EC usually only makes up about 0.14-0.30 of its corresponding road capacity.

The utility function producing EUV from measured factors (noise, air pollution, pedestrian delay and accident rate) as discussed in sections 7.3 (Analysis of Preferential Data) and 8.1 (Calibration of the Environmental Utility Functions), suggested the weights of environmental factors as presented in Table 8.5 (in Chapter 8). The figures also show that Noise contributed for around 35% of the total environmental utility of a road site. In the conventional EC, this was assumed to be 100%, as noise was considered as controlling factor that produces the minimum EC. In the MFEC, the actual contribution of noise as stated by people's preference was only 35%, meaning that if noise is the only factor considered, the actual EC may be increased up to around three times. In that sense, it is quite reasonable that MFEC produces almost three times higher than the Noise EC. This increase in fact equals to about 7.5% increase of the noise limit level or about 5.0 dB(A).

In this case, the MFEC does not necessarily say that people may accept higher noise level in return of lower other environmental factors, because it is very possible that the other factors are increasing too. But, it would rather say that people do regard noise as part of the whole environmental factors that they sense simultaneously. Therefore, the actual acceptance is greater than if noise is considered as an isolated factor.

TABLE 10.7 DATA OF THE HYPOTHETICAL CASE

Road ID		Road data							Landuse	Traffic data			Meteorological data			Others	
Name	Code	Class	Pavmnt	W	Ln	Lw	G	RD	Type	V	S	HV	T	WS	WD	Shoulder	Reflection
A	MC01	Major	AC	12.00	4	3.00	1.50	110.0	Com	3142	19.00	4.00	32.0	6.7	213.8	soft	wall opp.
B	MC02	Major	AC	8.00	3	3.00	2.00	5.0	Com	1514	31.00	1.00	22.5	0.0	11.3	soft	wall opp.
C	MC03	Major	AC	13	4	3.00	10.00	7.0	Com	1600	26.00	4.00	26.0	2.5	101.3	soft	none
D	MC04	Major	AC	13	4	3.00	10.00	8.0	Com	1500	27.00	3.00	26.0	4.0	90.0	soft	none
E	MC05	Major	AC	8.4	3	3.00	7.00	9.0	Com	1550	40.00	2.00	25.0	2.0	101.0	soft	wall opp.
F	MC06	Major	AC	8.4	3	3.00	7.00	40.0	Com	1300	38.00	2.00	28.0	2.3	123.0	soft	wall near
G	MC07	Major	CS	12	4	3.00	8.00	60.0	Com	1500	45.00	1.00	29.0	0.5	50.0	soft	wall near
H	MC08	Major	AC	9.00	3	3.00	1.00	101.0	Com	1500	30.00	1.00	30.0	6.0	23.0	soft	none
I	MR01	Major	AC	12.60	4	3.00	2.00	177.0	Res	2000	46.00	1.00	34.0	6.7	348.8	soft	wall opp.
J	MR02	Major	AC	5.00	2	3.00	15.00	0.0	Res	455	24.00	0.49	23.0	0.3	11.3	soft	wall opp.
K	MR03	Major	AC	6.00	2	3.00	2.00	95.0	Res	1230	25.00	2.00	29.0	2.0	123.0	soft	none
L	MR04	Major	AC	7.00	2	3.00	3.00	122.5	Res	1450	27.00	1.00	31.0	3.0	124.0	soft	wall opp.
M	MR05	Major	AC	8.00	3	3.00	2.50	128.0	Res	1670	40.00	2.00	31.0	2.5	125.0	soft	wall opp.
N	MR06	Major	CS	9.00	3	3.00	1.00	164.0	Res	2050	35.00	1.50	31.0	6.0	60.0	soft	none
O	MR07	Major	AC	10.00	3	3.00	1.00	90.0	Res	1350	25.00	2.50	31.0	4.0	325.0	soft	none
P	MR08	Major	AC	11.00	4	3.00	4.00	85.0	Res	1500	27.00	0.80	30.0	1.5	122.5	soft	wall opp.
Q	LC01	Local	AC	10.00	3	3.00	2.00	166.5	Com	989	37.00	3.10	34.0	1.7	348.8	soft	wall near
R	LC02	Local	AC	7.00	2	3.00	1.00	0.0	Com	500	30.00	0.16	23.0	0.0	11.3	soft	wall near
S	LC03	Local	AC	6.40	2	3.00	1.00	20.0	Com	550	36.00	1.00	30.0	1.1	12.0	soft	none
T	LC04	Local	AC	6.40	2	3.00	1.00	28.0	Com	600	37.00	1.00	25.0	1.5	135.0	soft	wall opp.
U	LC05	Local	CS	6.40	2	3.00	2.00	64.0	Com	650	37.00	1.00	26.0	0.5	95.0	soft	wall opp.
V	LC06	Local	AC	7.50	3	3.00	1.50	144.0	Com	750	34.00	1.00	28.0	0.8	85.0	soft	none
W	LC07	Local	AC	9.00	3	3.00	2.00	122.0	Com	800	37.00	0.90	24.0	0.9	67.5	soft	wall opp.
X	LC08	Local	AC	9.50	3	3.00	2.00	98.0	Com	950	36.00	1.50	29.0	1.2	64.5	soft	wall opp.
Y	LR01	Local	AC	7.00	2	3.00	1.00	104.0	Res	1003	36.00	2.72	27.0	2.0	168.8	soft	none
Z	LR02	Local	AC	4.00	1	3.00	14.00	0.0	Res	185	23.00	0.00	21.0	0.3	56.3	soft	none
AA	LR03	Local	AC	5.00	2	3.00	3.00	100.0	Res	200	28.00	0.00	27.0	2.0	23.5	soft	wall opp.
AB	LR04	Local	CS	6.00	2	3.00	2.00	80.0	Res	300	30.00	0.10	26.0	2.0	45.5	soft	wall near
AC	LR05	Local	AC	6.50	2	3.00	1.00	75.0	Res	350	26.00	0.20	27.0	1.8	95.0	soft	wall near
AD	LR06	Local	AC	7.00	2	3.00	1.00	64.0	Res	450	24.00	1.00	25.0	1.6	128.0	soft	none
AE	LR07	Local	AC	6.80	2	3.00	4.00	25.0	Res	750	25.00	0.50	26.0	1.5	160.0	soft	wall opp.
AF	LR08	Local	AC	6.50	2	3.00	3.00	13.0	Res	800	33.00	1.20	25.0	2.0	122.5	soft	wall opp.

TABLE 10.8 TYPICAL OUTPUT OF MULTI-FACTOR ENVIRONMENTAL CAPACITY MODEL (WITH 70TH SELF-GENERATED PERCENTILE)

Road Information			Environmental Impact Conditions				Environmental Appraisal							Comparable Ratio		
Road Name	Link Code	Category	Noise	CO	Delay	Accident	EUV	MFEC	NoiseEC	COEC	DelayEC	AccidEC	EC	Capacity	MFEC-EC	MFEC/Cap
A	MC01	Major	77.5	2.29	4.78	2.53	50.0	3364	2711	5009	3560	1540	1540	4114	1824	0.82
B	MC02	Major	72.0	6.01	1.95	1.34	49.3	1789	4714	920	4054	1540	920	2743	869	0.65
C	MC03	Major	76.3	3.81	3.54	2.33	45.8	2268	1833	2736	4154	1540	1540	3086	727	0.73
D	MC04	Major	75.5	1.29	2.02	1.33	44.3	2169	2062	4255	4113	1540	1540	3257	629	0.67
E	MC05	Major	77.9	2.29	2.03	1.37	44.5	2140	1233	2475	4154	1540	1233	3086	908	0.69
F	MC06	Major	77.0	1.52	1.77	1.17	45.1	2098	1280	3112	4154	1540	1280	3086	818	0.68
G	MC07	Major	75.3	6.65	1.98	1.33	45.8	2183	2157	823	4154	1540	823	3086	1359	0.71
H	MC08	Major	74.6	0.80	1.98	1.33	45.8	2055	2558	6869	4154	1540	1540	3086	515	0.67
I	MR01	Major	74.8	2.70	3.13	1.71	68.0	2106	1842	2599	3417	1027	1027	4320	1080	0.49
J	MR02	Major	72.1	3.48	1.11	0.45	26.0	1268	779	459	2165	1027	459	1714	808	0.74
K	MR03	Major	73.3	3.03	1.87	1.12	38.2	1501	1596	1423	2979	1027	1027	2057	474	0.73
L	MR04	Major	73.4	8.99	1.93	1.29	39.4	1669	1830	566	3651	1027	566	2400	1103	0.70
M	MR05	Major	75.0	6.96	2.12	1.46	56.6	1125	1467	842	4054	1027	842	2743	284	0.41
N	MR06	Major	74.5	0.97	2.59	1.75	61.3	1747	1986	7442	4154	1027	1027	3086	720	0.57
O	MR07	Major	72.7	0.53	1.90	1.21	46.7	2691	1989	8906	4032	1027	1027	3429	1665	0.78
P	MR08	Major	72.8	3.52	2.18	1.33	46.3	2860	2173	1496	3806	1027	1027	3771	1833	0.76
Q	LC01	Local	72.3	3.17	1.49	0.92	53.6	375	620	947	4032	800	620	3429	-246	0.11
R	LC02	Local	65.7	2.08	0.95	0.50	24.9	682	1430	730	3651	800	730	2400	-48	0.28
S	LC03	Local	67.3	3.48	1.00	0.54	26.7	682	1104	480	3651	800	480	2400	202	0.28
T	LC04	Local	69.7	0.84	1.04	0.59	35.6	486	683	2162	4054	800	683	2743	-197	0.18
U	LC05	Local	70.4	3.09	1.09	0.63	34.0	581	638	640	4139	800	638	2914	-56	0.20
V	LC06	Local	70.3	2.11	1.18	0.72	39.4	531	744	1083	3891	800	744	2571	-213	0.21
W	LC07	Local	68.6	2.00	1.25	0.76	46.1	395	1182	1217	4154	800	800	3086	-405	0.13
X	LC08	Local	71.5	2.57	1.42	0.89	50.6	420	727	374	4113	800	374	3257	47	0.13
Y	LR01	Local	74.6	1.19	1.46	0.93	44.4	588	368	854	3651	800	368	2400	220	0.24
Z	LR02	Local	67.7	0.85	0.88	0.19	14.6	433	328	220	1355	800	220	1371	213	0.32
AA	LR03	Local	64.6	0.27	0.75	0.20	13.2	479	720	745	2165	800	720	1714	-241	0.28
AB	LR04	Local	66.0	0.56	0.79	0.31	14.4	551	783	542	2979	800	542	2057	9	0.27
AC	LR05	Local	68.1	1.02	0.82	0.35	13.1	630	565	348	3342	800	348	2229	282	0.28
AD	LR06	Local	67.7	0.87	0.90	0.45	14.8	692	805	520	3651	800	520	2400	172	0.29
AE	LR07	Local	70.5	1.71	1.21	0.72	31.9	666	706	442	3535	800	442	2331	224	0.29
AF	LR08	Local	71.4	0.98	1.29	0.76	36.1	569	613	828	3342	800	613	2229	-44	0.26
		Average	71.9	2.55	1.70	1.02	39.0	1306	1382	1940	3639	1042	821	2769	485	0.45

TABLE 10.9 TYPICAL OUTPUT OF MULTI-FACTOR ENVIRONMENTAL CAPACITY MODEL (WITH STANDARD LIMITS)

Road Information			Environmental Impact Conditions					Environmental Appraisal						Comparable Ratio		
Road Name	Link Code	Category	Noise	CO	Delay	Accident	EUV	MFEC	NoiseEC	COEC	DelayEC	AccidEC	EC	Capacity	MFEC-EC	MFEC/Cap
A	MC01	Major	77.5	2.29	4.78	2.53	50.0	3468	349	13724	3560	966	349	4114	3118	0.84
B	MC02	Major	72.0	6.01	1.95	1.34	49.3	1858	607	2521	4054	966	607	2743	1251	0.68
C	MC03	Major	76.3	3.81	3.54	2.33	45.8	2346	236	7497	4154	966	236	3086	2109	0.76
D	MC04	Major	75.5	1.29	2.02	1.33	44.3	2252	266	11656	4113	966	266	3257	1986	0.69
E	MC05	Major	77.9	2.29	2.03	1.37	44.5	2218	159	6781	4154	966	159	3086	2059	0.72
F	MC06	Major	77.0	1.52	1.77	1.17	45.1	2176	165	8526	4154	966	165	3086	2011	0.71
G	MC07	Major	75.3	6.65	1.98	1.33	45.8	2261	278	2255	4154	966	278	3086	1983	0.73
H	MC08	Major	74.6	0.80	1.98	1.33	45.8	2133	330	18819	4154	966	330	3086	1803	0.69
I	MR01	Major	74.8	2.70	3.13	1.71	68.0	2481	422	7404	3417	966	422	4320	2059	0.57
J	MR02	Major	72.1	3.48	1.11	0.45	26.0	1642	179	1309	2165	966	179	1714	1464	0.96
K	MR03	Major	73.3	3.03	1.87	1.12	38.2	1875	366	4054	2979	966	366	2057	1510	0.91
L	MR04	Major	73.4	8.99	1.93	1.29	39.4	2043	419	1613	3651	966	419	2400	1624	0.85
M	MR05	Major	75.0	6.96	2.12	1.46	56.6	1500	336	2398	4054	966	336	2743	1164	0.55
N	MR06	Major	74.5	0.97	2.59	1.75	61.3	2121	455	21203	4154	966	455	3086	1666	0.69
O	MR07	Major	72.7	0.53	1.90	1.21	46.7	3066	456	25373	4032	966	456	3429	2610	0.89
P	MR08	Major	72.8	3.52	2.18	1.33	46.3	3234	498	4263	3806	966	498	3771	2736	0.86
Q	LC01	Local	72.3	3.17	1.49	0.92	53.6	1035	365	3116	4032	966	365	3429	669	0.30
R	LC02	Local	65.7	2.08	0.95	0.50	24.9	1342	842	2403	3651	966	842	2400	500	0.56
S	LC03	Local	67.3	3.48	1.00	0.54	26.7	1342	650	1579	3651	966	650	2400	692	0.56
T	LC04	Local	69.7	0.84	1.04	0.59	35.6	1146	402	7113	4054	966	402	2743	744	0.42
U	LC05	Local	70.4	3.09	1.09	0.63	34.0	1241	375	2104	4139	966	375	2914	866	0.43
V	LC06	Local	70.3	2.11	1.18	0.72	39.4	1191	438	3562	3891	966	438	2571	753	0.46
W	LC07	Local	68.6	2.00	1.25	0.76	46.1	1055	696	4002	4154	966	696	3086	359	0.34
X	LC08	Local	71.5	2.57	1.42	0.89	50.6	1080	428	3699	4113	966	428	3257	652	0.33
Y	LR01	Local	74.6	1.19	1.46	0.93	44.4	1174	222	8451	3651	966	222	2400	952	0.49
Z	LR02	Local	67.7	0.85	0.88	0.19	14.6	1019	198	2181	1355	966	198	1371	821	0.74
AA	LR03	Local	64.6	0.27	0.75	0.20	13.2	1065	434	7374	2165	966	434	1714	631	0.62
AB	LR04	Local	66.0	0.56	0.79	0.31	14.4	1137	472	5365	2979	966	472	2057	664	0.55
AC	LR05	Local	68.1	1.02	0.82	0.35	13.1	1216	340	3445	3342	966	340	2229	876	0.55
AD	LR06	Local	67.7	0.87	0.90	0.45	14.8	1278	485	5148	3651	966	485	2400	793	0.53
AE	LR07	Local	70.5	1.71	1.21	0.72	31.9	1251	425	4374	3535	966	425	2331	826	0.54
AF	LR08	Local	71.4	0.98	1.29	0.76	36.1	1155	369	8199	3342	966	369	2229	786	0.52
		Average	71.9	2.55	1.70	1.02	39.0	1731	396	6610	3639	966	396	2769	1336	0.63

TABLE 10.10 TYPICAL OUTPUT OF MULTI-FACTOR ENVIRONMENTAL CAPACITY MODEL (WITH PRE-DETERMINED EUV=60)

Road Information			Environmental Impact Conditions				Environmental Appraisal							Comparable Values		
Road Name	Link Code	Category	Noise	CO	Delay	Accident	EUV	MFEC	NoiseEC	COEC	DelayEC	AccidEC	EC	Capacity	MFEC-EC	MFEC/Cap
A	MC01	Major	77.5	2.29	4.78	2.53	50.0	4095	349	13724	3560	966	349	4114	3746	1.00
B	MC02	Major	72.0	6.01	1.95	1.34	49.3	2277	607	2521	4054	966	607	2743	1669	0.83
C	MC03	Major	76.3	3.81	3.54	2.33	45.8	2816	236	7497	4154	966	236	3086	2580	0.91
D	MC04	Major	75.5	1.29	2.02	1.33	44.3	2748	266	11656	4113	966	266	3257	2483	0.84
E	MC05	Major	77.9	2.29	2.03	1.37	44.5	2689	159	6781	4154	966	159	3086	2530	0.87
F	MC06	Major	77.0	1.52	1.77	1.17	45.1	2646	165	8526	4154	966	165	3086	2481	0.86
G	MC07	Major	75.3	6.65	1.98	1.33	45.8	2731	278	2255	4154	966	278	3086	2453	0.89
H	MC08	Major	74.6	0.80	1.98	1.33	45.8	2604	330	18819	4154	966	330	3086	2274	0.84
I	MR01	Major	74.8	2.70	3.13	1.71	68.0	2804	422	7404	3417	966	422	4320	2382	0.65
J	MR02	Major	72.1	3.48	1.11	0.45	26.0	1966	179	1309	2165	966	179	1714	1787	1.15
K	MR03	Major	73.3	3.03	1.87	1.12	38.2	2198	366	4054	2979	966	366	2057	1833	1.07
L	MR04	Major	73.4	8.99	1.93	1.29	39.4	2367	419	1613	3651	966	419	2400	1947	0.99
M	MR05	Major	75.0	6.96	2.12	1.46	56.6	1823	336	2398	4054	966	336	2743	1487	0.66
N	MR06	Major	74.5	0.97	2.59	1.75	61.3	2444	455	21203	4154	966	455	3086	1990	0.79
O	MR07	Major	72.7	0.53	1.90	1.21	46.7	3389	456	25373	4032	966	456	3429	2934	0.99
P	MR08	Major	72.8	3.52	2.18	1.33	46.3	3558	498	4263	3806	966	498	3771	3060	0.94
Q	LC01	Local	72.3	3.17	1.49	0.92	53.6	1167	365	3116	4032	966	365	3429	802	0.34
R	LC02	Local	65.7	2.08	0.95	0.50	24.9	1474	842	2403	3651	966	842	2400	632	0.61
S	LC03	Local	67.3	3.48	1.00	0.54	26.7	1474	650	1579	3651	966	650	2400	824	0.61
T	LC04	Local	69.7	0.84	1.04	0.59	35.6	1278	402	7113	4054	966	402	2743	876	0.47
U	LC05	Local	70.4	3.09	1.09	0.63	34.0	1373	375	2104	4139	966	375	2914	998	0.47
V	LC06	Local	70.3	2.11	1.18	0.72	39.4	1323	438	3562	3891	966	438	2571	885	0.51
W	LC07	Local	68.6	2.00	1.25	0.76	46.1	1187	696	4002	4154	966	696	3086	491	0.38
X	LC08	Local	71.5	2.57	1.42	0.89	50.6	1212	428	3699	4113	966	428	3257	784	0.37
Y	LR01	Local	74.6	1.19	1.46	0.93	44.4	1349	222	8451	3651	966	222	2400	1128	0.56
Z	LR02	Local	67.7	0.85	0.88	0.19	14.6	1195	198	2181	1355	966	198	1371	997	0.87
AA	LR03	Local	64.6	0.27	0.75	0.20	13.2	1240	434	7374	2165	966	434	1714	807	0.72
AB	LR04	Local	66.0	0.56	0.79	0.31	14.4	1312	472	5365	2979	966	472	2057	840	0.64
AC	LR05	Local	68.1	1.02	0.82	0.35	13.1	1392	340	3445	3342	966	340	2229	1051	0.62
AD	LR06	Local	67.7	0.87	0.90	0.45	14.8	1454	485	5148	3651	966	485	2400	969	0.61
AE	LR07	Local	70.5	1.71	1.21	0.72	31.9	1427	425	4374	3535	966	425	2331	1002	0.61
AF	LR08	Local	71.4	0.98	1.29	0.76	36.1	1331	369	8199	3342	966	369	2229	961	0.60
		Average	71.9	2.55	1.70	1.02	39.0	2011	396	6610	3639	966	396	2769	1615	0.73

10.6 Model Sensitivity

In order to investigate further the range of applicability of the suggested model, sensitivity analyses were conducted on the MFEC models. The analyses were particularly intended to see how the model responded to changes in traffic speed S and road width W. In doing so, the models were run using various combinations of speed and width. For the purpose, standard acceptable limits were used to determine EUV_L. Results of the analyses are described in the following sections.

10.6.1 Major-Commercial

For the Major-Commercial category, the model generally produced higher MFECs with increasing road width and reducing speed. But, the MFEC seemed to be more sensitive to changes in road width than it was to traffic speed. Typically, every 1m widening of road would increase MFEC by up to 280 vph, whereas reducing speed by 1 km/h would only increase MFEC by 24 vph.

The road width applicable in the model was of 8m to 13m inclusive, while speed might vary between 19-31 km/h. Maximum MFEC of 3644 vph was achieved when the road had 13m width and 19 km/h traffic speed, while minimum MFEC (1118 vph) occurred at 5m road width and 31 km/h traffic speed (see Figure 10.2).

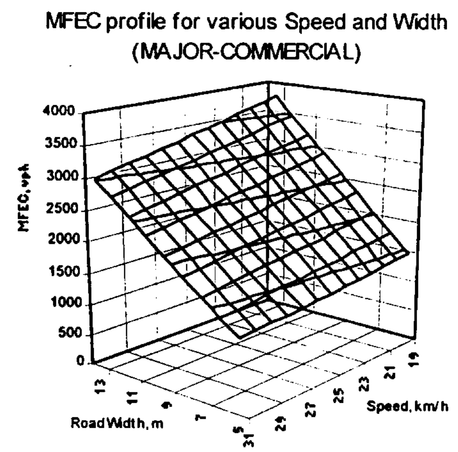
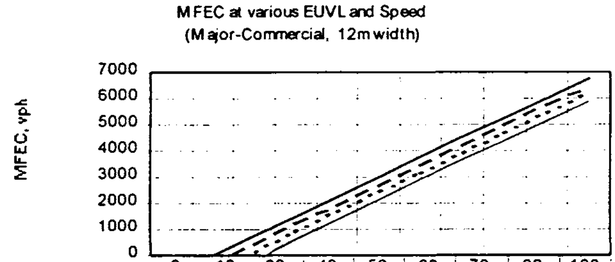


FIGURE 10.2 MFEC VS. SPEED AND WIDTH FOR MAJOR-COMMERCIAL CATEGORY (WITH STANDARD LIMITS)

In terms of EUV_L the model suggested that MFEC would generally increase as the EUV_L increased. As can be observed from Figure 10.3, the gradient was around 815 vph by every increase of EUV_L by 10. Applicable values of EUVL for this category were from 20 upwards. This suggested that in Major-Commercial roads the conditions of environment could not be better than an EUV of 20. In other words, Major-Commercial roads are environmentally very likely to be amongst the worst road links in urban areas. The best possible conditions that could be achieved for such a road would be around the 20th percentile of the whole networks.



	0	10	20	40	50	60	70	90	100
25 km/h	-776	-21	734	2244	2999	3754	4509	6019	6774
30 km/h	-1059	-304	451	1960	2715	3470	4225	5735	6490
35 km/h	-1343	-588	167	1677	2432	3187	3942	5452	6207
40 km/h	-1626	-871	-116	1394	2149	2904	3658	5168	5923

FIGURE 10.3 MFEC VS. EUV_L AND SPEED FOR MAJOR COMMERCIAL CATEGORY (ROAD WIDTH=12M)

10.6.2 Major-Residential

For the Major-Residential category, generally MFEC reacted in the similar way of Major-Commercial only that the gradients for both towards changes in width and speed were higher. In this category, MFEC would increase by 297 vph for every increase of width by 1m, and would decrease by around 65 vph for every increase of speed by 1km/h. The maximum MFEC (3352 vph) was observable at a road with 12m width and traffic speed of 24 km/h, whereas the minimum (103 vph) was occurred at 5m width and 42 km/h speed.

Again, when the model was set at a 10m road width, for the same traffic speed, MFEC tended to increase with increasing EUV_L. The rate of the increase was about 444 vph for every 10 point increase of EUV_L. The minimum EUV that could be achieved is about 0 (for speed less than 35 km/h) which means the best Major-Residential road could be within the environmentally best road links in the whole networks. For speeds of more than 35 km/h the minimum EUV_L could not go lower than 10 (see Figure 10.6).

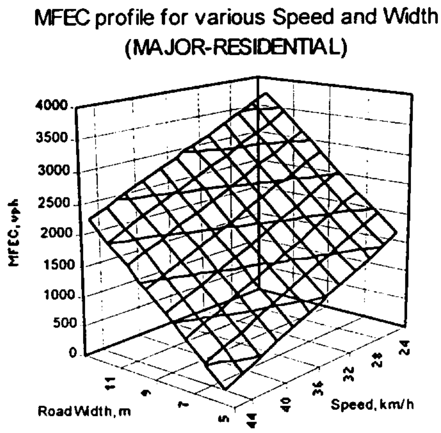
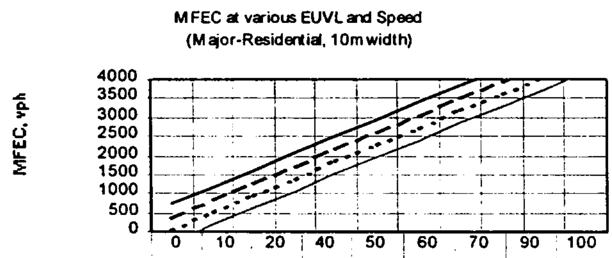


FIGURE 10.4 MFEC VS. ROAD WIDTH AND TRAFFIC SPEED FOR MAJOR-RESIDENTIAL CATEGORY (STANDARD LIMITS)



	0	10	20	40	50	60	70	90	100
25 km/h	723	1167	1611	2500	2945	3389	3834	4723	5167
30 km/h	399	843	1288	2177	2621	3066	3510	4399	4843
35 km/h	75	520	964	1853	2298	2742	3187	4075	4520
40 km/h	-248	196	641	1530	1974	2419	2863	3752	4196

EUVL

FIGURE 10.5 MFEC VS. EUVL AND SPEED FOR MAJOR-RESIDENTIAL CATEGORY (AT WIDTH =10M)

10.6.3 Local-Commercial Category

For this category the model responded rather differently. Unlike the previous categories, MFEC tended to decrease when road width or speed was increased. MFEC would decrease by about 20 vph for every 1m road widening, whereas with traffic speed the rate was about 35 vph for every 1 km/h increase.

The maximum observable MFEC (682) was at road with 7m width and 30 km/h speed. While a minimum MFEC of 375 vph was at road with 10m width and 37 km/h speed.

Regarding the EUVL, in this category MFEC tended to increase by 278 vph for every EUVL increase by 10 points. Minimum applicable EUVL was around 20 where estimated MFEC was below 100. The worst site in the category (EUVL=100), could have an MFEC as high as 2761 (at traffic speed of 25 km/h) and as low as 2234 (with traffic speed of 40 km/h).

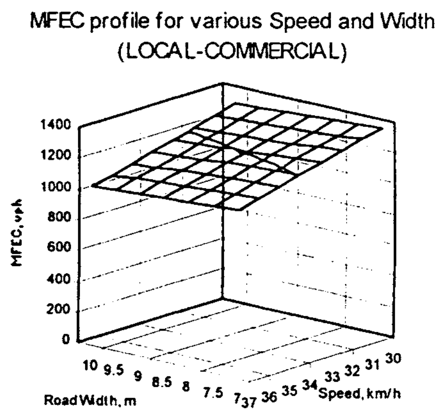
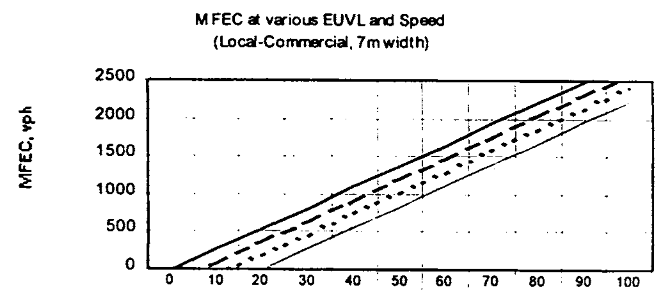


FIGURE 10.6 MFEC VS. ROAD WIDTH AND SPEED FOR LOCAL-COMMERCIAL CATEGORY (STANDARD LIMITS)



EUVL	0	10	20	30	40	50	60	70	80	90	100
25km/h	-17	261	539	817	1094	1372	1650	1928	2206	2483	2761
30km/h	-192	85	363	641	919	1197	1474	1752	2030	2308	2585
35km/h	-368	-90	187	465	743	1021	1299	1576	1854	2132	2410
40km/h	-544	-266	12	290	567	845	1123	1401	1678	1956	2234

FIGURE 10.7 MFEC VS. EUVL AND SPEED FOR LOCAL-COMMERCIAL CATEGORY (AT 7M WIDTH)

10.6.4 Local-Residential Category

For Local-Residential category, MFEC again increased when road was widened and speed reduced. The rate of increase was about 45 vph for 1m width and 8.5 vph for 1 km/h speed. Maximum MFEC of 701 vph was occurred at a road with 7m width and 23 km/h speed, while the minimum (311) was as 4m width and 37 km/h speed (see Figure 10.8).

When it was analyzed against EUVL, MFEC tended to increase by 222 vph by increasing EUVL by 10. At the best environmental conditions (EUVL below 10), the MFEC was about 200 vph, while at the worst conditions (EUVL equal 100), the MFEC could go as high as 2334 vph (see Figure 10.9).

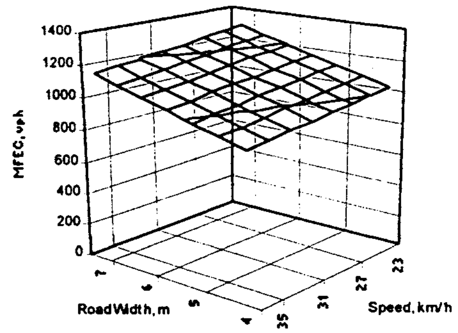
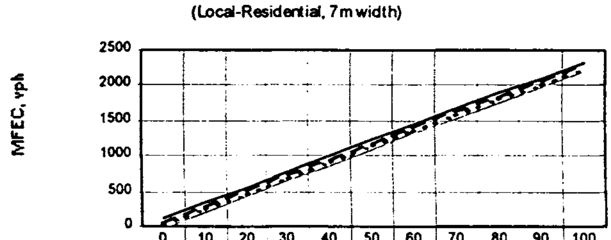


FIGURE 10.8 MFEC VS. ROAD WIDTH AND SPEED FOR LOCAL-RESIDENTIAL CATEGORY (STANDARD LIMITS)



EUVL	0	10	20	30	40	50	60	70	80	90	100
25km/h	112	334	556	778	1001	1223	1445	1667	1889	2112	2334
30km/h	68	290	513	735	957	1179	1401	1624	1846	2068	2290
35km/h	25	247	469	691	913	1136	1358	1580	1802	2025	2247
40km/h	-19	203	425	648	870	1092	1314	1537	1759	1981	2203

EUVL

FIGURE 10.9 MFEC VS. EUVL AND SPEED FOR LOCAL-RESIDENTIAL CATEGORY (AT 7M WIDTH)

10.7 Summary

In this chapter application of the proposed MFEC has been demonstrated. Mechanisms of the overall models were described and hypothetical examples provided. The examples showed that the approach could produce higher environmental capacities compared to the traditional approach. An average improvement of environmental capacity between 485-1615 vph was identifiable. This fact led to a ratio between environmental capacity and road capacity (physical) of between 0.45-0.73, which was more realistic than the traditionally obtained values of 0.14-0.30.

Sensitivity analyses of the model showed that, in general, MFEC would increase with increasing road width (widening) and/or reducing speed. The MFEC would also increase with increasing EUV_L. A summary of the increasing rates of MFEC with the increases of these parameters is presented in Table 10.11.

TABLE 10.11 SENSITIVITY OF MFEC TOWARDS THE PARAMETERS (VPH)

Category	Width	Speed	EUV_L
Major-Commercial	280	-24	815
Major-Residential	297	-65	444
Local-Commercial	-20	-35	278
Local-Residential	45	-8.5	222

Note: width per 1m increase, speed per 1km/h increase, EUV_L per 10 point increase

These findings indicated that the proposed model was quite promising in providing an alternative approach of determining environmental capacity that was both simple and realistic. As with all models of this type, the range of parameter spaces on which it is based bound the applicability of the present model. Possibilities for expanding and improving the model would require further research will be discussed in the next chapter.

Chapter 11

Chapter 11

DISCUSSION

In the previous chapter application of the proposed Multi-Factor Environmental Capacity (MFEC) has been demonstrated. The results suggest that the approach could significantly increase the environmental capacity.

This chapter discusses the major findings of the present study and its main contributions to existing knowledge. It also identifies the advantages and disadvantages of the proposed model and suggests future development of the model.

11.1 Major Findings and Contribution to Knowledge

The present study has generated a number of important results. Several major findings, which could be considered as significant contributions to existing knowledge, are as identified in the following paragraphs.

11.1.1 People Preferences

- *Several different techniques could be used to determine the weights of environmental factors.* The study showed that various techniques could be used to determine the preferential coefficients or weights of the environmental factors concerned. Although the techniques gave different values, they were basically consistent in determining the priority amongst the factors. The present study showed that the weights could be determined either using a direct ranking, a direct rating or a pair-wise comparison technique (Analytical Hierarchy Process).

- *Direct weighting method was more preferable.* Direct rating or weighting technique was considered more preferable in respect of comparability between categories. By using this method it was possible to compare the aggregate values between categories using typical parametric statistical analysis, whereas for the other methods such analysis was not applicable.

- *Community and experts preferences towards environmental factors were significantly different:* Results from the analyses showed that the community and experts disagreed in determining the relative degree of annoyance amongst environmental factors. The disagreement was particularly obvious in considering the most annoying factor of noise. While the community tended to say noise was the most annoying, the experts chose air pollution. This might be due to the different level of understanding and perception of the traffic-related impacts between both parties. Community might have set the preferences based on their direct and actual disturbance experiences, whereas the experts might have determined their priority from the theoretical and perceived risk point of view. Nevertheless, there was not enough evidence in this study to really explain this disagreement which might need to be addressed by a further research.

- *Weights of individual factors were also significantly different one to another.* This study also showed that people did not equally treat the individual environmental factors. There was enough evidence to say that people tended to have significantly different preferences towards the individual environmental factors. These differences were reflected in the weights that were directly assigned to each factor. In general noise constituted about 0.35 of the overall annoying score, with air pollution 0.27, pedestrian delay 0.23 and accident risks 0.17. That means the people considered noise as twice as annoying than accident risk, 1.5 times than the pedestrian delay and 1.25 times than air pollution. These figures might further suggest the relative trade-offs between environmental factors. Some of factors might be increased while at the same time the other factors decreased or vice versa without necessarily altering the overall perceived conditions of the environment.

- *Community from major roads (arterial and collector) stated significantly different preferences towards environmental factors from that of local roads.* The study also found that people in Major roads such as arterials and collectors tended to have different preferences towards environmental factors. They tended to consider noise and air pollution as less annoying compared to what people from Local roads. But, on the other hand they valued pedestrian delay and accident risks more than Local road people did. These outcomes suggested that people in Major roads tended to be more disturbed by delay and accident risks than to the other factors. Whereas Local road people tended to give more attention to noise and air pollution.

- *Community from commercial land-use category stated significantly different weights of environmental factors from that of residential land-use (including mixed land-use).* The study showed that people from sites with predominantly commercial land-use tended to give different preferences towards environmental impacts compared to people from predominantly residential or mixed land-uses. Similar to above finding, the former tended to give annoyance score of noise and air pollution less than that of the latter. They also tended to value delay and accident risks more than that of people from the residential category.

- *Four combinations between road class and land-use type were recommended.* Based on the previous findings it was recommended to categorize the sites into four major categories to accommodate the differences. The four categories were Major-Commercial, Major-Residential, Local-Commercial and Local-Residential.

11.1.2 EUV and MFEC

- *A method of determining environmental capacity for roads using multi-factor approach was theoretically possible and practically viable.* As has been demonstrated and shown throughout this thesis the Multi-Attribute Utility Theory (MAUT) was employed to develop the Multi-Factor Environment Capacity (MFEC) approach. The approach comprised an Environmental Utility Value (EUV), which was simply a representative score of the conditions of environment of the road concerned. These values were then correlated with their corresponding values of road and traffic parameters (width W, volume V, and speed S), and the assuming relationship was used to explain how the traffic volume V responded to the changes in EUVs, road width W and traffic speed S. The environmental capacity was then determined by simply substituting the EUV with EUV_L or EUV at the acceptable limits. The study has shown that this approach was theoretically possible and practically viable.

- *The environmental conditions of roads could be represented by a single environmental utility value.* Using the multi-attribute utility theory, it was possible to judge the general environmental conditions of roads using a single value (score). The utility score might be any value between 0-100 (or 0-1.0) that represented the general conditions of the environment. Conditions of environment with utility score equal to 0 might be considered the best conditions, while 100 might be considered the worst or vice versa depending on the assumed convention. This utility score was calculated using weights or coefficients from the community stated preferences. The EUV was then obtained by substituting the normalized values of the environmental impacts into the Environmental Utility Function.

- *The environmental utility value could be predicted using some common road and traffic parameters such as traffic volume V, speed S and road width W.* The EUV could also be determined without necessarily knowing the individual environmental impacts. The MFEC model of the present study showed that there was a significant and high correlation between EUVs and road and traffic parameters (V, S and W). From this relationship, EUV could be determined by knowing the required basic parameters of the road concerned.

- *The resulting environmental capacity determined by the multi-factor approach was considerably higher than that determined by the single-factor approach.* As has been shown in Chapter 10, MFEC could generate an environmental capacity that was considerably higher than the existing approach. The example showed that the average difference between MFEC and traditional EC could be as high as 1600 vph. This fact could probably lead to wider applications of environmental capacity in real engineering development projects.

- *The new approach gave an average MFEC/Capacity ratio higher than the existing approach.* As shown in the application example of the MFEC, more realistic ratio between environmental capacity and physical capacity of 0.45-0.73 was obtained using the new approach. This was a considerable improvement from the existing approach, which only produced environmental capacity of about 15% of the road capacity. This improvement indicated that the approach had found to be very promising as an alternative approach in determining the environmental capacity for roads.

11.1.3 Prediction Models

- *UK DoT noise prediction model has proved to be reliable and robust model in predicting noise level.* Calibration and validation of the model suggest that the UK DoT (1988) noise prediction model performed very convincingly in predicting noise level (L_{10}). Therefore adoption of the model for noise prediction purposes was highly recommended.

- *General Motors simple line source air pollution prediction model has shown to be a satisfactorily predictor of air pollutant concentration.* Provided that the emission rate prediction model was reliable, the GM model (Chock, 1978) could predict the concentration of air pollutant with satisfactory accuracy. This suggested that the use of the model for predicting air pollutant concentration is recommended.

- *The Pedestrian delay model as well as the accident rate prediction model needs to be further validated using larger scale data set.* Results of the calibration and validation of both pedestrian delay (Austroads, 1995) and accident rate prediction models (Zeeger, 1990) were unsatisfactory. The results suggested quite low correlation between predicted and measured/recorded values. Nevertheless, conclusive suggestions could not be drawn due to insufficient size and quality of data collected in the present study. Therefore a more in-depth study with a larger scale data set and higher quality control should be conducted to calibrate and validate the model before adoption was made for real engineering application of the models.

11.2 Advantages and Disadvantages of the Models

Some advantages of the proposed approach include the following:

- *It was relatively simple and straightforward.* The methodology that was proposed in the present study is relatively simple to implement and straightforward to apply. The method requires only some basic algebra to understand and a fundamental understanding of the road and traffic environmental impact mechanisms.

- *The result was relatively more realistic.* Another advantage of the approach is that it generates more realistic environmental capacity figures compared to the existing approach. The evidence suggests that the average improvement is in the order of three to five, moving from about 15% of physical capacity to become 43-73%.

- *The environmental conditions of roads could be assessed using basic information.* By using basic road and traffic information such as volume, speed and road width, the relative conditions of environment of the individual road link could be determined. This could be very useful particularly in the preliminary stage of planning, where not enough detail might be available and more general information is required.

- *Different scenarios of acceptable limits could be used.* Various set and conditions of acceptable limits could be used in determining the environmental capacity using the proposed method. The options might include using standard acceptable limits, using self-generated percentile or pre-determined EUV_L. As EUVL could go from 0 to 100, where by consensus 0 is the best and 100 is the worst, to some extent EUVL could be interpreted as a percentile. With EUV_L equal to 60 for instance, it is very likely that about 60% of sites would have an EUV equal to or less than 60. This flexibility might lead to the possibility of using the model for various applications or scenarios for decision-making purposes.

- *Practical measures to improve the environmental conditions could be directly identified.* As the model suggested, parameters that made up the environmental capacity included EUV_L, road width and speed. Without any intention to disregard other aspects, altering one or more of the parameters could possibly improve the conditions of environment. Therefore interactions between road and traffic and their environmental consequences might be more easily understood.

The disadvantages might include:

- *The models could not be applied beyond the conditions where they were calibrated.* Unless it is assumed that the nature of a whole city or its road networks is similar to those used for calibrating the models in the present study, application of the models into different conditions might not be valid. In such cases, the model should be re-calibrated due to the following three reasons:
    - the preferences and the stated weights of the environmental factors might be different from that observed in the present study;
    - the Environmental Utility Value might change due to the differences in the preferences;
    - the relationship between EUVs and road and traffic parameters might also be changing.

- *One or more factor might become in excess of its acceptable limits.* As there had been some trade-off between environmental factors, it is possible that the model could produce one or more factors that turn out to be slightly higher than their acceptable limits. This is an inevitable possible consequence of the approach. Nevertheless, the model optimizes the MFEC so that the average excess would be no more than say 10-15% of the standard limits or not more than any nominated absolute limit.

11.3 Future Research and Possible Development of the Models

A consideration of the outcomes of the present study has led to some suggestions for future research and development of the models. They include:

- *Exploring the cause(s) of the observed differences between community and experts' preferences.* As indicated earlier, the present study found a significant difference between community and experts preferences without any evidence to explain what were the possible causes of this difference. This problem might be interesting to address by further research.

- *In-depth individual research regarding environmental prediction models.* As some of environmental prediction models did not perform satisfactorily, it might be worth conducting a more specific study to find out whether it was due to data insufficiency in regard to size and quality or due to any other factors.

- *Development of computer software.* In order to facilitate potential users in applying the model in the real engineering world, it is desirable to develop a sophisticated and user-friendly computer program. The software could either be part of a bigger urban planning software or independent environmental impact software.

11.4 Summary

This chapter has discussed the major findings of the present study and identified its major contributions to knowledge. Advantages and disadvantages of the proposed method were also discussed in length. The discussion completed with some suggestions for possible further research to be addressed in the future.

Amongst the major findings was that the study had shown that the proposed approach could generate a more realistic figure of environmental capacity compared to the existing method. Simplicity and flexibility were amongst the advantages of the method, although applicability of the model to different conditions might be exercised with caution. For further research, one of the suggestions was to develop commercial computer software to facilitate the application of the method in the real engineering world.

The following chapter will simply wrap up the thesis. Some conclusions will be drawn and recommendations identified.

Chapter 12

Chapter 12

CONCLUSIONS and RECOMMENDATIONS

This chapter concludes and summarizes all that the present study has achieved. Study objectives are evaluated and achievements identified. Finally, recommendations are put forward and major findings summarized.

12.1 Conclusions

As introduced in the first chapter, the goals of the present study were to review the existing methodology and to attempt to develop an alternative approach in determining environmental capacity. The former goal was broken down into several objectives such as reviewing the literature, existing models and background knowledge in relevant subjects. Whereas the latter was divided into developing a complete model, calibrating and validating the sub-models components of the complete model, as well as analyzing and discussing the results.

State-of-the-art Review

A state-of-the-art of the relevant topics suggested that inclusion of environmental aspects in transportation and land-use planning processes is inevitable. Some urban/regional planning program packages such as TRANSTAR, CityPlan and TOPAZ URBAN have been incorporating environmental sub-module in their recent versions. Environmental factors covered in the models were mostly noise and air pollution. This was in line with what had been suggested by Sharpe and Maxman (1972) that the most annoying factors to the community were noise, air pollution and safety. In this regard the present study includes the four environmental factors in its model of noise, air pollution, pedestrian delay and accident risk.

Regarding the many available noise prediction models, UK DoT (1988) model is considered amongst the most comprehensive and reliable one and therefore recommended to predict traffic noise level. The review also suggests to consider the simple line-source air pollution model developed by General Motors (Chock, 1978), which also recommended by some later studies (Watsons, 1983; Mainwaring, 1983, Taylor *et.al*, 1985).

Regarding pedestrian delay, model recommended by Austroads (1994) was considered appropriate for predicting delay to pedestrians in the present study as it includes number of lanes and road width in the parameters. For accident rate/risk, there were very few prediction models available in the literature. Nevertheless model by Zeeger (1986) was decided to adopt, although it may not be applicable for urban situations as the present study deal with.

Background knowledge required in conducting the study was also considered at length. This include some essential background on multi-attribute utility theory as well as several major environmental factors. The background provided sufficient information and knowledge on which the subsequent stages of the study would be based. Multi-attribute utility theory was described and techniques for determining weights of attributes overviewed. It was suggested that the additive form of the utility decomposition function family be adopted on the basis that it was practically simple and theoretically adequate. It was also suggested that various techniques for determining weights such as direct rating, direct ranking and pair-wise comparisons be employed to see which one is practically better.

In the environmental factors department, the nature and important characteristics of factors such as noise, air pollution, pedestrian delay and accident risk were considered. Definitions, units of measurement, consequences as well as basic modeling of the factors were amongst the subjects covered. Information was put forward on the acceptable ambient levels of the factors concerned. The levels quoted were either the legal limits as in the case of noise and air pollution or theoretical and hypothetical limits as in pedestrian delay and accident risk cases.

Alternative Approach

Methodologies for developing an alternative approach in determining environmental capacity were explored and a multi-factor environmental capacity concept was proposed. This concept employs an environmental utility function that blends all the factors together into a single value. Prior to the description of the model, sensitivity analyses of several environmental prediction models were undertaken. Overall, there was a general agreement that almost all the models have similar parameters namely traffic volume, speed and road geometry parameters. This commonality may led to the suggestion that the models can be represented by single model or value namely Environmental Utility Value (EUV). This EUV can then be correlated with the road and traffic parameters to create a Multi-factor Environmental Capacity model.

An experimental design for the study was proposed, the study area selected and the required data determined. Sürvey instruments and methods were put forward and a sample design prepared. Bandung was chosen as the study area to represent a medium sized city in Indonesia, which is expected to suffer environmental problem in the near future. Methods employed in the study were described and the required number of samples determined. Data procedures required that around 37 sites were surveyed of which 27 were used for model calibration purposes and 9 for subsequent model validation. Traffic, road geometry and land use as well as environmental factors were also observed. At the same time community preferences were surveyed through interview and mail-back questionnaires. All data were processed and the survey results were stored.

Analyses of the data were conducted and complete data and calculations are available in relevant appendices. Manual traffic counting data were used to replace the unsatisfactory results of the automatic counting system as originally designed. This was done using video recorded data previously intended for observing pedestrians. Fortunately, traffic speed data from the automatic system still could be used since it was not really affected by the inaccuracy of the system in detecting types of vehicles.

Analyses of the environmental data suggested that no major difficulties occurred. The analyses included the application of various prediction models as proposed in the methodology and study design. Nevertheless, changes to the original design were inevitable due to the modest performance of three of the models. The only model that performed quite well was the DoT noise model. In the air pollution department for example, prediction of NOx could not satisfactorily be obtained from the proposed model. This was probably due to poor performance of the emission rate model rather than the air pollution dispersion model itself. Consequently, inclusion of NOx in the air pollution module had to be suspended, and CO became the only air pollutant considered in the present study.

Pedestrian delay model as suggested by Austroads (1995), performed to a degree that was regarded as unsatisfactory. It was not very clear though whether it was because of inappropriateness with the conditions or any other reasons such as inaccuracy of measurements. For accident rate, model proposed by Zeeger did not seem to be predicting very well either, since the model was developed for rural road situations. Therefore, a new multivariate regression model was developed. Attempts to correlate, from the outputs of the model, accident rates and various road and traffic parameters again only produced modest results.

Three different types of preferential data, namely ranking, rating and pair-wise comparison were treated separately using different technique of analysis. These suggested that amongst the proposed methods, only the direct rating comparisons between different categories were applicable. For the other two methods did not provide comparisons between categories and thus it was decided to employ direct rating alone for further analysis of preferential data. Data on the preferences of both community and experts towards environmental factors were analyzed. The results suggested that the community preferences were different significantly (at 95% level) from those of a group of experts, particularly in determining the most annoying factors. Noise was considered as the most annoying factor according the community, while the reverse was true according to the group of experts. Other factors, such as air pollution, pedestrian delay and accidents, were not considered as important as noise according the community. The experts, on the other hand, tended to say that the three factors were almost equally more important than noise.

In terms of road class, it was found that no significant differences in responses were observed between those from residents in arterials and collectors categories, while significant differences occurred between locals and both arterials and collectors. Similar results were also found between land-uses. The analyses suggested that influences of land-use were apparent between two groups, namely commercial and residential. These outcomes led to the development and adoption of models considering two different classes of roads and two different types of land-uses.

Calibration of the environmental impact prediction models suggested the following. Of the noise model, method developed by Department of Transport UK (1988) performed satisfactorily and therefore was confirmed as being the adopted noise prediction model in the present study. For predicting the concentration of air pollutant, GM model was proved to perform satisfactorily for CO concentration, but failed to predict the NOx concentration. This fact suggested the model in for predicting NOx be dropped and that CO alone be included in air pollution module of the environmental capacity model.

Adoption of the pedestrian delay prediction model as proposed by Austroads (1995) was confirmed although the performance was not satisfactory. On the other hand, the accident rate prediction model as developed by Zeeger did not perform very well in the urban situation.

A summary of the performance of all models along with their correction factors is as shown in 12.1.

TABLE 12.1 SUMMARY OF MODEL CALIBRATION PERFORMANCE

Model	Author	Correction	95% C.I.	r	Remark
Noise	DoT (1988)	0.6 dB(A)	± 3.0	0.92	Under-predict
Air Pollution	Chock (1979)	0.5 mg/m^3	± 6.0	0.32	under-predict
%Pedestrian Delay	Austroads (1995)	-0.06	± 0.32	0.74	over-predict
Accident	Widiantono (1999)			$R^2 = 0.91$	

Validation of calibrated models employed in the present study was then conducted. Measured and predicted values were compared and regression analyses were conducted to see how the models had performed. Scatter diagrams of the measured and predicted values had also been plotted for each model. The results suggested that basically the models performed better than previously (before calibrated). The only model that performed below the expectation was of pedestrian delay model.

Application and Findings

Application of the proposed MFEC was then demonstrated. The mechanism of the overall model was described and a hypothetical example was provided. The example showed that the approach could produce higher environmental capacity compared to the traditional approach. An average improvement of environmental capacity between 485-1615 was identifiable. This fact led to a ratio between environmental capacity and road capacity (physical) of between 0.45-0.73, which was regarded as being more realistic.

TABLE 12.2 SENSITIVITY OF MFEC TOWARDS THE PARAMETERS (VPH)

Category	Width	Speed	EUV_L
Major-Commercial	280	-24	815
Major-Residential	297	-65	444
Local-Commercial	-20	-35	278
Local-Residential	45	-8.5	222

Note: width per 1m increase, speed per 1km/h increase, EUV_L per 10 point increase

Sensitivity analyses of the model showed that generally MFEC would increase by increasing road width (widening) and/or reducing speed. The MFEC would also increase by increasing

EUV_L. Summary of the increasing rates of MFEC with the increase of three parameters is as presented in Table 12.2.

These findings indicated that the proposed model was quite promising in providing an alternative approach of determining environmental capacity that was both simple and realistic. Nevertheless, caution as to be given towards the range of applicability of the model before applying the approach in the real world cases.

It is considered that a major finding of the present study was that the proposed approach could generate a more realistic figure of environmental capacity compared to the existing method. Simplicity and flexibility were amongst the advantages of the proposed method, although applicability of the model to different conditions should be exercised with caution.

12.2 Recommendations

Application in engineering works. From the above facts and findings, application of the model for planning and evaluation of urban road network purposes may be recommended. Nevertheless, the model should be applied with caution. Unless it was assumed that the nature of whole city or networks was similar to that what had been used for calibrating and validating the models in the present study, application of the models into different conditions might not be valid. In that case the model should be re-calibrated using the same methods as described in this thesis.

The parameter spaces covered by the model are as presented in Table 12.3. Although the table shows the maximum and minimum values for every variable, it does not mean that all combinations within each range are applicable. Some combinations between extreme values may not be appropriate.

Software development. In order to facilitate the application of the model in the real engineering works, it would be desirable to develop a more sophisticated and user-friendly computer program. The software could either be part of a bigger urban planning software suite or be set up as independent environmental impact software.

TABLE 12.3 PARAMETER SPACE COVERED BY THE MODEL

Variables	Overall		Major-Com		Major-Res		Local-Com		Local-Res	
	max	min	max	min	max	min	Max	min	max	min
W, metres	13.0	4.0	13.0	5.0	12.6	5.0	12.0	5.0	7.0	4.0
Ln	4.0	2.0	4.0	2.0	4.0	2.0	3.0	2.0	2.0	2.0
Lw, metres	5.1	2.0	4.0	2.5	5.1	2.5	4.0	2.5	3.5	2.0
G, %	15.0	1.0	15.0	1.5	15.0	1.0	2.0	1.0	14.0	1.0
RD, degrees	177.0	0.0	110.0	5.0	177.0	0.0	166.5	0.0	104.0	0.0
WS, ms^{-1}	6.7	0.0	6.7	0.0	6.7	0.25	1.67	0.0	2.0	0.3
WD, degrees	348.7	11.2	213.7	11.2	348.7	11.2	348.7	11.2	168.7	56.2
T, centigrade	34.0	21.0	32.0	22.5	34.0	23.0	34.0	23.0	27.0	21.0
V, vph	3162	185	2880	1370	3162	455	989	346	1003	185
HV, %	4.0	0.00	4.0	1.0	3.4	0.5	3.1	0.2	2.7	0.0
S, km/h	46.0	23.0	31.0	19.0	46.0	24.0	37.0	24.0	36.0	23.0
$L_{10\text{-}1hr}$, dB(A)	77.9	62.9	77.9	72.7	77.6	67.1	73.9	66.8	74.1	62.9
Leq, dB(A)	76.0	58.4	76.0	70.1	74.5	64.8	72.1	63.2	71.2	58.4
NOx, ppm	0.70	0.01	0.21	0.03	0.25	0.01	0.70	0.02	0.26	0.02
CO, ppm	7.30	1.05	6.05	1.07	7.30	1.05	6.35	1.26	3.42	1.20
HC, ppm	5.07	1.68	4.89	2.50	5.07	2.07	5.07	1.98	3.91	1.68
Delay, seconds	13.71	0.00	7.81	0.22	13.71	0.02	3.71	0.00	2.95	0.00
% Delayed, %	0.95	0.00	0.78	0.06	0.95	0.02	0.29	0.00	0.50	0.00
acc./km/yr.	3.33	0.00	3.33	0.06	0.82	0.00	0.98	0.00	0.67	0.00

Note: *W*= road width; *Lw*=lane width; *Ln*=number of lanes; *G*=gradient; *RD*= road direction, measured clockwise from North; *WS*=equivalent wind speed at 4.5 m height, *WD*, wind direction, measured clockwise from North; *T*= temperature; *V*=traffic volume; *HV*=proportion of heavy vehicles; *S*=average traffic speed.

Further Research. Following the findings and results of this study some further research may worth be pursued.

- *Identifying and explaining the nature and the cause of the observed differences between community and expert preferences on environmental factors.* As indicated earlier, the present study found a significant difference between community and experts preferences without any evidence to explain what were the causes of this difference. This problem might be addressed by further research.
- *In-depth individual research regarding environmental prediction models.* As some of environmental prediction models did not perform as well as would be preferred, it might be worth conducting a more specific study to find out whether it was due to inadequacy of the models or due to any other factors.

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Appendix A

APPENDIX A:
DESKTOP RUN THROUGH

This document provides the desk-top run through of the scheduled surveys in the study. Part A of this document describes the activities in an ideal condition, followed by Part B that describes the contingency plan when some possible difficulties occur. In Part C, the aspect of instrumentation, logistics and operations of the surveys are being discussed.

Part A - Ideal Condition

1. Observational and Questionnaire Surveys.

Observational and questionnaire surveys are surveys that directly carried out in field. They include measurements of road traffic parameters as well as environmental factors. Questionnaire surveys are surveys that targeting to gather information on public preferences either through direct interview s and mail-back questionnaires. Table A.1 summarizes the activities in conducting such surveys along with their estimated duration.

TABLE A.1 SCENARIO FOR OBSERVATIONAL AND QUESTIONNAIRE SURVEYS.

Activities	Duration	Remarks
1. Pilot Survey I • site lay-out exercise; • equipment installation exercise; • testing out operational procedure.	• 1/2 day	• Conducted in Sydney prior to departure; • Possible location is around Botany St., Randwick.
2. Preparation: • Check all equipment; • Multiply forms; • Contact related institutions; • Recruit Surveyors; • Train Surveyors; • Prepare covering letter; • Re-calculate sample size; • Nominate sites; • Prepare survey accessories (traffic cones, identity cards, clipboards, ballpoints etc.).	• 1 week	

TABLE A.1 SCENARIO FOR OBSERVATIONAL AND QUESTIONNAIRE SURVEYS (CONT'D)

4. **Pilot Survey II** • part of training • equipment calibration; • identification of difficulties; • set-up and disassemble timing; • standard site lay-out; • operational procedure.	• 1-2 days	• full scale; • location: arterial road in front of RIRE office.
4. **Reconnaissance Survey** • observe nominated sites; • identify possible locations; • contact local people/authority (if necessary); • identify any possible difficulties.	• 2-3 days or possibly done every day prior to the surveys.	• locations must have enough shoulder to set up the equipment; • locations must have a reasonably uninterrupted traffic; • location around road bend is not recommended; • avoid any location near to pedestrian crossing facilities; • must have good acoustic environment.
4. **Field Surveys:**	• 3 weeks (12 sites per week): -1st week locals; -2nd week collectors; -3rd week arterials • Survey duration for each site: -preparation 30 min. -observations 3 hours -disassembling 30 min.	• Total sites: 36 sites: Calibration: 27 sites; Validation: 9 sites; Arterials: 12 sites; Collectors: 12 sites; Locals: 12 sites. • Survey Days: Mon-Sat. • Number of sites per day: 2 sites • Survey Times: -morning 8.30 – 12.30 AM -afternoon 2.00 - 6.00PM
4a. **Questionnaire Survey** • Number of Interviewers: 2 • Target results (see Tables of results)	• Estimated interview time: 15-20 minute/respondent	• Target per site: 10-15 respondents.
4b. **Environmental Surveys** • Number of surveyors: 3 persons: -1 for Noise measurements; -1 for Air pollution measurements; -1 for Pedestrian observation. • Target results (see Tables of results)	• Data measured for 3 consecutive hours with 15-20 minute sample; • Simultaneously measured with traffic and road surveys.	• Target number of data aggregates : 3 data / site / factor.

TABLE A.1 SCENARIO FOR OBSERVATIONAL AND QUESTIONNAIRE SURVEYS (CONT'D)

4c. Traffic and Road Surveys • Number of surveyors: 3 persons: -2 responsible for TC and Speed measurements; -1 responsible for road geometry & landuse data. • Target results (see Tables of results)	• Data measured for 3 consecutive hours with 15-20 minute sample; • simultaneously measured with environmental surveys.	• Target number of data: 3 data-points/site/parameter

2. Documentary Survey

Documentary survey would be carried out after all the observational surveys have been done. It is also possible done whenever observational surveys are suspended due to rain or other unwanted weather condition. Table A.2 provides the overview of the activities, involved institutions, contact persons and estimated required time.

TABLE A.2 DATA COLLECTION ITINERARY FOR DOCUMENTARY SURVEYS.

Activities	Institution	Duration
1. Preparation -Visiting schedule; -Introductory letter		3 days
2. Zone Data -Zoning system; -Zones area; -Coordinate of centroid; -Trip Costs	• Statistical Office Bureau • Regional Planning Bureau: Hibarni Andam Dewi • National Land Body: Yetty Nteseo	1 week
3. Landuse Data -Existing landuse; -Reserved landuse; -Establishing costs.	• Statistical Office Bureau • Regional Planning Bureau Hedy Rahardian, PhD • National Land Body	1 week
4. Transport Data -Trip Generation rates; -Trip Impedance values; -Number of trip days.	• MBUDP Reports • Transport Magister Program, ITB: Offyar Tamim Willy Tumewu Trisno Soegondo • RIRE: Poernomosidhi	1 week

TABLE A.3 DATA COLLECTION ITINERARY FOR DOCUMENTARY SURVEYS (CONT'D)

5. Network data -Link name; -LinkID; -Start-End nodes; -Road type; -Capacity; -Level of service; -Length; -Construction costs; -Design Speed.	• Regional Office of Public Works • Sub-Directorate of Road Inventory MPW • Directorate of Urban Road MPW: Gandhi Harahap	1 week

Part B - Contingency Plan

To anticipate any unwanted scenarios Table A.3 provides contingency plan for any possible cases.

TABLE A.4 DATA COLLECTION CONTINGENCY PLAN

Activities	Possible Problems	Actions
1. Observational Surveys	• Rain • Heavy wind • Measurements error • Equipment failure • External interferences • Data loss • Surveyors Strike • Financial problem	• Survey suspension • Survey being delayed until the condition is back to normal. • Additional survey • Borrow from other institution (Padjadjaran University Bandung) • Suspend the survey until the problem is resolved • Hardcopy and softcopy backups • Negotiations, re-recruitment • Reduce data size.
2. Questionnaire Surveys	• Refusals • Bias response • Human pitfalls • Low response rate	• Use extra samples. • Cross checking and clarification • Control of interviewers • Use of incentives
3. Documentary Surveys	• Unavailability of data • Confidentiality • Lack of accuracy • Missing parts • Inconsistent format	• Approximation from other related information • Send formal letter to higher authority • Expert consultancy • Extrapolate and intrapolate • Reformatting and adjustment

Very special contingency plan may be applied when there is not possible whatsoever to collect data in Indonesia. In this particular case, data collection will be carried out in Australia. Some possible location to conduct the surveys are:

- Botany City, Sydney;
- Randwick City, Sydney;
- Wollongong.

Part C - Instrumentation, Logistics & Operation

Table A.5 summarizes the aspects of instrumentation, logistics and operation of the surveys. Note that measurements of noise, air pollution, pedestrian and traffic are carried out simultaneously in every site.

TABLE A.5 INSTRUMENTATION, LOGISTICS & OPERATION OF THE SURVEYS

Items	Instrumentation	Logistics and Operation
1. Noise Measurements	ONO SOKKI LA-5120/5110/2110	• Prior to every survey calibration of the equipment is being made. • Measurements are made with 15-20 minute sample time for every 1 hour. • By the end of sample period data are down-loaded into portable PC. • Summary of the measurements are also put into survey form (as hardcopy backup).
2. Air Pollution	Atmospheric NO Analyzer GLN-32 Atmospheric CO Analyzer GIA-72M Non-Methane Hydrocarbon Analyzer GHC-75M	• Calibration of equipment are being made prior to every survey. • the same 15-20 minutes sample time is adopted for every one hour. • data are down loaded into PC by the end of every sample time. • Summaries of measurements are put into field form.
3. Pedestrian Observation	SONY Handycam video camera	• Video camera is mounted on the roadside where pedestrian crossing can most likely be covered. • The same observation time interval is used as the other measurements. • to backup the data, a simple manual counting is also made during the period.

TABLE A.5 INSTRUMENTATION, LOGISTICS & OPERATION OF THE SURVEYS (CONT'D)

4. Traffic Observation	Marksman 2000 - Golden River Data Logger	• Pneumatic tubes are being mounted on the road surface. • Data logger is set to identify cars and heavy vehicles only. • Data are measured in the same time interval of other observations. • Data are being down loaded every the end of measurement period (15-20 minute/hour).
5. Accidents Records	--	• Data on accidents are obtained from Micro-computer Accidents Analysis Package (MAAP) in traffic police office or RIRE.
6. Site Conditions and Details	Wheel meter, drawing equipment.	• The conditions and details of every site are being measured and recorded in road and landuse form. • Identification of landuse is being made up to 500 meters along the road.

Summary

The desktop run through of data collection plan has been overviewed. In the first part, data collection acitivities in an ideal condition were simulated. A contingency plan was described in part B to consider all the possible unexpected things. The aspect of instrumentation, logistics and operation was described briefly in part C. Overall, the data collection activities seem to be well prepared and ready to run. Minor adjustments still have to be made though, according with the real situations in the field.

Appendix B

APPENDIX B:
LISTS OF SURVEY EQUIPMENT

TABLE B.1 LIST OF TRAFFIC SURVEY EQUIPMENT

Items	Quantity	Remarks
Big hammers	4	purchased
Cable connectors	6	IRE
Car batteries 12 Volts	3	IRE
Chalks	1 box	purchased
Communication cable	1	IRE
Concrete nails	3 boxes	purchased
Data logger power cables	6	IRE
Data loggers	6	IRE
Diskettes	20	purchased
Extension cables	6 rolls	IRE
Hard lock for PRECDIA program	1	Borrowed from Sweroad
Laptop PC charger	1	personal
Laptop portable computer, ACER 735C	1	personal
Masking tape	4 rolls	purchased
Measuring tape	1	purchased
Nails remover	2	IRE
Pneumatic tube adaptor	12	IRE
Pneumatic tubes	6 pairs	IRE
PRECDIA data processing program	1	Copy from Sweroad
TMSLOG communication program	1	IRE
Tube clamps	30	purchased

TABLE B.2 LIST OF ROAD GEOMETRY AND LAND USE SURVEY EQUIPMENT

Items	Quantity	Remarks
Band meter	1	purchased
Clipboard	1	IRE
Drawing pens	1 set	purchased
Magnetic compass	1	purchased
Millimeter block	1 book	purchased
Pencils	2	purchased
Rulers	1 set	purchased
Wheel meter	1	IRE

TABLE B.3 LIST OF NOISE MEASURING EQUIPMENT

Items	Quantity	Remarks
AA size Alkaline batteries	16	purchased
Ballpoint/pencils	2	purchased
Microphone extension cable, AG-3301 (5m)	2	IRE
Sound Level Meter, ONO SOKKI LA-5110	2	IRE
Tripod, LA-0203	2	IRE
Umbrella	1	purchased

TABLE B.4 LIST OF AIR POLLUTION MEASURING EQUIPMENT

Items	Quantity	Remarks
Air pumps	2	purchased
JICA Mobile Laboratory	1	IRE
Plastic tube extension	20m	purchased
Sampling bags	35	IRE
Thermometer and hydrometer	1	IRE
Wind speedometer	1	IRE

TABLE B.5 LIST OF EQUIPMENT FOR PEDESTRIAN OBSERVATION

Items	Quantity	Remarks
Camcorder SONY VCR EVS 550-E	1	IRE
Elastic straps	3	IRE
Small umbrella	1	purchased
Small video cassettes	36	purchased
Tripod Velbond SGB-3	1	IRE

TABLE B.6 LIST OF GENERAL PURPOSE EQUIPMENT

Items	Quantity	Remarks
Bandung official road map	1	purchased
Canon Prima Zoom 70 camera	1	personal
Haevy duty suitcases	2	IRE
Station Wagon Daihatsu Panther	1	IRE
Station Wagon Toyota KIJANG	1	IRE

Appendix C

APPENDIX C:
SURVEY FORMS

The following pages document typical survey forms used in the present study. Generally the forms are differentiated and numbered into 3 major categories:

I. Preference Survey Forms, which include Forms 011 for direct interview survey and Form 012 for mail-back questionnaire.

II. Environmental Survey Forms, which include Form 021 for noise observation, Form 022 for air pollution observation and 023 for pedestrian delay observation.

III. Road and Traffic Survey Forms, which include Form 031 for traffic counting survey, Form 032 for speed survey and Form 033 for road geometry and landuse survey.

Research Institute of Road Engineering
Agency for Research and Development, Ministry of Public Works
Department of Transport Engineering
School of Civil Engineering, University of New South Wales, Australia.

Interview Survey Form - 011

Survey on Public Preferences Towards
Traffic-related Environmental Impacts.

Bandung, 1997.

QUESTIONNAIRE

columns 1 2 3 4
Respondent number : [ ][ ] [ ][ ]
category code individual number

5 6 7 8 9
Respondent Address : [ ][ ] [ ][ ][ ]
street code house number

Name of interviewer : ....
Time started : .... am/pm
Time finished : ....am/pm
Date of interview : ..../ ..../ 19 ....

I, ...(interviewer's intials) certify that this questionnaire is a true record of an interview that I performed at the house shown in the above respondent address code.

____
Signature

COMMENCE INTERVIEW HERE.

"Good morning/afternoon/evening. I am conducting a survey for the Research Institute of Road Engineering, Ministry of Public Works and Department of Transportation Engineering, School of Civil Engineering, UNSW. You will have received a letter recently from us asking for your co-operation in a survey to find out what people think of traffic-related environmental impacts of the area where they live."

Q.1 *"How do you rate your environment around you in general ?"* 10

A.1 Very Good = 1
Good = 2
Fair = 3
Poor = 4
Very Poor = 5

Q.2 *"In your opinion, what aspect of traffic-related environmental impact of your area considered as the most annoying factor ? "* 11

1. Noise
2. Air Pollution
3. Pedestrian Delay/Safety
4. Accidents
5. Other (please specify) ....

Q.3 *"What is the second ?"* 12

1. Noise
2. Air Pollution
3. Pedestrian Delay/Safety
4. Accidents
5. Other (please specify) ....

Q.4 *"What is the third ? "* 13

1. Noise
2. Air Pollution
3. Pedestrian Delay/Safety
4. Accidents
5. Other (please specify) ....

Q.5 *"Do you ever complain to yourself about anything in this area? "* 14

Don't know = 0
Yes = 1
No = 2

If the answer is 'No' or 'Don't know', GOTO question Q.7.

Q.6 *"What things in particular ? "* 15

1. Noise
2. Air Pollution
3. Pedestrian Delay/Safety
4. Accidents
5. Other (please specify) ....

Q.7 *"In your area, is noise more annoying to you than air pollution or air pollution is more annoying than noise ? "* 16

Noise is more annoying than air pollution = 1
Air pollution is more annoying than noise = 2

Q.8 "*How do you rate the difference ?* " 17

Equal	Weak	Strong	Very strong	Absolut
(1)	(3)	(5)	(7)	(9)

Q.9 "*In your area, is noise more annoying to you than pedestrian delay/safety or pedestrian delay/safety is more annoying than noise ?* " 18

Noise is more annoying than pedestrian delay/safety = 1
Pedestrian delay/safety is more annoying than noise = 2

Q.10 "*How do you rate the difference ?* " 19

Equal	Weak	Strong	Very Strong	Absolute
(1)	(3)	(5)	(7)	(9)

Q.11 "*In your area, is noise more annoying to you than accident risks or accident risks is more annoying than noise ?* " 20

Noise is more annoying than accident risks = 1
Accident risks is more annoying than noise = 2

Q.12 "*How do you rate the difference ?* " 21

Equal	Weak	Strong	Very Strong	Absolute
(1)	(3)	(5)	(7)	(9)

Q.13 "*In your area, is air pollution more annoying to you than pedestrian delay/safety or pedestrian delay/safety is more annoying than air pollution ?* " 22

Air pollution is more annoying than pedestrian delay/safety = 1
Pedestrian delay/safety is more annoying than air pollution = 2

Q.14 "*How do you rate the difference ?* " 23

Equal	Weak	Strong	Very Strong	Absolute
(1)	(3)	(5)	(7)	(9)

Q.15 "*In your area, is air pollution more annoying to you than accident risks or accident risks is more annoying than air pollution ?* " 24

Air pollution is more annoying than accident risks = 1
Accident risks is more annoying than air pollution = 2

Q.16 "*How do you rate the difference ?*" 25

Equal	Weak	Strong	Very Strong	Absolute
(1)	(3)	(5)	(7)	(9)

Q.17 "*In your area, is pedestrian delay/safety more annoying to you than accident risks or accident risks is more annoying than pedestrian safety ?* " 26

Pedestrian safety is more annoying than accident risks = 1
Accident risks is more annoying than pedestrian safety = 2

Q.18 "*How do you rate the difference ?*" 27

Equal	Weak	Strong	Very Strong	Absolute
(1)	(3)	(5)	(7)	(9)

Q.19 "*In your area, what score do you give to noise, relative to other impacts, in 100 scales?*" 28

0 = Very Bad ....100 = Exellent .

Q.20 *"In your area, what score do you give to <u>air pollution</u>, relative to other impacts, in 100 scales ?"*

29

0 = Very Bad ....100 = Exellent . ☐

Q.21 *"In your area, what score do you give to <u>pedestrian delay/safety</u>, relative to other impacts, in 100 scales ?"*

30

0 = Very Bad ....100 = Exellent . ☐

Q.22 *"In your area, what score do you give to <u>accident risks</u>, relative to other impacts, in 100 scales ?"*

31

0 = Very Bad ....100 = Exellent . ☐

Q.23 *"Do you have any particular suggestion to improve the quality of environment of your area ?"*

....

....

....

....

....

"Thank you for your time and your co-operation in this survey, have a nice day/evening".

--- The End of Questionnaire ---

Research Institute of Road Engineering
Agency for Research and Development, Ministry of Public Works

Department of Transport Engineering
School of Civil Engineering, University of New South Wales, Australia.

Questionnaire Survey Form 012

Survey on Experts/Planners/Decision Makers' Preferences Towards Traffic-related Environmental Impacts.

Bandung, 1997.

QUESTIONNAIRE

Confidentiality

Your completed form remains confidential to the Research Institute of Road Engineering. No information will be released in a way that would be enable an individual or household to be identified.

Objectives

This survey is part of study on the development of the environmental capacity of roads, conducted by RIRE in collaboration with UNSW and CSIRO, Australia. This questionnaire is intended to collect information on experts/planners' preferences towards traffic-related environmental impacts. The result of this survey will be used to develop the environmental capacity model for Bandung area.

What you need to do

- Please answer all the questions. If you do not know an answer, give the best answer you can.
- Please take your time to complete the form, and send them back to the address below using the already stamped envelope, before 15 August 1997.
- Please use a black or blue pen.
- If you have any difficulty filling out this form, please contact Doni Widiantono or any officer on 022-7802551-3.

Mailing Address

Please send any enquiries to:

Kelompok Bidang Keahlian Lingkungan Jalan,
Pusat Penelitian dan Pengembangan Jalan, Departemen Pekerjaan Umum.
Jl. Raya Timur 264, P.O. Box 2 UJB, Bandung 40264, INDONESIA
Tel. (022) 7802251 -7802253; Fax. (022) 78002726; Email : Rudjito@indo.net.id

Respondent Detail

Name : .... (M/F)
Title : ....
Position : ....
Address : ....
....
.... Postcode ....
Telp./Fax : (....) .... (....) ....

Q.1 *How do you categorize yourself in respect of environmental engineering* ? 1 ☐

Expert
Planner
Educator
Decision maker
Other, please specify : ....

Q.2 "*How do you rate the road environment in Bandung in general* ?" 2 ☐

Very Good
Good
Fair
Poor
Very Poor

Q.3 "*In your opinion, what aspect of traffic-related environmental impact in Bandung considered as the most annoying factor* ? " 3 ☐

Noise
Air Pollution
Pedestrian Delay/Safety
Accidents
Other (please specify) : ....

Q.4 "*What is the second* ?" 4 ☐

Noise
Air Pollution
Pedestrian Delay/Safety
Accidents
Other (please specify) : ....

Q.5 "*What is the third* ? " 5 ☐

Noise
Air Pollution
Pedestrian Delay/Safety
Accidents
Other (please specify) : ....

Q.6 *"Do you ever complain to yourself about anything in Bandung ?"* 6 ☐

Don't know
Yes
No

If the answer is 'No' or 'Don't know', GOTO question Q.8.

Q.7 *"What things in particular ?"* 7 ☐

Noise
Air pollution
Pedestrian delay/safety
Accidents
Traffic congestion
Cable/pipe laying
Public transport service
Drivers behaviour
Traffic lights problem
Other (please specify) ....

Q.8 *"In Bandung, is noise more annoying to you than air pollution or air pollution is more annoying than noise ?"* 8 ☐

Noise is more annoying than air pollution.
Air pollution is more annoying than noise.

Q.9 *"How do you rate the difference ?"* 9 ☐

Equal
Weak
Strong
Very strong
Absolute

Q.10 *"In Bandung, is noise more annoying to you than pedestrian delay/safety or pedestrian delay/safety is more annoying than noise ?"* 10 ☐

Noise is more annoying than pedestrian delay/safety.
Pedestrian delay/safety is more annoying than noise.

Q.11 *"How do you rate the difference ?"* 11 ☐

Equal
Weak
Strong
Very strong
Absolute

Q.12 *"In Bandung, is noise more annoying to you than accident risks or accident risks is more annoying than noise ?"* 12 ☐

Noise is more annoying than accident risks.
Accident risks is more annoying than noise.

Q.13 *"How do you rate the difference ? "* 13 ☐

Equal
Weak
Strong
Very strong
Absolute

Q.14 *"In Bandung, is air pollution more annoying to you than pedestrian delay/safety or pedestrian delay/safety is more annoying than air pollution ? "* 14 ☐

Air pollution is more annoying than pedestrian delay/safety.
Pedestrian delay/safety is more annoying than air pollution.

Q.15 *"How do you rate the difference ? "* 15 ☐

Equal
Weak
Strong
Very strong
Absolute

Q.16 *"In Bandung, is air pollution more annoying to you than accident risks or accident risks is more annoying than air pollution ? "* 16 ☐

Air pollution is more annoying than accident risks.
Accident risks is more annoying than air pollution.

Q.17 *"How do you rate the difference ?"* 17 ☐

Equal
Weak
Strong
Very strong
Absolute

Q.18 *"In Bandung, is pedestrian delay/safety more annoying to you than accident risks or accident risks is more annoying than pedestrian safety ? "* 18 ☐

Pedestrian safety is more annoying than accident risks.
Accident risks is more annoying than pedestrian safety.

Q.19 *"How do you rate the difference ?"* 19 ☐

Equal
Weak
Strong
Very strong
Absolut

Q.20 *"In Bandung, what score do you give to noise, relative to other impacts, in 100 scales?"* (0 = Very Bad , 100 = Exellent) . 20 ☐

....

Q.21 *"In Bandung, what score do you give to* <u>*air pollution*</u>*, relative to other impacts, in 100 scales ?"*

(0 = Very Bad , 100 = Exellent) . 21 ☐

....

Q.22 *"In Bandung, what score do you give to* <u>*pedestrian delay/safety*</u>*, relative to other impacts, in 100 scales ?"*

(0 = Very Bad , 100 = Exellent) . 22 ☐

....

Q.23 *"In Bandung, what score do you give to* <u>*accident risks*</u>*, relative to other impacts, in 100 scales ?"*

(0 = Very Bad , 100 = Exellent) . 23 ☐

....

Q.24 *"Do you have any particular suggestion to improve the quality of environment of Bandung ?"*

....

....

....

....

....

Q.25 *Finished.*

Please check you have not missed any pages or questions and sign here.

Signature	*Date*

Thank you for completing this form.

Noise Measurements Form (Summary) - Form 021

Site Code: ....

Location: ....

Sheet no.: ....

Effective road width: .... metres.

Date/Month/Year : ....../....../97

Technician :..

Weather : clear/cloudy/rain

Time	$L_{10\text{-}1\,hour}$, dB(A)	Time	$L_{10\text{-}1\,hour}$, dB(A)

Checked by,

Name: ....

Signature: ....

Pedestrian Observation Form (Summary) - Form 022

Site Code: ....

Date/Month/Year : ....../....../97

Location: ....

Observer:..

Sheet no: ....

Weather: clear/cloudy/rain

Effective road width: .... metres.

Ped. No.	Arrival Time (hh:mm:ss)	Start Crossing (hh:mm:ss)	Delay (sec.)	Finish Crossing (hh:mm:ss)	Walking Speed (m/s)

Checked by:

Name: ....

Signature: ....

Air Pollution Survey Form (Summary) - Form 023

Site Code: ....

Location: ....

Sheet no.: ....

Effective road width: .... metres.

Date/Month/Year : ....../....../97

Observer :..

Weather : clear/cloudy/rain

Time	CO, ppm	HC, ppm	NOx, ppm	Comments

Checked by,

Name : ....

Signature : ....

Traffic Counting Form (Summary) - Form 031

Site Code: ....

Location: ....

Sheet no.: ....

Date/Month/Year : ....../....../97

Wheather : clear/cloudy/rain

Observer :...

Time	**Cars** sedan, p.up, minibus	**Heavy Vehicles** truck, bus, trailer	**Motor Cycles**

Checked by,

Name: ....

Signature: ....

Speed Measurements Survey Form (Summary) - Form 032

Site Code: .... Date/Month/Year : ....../....../97

Location: .... Weather : clear/cloudy/rain

Sheet no.: .... Observer :...

Time Period	Average Speed	Remarks

Checked by,

Name: ....

Signature: ....

Road Geometry and Landuse Survey Form - Form 033

Site Code: ....
Date/Month/Year : ....../....../97

Location: ....
Wheather : clear/cloudy/rain

Sheet no.: ....
Observer :..

1. Road Geometry Data:

Road Class	: 1. Local 2. Collector 3. Arterial
Number of lanes (2-way)	: ....
Effective road width	: .... m
Inner lane width	: .... m
Outer lane width	: .... m
Parking lane	: yes/no
Overall shoulder width	: .... m
Effective shoulder width	: .... m
Median	: yes/no
Median width	: .... m
Road marking	: 1. good 2. fair 3. not any
Pedestrian crossing facility	: 1. N/A 2. Zebra Cross 3. Pelican Crossing 4. Road Island

2. Roadway Data:

Type of facility	: 1. 2-way-2-lane 2. 2-way-4-lane (undivided) 3. 1-way-2-lane 4. 4-lane-divided 5. 6-lane-divided
Roadway conditions	: 1. Exellent 2. Fair 3. Poor
Type of pavement	: 1. Hotmix 2. Macadam 3. Concrete 4. Other
Type of Shoulder	: 1. Paved 2. unpaved

3. **Landuse Data:**

Main activities : 1. Residentials
2. Mix
3. Commercials

Street landscape : 1. Good
2. Fair
3. Poor

Parks : 1. Yes
2. No

4. **Sketch of Survey Site**

- Indicate North arrow
- Include 100m landuse activities along both sides of the road

5. Typical Cross Section

Checked by,

Name : ....

Signature : ....

DEPARTEMEN PEKERJAAN UMUM
BADAN PENELITIAN DAN PENGEMBANGAN PU
PUSAT PENELITIAN DAN PENGEMBANGAN JALAN
Jalan Raya Timur No. 264 Kotak Pos 2 Ujungberung ☎(022) 7802251 (Hunting)
Fax. (022) 7802726 Bandung 40294

Survai Pendapat Ahli/Perencana/Pengambil Keputusan Mengenai Dampak Lingkungan Akibat Lalu Lintas.

Bandung, 1997

KUESIONER

Kerahasiaan

Informasi yang diberikan oleh responden dalam kusioner ini dijamin kerahasiaannya oleh Pusat Penelitian dan Pengembangan Jalan PU. Data mengenai individu tidak akan disebarluaskan dan akan dimusnahkan setelah pemrosesan data selesai.

Tujuan

Kuesioner ini bertujuan untuk memperoleh data mengenai pendapat/ketertarikan (preferensi) para ahli/perencana/pengambil keputusan terhadap faktor-faktor dampak lingkungan akibat lalu lintas jalan. Hasil survai ini nantinya akan digunakan sebagai bahan dalam pengembangan model terpadu untuk menentukan kapasitas lingkungan jalan kota di Indonesia.

Petunjuk Menjawab

- Waktu yang dibutuhkan untuk mengisi kusioner ini adalah sekitar 15-20 menit.
- Usahakan untuk dapat menjawab semua pertanyaan. Jika Anda kurang pasti tentang jawaban suatu pertanyaan, isilah dengan jawaban maksimal yang Anda ketahui.
- Setelah selesai, masukkan ke dalam amplop berperangko yang kami lampirkan, dan kirimkan sebelum tanggal 19 Oktober 1997.
- Jika Anda mengalami kesulitan dalam menjawab atau memahami maksud suatu pertanyaan silahkan menghubungi Subagus Dwi Nurjaya, Doni Widiantono atau petugas lain pada alamat di bawah ini.

Alamat Surat-Menyurat

Untuk keterangan lebih lengkap, silahkan menghubungi
Kelompok Bidang Keahlian Lingkungan Jalan
pada alamat tersebut di atas.

I. Data Responden

Nama : Lili Rochies ....(tidak wajib) (L/P)
Institusi : P3J
Jabatan : Surveyor
Alamat : Jl. Raya Timur No. 284
....
.... Kode Pos ....
Telp./Fax : (....) .... (....) ....

P.1 Dalam kategori mana Anda mengelompokkan diri Anda dalam hal lingkungan?

- ☐ Ahli/*Expert*
- ☐ Perencana/*Planner*
- ☐ Pengajar/*Educator*
- ☐ Pengambil Keputusan/*Decision maker*
- ☑ Lain-lain, sebutkan : Senior Surveyor

II. Latar Belakang

Umumnya kita mengenal beberapa dampak lingkungan akibat lalu lintas jalan, yaitu antara lain:

- *Kebisingan.* Yaitu suara yang ditimbulkan oleh deru mesin, roda atau knalpot kendaraan.
- *Polusi Udara.* Yaitu emisi buangan bahan bakar kendaraan kendaraan seperti gas CO, HC, partikulat, NOx atau bahan-bahan lain yang dapat membahayakan kesehataan manusia yang tinggal di sepanjang sisi jalan.
- *Resiko Penyeberang Jalan.* Dampak ini dapat timbul jika tingkat kesempatan untuk melakukan penyeberangan sudah sangat rendah, sehingga dapat mengakibatkan frustasi atau rasa ketidaksabaran bagi pejalan kaki, yang akhirnya dapat membahayakan keselamatan dirinya.
- *Resiko Tabrakan/kecelakaan.* Tabrakan/kecelakaan yang terjadi antara kendaraan yang ada di jalan dapat memberikan dampak terhadap masyarakat di sekitar kejadian berupa kerugian materil seperti kerusakan fasilitas bangunan dan kerugian non-materil seperti trauma atau rasa ketidakamanan.

III. Ranking terhadap Dampak Lingkungan

P.2 "Secara umum bagaimana Anda menentukan urutan tingkat gangguan dampak-dampak lingkungan akibat lalu lintas tersebut?" (urutan 1 memiliki tingkat gangguan tertinggi, dan 5 mewakili tingkat gangguan terendah).

Jawab: (lingkari ranking yang sesuai untuk masing-masing faktor).

Faktor	Ranking				
Kebisingan	1	2	3	4	(5)
Polusi Udara	(1)	2	3	4	5
Resiko Pejalan Kaki (waktu tunda)	(1)	2	3	4	5
Resiko Tabrakan/kecelakaan	(1)	2	3	4	5
Lain-lain (sebutkan): Akses Jalan	(1)	2	3	4	5

IV. Perbandingan Antar Faktor

P.3 "Menurut Anda pernyataan mana yang lebih benar ?" (pilih salah satu ✓)
- ☐ Kebisingan lebih mengganggu daripada polusi udara.
- ☑ Polusi udara lebih mengganggu daripada kebisingan.

P.4 "Berapa besar perbedaannya ? " (✓ salah satu)

☐ Sama	(1)	☐ Begitu tinggi	(6)
☐ Hampir sama	(2)	☐ Sangat Tinggi	(7)
☐ Agak tinggi	(3)	☐ Tinggi sekali	(8)
☑ Cukup tinggi	(4)	☐ Sangat Mutlak	(9)
☐ Tinggi	(5)		

P.5 "Menurut Anda pernyataan mana yang lebih benar ?" (pilih salah satu ✓)
- ☐ Kebisingan lebih mengganggu daripada resiko pejalan kaki.
- ☑ Resiko pejalan kaki lebih mengganggu daripada kebisingan.

P.6 "Berapa besar perbedaannya ? " (✓ salah satu)

☐ Sama	(1)	☐ Begitu tinggi	(6)
☐ Hampir sama	(2)	☐ Sangat Tinggi	(7)
☐ Agak tinggi	(3)	☐ Tinggi sekali	(8)
☑ Cukup tinggi	(4)	☐ Sangat Mutlak	(9)
☐ Tinggi	(5)		

P.7 "Menurut Anda pernyataan mana yang lebih benar ?" (pilih salah satu ✓)
- ☐ Kebisingan lebih mengganggu daripada resiko tabrakan/kecelakaan.
- ☑ Resiko tabrakan/kecelakaan lebih mengganggu daripada kebisingan.

P.8 "Berapa besar perbedaannya ? " (✓ salah satu)

☐ Sama	(1)	☐ Begitu tinggi	(6)
☐ Hampir sama	(2)	☐ Sangat Tinggi	(7)
☐ Agak tinggi	(3)	☐ Tinggi sekali	(8)
☑ Cukup tinggi	(4)	☐ Sangat Mutlak	(9)
☐ Tinggi	(5)		

P.9 "Menurut Anda pernyataan mana yang lebih benar ?" (pilih salah satu ✓)
- ☐ Polusi Udara lebih mengganggu daripada resiko pejalan kaki.
- ☑ Resiko pejalan kaki lebih mengganggu daripada polusi udara.

P.10 "Berapa besar perbedaannya ? " (✓ salah satu)

☐ Sama	(1)	☐ Begitu tinggi	(6)
☐ Hampir sama	(2)	☐ Sangat Tinggi	(7)
☑ Agak tinggi	(3)	☐ Tinggi sekali	(8)
☐ Cukup tinggi	(4)	☐ Sangat Mutlak	(9)
☐ Tinggi	(5)		

P.11 "Menurut Anda pernyataan mana yang lebih benar ?" (pilih salah satu ✓)
- ☐ Polusi Udara lebih mengganggu daripada resiko tabrakan/kecelakaan.
- ☑ Resiko tabrakan/kecelakaan lebih mengganggu daripada polusi udara.

P.12 "Berapa besar perbedaannya ? " (✓ salah satu)

☐ Sama	(1)	☐ Begitu tinggi	(6)
☐ Hampir sama	(2)	☐ Sangat Tinggi	(7)
☑ Agak tinggi	(3)	☐ Tinggi sekali	(8)
☐ Cukup tinggi	(4)	☐ Sangat Mutlak	(9)
☐ Tinggi	(5)		

P.13 "Menurut Anda pernyataan mana yang lebih benar ?" (pilih salah satu ✓)

☑ Resiko pejalan kaki lebih mengganggu daripada resiko tabrakan/kecelakaan.

☐ Resiko tabrakan/kecelakaan lebih mengganggu daripada resiko pejalan kaki.

P.14 "Berapa besar perbedaannya ? " (✓ salah satu)

☐ Sama	(1)	☐ Begitu tinggi	(6)
☐ Hampir sama	(2)	☐ Sangat Tinggi	(7)
☑ Agak tinggi	(3)	☐ Tinggi sekali	(8)
☐ Cukup tinggi	(4)	☐ Sangat Mutlak	(9)
☐ Tinggi	(5)		

V. Pembobotan Langsung

P.15 "Berapa skor yang Anda berikan kepada faktor Kebisingan relatif terhadap faktor lain, dalam skala 100?"
(0 = Tidak mengganggu , 100 = Sangat mengganggu) .
Skor maksimum ..~~40~~.55. Skor minimum ...40.....
(contoh: Skor maksimum 55 skor minimum 40)

P.16 "Berapa skor yang Anda berikan kepada faktor Polusi Udara relatif terhadap faktor lain, dalam skala 100?"
(0 = Tidak mengganggu , 100 = Sangat mengganggu) .
Skor maksimum ..80....... Skor minimum ...60.....

P.17 "Berapa skor yang Anda berikan kepada faktor Resiko Pejalan Kaki, relatif terhadap faktor lain, dalam skala 100?"
(0 = Tidak mengganggu , 100 = Sangat mengganggu) .
Skor maksimum ..80....... Skor minimum ......60....

P.18 "Berapa skor yang Anda berikan kepada faktor Resiko Tabrakan/kecelakaan, relatif terhadap faktor lain, dalam skala 100?"
(0 = Tidak mengganggu , 100 = Sangat mengganggu) .
Skor maksimum ....80..... Skor minimum ....60.......

VI. Penutup

P.19 "Apakah Anda memiliki usulan tertentu dalam upaya meningkatkan kondisi lingkungan jalan di dalam kota?"

- Pemeriksaan kondisi kendaraan (mem) yg operasional perlu ditingkatkan
- Meningkatkan kegunaan fasilitas yg ada (~~fasilitas~~ pejalan kaki
-

Selesai.

Mohon dipastikan semua pertanyaan telah terjawab.

Terima kasih atas kesediaannya mengisi kuesioner ini.

Pusat Penelitian dan Pengembangan Jalan,
Badan Penelitian dan Pengembangan PU, Departemen Pekerjaan Umum
dan
Departemen Teknik Transportasi
Jurusan Teknik Sipil dan Lingkungan, University of New South Wales, Australia.

Survai Pendapat Masyarakat Tentang Dampak Lingkungan Akibat Lalu Lintas Jalan

Bandung, 1997.

KUESIONER WAWANCARA

Pak Budi.
Jl. Markonata 37
(PSB. Uningati).

No. Responden : columns 1 2 [ ][ ] category code; 3 4 [0][5] individual number

Alamat : 5 6 [ ][ ] street code; 7 8 9 [ ][ ][ ] house number

Pewawancara : ...35...

Jam Mulai : ...14... am/pm

Tanggal Wawancara : ...1.../...10.../ 1997

Saya.....[signature]..... (nama pewawancara) menyatakan bahwa kuesioner ini merupakan catatan yang sesungguhnya dari wawancara yang saya lakukan terhadap responden yang bertempat tinggal pada alamat di atas.

Tanda tangan

Mulai wawancara di sini.

"Selamat pagi/siang. Kami dari tim penelitian Pusat Litbang Jalan PU bermaksud mewawancarai Anda, untuk mendapatkan data mengenai pendapat masyarakat tentang dampak lingkungan akibat lalu lintas jalan. Untuk itu kami mohon kesediaan Anda meluangkan waktu kurang lebih 30 menit untuk wawancara. Terima kasih."

I. **Data Responden**

P.1 Usia
1. < 17 tahun — 2. 17 - 40 tahun — (3.) > 40 tahun — 10 [ ]

P.2 Pendidikan
1. SMA — (2.) Akademi — 3. Sarjana — 4. Pasca Sarjana — 11 [ ]

P.3 Jenis Kelamin 12

(1.) Laki-laki 2. Perempuan ☐

P.4 Posisi dalam rumah tangga 13

1. Suami 2. Istri 3. Anak 4. Famili 5. lain ☐

II. Latar Belakang

Umumnya kita mengenal beberapa dampak lingkungan akibat lalu lintas jalan, yaitu antara lain:

- Kebisingan. Yaitu suara yang ditimbulkan oleh deru mesin, roda atau knalpot kendaraan.
- Polusi Udara. Yaitu emisi buangan bahan bakar kendaraan kendaraan seperti gas CO, HC, partikulat, Nox atau bahan-bahan lain yang dapat membahayakan kesehataan manusia yang tinggal di sepanjang sisi jalan.
- Resiko Pejalan Kaki. Dampak ini dapat timbul jika tingkat kesempatan untuk melakukan penyeberangan sudah sangat rendah, sehingga dapat mengakibatkan frustasi atau rasa ketidaksabaran bagi pejalan kaki, yang akhirnya dapat membahayakan keselamatan dirinya.
- Resiko kerugian akibat kecelakaan. Kecelakaan yang terjadi antara kendaraan yang ada di jalan dapat memberikan dampak terhadap masyarakat di sekitar kejadian berupa kerugian materil seperti kerusakan fasilitas bangunan dan kerugian non-materil seperti trauma atau rasa ketidakamanan.

III. Ranking terhadap Dampak Lingkungan

P.5 "Secara umum bagaimana Anda menentukan urutan tingkat gangguan dampak-dampak lingkungan akibat lalu lintas tersebut?" (urutan 1 memiliki tingkat gangguan tertinggi, dan 5 mewakili tingkat gangguan terendah).

Jawab: (lingkari ranking yang sesuai untuk masing-masing faktor).

Faktor	Ranking				
Kebisingan	1	2	3	(4)	5
Polusi Udara	1	2	(3)	4	5
Waktu tunda Pejalan Kaki	1	(2)	3	4	5
Resiko Kecelakaan	(1)	2	3	4	5
Lain-lain (sebutkan)	1	2	3	4	5

IV. Bobot Langsung Terhadap Faktor-faktor Dampak Lingkungan Akibat Lalu Lintas Jalan.

P.6 "Tadi Anda mengatakan bahwa Kebisingan memberikan gangguan yang tertinggi/ kedua/ ketiga/ terendah, lalu jika nilai 0 adalah nilai untuk gangguan yang dapat diabaikan dan 100 adalah nilai untuk kondisi yang sangat mengganggu, berapa nilai yang Anda berikan terhadap Kebisingan?"

.... (contoh 45)

"Jika Anda diminta untuk memberikan nilai yang lebih tinggi, berapa angka maksimum yang Anda berikan?"

.... (contoh 55) 20

"Jika Anda diminta untuk memberikan nilai yang lebih rendah, berapa angka minimum yang dapat Anda berikan?"

.... (contoh 35) 10

P.7 "Tadi Anda mengatakan bahwa Polusi Udara memberikan gangguan yang tertinggi/ kedua/ ketiga/ terendah, lalu jika nilai 0 adalah nilai untuk gangguan yang dapat diabaikan dan 100 adalah nilai untuk kondisi yang sangat mengganggu, berapa nilai yang Anda berikan terhadap Polusi Udara?"

....
"Jika Anda diminta untuk memberikan nilai yang lebih tinggi, berapa angka maksimum yang Anda berikan?"
.... 30
"Jika Anda diminta untuk memberikan nilai yang lebih rendah, berapa angka minimum yang dapat Anda berikan?"
.... 10

P.8 "Tadi Anda mengatakan bahwa Resiko Pejalan Kaki memberikan gangguan yang tertinggi/ kedua/ ketiga/ terendah, lalu jika nilai 0 adalah nilai untuk gangguan yang dapat diabaikan dan 100 adalah nilai untuk kondisi yang sangat mengganggu, berapa nilai yang Anda berikan terhadap Resiko Pejalan Kaki?"
....
"Jika Anda diminta untuk memberikan nilai yang lebih tinggi, berapa angka maksimum yang Anda berikan?"
.... 40
"Jika Anda diminta untuk memberikan nilai yang lebih rendah, berapa angka minimum yang dapat Anda berikan?"
.... 20

P.9 "Tadi Anda mengatakan bahwa Resiko Kecelakaan memberikan gangguan yang tertinggi/ kedua/ ketiga/ terendah, lalu jika nilai 0 adalah nilai untuk gangguan yang dapat diabaikan dan 100 adalah nilai untuk kondisi yang sangat mengganggu, berapa nilai yang Anda berikan terhadap Resiko Kecelakaan?"
....
"Jika Anda diminta untuk memberikan nilai yang lebih tinggi, berapa angka maksimum yang Anda berikan?" 80
....
"Jika Anda diminta untuk memberikan nilai yang lebih rendah, berapa angka minimum yang dapat Anda berikan?"
.... 50

V. Perbandingan Tingkat Kepentingan Antar Faktor Lingkungan Lalu Lintas Jalan.

P.10 "Tadi Anda mengatakan bahwa faktor Kebisingan/ Polusi Udara lebih mengganggu daripada faktor Kebisingan/ Polusi Udara. Lalu jika angka 1 mewakili kondisi gangguan yang sama dan angka 9 mewakili perbedaan gangguan yang sangat mutlak, berapa kira-kira menurut Anda tingkat perbedaan gangguan tersebut?"
(1) sama
(2) hampir sama ✓
(3) agak tinggi
(4) cukup tinggi
(5) tinggi
(6) begitu tinggi
(7) sangat tinggi
(8) tinggi sekali
(9) sangat mutlak

P.11 "Tadi Anda mengatakan bahwa faktor Kebisingan/ Resiko Pejalan Kaki lebih mengganggu daripada faktor Kebisingan/ Resiko Pejalan Kaki. Lalu jika angka 1 mewakili kondisi gangguan yang sama dan angka 9 mewakili perbedaan gangguan yang sangat mutlak, berapa kira-kira menurut Anda tingkat perbedaan gangguan tersebut?"
(1) sama
(2) hampir sama ✓
(3) agak tinggi
(4) cukup tinggi
(5) tinggi

(6) begitu tinggi
(7) sangat tinggi
(8) tinggi sekali
(9) sangat mutlak

P.12 "Tadi Anda mengatakan bahwa faktor Kebisingan/Resiko Kecelakaan lebih mengganggu daripada faktor Kebisingan/ Resiko Kecelakaan. Lalu jika angka 1 mewakili kondisi gangguan yang sama dan angka 9 mewakili perbedaan gangguan yang sangat mutlak, berapa kira-kira menurut Anda tingkat perbedaan gangguan tersebut?"
(1) sama
(2) hampir sama
(3) agak tinggi
(4) cukup tinggi
(5) tinggi
(6) begitu tinggi ✓
(7) sangat tinggi
(8) tinggi sekali
(9) sangat mutlak

P.13 "Tadi Anda mengatakan bahwa faktor Polusi Udara/ Resiko Pejalan Kaki lebih mengganggu daripada faktor Polusi Udara/ Resiko Pejalan Kaki. Lalu jika angka 1 mewakili kondisi gangguan yang sama dan angka 9 mewakili perbedaan gangguan yang sangat mutlak, berapa kira-kira menurut Anda tingkat perbedaan gangguan tersebut?"
(1) sama
(2) hampir sama ✓
(3) agak tinggi
(4) cukup tinggi
(5) tinggi
(6) begitu tinggi
(7) sangat tinggi
(8) tinggi sekali
(9) sangat mutlak

P.14 "Tadi Anda mengatakan bahwa faktor Polusi Udara/ Resiko Kecelakaan lebih mengganggu daripada faktor Polusi Udara/ Resiko Kecelakaan. Lalu jika angka 1 mewakili kondisi gangguan yang sama dan angka 9 mewakili perbedaan gangguan yang sangat mutlak, berapa kira-kira menurut Anda tingkat perbedaan gangguan tersebut?"
(1) sama
(2) hampir sama
(3) agak tinggi ✓
(4) cukup tinggi
(5) tinggi
(6) begitu tinggi
(7) sangat tinggi
(8) tinggi sekali
(9) sangat mutlak

P.15 "Tadi Anda mengatakan bahwa faktor Resiko Pejalan Kaki/ Resiko Kecelakaan lebih mengganggu daripada faktor Resiko Pejalan Kaki/ Resiko Kecelakaan. Lalu jika angka 1 mewakili kondisi gangguan yang sama dan angka 9 mewakili perbedaan gangguan yang sangat mutlak, berapa kira-kira menurut Anda tingkat perbedaan gangguan tersebut?"
(1) sama
(2) hampir sama
(3) agak tinggi ✓
(4) cukup tinggi
(5) tinggi
(6) begitu tinggi

(7) sangat tinggi
(8) tinggi sekali
(9) sangat mutlak

VI. Penutup

P.16 "Apakah Anda memiliki usulan atau komentar terhadap peningkatan kondisi lingkungan jalan di daerah Anda?

- parkir ?
- pohon, sebagai penyebab kecelakaan -
- penerangan kurang ..

"Terima kasih atas kesediaan dan kerja sama Anda dalam wawancara ini".

--- Selesai ---

Appendix D

APPENDIX D:

TRAFFIC, ROAD, LAND-USE AND ENVIRONMENT DATA (CALIBRATION)

D.1. Overall Database

Typical data recorded in overall database are as summarized in Table D.1. The complete set of calibration purposes data is as presented in Table D.2.

TABLE D.1 TYPICAL DATA FIELDS

Data Category	Data Field	Unit or Options
1. Road ID:	Site Code	-
	LinkName	-
2. Road data:	RoadClass	1. Major - arterial or collector; 2. Local
	Pavement	1. Chip Seal; 2. PC Concrete; 3. Dense Graded AC; 4. Open Graded AC
	Direction	Road direction in degrees from North
	Width	Road width in metres
	Grad(%)	Road gradient in %
	# lanes	number of lanes
	Lane Width	Metres
3. Landuse Data:	LanduseType	1. Commercial; 2. Residential
4. Meteorological data:	WindDir	Wind direction in degrees from North
	WindSpd	Wind speed in ms^{-1}
	Temperature	°C
5. Traffic data:	Volume	v.p.h.
	%HV	Heavy vehicles in %
	%MC	Motor cycle in %
	Speed	km/h
6. Noise	L10-1hr Leq	dB(A) dB(A)
7. Air pollution	NOX CO HC	ppm; ppm; ppm
8. Pedestrian Delay	Ave. Delay %Delayed	Average pedestrian delay in seconds Percent pedestrian delayed
9. Accident	Acc/km/yr.	Accident rate, accidents/km/year
10. Remarks		-

TABLE D.2 OVERALL DATABASE (CALIBRATION SET)

					Road geometry and Landuse				
SiteNo	LinkName	Road Class	type	Pavement	Direction	Width	Grad(%)	# lanes	Lane width
ac01	Setiabudi	arterial	mc	AC	7	13	25	4	3.25
ac01	Setiabudi	arterial	mc	AC	7	13	25	4	3.25
ac02	Suci	arterial	• mc	AC	90	8	1.7	2	4
ac02	Suci	arterial	mc	AC	90	8	1.7	2	4
am01	Juanda	arterial	• mr	AC	6.5	12.6	15	4	3
am01	Juanda	arterial	mr	AC	6.5	12.6	15	4	3
am01	Juanda	arterial	mr	AC	6.5	12.6	15	4	3
am02	Ramdhan	arterial	mr	AC	50	10.2	1.5	2	5.1
am02	Ramdhan	arterial	mr	AC	50	10.2	1.5	2	5.1
ar01	Sukajadi	arterial	mr	AC	177	8.4	15	2	4.2
ar01	Sukajadi	arterial	mr	AC	177	8.4	15	2	4.2
ar02	Cipaganti	arterial	mr	AC	5	8.4	15	2	4.2
ar02	Cipaganti	arterial	mr	AC	5	8.4	15	2	4.2
cc01	Geger Kalong	collector	mc	AC	110	6.6	1.5	2	3.3
cc01	Geger Kalong	collector	mc	AC	110	6.6	1.5	2	3.3
cc02	M. Thoha	collector	mc	AC	5	12	1.5	4	3
cc02	M. Thoha	collector	mc	AC	5	12	1.5	4	3
cc02	M. Thoha	collector	mc	AC	5	12	1.5	4	3
cc03	Pagarsih	collector	mc	AC	93	7	1.5	2	3.5
cc03	Pagarsih	collector	mc	AC	93	7	1.5	2	3.5
cm01	Dipati Ukur	collector	mr	AC	152	8.5	15	2	4.25
cm01	Dipati Ukur	collector	mr	AC	152	8.5	15	2	4.25
cm02	Gandapura	collector	mr	AC	14	6.5	1.5	2	3.25
cm02	Gandapura	collector	mr	AC	14	6.5	1.5	2	3.25
cm03	Burangrang	collector	mr	AC	10	10	1.5	2	5
cm03	Burangrang	collector	mr	AC	10	10	1.5	2	5
cr01	Karawitan	collector	mr	CS	120	5	0	2	2.5
cr01	Karawitan	collector	mr	CS	120	5	0	2	2.5
cr02	Reog	collector	mr	AC	12.5	6.5	0	2	3.25
cr02	Reog	collector	mr	AC	12.5	6.5	0	2	3.25
cr03	Sriwijaya	collector	mr	AC	0	7	0	2	3.5
cr03	Sriwijaya	collector	mr	AC	0	7	0	2	3.5
lc01	Purwakarta	local	lc	AC	140	6.4	2	2	3.2
lc01	Purwakarta	local	lc	AC	140	6.4	2	2	3.2
lc01	Purwakarta	local	lc	AC	140	6.4	2	2	3.2
lc02	Kurdi	local	lc	CS	95	8	0	2	4
lc02	Kurdi	local	lc	CS	95	8	0	2	4
lc03	Selontongan	local	lc	CS	20	6	0	2	3
lc03	Selontongan	local	lc	CS	20	6	0	2	3
lc04	Suryani	local	lc	CS	166.5	12	0	3	4
lc04	Suryani	local	lc	CS	166.5	12	0	3	4
lm01	Jurang	local	lr	AC	25	6.5	14	2	3.25
lm01	Jurang	local	lr	AC	25	6.5	14	2	3.25
lm02	Palasari	local	lr	CS	10	6.6	1	2	3.3
lm02	Palasari	local	lr	CS	10	6.6	1	2	3.3
lm03	Kinanti	local	lr	CS	15	4	0	2	2
lm03	Kinanti	local	lr	CS	15	4	0	2	2
lm04	Logam	local	lr	AC	17.5	5	0	2	2.5
lm04	Logam	local	lr	AC	17.5	5	0	2	2.5
lr01	Sejahtera	local	lr	AC	24	5.4	5	2	2.7
lr01	Sejahtera	local	lr	AC	24	5.4	5	2	2.7
lr02	Vandeventer	local	lr	CS	50	6.7	1	2	3.35
lr02	Vandeventer	local	lr	CS	50	6.7	1	2	3.35
lr03	Bahureksa	local	lr	CS	81	7	0	2	3.5
lr03	Bahureksa	local	lr	CS	81	7	0	2	3.5
lr04	Patrakomala	local	lr	AC	104	6.4	2	2	3.2
lr04	Patrakomala	local	lr	AC	104	6.4	2	2	3.2

Note

• manual counting missing

Table D.2 Overall Database (Calibration Set)

	Survey	Meteorological Data			Traffic Volume and Speed				Noise (dBA)		Air
Landuse type	Time	WindDir	WindSpd	Temp.	Manual	%HV	%MC	Speed	L10-1hr	Leq	NOx
commercial	16-17	5	3.0	27.00	2853	4%	25%	26	77.6	75.0	0.111
commercial	17-18	5	3.0	25.00	2827	3%	21%	27	77.6	76.0	0.128
commercial	9-10	4	4.0	31.00	2880	2%	39%	22	76.0	73.4	0.039
commercial	10-11	5	8.0	31.00	2799	1%	38%	24	75.3	72.6	0.029
mixed	9-10	5	0.5	24.00	2443	1%	28%	45	77.2	74.5	0.156
mixed	10-11	5	0.5	25.00	3161	1%	25%	46	76.9	74.3	0.053
mixed	11-12	5	0.7	26.00	3162	1%	24%	45	76.7	74.2	0.138
mixed	15-16	15	8.0	33.00	1722	3%	30%	34	71.9	69.1	0.074
mixed	16-17	15	8.0	31.00	1835	3%	34%	32	70.7	67.8	0.087
residential	15-16	9	2.0	30.00	1587	1%	25%	40	77.6	74.4	0.014
residential	16-17	9	2.0	28.00	1858	2%	27%	38	77.3	74.2	0.014
residential	14-15	15	1.0	31.00	2193	2%	24%	40	76.6	73.6	0.249
residential	15-16	14	2.0	29.00	2168	2%	25%	38	76.7	73.9	0.221
commercial	9-10	2	0.5	25.00	1514	1%	26%	25	75.4	72.1	0.093
commercial	10-11	2	0.5	26.00	1532	1%	29%	19	74.8	72.2	0.055
commercial	14-15	5	1.0	32.00	2148	3%	29%	25	75.9	73.5	0.212
commercial	15-16	10	0.0	30.00	2403	3%	29%	25	75.5	73.0	0.179
commercial	16-17	1	0.0	29.00	2403	3%	29%	25	76.5	73.6	0.130
commercial	9-10	4	0.5	22.50	1655	1%	48%	28	75.4	72.3	0.085
commercial	10-11	4	0.5	25.00	1800	1%	49%	29	74.5	71.6	0.047
mixed	15-16	16	1.0	30.00	2148	1%	28%	32	76.5	73.7	0.124
mixed	16-17	16	1.0	28.00	2403	1%	32%	34	76.8	74.0	0.100
mixed	13-14	15	1.0	32.00	980	1%	41%	32	71.7	70.7	0.047
mixed	14-15	15	1.0	32.00	901	1%	44%	32	71.2	68.9	0.055
mixed	14-15	11	1.0	30.00	1894	1%	25%	31	74.4	72.0	0.025
mixed	15-16	11	1 0	30.00	2028	0%	25%	31	74.3	72.1	0.038
residential	9-10	1	1.3	25.00	1236	1%	30%	32	74.5	71.8	0.070
residential	10-11	1	1.0	26.00	1265	1%	31%	32	74.0	71.5	0.024
residential	14-15	10	1 0	31.00	455	1%	29%	26	67.1	64.8	0.044
residential	15-16	10	1 0	30.00	470	1%	26%	30	68.3	65.7	0.044
residential	9-10	2	0 8	23.00	1049	2%	31%	32	70.2	67.4	0.081
residential	10-11	2	0 3	25.00	1196	2%	34%	28	70.5	67.4	0.057
commercial	13-14	16	2.0	34.00	917	1%	42%	37	72.5	70.6	0.695
commercial	14-15	16	2.0	33.00	989	1%	42%	36	73.9	72.1	0.239
commercial	15-16	16	2.0	31.00	868	1%	43%	36	73.8	71.3	0.058
commercial	8-9	5	0.6	23.00	400	0%	48%	24	66.8	63.2	0.072
commercial	9-10	5	0.8	24.00	470	0%	47%	24	66.8	63.2	0.072
commercial	14-15	5	2.0	31.00	610	0%	36%	24	69.1	65.9	0.023
commercial	15-16	5	2.0	30.00	534	0%	33%	25	69.0	65.8	0.026
commercial	13-14	16	0.0	31.00	354	1%	34%	31	68.7	67.5	0.034
commercial	14-15	16	0.0	30.00	346	1%	34%	29	69.9	67.1	0.026
mixed	10-11	5	0.6	25	478	3%	37%	27	71.8	68.7	0.031
mixed	11-12	5	0.5	26	670	2%	28%	25	71.4	68.7	0.031
mixed	9-10	4	0.8	23	1003	0%	29%	31	72.3	70.4	0.097
mixed	10-11	4	0.6	27	998	0%	27%	31	71.8	68.9	0.083
mixed	10-11	4	2.0	26	241	0%	33%	28	66.4	63.4	0.015
mixed	11-12	4	2.0	26	185	1%	31%	28	66.6	64.1	0.027
mixed	9-10	7	0.8	23	517	1%	41%	30	74.1	71.0	0.263
mixed	10-11	7	0.5	24	449	0%	45%	31	73.5	71.2	0.050
residential	9-10	7	0.5	25	249	1%	35%	24	66.8	64.0	0.110
residential	10-11	7	0.5	26	207	0%	42%	26	65.8	64.0	0.110
residential	9-10	8	0.4	23	292	0%	42%	28	65.1	64.2	0.067
residential	10-11	8	1 0	25	401	0%	44%	29	66.5	64.3	0.087
residential	9-10	3	0.5	23	274	1%	28%	35	65.8	61.7	0.034
residential	10-11	3	0.6	25	316	0%	28%	36	67.8	64.8	0.036
residential	9-10	8	0 6	23	680	0%	25%	32	69.4	65.5	0.050
residential	10-11	8	1.8	23.5	646	1%	29%	32	69.5	65.9	0.037
		mean	1.44	27.4	1299	1.2%	33.1%	30.6	72.3	69.6	0.091
		st dev	1.76	3.3	897	1.0%	7.5%	5.8	3.8	3.9	0.102
		max	8 00	34.0	3162	4.0%	49.1%	46.0	77.6	76.0	0.695
		min	0 00	22.5	185	0.0%	20.6%	19 0	65.1	61.7	0.014

Pollution (ppm)		Pedestrian		Accidents	
CO	HC	Ave. Delay	%Ped Delayed	acc./km/yr.	remarks
4.041	3.630	5.04	0.54	2.73	
4.350	3.017	0.86	0.18	2.73	
1.415	2.503	5.27	0.60	0.51	
1.067	2.503	3.54	0.50	0.51	
4.970	2.795	13.71	0.71	0.48	
2.135	3.493	11.67	0.79	0.48	
4.177	3.633	12.18	0.91	0.48	
3.228	4.435	6.89	0.56	0.82	
4.051	4.078	1.77	0.38	0.82	
3.431	4.002	3.53	0.42	0.00	
2.006	3.181	5.68	0.42	0.00	
6.300	5.069	5.98	0.55	0.67	
6.177	4.061	5.47	0.62	0.67	
3.310	3.493	1.62	0.16	0.16	
3.493	3.493	1.44	0.25	0.16	
6.046	4.745	2.44	0.69	0.48	traffic data was damaged
5.724	4.888	2.44	0.69	0.48	traffic data was damaged
5.999	3.879	1.73	0.63	0.48	traffic data was damaged
3.093	3.493	1.86	0.29	1.01	
3.310	4.891	2.44	0.44	1.01	
4.646	4.130	2.44	0.69	0.48	
4.690	3.384	1.73	0.63	0.48	
2.296	2.534	0.48	0.19	0.41	
3.230	2.534	3.71	0.47	0.41	
1.054	2.777	0.02	0.02	0.00	
2.237	2.327	2.12	0.19	0.00	
3.140	3.074	1.46	0.80	0.00	
2.270	2.124	1.92	0.95	0.00	
1.268	2.651	0.78	0.12	0.00	
1.381	2.319	1.00	0.19	0.00	
2.840	2.515	3.05	0.32	0.00	
2.602	3.354	3.17	0.39	0.00	
4.510	5.070	0.95	0.09	0.00	
6.351	5.069	1.05	0.08	0.00	
5.156	5.052	0.09	0.04	0.00	
2.950	3.521	0.50	0.09	0.00	
2.950	3.521	0.00	0.00	0.00	
1.558	3.144	0.27	0.09	0.00	
2.044	2.672	0.56	0.11	0.00	
1.603	5.070	0.20	0.14	0.00	
2.526	1.975	0.00	0.00	0.00	
1.616	1.975	0.09	0.04	0.00	
1.616	1.975	1.35	0.16	0.00	
3.418	2.655	1.88	0.40	0.67	
2.844	2.306	1.53	0.26	0.67	
2.663	3.186	0.00	0.00	0.00	
1.200	3.074	0.00	0.00	0.00	
2.640	3.130	1.19	0.19	0.00	
2.467	3.689	2.95	0.32	0.00	
3.078	3.074	0.11	0.06	0.00	
3.078	3.074	0.05	0.05	0.00	
2.043	2.096	0.76	0.10	0.00	
2.694	2.515	0.37	0.05	0.00	
2.368	3.913	0.50	0.26	0.00	
1.875	3.507	0.00	0.00	0.00	
1.585	1.956	1.27	0.33	0.00	
1.803	3.353	1.63	0.38	0.00	
3.102	3.326	2.36	0.33	0.31	
1.452	0.910	2.96	0.26	0.56	
6.351	5.070	13.71	0.95	2.73	
1.054	1.956	0.00	0.00	0.00	

D.2. Noise Model Calibration:

Plot of the values is as depicted by Figure D.1. Results of regression between measured and predicted values are as presented in Table D.3. Measured and predicted noise levels as suggested by DoT model are as presented in Table D.4.

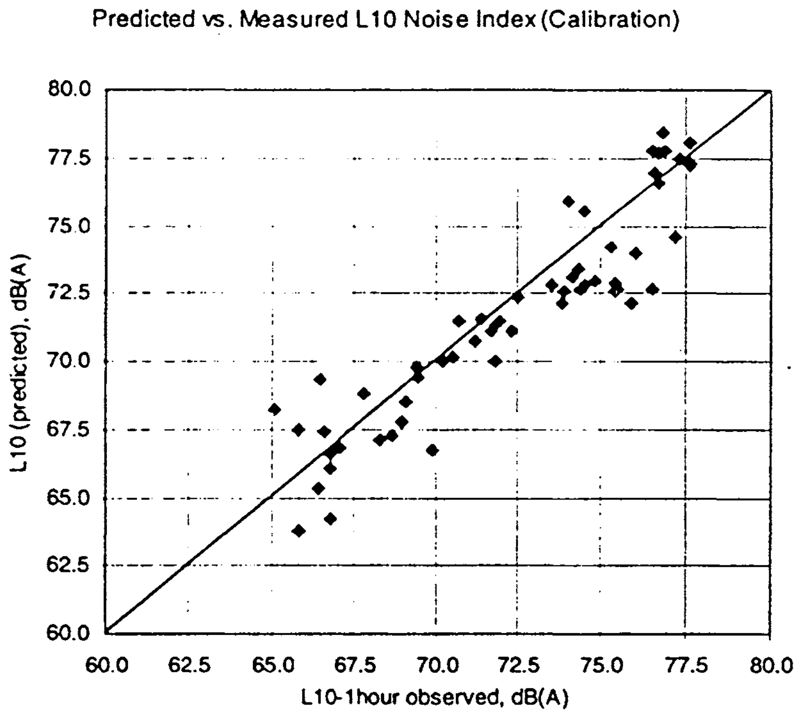

FIGURE D.1 PREDICTED VS. OBSERVED NOISE LEVELS (CALIBRATION)

TABLE D.3 SUMMARY OF REGRESSION ANALYSIS OF NOISE LEVELS (CALIBRATION)

Regression Statistics						
Multiple R	0.96					
R Square	0.92					
Adjusted R Square	0.92					
Standard Error	1.28					
Observations	57					
ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*	
Regression	1	1006.765	1006.765	613.338	0.000	
Residual	55	90.280	1.641			
Total	56	1097.045				
Variables	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-6.770	3.220	-2.102	0.040	-13.223	-0.317
Predicted L10 1hr	1.102	0.044	24.766	0.000	1.012	1.191

TABLE D.4 MEASURED AND PREDICTED NOISE LEVELS

Table D4 Noise

				Road geometry and Landuse					Survey	Tr
SiteNo	LinkName	Road Class	Pavement	Width	Grad(%)	# lanes	Lane width	Landuse type	Time	Volume
ak01	Setiabudi	arterial	AC	13	15	4	3.25	commercial	16-17	2853
		arterial	AC	13	15	4	3.25	commercial	17-18	2827
ak02	Suci	arterial	AC	8	1.7	2	4	commercial	9-10	2880
		arterial	AC	8	1.7	2	4	commercial	10-11	2799
am01	Juanda	arterial	AC	12.6	15	4	3	mixed	9-10**	2443
		arterial	AC	12.6	15	4	3	mixed	10-11	3161
		arterial	AC	12.6	15	4	3	mixed	11-12	3162
am02	Ramdhan	arterial	AC	10.2	1.5	2	5.1	mixed	15-16	1722
		arterial	AC	10.2	1.5	2	5.1	mixed	16-17	1835
ap01	Sukajadi	arterial	AC	8.4	15	2	4.2	residential	15-16	1587
		arterial	AC	8.4	15	2	4.2	residential	16-17	1858
ap02	Cipaganti	arterial	AC	8.4	15	2	4.2	residential	14-15	2193
		arterial	AC	8.4	15	2	4.2	residential	15-16	2168
kk01	Geger Kalong	collector	AC	6.6	1.5	2	3 3	commercial	9-10	1514
		collector	AC	6.6	1.5	2	3 3	commercial	10-11	1532
kk02	M. Thoha	collector	AC	12	1.5	4	3	commercial	14-15***	2148
		collector	AC	12	1.5	4	3	commercial	15-16***	2403
		collector	AC	12	1.5	4	3	commercial	16-17***	2403
kk03	Pagarsih	collector	AC	7	1.5	2	3 5	commercial	9-10	1655
		collector	AC	7	1.5	2	3 5	commercial	10-11	1800
km01	Dipati Ukur	collector	AC	8.5	15	2	4.25	mixed	15-16	2148
		collector	AC	8.5	15	2	4.25	mixed	16-17	2403
km02	Gandapura	collector	AC	6.5	1.5	2	3.25	mixed	13-14	980
		collector	AC	6.5	1.5	2	3.25	mixed	14-15	901
km03	Burangrang	collector	AC	10	1.5	2	5	mixed	14-15	1894
		collector	AC	10	1.5	2	5	mixed	15-16	2028
kp01	Karawitan	collector	CS	5	0	2	2 5	residential	9-10	1236
		collector	CS	5	0	2	2.5	residential	10-11	1265
kp02	Reog	collector	AC	6.5	0	2	3.25	residential	14-15	455
		collector	AC	6.5	0	2	3.25	residential	15-16	470
kp03	Sriwijaya	collector	AC	7	0	2	3.5	residential	9-10	1049
		collector	AC	7	0	2	3.5	residential	10-11	1196
lk01	Purwakarta	local	AC	6.4	2	2	3.2	commercial	13-14	917
		local	AC	6.4	2	2	3.2	commercial	14-15	989
		local	AC	6.4	2	2	3.2	commercial	15-16	868
lk02	Kurdi	local	CS	8	0	2	4	commercial	8-9**	400
		local	CS	8	0	2	4	commercial	9-10**	470
lk03	Selontongan	local	CS	6	0	2	3	commercial	14-15	610
		local	CS	6	0	2	3	commercial	15-16	534
lk04	Suryani	local	CS	12	0	3	4	commercial	13-14	354
		local	CS	12	0	3	4	commercial	14-15	346
lm01	Jurang	local	AC	6.5	14	2	3 25	mixed	10-11	478
		local	AC	6.5	14	2	3 25	mixed	11-12	670
lm02	Palasari	local	CS	6 6	1	2	3 3	mixed	9-10	1003
		local	CS	6 6	1	2	3 3	mixed	10-11	998
lm03	Kinanti	local	CS	4	0	2	2	mixed	10-11	241
		local	CS	4	0	2	2	mixed	11-12	185
lm04	Logam	local	AC	5	0	2	2.5	mixed	9-10	517
		local	AC	5	0	2	2 5	mixed	10-11	449
lp01	Sejahtera	local	AC	5 4	5	2	2 7	residential	9-10	249
		local	AC	5 4	5	2	2 7	residential	10-11	207
lp02	Vandeventer	local	CS	6 7	1	2	3 35	residential	9-10	292
		local	CS	6 7	1	2	3 35	residential	10-11	401
lp03	Bahureksa	local	CS	7	0	2	3 5	residential	9-10	274
		local	CS	7	0	2	3 5	residential	10-11	316
lp04	Patrakomala	local	AC	6.4	2	2	3 2	residential	9-10	680
		local	AC	6.4	2	2	3 2	residential	10-11	646

Note

error = measured-predicted

Model Calibration

...ific Volume and Speed			Measured Noise		Predicted Noise Level							
%HV	%MC	Speed	L10-1hr	Leq	L10basic	cor1(S,p)	cor2(G)	cor3(d)	cor4(pav)	cor5(ref)	L10-pred.	residual
4%	25%	26	77.6	75.0	76.8	-2.6	4.5	0.7	-1.0	0.0	78.3	-0.7
3%	21%	27	77.6	76.0	76.7	-3.2	4.5	0.7	-1.0	0.0	77.6	0.0
2%	39%	22	76.0	73.4	76.8	-3.8	0.5	1.7	-1.0	2.5	76.8	-0.8
1%	38%	24	75.3	72.6	76.7	-4.1	0.5	1.7	-1.0	2.5	76.3	-1.0
1%	28%	24	77.2	74.5	76.1	-4.5	4.5	0.8	-1.0	0.0	75.8	1.4
1%	25%	46	76.9	74.3	77.2	-2.9	4.5	0.8	-1.0	0.0	78.6	-1.7
1%	24%	45	76.7	74.2	77.2	-3.0	4.5	0.8	-1.0	0.0	78.5	-1.8
3%	30%	34	71.9	69.1	74.6	-2.8	0.5	1.2	-1.0	1.0	73.5	-1.6
3%	34%	32	70.7	67.8	74.8	-2.9	0.5	1.2	-1.0	1.0	73.6	-2.9
1%	25%	40	77.6	74.4	74.2	-3.3	4.5	1.6	-1.0	2.5	78.6	-1.0
2%	27%	38	77.3	74.2	74.9	-3.2	4.5	1.6	-1.0	2.5	79.3	-2.0
2%	24%	40	76.6	73.6	75.6	-3.1	4.5	1.6	-1.0	1.0	78.7	-2.1
2%	25%	38	76.7	73.9	75.6	-3.1	4.5	1.6	-1.0	1.0	78.6	-1.9
1%	26%	25	75.4	72.1	74.0	-4.1	0.5	2.1	-1.0	3.5	74.9	0.5
1%	29%	19	74.8	72.2	74.1	-4.0	0.5	2.1	-1.0	3.5	75.1	-0.3
3%	29%	25	75.9	73.5	75.5	-3.1	0.5	0.9	-1.0	3.5	76.3	-0.4
3%	29%	25	75.5	73.0	76.0	-3.1	0.5	0.9	-1.0	3.5	76.7	-1.2
3%	29%	25	76.5	73.6	76.0	-3.1	0.5	0.9	-1.0	3.5	76.7	-0.2
1%	48%	28	75.4	72.3	74.4	-4.3	0.5	2.0	-1.0	2.5	74.1	1.3
1%	49%	29	74.5	71.6	74.8	-4.0	0.5	2.0	-1.0	2.5	74.7	-0.2
1%	28%	32	76.5	73.7	75.5	-4.0	4.5	1.6	-1.0	2.5	79.1	-2.6
1%	32%	34	76.8	74.0	76.0	-3.8	4.5	1.6	-1.0	2.5	79.8	-3.0
1%	41%	32	71.7	70.7	72.1	-4.4	0.5	2.1	-1.0	2.5	71.8	-0.1
1%	44%	32	71.2	68.9	71.7	-4.3	0.5	2.1	-1.0	2.5	71.5	-0.3
1%	25%	31	74.4	72.0	75.0	-4.0	0.5	1.3	-1.0	2.5	74.2	0.2
0%	25%	31	74.3	72.1	75.3	-4.4	0.5	1.3	-1.0	2.5	74.1	0.2
1%	30%	32	74.5	71.8	73.1	-3.8	0.0	2.5	3.0	2.5	77.3	-2.8
1%	31%	32	74.0	71.5	73.2	-4.0	0.0	2.5	3.0	2.5	77.2	-3.2
1%	29%	26	67.1	64.8	68.8	-4.6	0.0	2.1	-1.0	2.5	67.8	-0.7
1%	26%	30	68.3	65.7	68.9	-4.3	0.0	2.1	-1.0	2.5	68.3	0.0
2%	31%	32	70.2	67.4	72.4	-3.5	0.0	2.0	-1.0	2.5	72.4	-2.2
2%	34%	28	70.5	67.4	73.0	-3.7	0.0	2.0	-1.0	2.5	72.8	-2.3
1%	42%	37	72.5	70.6	71.8	-3.8	0.6	2.1	-1.0	3.5	73.3	-0.8
1%	42%	36	73.9	72.1	72.2	-3.9	0.6	2.1	-1.0	3.5	73.5	0.4
1%	43%	36	73.8	71.3	71.6	-4.0	0.6	2.1	-1.0	3.5	72.8	1.0
0%	48%	24	66.8	63.2	68.2	-4.9	0.0	1.7	-1.0	2.5	66.5	0.3
0%	47%	24	66.8	63.2	68.9	-4.8	0.0	1.7	-1.0	2.5	67.4	-0.6
0%	36%	24	69.1	65.9	70.1	-5.0	0.0	2.2	-1.0	2.5	68.8	0.3
0%	33%	25	69.0	65.8	69.5	-4.8	0.0	2.2	-1.0	2.5	68.4	0.6
1%	34%	31	68.7	67.5	67.7	-4.2	0.0	0.9	3.0	1.0	68.3	0.4
1%	34%	29	69.9	67.1	67.6	-4.1	0.0	0.9	3.0	1.0	68.3	1.6
3%	37%	27	71.8	68.7	69.0	-3.3	4.2	2.1	-1.0	2.5	73.5	-1.7
2%	28%	25	71.4	68.7	70.5	-3.5	4.2	2.1	-1.0	2.5	74.7	-3.3
0%	29%	31	72.3	70.4	72.2	-4.6	0.3	2.1	-1.0	2.5	71.5	0.8
0%	27%	31	71.8	68.9	72.2	-4.8	0.3	2.1	-1.0	2.5	71.3	0.5
0%	33%	28	66.4	63.4	66.0	-5.0	0.0	2.8	-1.0	2.5	65.3	1.1
1%	31%	28	66.6	64.1	64.9	-4.2	0.0	2.8	3.0	2.5	69.0	-2.4
1%	41%	30	74.1	71.0	69.3	-4.4	0.0	2.5	3.0	3.5	73.9	0.2
0%	45%	31	73.5	71.2	68.7	-4.6	0.0	2.5	3.0	3.5	73.1	0.4
1%	35%	24	66.8	64.0	66.2	-4.5	1.5	2.4	-1.0	1.0	65.6	1.2
0%	42%	26	65.8	64.0	65.4	-4.7	1.5	2.4	-1.0	1.0	64.6	1.2
0%	42%	28	55.1	64.2	66.9	-5.0	0.3	2.1	-1.0	1.0	64.2	0.9
0%	44%	29	66.5	64.3	68.2	-4.6	0.3	2.1	-1.0	1.0	66.0	0.5
1%	28%	35	65.8	61.7	66.6	-3.8	0.0	2.0	-1.0	1.0	64.8	1.0
0%	28%	36	67.8	64.8	67.2	-4.3	0.0	2.0	3.0	1.0	68.8	-1.0
0%	25%	32	69.4	65.5	70.5	-4.4	0.6	2.1	-1.0	2.5	70.4	-1.0
1%	29%	32	69.5	65.9	70.3	-4.3	0.6	2.1	-1.0	2.5	70.2	-0.7
		mean	72.3	69.6	72.1	-4.0	1.3	1.8	-0.4	2.1	72.9	-0.6
		st dev	3.3	3.9	3.6	0.6	1.8	0.6	1.4	1.0	4.4	1.3
		hi	77.6	76.0	77.2	-2.6	4.5	2.8	3.0	3.5	79.8	1.6
		lo	65.1	61.7	64.9	-5.0	0.0	0.7	-1.0	0.0	64.2	-3.3

D.3. Air Pollution Model Calibration:

Plot of the values is as depicted by Figure D.2. Results of regression between measured and predicted values are as presented in Table D.5. Measured and predicted air pollution concentration as suggested by GM model (Chock, 1978) are as presented in Table D.6.

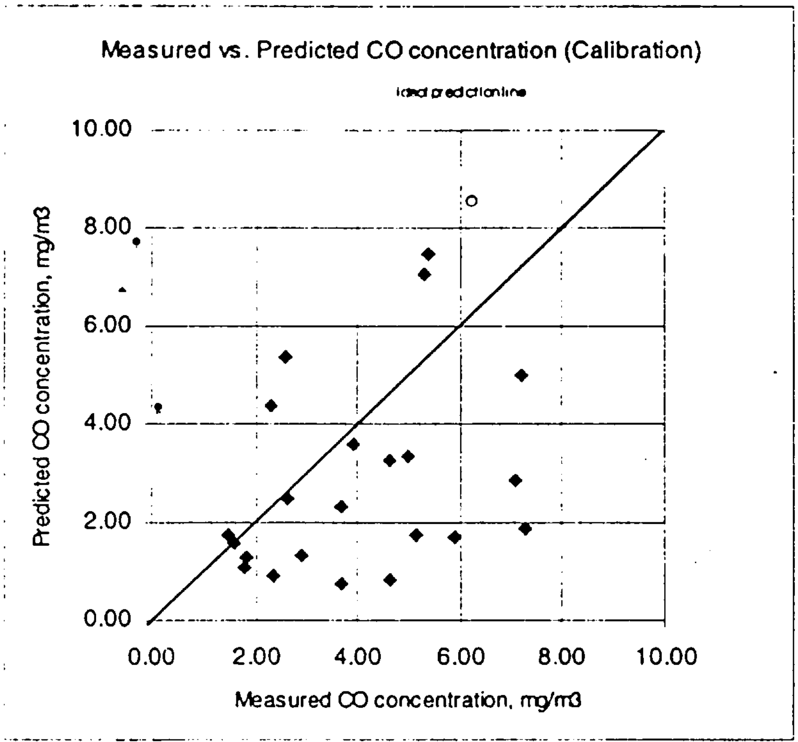

FIGURE D.2 PREDICTED VS. OBSERVED CO CONCENTRATION (CALIBRATION)

TABLE D.5 SUMMARY OF REGRESSION ANALYSIS OF CO CONCENTRATION (CALIBRATION)

Regression Statistics						
Multiple R	0.32					
R Square	0.10					
Adjusted R Square	0.06					
Standard Error	1.90					
Observations	22					
ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*	
Regression	1	8.365	8.365	2.318	0.144	
Residual	20	72.169	3.608			
Total	21	80.534				
Variables	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	1.463	0.975	1.500	0.149	-0.571	3.497
Predicted CO	0.337	0.222	1.523	0.144	-0.125	0.799

D.3. Air Pollution Model Calibration:

Plot of the values is as depicted by Figure D.2. Results of regression between measured and predicted values are as presented in Table D.5. Measured and predicted air pollution concentration as suggested by GM model (Chock, 1978) are as presented in Table D.6.

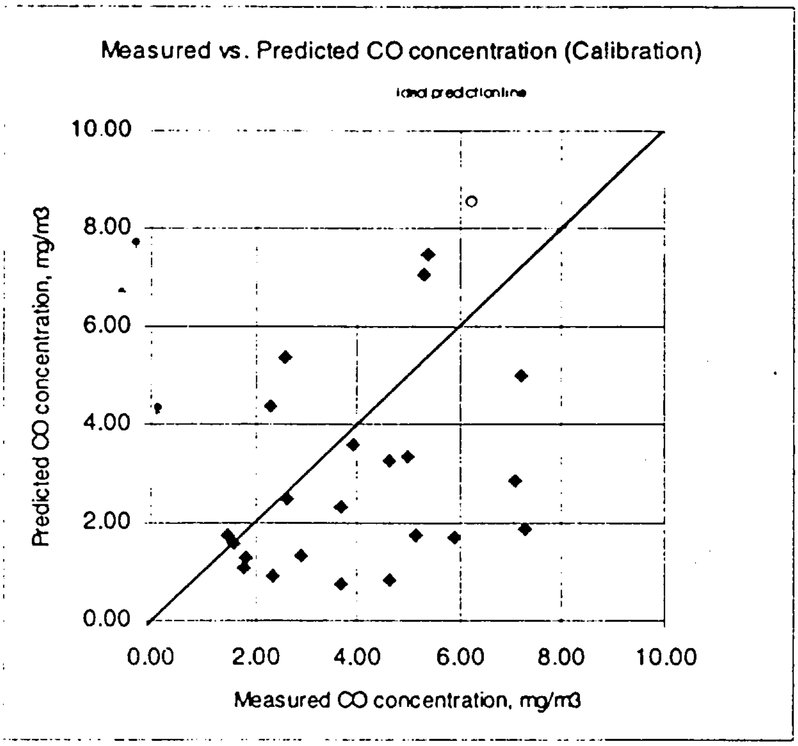

FIGURE D.2 PREDICTED VS. OBSERVED CO CONCENTRATION (CALIBRATION)

TABLE D.5 SUMMARY OF REGRESSION ANALYSIS OF CO CONCENTRATION (CALIBRATION)

Regression Statistics	
Multiple R	0.32
R Square	0.10
Adjusted R Square	0.06
Standard Error	1.90
Observations	22

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	1	8.365	8.365	2.318	0.144
Residual	20	72.169	3.608		
Total	21	80.534			

Variables	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	1.463	0.975	1.500	0.149	-0.571	3.497
Predicted CO	0.337	0.222	1.523	0.144	-0.125	0.799

TABLE D.6 MEASURED AND PREDICTED AIR POLLUTION

Table D.6 Prediction of Air Pollution Concentration

LinkName	Pavement	Width	Grad(%)	# lanes	Lane width	Vol	%HV	%MC	Speed	NOx	CO	
											ppm	g/m3
Setiabudi	AC	13	25	4	3.25	2853	4%	25%	26	0.111	4.041	4.618
Setiabudi	AC	13	25	4	3.25	2827	3%	21%	27	0.128	4.350	4.971
Suci	AC	8	1.7	2	4	1880	1%	38%	24	0.029	1.415	1.617
Suci	AC	8	1.7	2	4	2799	2%	39%	22	0.039	1.067	1.219
Ramdhan	AC	10.2	1.5	2	5.1	2722	3%	30%	34	0.074	3.228	3.689
Ramdhan	AC	10.2	1.5	2	5.1	1835	3%	34%	32	0.087	4.051	4.630
Sukajadi	AC	8.4	15	2	4.2	1587	1%	25%	40	0.014	3.431	3.921
Sukajadi	AC	8.4	15	2	4.2	1858	2%	27%	38	0.014	2.006	2.293
Cipaganti	AC	8.4	15	2	4.2	2193	2%	24%	40	0.249	6.300	7.200
Cipaganti	AC	8.4	15	2	4.2	2168	2%	25%	38	0.221	6.177	7.059
Dipati Ukur	AC	8.5	15	2	4.25	2148	1%	28%	32	0.124	4.646	5.310
Dipati Ukur	AC	8.5	15	2	4.25	2403	1%	32%	34	0.100	4.690	5.360
Gandapura	AC	6.5	1.5	2	3.25	980	1%	41%	32	0.047	2.296	2.624
Gandapura	AC	6.5	1.5	2	3.25	901	1%	44%	32	0.055	3.230	3.691
Burangrang	AC	10	1.5	2	5	1894	1%	25%	31	0.025	1.054	1.205
Burangrang	AC	10	1.5	2	5	2028	0%	25%	31	0.038	2.237	2.557
Reog	AC	6.5	0	2	3.25	455	1%	29%	26	0.044	1.268	1.449
Reog	AC	6.5	0	2	3.25	470	1%	26%	30	0.044	1.381	1.578
Purwakarta	AC	6.4	2	2	3.2	917	1%	42%	37	0.695	4.510	5.154
Purwakarta	AC	6.4	2	2	3.2	989	1%	42%	36	0.239	6.351	7.258
Purwakarta	AC	6.4	2	2	3.2	868	1%	43%	36	0.058	5.156	5.893
Selontongan	CS	6	0	2	3	610	0%	36%	24	0.023	1.558	1.781
Selontongan	CS	6	0	2	3	534	0%	33%	25	0.026	2.044	2.336
Suryani	CS	12	0	3	4	354	1%	34%	31	0.034	1.603	1.832
Suryani	CS	12	0	3	4	346	1%	34%	29	0.026	2.526	2.887
	mean	8.6	6.3	2.2	3.9	1544.8	0.01	0.32	31.5	0.102	3.225	3.685
	st.dev	2.2	8.2	0.6	0.7	862.7	0.01	0.07	5.2	0.141	1.716	1.961
	max	13.0	25.0	4.0	5.1	2853.0	0.04	0.44	40.0	0.695	6.351	7.258
	min	6.0	0.0	2.0	3.0	346.0	0.00	0.21	22.0	0.014	1.054	1.205

(Calibration)

HC	SPM	WindDir	winddir1	RoadDir	theta	WindSpd	WS1	Ua	volume	%HV	Speed	CO E Cars
3.630	95	5	101.25	7.0	94.25	3.00	2.51	2.51	2853.00	0.04	26.00	41.51
3.017	121	5	101.25	7.0	94.25	3.00	2.51	2.51	2827.00	0.03	27.00	40.20
2.503	46	5	101.25	90.0	11.25	8.00	6.70	1.31	2799.00	0.01	24.00	44.43
	59	4	78.75	90.0	11.25	4.00	3.35	0.65	2880.00	0.02	22.00	47.84
4.435	62	15	326.25	50.0	83.75	8.00	6.70	6.66	1722.00	0.03	34.00	33.04
4.078	68	15	326.25	50.0	83.75	8.00	6.70	6.66	1835.00	0.03	32.00	34.79
4.002		9	191.25	177.0	14.25	2.00	1.67	0.41	1587.00	0.01	40.00	28.78
3.181		9	191.25	177.0	14.25	2.00	1.67	0.41	1858.00	0.02	38.00	30.06
5.069	85	15	326.25	5.0	38.75	1.00	0.84	0.52	2193.00	0.02	40.00	28.78
4.061	95	14	303.75	5.0	61.25	2.00	1.67	1.47	2168.00	0.02	38.00	30.06
4.130	117	16	348.75	152.0	16.75	1.00	0.84	0.24	2148.00	0.01	32.00	34.79
3.384	101	16	348.75	152.0	16.75	1.00	0.84	0.24	2403.00	0.01	34.00	33.04
	59	15	326.25	14.0	47.75	1.00	0.84	0.62	980.00	0.01	32.00	34.79
2.534	120	15	326.25	14.0	47.75	1.00	0.84	0.62	901.00	0.01	32.00	34.79
2.777	53	11	236.25	10.0	46.25	1.00	0.84	0.60	1894.00	0.01	31.00	35.74
2.327	44	11	236.25	10.0	46.25	1.00	0.84	0.60	2028.00	0.00	31.00	35.74
2.651	83	10	213.75	12.5	21.25	1.00	0.84	0.30	455.00	0.01	26.00	41.51
2.319	79	10	213.75	12.5	21.25	1.00	0.84	0.30	470.00	0.01	30.00	36.75
5.070	70	16	348.75	140.0	28.75	2.00	1.67	0.81	917	0.01	37.00	30.75
5.069	76	16	348.75	140.0	28.75	2.00	1.67	0.81	989	0.01	36.00	31.48
5.052	64	16	348.75	140.0	28.75	2.00	1.67	0.81	868	0.01	36.00	31.48
3.144	37	5	101.25	20.0	81.25	2.00	1.67	1.66	610	0.00	24.00	44.43
2.672	37	5	101.25	20.0	81.25	2.00	1.67	1.66	534	0.00	25.00	42.91
5.070	76	16	348.75	166.5	2.25	0.00	0.00	0.00	354	0.01	31.00	35.74
1.975	69	16	348.75	166.5	2.25	0.00	0.00	0.00	346	0.01	29.00	37.83
3.572	74.6	11.6	249.8	73.1	41.0	2.4	2.0	1.3				
1.039	24.9	4.5	102.1	68.5	30.1	2.3	1.9	1.7				
5.070	121.0	16.0	348.8	177.0	94.3	8.0	6.7	6.7				
1.975	37.0	4.0	78.8	5.0	2.3	0.0	0.0	0.0				

Emission Rate g/km		Neutral									
		Effective	Sigma		Plume	CO predicted, mg/m3					Effective
HV	All	Wind	F(theta)	Sigma z	height, ho	g2	CO	measured	delta	k	Wind
76.49	122445 51	2 89	1.00	1.42	0.34	1.15	3.80	4 62	-0.81	0.82	2.74
74.08	116281 10	2 89	1.00	1.42	0.34	1.15	3.61	4 97	-1.36	0.73	2.74
81.88	125745 84	1 69	3.17	2.04	0.40	1.51	6.12	1 22	4.90	5.02	1.54
98.17	139717 19	1 03	3.17	2.04	0.53	1.50	11.02	1.62	9.41	6.82	0.88
60.90	58518.35	7 04	1.00	1.42	0.31	1.15	0.74	3.69	-2.94	0.20	6.89
64.12	65632.39	7 04	1.00	1.42	0.31	1.15	0.84	4.63	-3.79	0.18	6.89
53.04	46185.02	0 79	2.89	1.97	0.66	1.46	4.79	3 92	0.87	1.22	0.64
56.40	56669 19	0 79	2.89	1.97	0.66	1.46	5.88	2 29	3.59	2.57	0.64
53.04	64038.76	0 90	1.48	1.56	0.59	1.25	6.29	7.20	-0.91	0.87	0.75
56.40	66242.34	1 85	1.06	1.44	0.39	1.17	3.21	7.06	-3.84	0.46	1.70
64.12	75407.91	0.62	2.68	1.91	0.86	1.41	9.95	5.31	4.64	1.87	0.47
60.90	80186.14	0.62	2.68	1.91	0.85	1.41	10.58	5.36	5.22	1.97	0.47
64 12	34242.88	1.00	1.25	1.49	0.54	1.21	3.07	2.62	0.44	1.17	0.85
64.12	31494.30	1.00	1.25	1.49	0.54	1.21	2.82	3.69	-0.87	0.76	0.85
65.87	68361.56	0.98	1.28	1.50	0.55	1.21	6.21	1.20	5.00	5.15	0.83
65.87	72789.68	0.98	1.28	1.50	0.55	1.21	6.61	2.56	4.05	2.59	0.83
76.49	18991.05	0.68	2.35	1.81	0.77	1.38	2.34	1.45	0.89	1.62	0.53
67.73	17398.31	0.68	2.35	1.81	0.77	1.38	2.15	1.58	0.57	1.36	0.53
56.67	28381.89	1.19	1.90	1.68	0.48	1.33	2.10	5.15	-3.05	0.41	1.04
58.01	31343.55	1.19	1.90	1.68	0.48	1.33	2.32	7.26	-4.94	0.32	1.04
58.01	27455.17	1.19	1.90	1.68	0.48	1.33	2.03	5.89	-3.86	0.34	1.04
81.88	27139.88	2.04	1.00	1.42	0.38	1.15	1.20	1.78	-0.58	0.67	1.89
79.09	22988.95	2.04	1.00	1.42	0.38	1.15	1.01	2 34	-1.32	0.43	1.89
55.87	12743.69	0.38	4.17	2.33	1.76	1.37	2.18	1 83	0.35	1.19	0.23
69.71	13216.22	0 38	4.17	2.33	1.76	1.37	2.26	2.89	-0.62	0.78	0.23
									0.4	1.6	
									3.6	1.7	
									9.4	6.8	
									-4.9	0.2	

Stable											
Sigma (stable)		Plume	CO predicted, mg/m3		CO			Effective	Sigma (unstable)		Plume
F(theta)	Sigma z	height, ho	g2	pred. CO	measured	delta	k	Wind	F(theta)	Sigma z	height, ho
1.00	1.67	0.33	1.33	3.96	4.62	-0.66	0.86	3.14	1.00	1.40	0.34
1.00	1.67	0.33	1.33	3.76	4.97	-1.22	0.76	3.14	1.00	1.40	0.34
4.61	2.66	0.38	1.69	5.77	1.22	4.55	4.73	1.94	4.61	2.24	0.40
4.61	2.66	0.50	1.69	11.10	1.62	9.48	6.87	1.28	4.61	2.24	0.53
1.00	1.67	0.31	1.33	0.75	3.69	-2.94	0.20	7.29	1.00	1.40	0.31
1.00	1.67	0.31	1.33	0.84	4.63	-3.79	0.18	7.29	1.00	1.40	0.31
4.15	2.54	0.63	1.65	5.17	3.92	1.24	1.32	1.04	4.15	2.12	0.66
4.15	2.54	0.63	1.65	6.34	2.29	4.05	2.76	1.04	4.15	2.12	0.66
1.78	1.89	0.55	1.44	7.15	7.20	-0.05	0.99	1.15	1.78	1.57	0.59
1.10	1.70	0.37	1.34	3.43	7.06	-3.63	0.49	2.10	1.10	1.42	0.39
3.79	2.45	0.85	1.60	11.57	5.31	6.26	2.18	0.87	3.79	2.04	0.86
3.79	2.45	0.85	1.60	12.30	5.36	6.94	2.29	0.87	3.79	2.04	0.86
1.39	1.78	0.51	1.39	3.47	2.62	0.85	1.32	1.25	1.39	1.49	0.54
1.39	1.78	0.51	1.39	3.20	3.69	-0.50	0.87	1.25	1.39	1.49	0.54
1.44	1.80	0.52	1.39	7.04	1.20	5.83	5.84	1.23	1.44	1.50	0.55
1.44	1.80	0.52	1.39	7.49	2.56	4.94	2.93	1.23	1.44	1.50	0.55
3.23	2.29	0.75	1.57	2.69	1.45	1.24	1.86	0.93	3.23	1.91	0.77
3.23	2.29	0.75	1.57	2.47	1.58	0.89	1.56	0.93	3.23	1.91	0.77
2.47	2.09	0.45	1.53	2.22	5.15	-2.93	0.43	1.44	2.47	1.73	0.48
2.47	2.09	0.45	1.53	2.45	7.26	-4.81	0.34	1.44	2.47	1.73	0.48
2.47	2.09	0.45	1.53	2.15	5.89	-3.74	0.36	1.44	2.47	1.73	0.48
1.00	1.67	0.36	1.33	1.27	1.78	-0.51	0.71	2.29	1.00	1.40	0.38
1.00	1.67	0.36	1.33	1.08	2.34	-1.26	0.46	2.29	1.00	1.40	0.38
6.32	3.09	2.27	1.45	2.87	1.83	1.04	1.57	0.63	6.32	2.66	1.76
6.32	3.09	2.27	1.45	2.98	2.89	0.09	1.03	0.63	6.32	2.66	1.76
						0.9	1.7				
						-3.8	1.8				
						9.5	6.9				
						-4.8	0.2				

Unstable							
CO predicted, mg/m3		CO			Meteorological conditions		
g2	CO	measured	delta	k	Temp.	stability	WindSpd
1.13	3.50	4.62	1.12	0.76	27.00	unstable	3
1.13	3.32	4.97	1.65	0.67	25.00	unstable	3
1.58	5.09	1.22	-3.87	4.17	31.00	neutral	8
1.57	8.48	1.62	-6.86	5.24	31.00	unstable	4
1.13	0.72	3.69	2.97	0.19	33.00	neutral	8
1.13	0.81	4.63	3.82	0.17	31.00	neutral	8
1.52	3.52	3.92	0.41	0.90	30.00	unstable	2
1.52	4.31	2.29	-2.02	1.88	28.00	unstable	2
1.26	4.92	7.20	2.28	0.68	31.00	unstable	1
1.15	2.83	7.06	4.23	0.40	29.00	unstable	2
1.46	6.88	5.31	-1.57	1.30	30.00	unstable	1
1.46	7.32	5.36	-1.96	1.37	28.00	unstable	1
1.20	2.45	2.62	0.17	0.94	32.00	unstable	1
1.20	2.26	3.69	1.43	0.61	32.00	unstable	1
1.21	4.95	1.20	-3.75	4.11	30.00	unstable	1
1.21	5.27	2.56	-2.72	2.06	30.00	unstable	1
1.42	1.68	1.45	-0.23	1.16	31.00	unstable	1
1.42	1.54	1.58	0.04	0.98	30.00	unstable	1
1.36	1.72	5.15	3.43	0.33	34.00	unstable	2
1.36	1.90	7.26	5.36	0 26	33.00	unstable	2
1.36	1.67	5.89	4.23	0 28	31.00	unstable	2
1.13	1 06	1 78	0.72	0 60	31.00	unstable	2
1.13	0 90	2.34	1.43	0 39	30.00	unstable	2
1.47	1 24	1 83	0.60	0 67	31.00	unstable	0
1.47	1 28	2 89	1.61	0 44	30.00	unstable	0
			0.5	1.2	30.4		
			2.9	1.3	1.9		
			5.4	5.2	34.0		
			-6.9	+0.2	25.0		

D.4. Pedestrian Delay Model Calibration:

Plot of the values is as depicted by Figure D.3. Results of regression between measured and predicted values are as presented in Table D.7. Measured and predicted pedestrian delay as suggested by Austroads model (Austroads, 1994) are as presented in Table D.8.

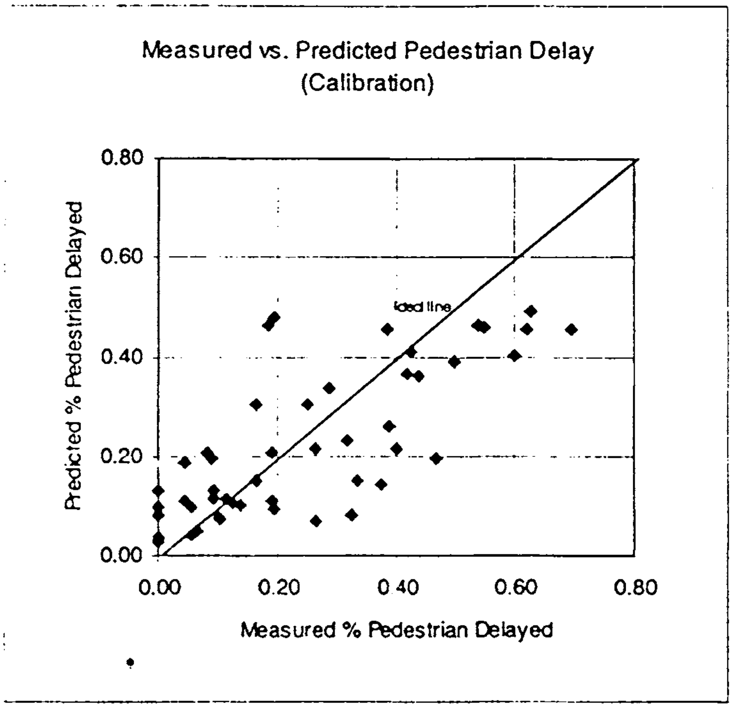

FIGURE D.3 PREDICTED VS. OBSERVED PEDESTRIAN DELAY (CALIBRATION)

TABLE D.7 SUMMARY OF REGRESSION ANALYSIS OF PEDESTRIAN DELAY (CALIBRATION)

Regression Statistics	
Multiple R	0.50
R Square	0.25
Adjusted R Square	0.23
Standard Error	0.70
Observations	52

ANOVA	*df*	*SS*	*MS*	F	*Significance F*
Regression	1	8.092	8.092	16.336	0.000
Residual	50	24.767	0.495		
Total	51	32.858			

Variables	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.748	0.124	6.039	0.000	0.499	0.997
Predicted delay	0.129	0.032	4.042	0.000	0.065	0.193

TABLE D.8 MEASURED AND PREDICTED NOISE LEVELS (CALIBRATION)

Table D.8 Prediction of Pedestr

Road geometry and Landuse						Traffic Volume		Pedestrian	
LinkName	direction	Width	Grad(%)	# lanes	Lane width	Time	Volume	Ave. Delay	%Delayed
Ramdhan	50	10.2	1.5	2	5.1	15-16	1722	6.89	0.56
Juanda	6.5	12.6	15	4	3	9-10**	2443	13.71	0.71
Juanda	6.5	12.6	15	4	3	10-11	3161	11.67	0.79
Juanda	6.5	12.6	15	4	3	11-12	3162	12.18	0.91
Burangrang	10	10	1.5	2	5	14-15	1894	0.02	0.02
Setiabudi	7	13	25	4	3.25	16-17	2853	5.04	0.54
Setiabudi	7	13	25	4	3.25	17-18	2827	0.86	0.18
Suci	90	8	1.7	2	4	9-10	1880	5.27	0.60
Suci	90	8	1.7	2	4	10-11	1799	3.54	0.50
Suci	50	10.2	1.5	2	5.1	16-17	1835	1.77	0.38
Sukajadi	177	8.4	15	2	4.2	15-16	1587	3.53	0.42
Sukajadi	177	8.4	15	2	4.2	16-17	1858	5.68	0.42
Cipaganti	5	8.4	15	2	4.2	14-15	2193	5.98	0.55
Cipaganti	5	8.4	15	2	4.2	15-16	2168	5.47	0.62
Geger Kalong	110	6.6	1.5	2	3.3	9-10	1514	1.62	0.16
Geger Kalong	110	6.6	1.5	2	3.3	10-11	1532	1.44	0.25
Pagarsih	93	7	1.5	2	3.5	9-10	1655	1.86	0.29
Pagarsih	93	7	1.5	2	3.5	10-11	1800	2.44	0.44
Dipati Ukur	152	8.5	15	2	4.25	15-16	2148	2.44	0.69
Dipati Ukur	152	8.5	15	2	4.25	16-17	2403	1.73	0.63
Gandapura	14	6.5	1.5	2	3.25	13-14	980	0.48	0.19
Gandapura	14	6.5	1.5	2	3.25	14-15	901	3.71	0.47
Gandapura	10	10	1.5	2	5	15-16	2028	2.12	0.19
Reog	12.5	6.5	0	2	3.25	14-15	455	0.78	0.12
Reog	12.5	6.5	0	2	3.25	15-16	470	1.00	0.19
Sriwijaya	0	7	0	2	3.5	9-10	1049	3.05	0.32
Sriwijaya	0	7	0	2	3.5	10-11	1196	3.17	0.39
Purwakarta	140	6.4	2	2	3.2	13-14	917	0.95	0.09
Purwakarta	140	6.4	2	2	3.2	14-15	989	1.05	0.08
Purwakarta	140	6.4	2	2	3.2	15-16	868	0.09	0.04
Kurdi	95	8	0	2	4	8-9**	400	0.50	0.09
Kurdi	95	8	0	2	4	9-10**	470	0.00	0.00
Selontongan	20	6	0	2	3	14-15	610	0.27	0.09
Selontongan	20	6	0	2	3	15-16	534	0.56	0.11
Suryani	166.5	12	0	3	4	13-14	354	0.20	0.14
Suryani	166.5	12	0	3	4	14-15	346	0.00	0.00
Jurang	25	6.5	14	2	3.25	10-11	478	0.09	0.04
Jurang	25	6.5	14	2	3.25	11-12	670	1.35	0.16
Palasari	10	6.6	1	2	3.3	9-10	1003	1.88	0.40
Palasari	10	6.6	1	2	3.3	10-11	998	1.53	0.26
Kinanti	15	4	0	2	2	10-11	241	0.00	0.00
Kinanti	15	4	0	2	2	11-12	185	0.00	0.00
Logam	17.5	5	0	2	2.5	9-10	517	1.19	0.19
Logam	17.5	5	0	2	2.5	10-11	449	2.95	0.32
Sejahtera	24	5.4	5	2	2.7	9-10	249	0.11	0.06
Sejahtera	24	5.4	5	2	2.7	10-11	207	0.05	0.05
Vandeventer	50	6.7	1	2	3.35	9-10	292	0.76	0.10
Vandeventer	50	6.7	1	2	3.35	10-11	401	0.37	0.05
Bahureksa	81	7	0	2	3.5	9-10	274	0.50	0.26
Bahureksa	81	7	0	2	3.5	10-11	316	0.00	0.00
Patrakomala	104	6.4	2	2	3.2	9-10	680	1.27	0.33
Patrakomala	104	6.4	2	2	3.2	10-11	646	1.63	0.38
								1.71	0.25
								1.69	0.20
								5.98	0.69
								0.00	0.00

rian Delay (Calibration)

Prediction								
veh/sec	tm	tc	theta	lambda	Pr	d	delta Pr	delta d
0.24	1.00	2.83	0.48	0.16	0.44	2.15	0.12	4.74
0.17	0.50	3.50	0.21	0.15	0.41	1.31	0.30	12.40
0.22	0.50	3.50	0.26	0.18	0.48	1.73	0.31	9.93
0.22	0.50	3.50	0.26	0.18	0.48	1.73	0.42	10.45
0.26	1.00	2.78	0.51	0.17	0.46	2.36	-0.43	-2.34
0.20	0.50	3.61	0.24	0.17	0.46	1.64	0.07	3.39
0.20	0.50	3.61	0.24	0.17	0.46	1.63	-0.28	-0.76
0.26	1.00	2.22	0.51	0.17	0.40	1.92	0.20	3.34
0.25	1.00	2.22	0.50	0.17	0.39	1.82	0.11	1.72
0.25	1.00	2.83	0.50	0.17	0.45	2.32	-0.07	-0.55
0.22	1.00	2.33	0.45	0.15	0.37	1.63	0.05	1.91
0.26	1.00	2.33	0.51	0.17	0.41	1.97	0.01	3.71
0.30	1.00	2.33	0.57	0.19	0.46	2.43	0.09	3.55
0.30	1.00	2.33	0.56	0.19	0.46	2.40	0.16	3.07
0.21	1.00	1.33	0.44	0.15	0.30	1.30	-0.14	0.32
0.21	1.00	1.83	0.44	0.15	0.31	1.32	-0.06	0.12
0.23	1.00	1.94	0.47	0.16	0.34	1.50	-0.05	0.36
0.25	1.00	1.94	0.50	0.17	0.36	1.66	0.08	0.78
0.30	1.00	2.36	0.56	0.19	0.46	2.39	0.24	0.05
0.33	1.00	2.36	0.60	0.20	0.49	2.78	0.13	-1.05
0.14	1.00	1.81	0.31	0.11	0.21	0.79	-0.02	-0.32
0.13	1.00	1.81	0.29	0.10	0.19	0.72	0.28	2.98
0.28	1.00	2.78	0.54	0.18	0.48	2.57	-0.29	-0.46
0.06	1.00	1.81	0.16	0.06	0.11	0.36	0.02	0.42
0.07	1.00	1.81	0.16	0.06	0.11	0.37	0.08	0.63
0.15	1.00	1.94	0.33	0.11	0.23	0.89	0.08	2.16
0.17	1.00	1.94	0.37	0.13	0.26	1.03	0.13	2.14
0.13	1.00	1.78	0.30	0.10	0.19	0.73	-0.11	0.22
0.14	1.00	1.78	0.31	0.11	0.21	0.79	-0.13	0.26
0.12	1.00	1.78	0.28	0.10	0.19	0.69	-0.14	-0.60
0.06	1.00	2.22	0.14	0.05	0.11	0.36	-0.02	0.14
0.07	1.00	2.22	0.16	0.06	0.13	0.43	-0.13	-0.43
0.08	1.00	1.67	0.21	0.07	0.13	0.46	-0.04	-0.19
0.07	1.00	1.67	0.18	0.07	0.11	0.40	0.00	0.15
0.03	0.67	3.33	0.06	0.03	0.10	0.24	0.04	-0.04
0.03	0.67	3.33	0.06	0.03	0.10	0.24	-0.10	-0.24
0.07	1.00	1.81	0.17	0.06	0.11	0.38	-0.07	-0.29
0.09	1.00	1.81	0.23	0.08	0.15	0.53	0.01	0.82
0.14	1.00	1.83	0.32	0.11	0.21	0.82	0.19	1.06
0.14	1.00	1.83	0.32	0.11	0.21	0.82	0.05	0.71
0.03	1.00	1.11	0.09	0.03	0.04	0.15	-0.04	-0.15
0.03	1.00	1.11	0.07	0.02	0.03	0.12	-0.03	-0.12
0.07	1.00	1.39	0.18	0.06	0.09	0.36	0.10	0.84
0.06	1.00	1.39	0.16	0.06	0.08	0.31	0.24	2.64
0.03	1.00	1.50	0.09	0.03	0.05	0.18	0.01	-0.07
0.03	1.00	1.50	0.08	0.03	0.04	0.15	0.01	-0.09
0.04	1.00	1.86	0.11	0.04	0.07	0.23	0.03	0.52
0.06	1.00	1.86	0.14	0.05	0.10	0.32	-0.04	0.05
0.04	1.00	1.94	0.10	0.04	0.07	0.22	0.19	0.28
0.04	1.00	1.94	0.11	0.04	0.08	0.26	-0.08	-0.26
0.09	1.00	1.78	0.23	0.08	0.15	0.53	0.18	0.73
0.09	1.00	1.78	0.22	0.08	0.14	0.51	0.23	1.12
				mean	0.23	0.97	0.03	0.74
				s d	0.15	0.79	0.13	1.27
				max	0.49	2.78	0.28	3.71
				min	0.03	0.12	-0.29	-1.05

D.5. Accident Rate Model Calibration:

Plot of the values is as depicted by Figure D.4. Results of regression between measured and predicted values are as presented in Table D.9. Recorded and predicted accident rates as suggested by Zeeger (1978) are as presented in Table D.10.

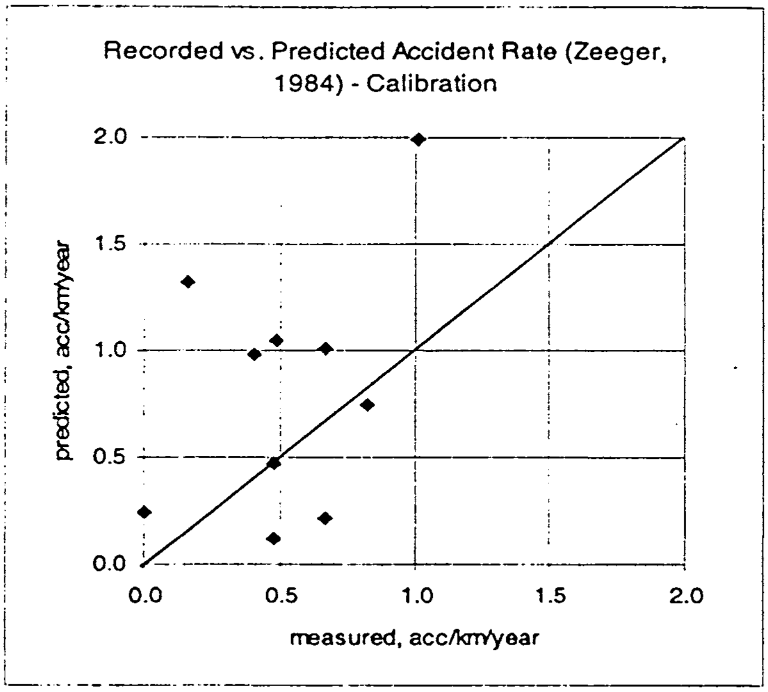

FIGURE D.4 PREDICTED VS. OBSERVED ACCIDENT RATE (CALIBRATION)

TABLE D.9 SUMMARY OF REGRESSION ANALYSIS OF ACCIDENT RATE (CALIBRATION)

Regression Statistics						
Multiple R	0.24					
R Square	0.06					
Adjusted R Square	-0.05					
Standard Error	0.92					
Observations	11					
ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*	
Regression	1	0.458	0.458	0.540	0.481	
Residual	9	7.639	0.849			
Total	10	8.097				
Variables	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.637	0.601	1.060	0.317	-0.723	1.998
Predicted accident rate	0.761	1.035	0.735	0.481	-1.581	3.102

TABLE D.10 RECORDED AND PREDICTED ACCIDENT RATE (CALIBRATION)

Table D.10 Measured and Predic

	Road geometry and Landuse					Traffic	Traffic	Paved	Unpaved
SiteNo	Width	Grad(%)	lanes	Lane width	Landuse	Volume	Speed	PA	UP
ak02	8	1.7	2	4	1	2.84	23	0	0
am01	12.6	15	4	3	1	2.922	38	0	2
am02	10.2	1.5	2	5.1	1	1.778	33	0	2
ap01	8.4	15	2	4.2	2	1.778	39	0	2
ap02	8.4	15	2	4.2	2	2.18	39	0	2
kk01	6.6	1.5	2	3.3	1	1.523	22	0	2
kk02	12	1.5	4	3	1	2.318	25	0	2
kk03	7	1.5	2	3.5	1	1.728	28.5	0	2
km01	8.5	15	2	4.25	1	2.276	33	0	2
km02	6.5	1.5	2	3.25	1	0.94	32	0	2
lm02	6.6	1	2	3.3	1	1	31	0	2

Note: length in km, width in metres; gradient in %, lane width in metres; landuse type 1=commercial, 2=residential; volume in 1000 veh/hour; speed in
PA=paved shoulder in m.; UP=unpaved shoulder in m; R= accident recovery area in m wide; TER1=type of terrain 1, 1=flat, 0 otherwise; TER2=
Fatal=accident involving fatality; HI=accident involving severed injury; SI=accident involving slight injury; DO=accident involving damage only; T

:ted Accident Rate

Recovery R	Terrain TER1	Terrain TER2	Link Length	Number of accidents between 1993-1995					Accident rate	
				Fatal	HI	SI	DO	Total	acc./yr	acc./yr./km
5	1	0	3.30	2	0	1	2	5	1.67	0.51
10	0	1	0.70	0	0	0	1	1	0.33	0.48
5	1	0	1.22	1	0	0	2	3	1.00	0.82
7	0	1	1.20	0	0	0	0	0	0.00	0.00
10	0	1	2.50	0	0	3	2	5	1.67	0.67
5	1	0	2.10	0	0	0	1	1	0.33	0.16
0	1	0	3.46	1	0	1	3	5	1.67	0.48
1	1	0	1.65	1	1	2	1	5	1.67	1.01
2	0	1	0.70	0	0	1	0	1	0.33	0.48
4	1	0	0.82	0	0	0	1	1	0.33	0.41
4	1	0	0.50	0	0	1	0	1	0.33	0.67
								mean	0.85	0.52
								st.dev	0.69	0.28
								max	1.67	1.01
								min	0.00	0.00

n kph;

=type terrain 2. 1=rolling, 0 otherwise;

'ctal=total accidents for all categories.

Accident Prediction Models					
Model1	error1	model2	error2	model3	error3
3.17	2.67	**0.31**	0.20	**1.34**	0.32
0.12	-0.35	**0.41**	0.07	**0.15**	0.18
0.74	-0.08	**0.47**	0.35	**0.54**	0.46
0.24	0.24	**0.12**	-0.12	**0.08**	-0.08
0.22	-0.45	**0.36**	0.31	**1.69**	-0.02
1.32	1.16	**0.33**	-0.17	**1.95**	-1.61
1.05	0.57	**0.83**	-0.35	**2.89**	-1.22
1.99	0.98	**0.42**	0.59	**0.49**	1.17
0.47	0.00	**0.43**	0.04	**1.73**	-1.40
0.98	0.57	**0.67**	-0.26	**0.65**	-0.32
1.01	0.35	**0.37**	0.30	**0.34**	-0.01
1.03	0.51	0.43	0.09	1.08	-0.23
0.90	0.88	0.19	0.29	0.90	0.85
3.17	2.67	0.83	0.59	2.89	1.17
0.12	-0.45	0.12	-0.35	0.08	-1.61

Attempt has been made to develop relationships between accident rate data and road and traffic parameters as suggested by Eqn. D.1.

$$A = k\,L\,T\,Q^{\alpha}\,S^{\beta}\,W^{\gamma}\,Lu^{\delta}\,Lw^{\varepsilon}\,G^{\phi} \qquad \text{D.1}$$

where:

A = number of accidents happened during time period T years, T.≥1;

T = time period years concerned;

L = length of the associated link;

Q = average daily traffic ≈ 9-10 times of average hourly traffic;

S = average travel speed, in km/h;

W = carriageway width, in metres;

Lu = type of landuse, 1=commercial, 2 = residential;

Lw = lane width, in metres;

G = road gradient, in %.

k, α, β, γ, δ, ε, and ϕ are constants to be determined.

From the coefficient of correlation values as shown in Table D.11 it can be observed that accident rate has positive correlation with road width W (0.50), ADT (0.36), and gradient G (0.50). Relationships with other parameters such as landuse Lu (-0.35), speed S (-0.22) and lane width Lw were negative. Correlation between parameters themselves shown that ADT had positive and high correlation with W (0.74), and S with either G (0.62) or Lu (0.86). The table also shows that accident rate had relatively low linear correlation with either G (0.14) or Lw (-0.14)

TABLE D.11 COEFFICIENT OF CORRELATION BETWEEN NOMINATED PARAMETERS

	Width	*Grad(%)*	*Landuse*	*ADT*	*Speed*	*Lane width*	*acc./yr./km*
Width	1						
Grad(%)	0.31	1					
Landuse	-0.12	0.41	1				
ADT	0.74	0.46	-0.31	1			
Speed	0.08	0.62	0.86	-0.05	1		
Lane width	-0.15	0.23	0.39	-0.01	0.34	1	
acc./yr./km	0.50	0.14	-0.35	0.36	-0.22	-0.14	1

In order to overcome the colinearity problem, it was then decided to use the following parameters in the model. ADT was combined with road width to become ADT/W and S was combined with landuse to become S/Lu. Whereas G and Lw were dropped from the model because the low correlation. The model then becomes as per Eqn. D.2

$$A/L/T = k\,(Q/W)^{\alpha}\,(S/Lu)^{\beta} \qquad \text{D.2}$$

The linear form of the model could then be obtained by transforming the equation into logarithmic scale, which then becomes:

$$\ln A = \ln k + \ln L + \ln T + \alpha \ln Q + \beta \ln S + \gamma \ln W + \delta \ln Lu + \varepsilon \ln Lw + \phi \ln G \qquad \text{D.3}$$

or:

$$\ln (A/L/T) = \ln k + \alpha \ln(Q/W) + \beta \ln(S/Lu) \qquad \text{D.4}$$

Multivariate regression analysis towards the available data came up with the results as summarized in Table D.12. The result suggests that the model give relatively poor explanation of the relationship between dependent variable and independent variables, which is reflected from the value of R-sq. The R-sq. value itself (0.29) was not significantly different from that of Zeeger model (0.24).

TABLE D.12 SUMMARY OF REGRESSION ANALYSIS OF ACCIDENT RATE (CALIBRATION)

Regression Statistics						
Multiple R	0.29					
R Square	0.08					
Adjusted R Square	-0.12					
Standard Error	0.84					
Observations	12					
ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*	
Regression	2	0.562	0.281	0.400	0.682	
Residual	9	6.329	0.703			
Total	11	6.891				
Variables	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
ln k	0.625	7.710	0.081	0.937	-16.816	18.067
ln(ADT/W)	-0.610	1.138	-0.536	0.605	-3.185	1.966
ln(S/Lu)	1.222	1.382	0.884	0.400	-1.905	4.348

On the other hand, the model shows very unusual relationship between ADT/W and accident rate which is negative (-0.610). This fact suggests that the more traffic it has the lower will be the accident rate which does not really make sense as ADT/W may represent the exposure. Therefore it was decided to adopt the Zeeger model in the present study, regardless of its low performance.

Appendix E

APPENDIX E:

TRAFFIC, ROAD, LAND-USE AND ENVIRONMENT DATA (VALIDATION)

E.1. Overall Database

Typical data recorded in overall database are as summarized in Table E.1. The complete set of validation purposes data is as presented in Table E.2.

TABLE E.1 TYPICAL DATA FIELDS (VALIDATION)

Data Category	Data Field	Unit or Options
Road ID:	Site Code	-
	LinkName	-
Road data:	RoadClass	1. Major - arterial or collector; 2. Local
	Pavement	1. Chip Seal; 2. PC Concrete; 3. Dense Graded AC; 4. Open Graded AC
	Direction	Road direction in degrees from North
	Width	Road width in metres
	Grad(%)	Road gradient in %
	# lanes	number of lanes
	Lane Width	Metres
Landuse Data:	LanduseType	1. Commercial; 2. Residential
Meteorological data:	WindDir	Wind direction in degrees from North
	WindSpd	Wind speed in ms^{-1}
	Temperature	°C
Traffic data:	Volume	v.p.h.
	%HV	Heavy vehicles in %
	%MC	Motor cycle in %
	Speed	km/h
Noise	L10-1hr Leq	D.1. dB(A) D.2. dB(A)
Air pollution	NOX CO HC	D.3. ppm; D.4. ppm; D.5. ppm
Pedestrian Delay	Ave. Delay %Delayed	D.6. Average pedestrian delay in seconds D.7. Percent pedestrian delayed
Accident	Acc/km/yr.	D.8. Accident rate, accidents/km/year
	Remarks	-

TABLE E.2 OVERALL DATABASE (VALIDATION SET)

Table E.2 Overall Datal

				Road geometry and Landuse					
SiteNo	LinkName	Road Class	Pavement	Direction	Width	Grad.	# lanes	Lane width	Landuse type
ac03	A. Yani	arterial	AC	65	12.8	4	4	3.2	commercial
ac03	A. Yani	arterial	AC	65	12.8	4	4	3.2	commercial
am03	Martadinata	arterial	AC	90	7.4	8	2	3.7	mixed
am03	Martadinata	arterial	AC	90	7.4	8	2	3.7	mixed
ar03	Gatot Subroto	arterial	AC	103	10	4	2	5	residential
ar03	Gatot Subroto	arterial	AC	103	10	4	2	5	residential
cc04	Margasari	collector	CS	110	5	4	2	2.5	commercial
cc04	Margasari	collector	CS	110	5	4	2	2.5	commercial
cm04	Tubagus Ismail	collector	CS	90	7	4	2	3.5	mixed
cm04	Tubagus Ismail	collector	CS	90	7	4	2	3.5	mixed
cr04	Banteng	collector	AC	105	6	2	2	3	residential
cr04	Banteng	collector	AC	105	6	2	2	3	residential
lc05	Sawah Kurung	local	CS	0	5	2	2	2.5	commercial
lc05	Sawah Kurung	local	CS	0	5	2	2	2.5	commercial
lm05	Imam Bonjol	local	CS	0	5	10	2	2.5	mixed
lm05	Imam Bonjol	local	CS	0	5	10	2	2.5	mixed
lr05	Halimun	local	CS	100	5	2	2	2.5	residential
lr05	Halimun	local	CS	100	5	2	2	2.5	residential
lr05	Halimun	local	CS	100	5	2	2	2.5	residential

ase (validation)

Survey	Meteorological Data			Traffic Volume and Speed				Noise		Air Pollution		
Time	WindDir	WindSpd	Temp	Manual	%HV	%MC	Speed	L10-1hr	Leq	NOx	CO	HC
9-10*	2	0 5	26	2283	1%	29%	24	72.7	70.1	0.063	3.243	4.304
10-11*	2	0 5	29	2295	1%	29%	24	73.1	71.0	0.027	2.327	4.304
13-14	4	2	32	1173	1%	29%	32	74.4	71.4	0.046	1.963	3.147
14-15	4	2	30	1769	1%	30%	30	74.4	71.4	0.080	3.441	2.897
15-16	8	1	32	2883	1%	36%	27	74.3	71.0	0.093	2.859	3.195
16-17	8	1	30	3081	1%	36%	26	74.3	71.9	0.120	4.169	3.091
14-15	9	1	34	1370	2%	32%	31	77.0	74.4	0.077	2.517	4.37
15-16	9	1	32	1481	2%	33%	29	77.9	74.5	0.080	3.097	3.413
13-14	2	2	30	1664	1%	33%	24	72.1	69.3	0.220	7.296	4.002
14-15	2	2	29	1234	2%	31%	27	72.1	70.1	0.134	4.359	3.158
13-14	1	2	34	1009	2%	24%	30	69.0	67.1	0.048	1.527	2.065
14-15	1	2	32	721	1%	25%	28	69.3	66.3	0.045	1.403	2.269
9-10**	1	0.4	28	516	3%	44%	26	71.4	68.3	0.046	1.765	3.857
10-11	1	0.4	27.5	634	2%	39%	26	71.1	67.8	0.059	1.264	3.326
9-10	5	0.58	21	188	0%	18%	32	64.2	61.6	0.055	2.242	1.677
10-11	5	0.33	23.5	218	0%	16%	32	63.3	58.4	0.040	1.702	2.18
11-12	8	0.5	24.5	231	0%	36%	23	63.3	58.4	0.025	1.650	3.354
12-13**	8	0.58	25	264	0%	33%	23	63.3	58.4	0.025	1.650	3.354
15-17***	8	0.58	26	264	0%	33%	23	62.9	61.0	0.025	1.650	3.354
	mean	1.07	28.7	1225	1.1%	30.7%	27.2	70.5	67.5	0.069	2.638	3.227
	st.dev	0.68	3.6	916	1.0%	6.7%	3.3	4.9	5.4	0.048	1.457	0.768
	hi	2.00	34.0	3081	3.1%	43.8%	32.0	77.9	74.5	0.220	7.296	4.370
	lo	0 33	21.0	188	0.0%	16.1%	23.0	62.9	58.4	0.025	1.264	1.677

Pedestrian		Accidents	remarks
Ave. Delay	%Delayed	acc./km/year	
6.71	0.58	3.33	
7.81	0.78	3.33	
3.90	0.67	0.00	
1.95	0.67	0.00	
4.28	0.63	0.39	
4.06	0.42	0.39	
0.22	0.06	0.06	
0.62	0.19	0.06	
1.45	0.79	0.00	
1.47	0.81	0.00	
1.24	0.48	0.00	
0.67	0.50	0.00	
3.71	0.29	0.98	
1.53	0.07	0.98	
0.03	0.02	0.00	
0.00	0.00	0.00	
0.88	0.50	0.39	
0.35	0.30	0.39	
0.35	0.30	0.39	traffic data damaged
2.17	0.42	0.56	
2.29	0.27	1.02	
7.81	0.81	3.33	
0.00	0.00	0.00	

E.2. Noise Model Validation:

Plot of the values is as depicted by Figure E.1. Results of regression between measured and predicted values are as presented in Table E.3. Measured and predicted noise levels as suggested by DoT model are as presented in Table E.4.

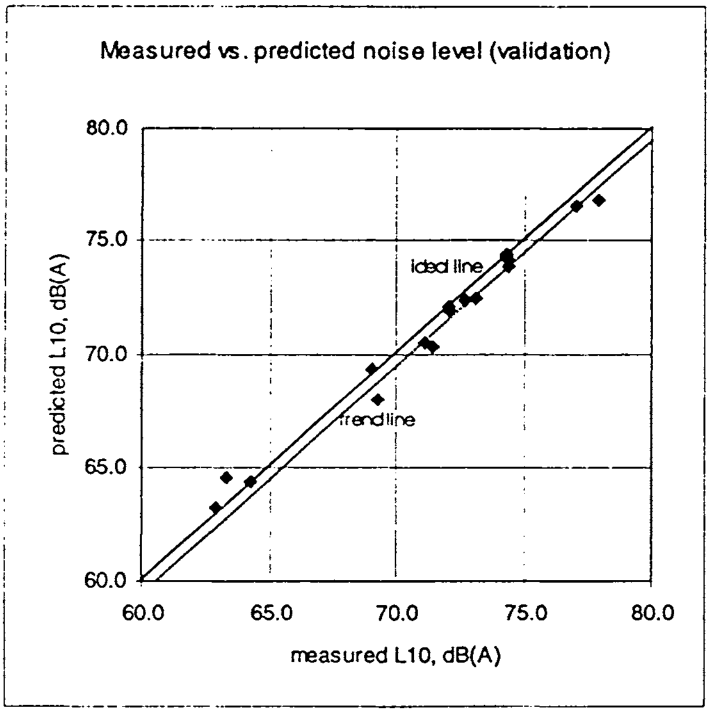

FIGURE E.1 PREDICTED VS. OBSERVED NOISE LEVELS (VALIDATION)

TABLE E.3 SUMMARY OF REGRESSION ANALYSIS OF NOISE LEVELS (VALIDATION)

Regression Statistics	
Multiple R	0.99
R Square	0.98
Adjusted R Square	0.98
Standard Error	0.52
Observations	17

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*	
Regression	1	265.722	265.722	966.356	0.000	
Residual	15	4.125	0.275			
Total	16	269.847				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	5.436	2.116	2.569	0.021	0.926	9.947
Predicted L_{10}	0.920	0.030	31.086	0.000	0.857	0.983

TABLE E.4 MEASURED AND PREDICTED NOISE LEVELS (VALIDATION)

Table E.4 Measured and Pr

				Road geometry and Landuse				Survey		
SiteNo	LinkName	Road Class	Pavement	Width	Grad.	# lanes	Lane width	Landuse type	Time	Manual
ak03	A Yani	arterial	AC	12.8	4	4	3.2	commercial	9-10*	2283
		arterial	AC	12.8	4	4	3.2	commercial	10-11*	2295
am03	Martadinata	arterial	AC	7.4	4	2	3.7	mixed	13-14	1573
		arterial	AC	7.4	4	2	3.7	mixed	14-15	1769
ap03	Gatot Subroto	arterial	AC	10	4	2	5	residential	15-16	2883
		arterial	AC	10	4	2	5	residential	16-17	3081
kk04	Margasan	collector	CS	7	4	2	3.5	commercial	14-15	1370
		collector	CS	7	4	2	3.5	commercial	15-16	1381
km04	Tubagus Ismail	collector	CS	7	4	2	3.5	mixed	13-14	1364
		collector	CS	7	4	2	3.5	mixed	14-15	1234
kp04	Banteng	collector	AC	6	2	2	3	residential	13-14	1009
		collector	AC	6	2	2	3	residential	14-15	721
lk05	Sawah Kurung	local	CS	5	2	2	2.5	commercial	9-10**	516
		local	CS	5	2	2	2.5	commercial	10-11	634
lm05	Imam Bonjol	local	CS	7	4	2	3.5	mixed	9-10	188
		local	CS	7	4	2	3.5	mixed	10-11	218
lp05	Halimun	local	CS	5	2	2	2.5	residential	11-12	231

Note

* manual counting missing

** automatic counting missing

residual L10 (measured - predicted) values edicted Noise Levels (validation)

Traffic Volume and Speed						Measured Noise		Predicted Noise Level				
%HV	%MC	ATC	%HV	%MC	Speed	L10-1hr	Leq	L10basic	cor1(S,p)	cor2(G)	cor3(d)	cor4(pav)
1%	29%	2039	18	25	24	72.7	70.1	75.8	-4.7	1.2	0.7	-1.0
1%	29%	2207	17	24	24	73.1	71.0	75.8	-4.7	1.2	0.7	-1.0
3%	29%	1463	5	20	40	74.4	71.4	74.2	-2.5	1.2	1.9	-1.0
2%	30%	1544	5	21	35	74.4	71.4	74.7	-3.3	1.2	1.9	-1.0
1%	36%	1978	9	19	27	74.3	71.0	76.8	-4.4	1.2	1.3	-1.0
1%	36%	2133	9	21	26	74.3	71.9	77.1	-4.6	1.2	1.3	-1.0
4%	32%	1223	7	23	40	77.0	74.4	73.6	-2.2	1.2	2.0	-1.0
5%	33%	1260	7	23	39	77.9	74.5	73.6	-1.9	1.2	2.0	-1.0
1%	33%	1363	5	15	24	72.1	69.3	73.5	-4.1	1.2	2.0	-1.0
2%	31%	1233	5	17	24	72.1	70.1	73.1	-3.8	1.2	2.0	-1.0
0%	24%	863	3	12	24	69.0	67.1	72.2	-5.2	0.6	2.2	-1.0
0%	25%	567	2	15	28	69.3	66.3	70.8	-5.0	0.6	2.2	-1.0
3%	44%	449	3	23	28	71.4	68.3	69.3	-3.1	0.6	2.5	-1.0
2%	39%	449	3	23	26	71.1	67.8	70.2	-3.7	0.6	2.5	-1.0
0%	18%	186	2	14	32	64.2	61.6	64.9	-4.7	1.2	2.0	-1.0
0%	16%	210	2	11	24	63.3	58.4	65.6	-5.1	1.2	2.0	-1.0
0%	36%	133	4	21	23	62.9	61.0	65.8	-5.2	0.6	2.5	-1.0
					mean	71.4	68.6	72.2	-4.0	1.0	1.9	-1.0
					st.dev	4.4	4.5	3.9	1.1	0.3	0.6	0.0
					hi	77.9	74.5	77.1	-1.9	1.2	2.5	-1.0
					lo	62.9	58.4	64.9	-5.2	0.6	0.7	-1.0

edicted Noise Levels (validation)

Traffic Volume and Speed						Measured Noise		Predicted Noise Level				
%HV	%MC	ATC	%HV	%MC	Speed	L10-1hr	Leq	L10basic	cor1(S,p)	cor2(G)	cor3(d)	cor4(pav)
1%	29%	2039	18	25	24	72.7	70.1	75.8	-4.7	1.2	0.7	-1.0
1%	29%	2207	17	24	24	73.1	71.0	75.8	-4.7	1.2	0.7	-1.0
3%	29%	1463	5	20	40	74.4	71.4	74.2	-2.5	1.2	1.9	-1.0
2%	30%	1544	5	21	35	74.4	71.4	74.7	-3.3	1.2	1.9	-1.0
1%	36%	1978	9	19	27	74.3	71.0	76.8	-4.4	1.2	1.3	-1.0
1%	36%	2133	9	21	26	74.3	71.9	77.1	-4.6	1.2	1.3	-1.0
4%	32%	1223	7	23	40	77.0	74.4	73.6	-2.2	1.2	2.0	-1.0
5%	33%	1260	7	23	39	77.9	74.5	73.6	-1.9	1.2	2.0	-1.0
1%	33%	1363	5	15	24	72.1	69.3	73.5	-4.1	1.2	2.0	-1.0
2%	31%	1233	5	17	24	72.1	70.1	73.1	-3.8	1.2	2.0	-1.0
0%	24%	863	3	12	24	69.0	67.1	72.2	-5.2	0.6	2.2	-1.0
0%	25%	567	2	15	28	69.3	66.3	70.8	-5.0	0.6	2.2	-1.0
3%	44%	449	3	23	28	71.4	68.3	69.3	-3.1	0.6	2.5	-1.0
2%	39%	449	3	23	26	71.1	67.8	70.2	-3.7	0.6	2.5	-1.0
0%	18%	186	2	14	32	64.2	61.6	64.9	-4.7	1.2	2.0	-1.0
0%	16%	210	2	11	24	63.3	58.4	65.6	-5.1	1.2	2.0	-1.0
0%	36%	133	4	21	23	62.9	61.0	65.8	-5.2	0.6	2.5	-1.0
					mean	71.4	68.6	72.2	-4.0	1.0	1.9	-1.0
					st.dev	4.4	4.5	3.9	1.1	0.3	0.6	0.0
					hi	77.9	74.5	77.1	-1.9	1.2	2.5	-1.0
					lo	62.9	58.4	64.9	-5.2	0.6	0.7	-1.0

cor5(ref)	L10-pred.	residual
1.0	72.4	0.3
1.0	72.4	0.7
1.0	74.1	0.3
1.0	73.8	0.6
1.0	74.3	0.0
1.0	74.4	-0.1
3.5	76.5	0.5
3.5	76.8	1.1
1.0	72.1	0.0
1.0	71.9	0.2
1.0	69.3	-0.3
1.0	68.0	1.3
2.5	70.3	1.1
2.5	70.5	0.6
2.5	64.3	-0.1
2.5	64.5	-1.2
1.0	63.2	-0.3
1.6	71.1	0.3
0.9	4.1	0.6
3.5	76.8	1.3
1.0	63.2	-1.2

E.3. Air Pollution Model Validation:

Plot of the values is as depicted by Figure E.2. Results of regression between measured and predicted values are as presented in Table E.5. Measured and predicted air pollution concentration as suggested by GM model (Chock, 1978) are as presented in Table E.6.

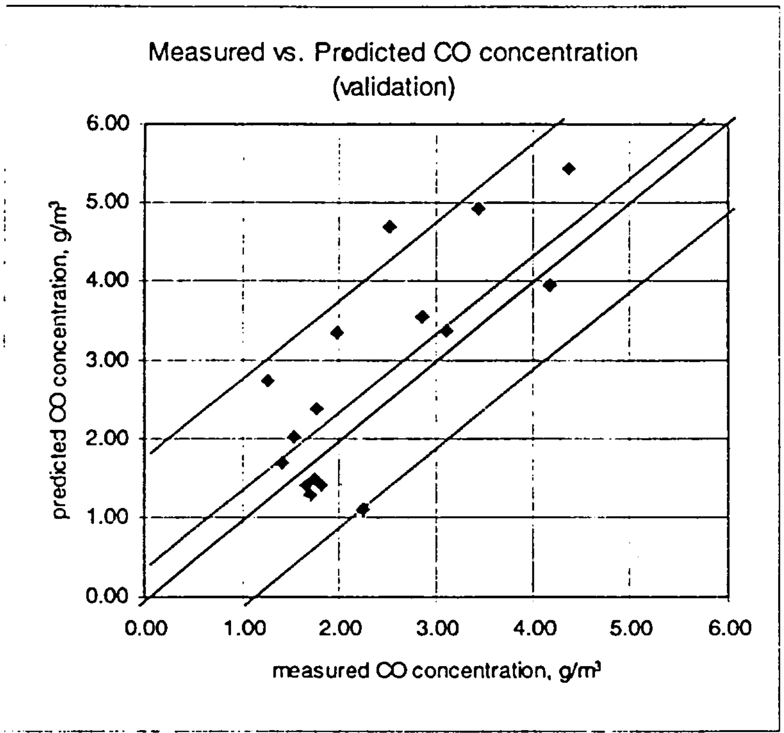

FIGURE E.2 PREDICTED VS. OBSERVED CO CONCENTRATION (VALIDATION)

TABLE E.5 SUMMARY OF REGRESSION ANALYSIS OF CO CONCENTRATION (VALIDATION)

Regression Statistics	
Multiple R	0.79
R Square	0.62
Adjusted R Square	0.59
Standard Error	0.91
Observations	16

ANOVA	*df*	*SS*	*MS*	F	*Significance F*
Regression	1	18.784	18.784	22.629	0.000
Residual	14	11.622	0.830		
Total	15	30.406			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.103	0.611	0.168	0.869	-1.207	1.412
Predicted CO	1.150	0.242	4.757	0.000	0.631	1.668

TABLE E.6 MEASURED AND PREDICTED CO CONCENTRATION (VALIDATION)

Table E.6 Measured and Predicted

							Air Pollution				
SiteNo	LinkName	Road Class		Manual	%HV	Speed	CO-ppm	CO-mg/m3	WindDir	winddir1	RoadDir
ak03	A. Yani	major	com	2283	1.00	24	3.243	3.707	2	33.75	65
	A. Yani	major	com	2295	1.00	24	2.327	2.659	2	33.75	65
am03	Martadinata	major	res	1173	0.51	32	1.963	2.243	4	78.75	90
	Martadinata	major	res	1769	1.02	30	3.441	3.933	4	78.75	90
ap03	Gatot Subroto	major	res	1370	2.48	31	2.859	3.267	8	168.75	110
	Gatot Subroto	major	res	1481	2.36	29	4.169	4.765	8	168.75	110
kk04	Margasan	major	com	1664	1.38	24	2.517	2.877	9	191.25	90
	Margasan	major	com	1234	1.78	27	3.097	3.539	9	191.25	90
km04	Tubagus Ismail	major	res	2883	0.90	27	7.296	8.338	2	33.75	103
km04	Tubagus Ismail	major	res	3061	0.65	26	4.359	4.982	2	33.75	103
kp04	Banteng	major	res	1009	1.68	30	1.527	1.745	1	11.25	105
	Banteng	major	res	721	1.39	28	1.403	1.603	1	11.25	105
lk05	Sawah Kurung	local	com	516	3.10	26	1.765	2.017	1	11.25	0
	Sawah Kurung	local	com	634	1.89	26	1.264	1.445	1	11.25	0
lm05	Imam Bonjol	local	res	188	1.00	32	2.242	2.562	5	101.25	0
	Imam Bonjol	local	res	218	1.00	32	1.702	1.945	5	101.25	0
lp05	Halimun	local	res	231	0.00	23	1.650	1.886	8	168.75	100
	Halimun	local	res	264	0.00	23	1.750	2.000	8	168.75	100
	Halimun	local	res	250	0.00	24	1.800	2.057	8	168.75	100
					mean	27.26	2.65	3.03	4.63	92.96	75.05
					stdev	3.19	1.45	1.65	3.13	70.44	41.70
					max	32.00	7.30	8.34	9.00	191.25	110.00
					min	23.00	1.26	1.44	1.00	11.25	0.00

ICO concentration (validation)

theta	WindSpd	WS1	Ua	volume	%HV	Speed	NOx Emission Rate g/km			Effective	Sig
							Cars	HV	All	Wind	F(theta)
31.25	0.5	0.5	0.26	2283	1.00	24	44.43	81.88	102279.32	0.64	1.78
31.25	0.5	0.5	0.26	2295	1.00	24	44.43	81.88	102842.06	0.64	1.78
11.25	2	1.67	0.33	1173	0.51	32	34.79	64.12	40987.08	0.71	3.17
11.25	2	1.67	0.33	1769	1.02	30	36.75	67.73	65575.51	0.71	3.17
58.75	1	0.84	0.72	1370	2.48	31	35.74	65.87	49993.35	1.10	1.09
58.75	1	0.84	0.72	1481	2.36	29	37.83	69.71	57140.08	1.10	1.09
101.25	1	0.84	0.82	1664	1.38	24	44.43	81.88	74793.24	1.20	1.00
101.25	1	0.84	0.82	1234	1.78	27	40.20	74.08	50349.10	1.20	1.00
69.25	2	1.67	1.57	2883	0.90	27	40.20	74.08	116770.27	1.95	1.02
69.25	2	1.67	1.57	3081	0.65	26	41.51	76.49	128585.55	1.95	1.02
93.75	2	1.67	1.67	1009	1.68	30	36.75	67.73	37611.47	2.05	1.00
93.75	2	1.67	1.67	721	1.39	28	38.97	71.82	28428.68	2.05	1.00
11.25	0.4	0.4	0.08	516	3.10	26	41.51	76.49	21977.86	0.46	3.17
11.25	0.4	0.4	0.08	634	1.89	26	41.51	76.49	26735.85	0.46	3.17
101.25	0.58	0.58	0.57	188	1.00	32	34.79	64.12	6596.05	0.95	1.00
101.25	0.33	0.33	0.32	218	1.00	32	34.79	64.12	7648.61	0.70	1.00
68.75	0.5	0.5	0.47	231	0.00	23	46.07	84.90	10641.46	0.85	1.02
68.75	0.58	0.58	0.54	264	0.00	23	46.07	84.90	12161.67	0.92	1.02
68.75	0.58	0.58	0.54	250	0.00	24	44.43	81.88	11107.55	0.92	1.02
61.17	1.07	0.94	0.70	1224.43	1.22	27.26	40.27	74.22	50117.09	1.08	1.55
33.85	0.68	0.54	0.53	917.13	0.85	3.19	3.97	7.32	38919.43	0.53	0.89
101.25	2.00	1.67	1.67	3081.00	3.10	32.00	46.07	84.90	128585.55	2.05	3.17
11.25	0.33	0.33	0.08	188.00	0.00	23.00	34.79	64.12	6596.05	0.46	1.00

Neutral							Stable					
ıa	Plume	CO predicted, mg/m3					Effective	Sigma (stable)		Plume	CO p	
Sigma z	height, ho	g2	predicted	measured	delta	k	Wind	F(theta)	Sigma z	height, ho	g2	predicted
1.65	0.83	1.29	13.86	3.707	10.15	3.74	0.49	2.27	2.03	0.82	1.47	16.72
1.65	0.83	1.29	13.94	2.659	11.28	5.24	0.49	2.27	2.03	0.82	1.47	16.81
2.04	0.75	1.48	4.66	2.243	2.41	2.08	0.56	4.61	2.66	0.72	1.66	5.10
2.04	0.75	1.48	7.45	3.933	3.52	1.89	0.56	4.61	2.66	0.72	1.66	8.16
1.45	0.51	1.17	4.10	3.267	0.83	1.25	0.95	1.13	1.71	0.48	1.35	4.62
1.45	0.51	1.17	4.68	4.765	-0.08	0.98	0.95	1.13	1.71	0.48	1.35	5.28
1.43	0.48	1.15	5.59	2.877	2.71	1.94	1.05	1.00	1.67	0.45	1.32	6.26
1.43	0.48	1.15	3.76	3.539	0.22	1.06	1.05	1.00	1.67	0.45	1.32	4.22
1.43	0.38	1.16	5.38	8.338	-2.96	0.65	1.80	1.03	1.67	0.37	1.33	5.73
1.43	0.38	1.16	5.93	4.982	0.94	1.19	1.80	1.03	1.67	0.37	1.33	6.31
1.42	0.38	1.15	1.64	1.745	-0.10	0.94	1.90	1.00	1.67	0.36	1.33	1.75
1.42	0.38	1.15	1.24	1.603	-0.36	0.78	1.90	1.00	1.67	0.36	1.33	1.32
2.04	1.30	1.39	3.61	2.017	1.59	1.79	0.31	4.61	2.66	1.45	1.54	4.58
2.04	1.30	1.39	4.39	1.445	2.94	3.04	0.31	4.61	2.66	1.45	1.54	5.57
1.43	0.57	1.16	0.63	2.562	-1.94	0.24	0.80	1.00	1.67	0.53	1.32	0.72
1.43	0.75	1.16	0.98	1.945	-0.97	0.50	0.55	1.00	1.67	0.72	1.31	1.20
1.43	0.63	1.16	1.13	1.886	-0.75	0.60	0.70	1.03	1.68	0.59	1.32	1.34
1.43	0.58	1.16	1.19	2.000	-0.81	0.59	0.77	1.03	1.68	0.55	1.32	1.38
1.43	0.58	1.16	1.08	2.057	-0.97	0.53	0.77	1.03	1.68	0.55	1.32	1.26
1.58	0.65	1.23	**4.49**	**3.03**	**1.46**	**1.53**	0.93	1.92	1.92	0.64	1.40	5.18
0.25	0.27	0.12	**3.88**	**1.65**	**3.68**	**1.28**	0.53	1.48	0.41	0.32	0.12	4.65
2.04	1.30	1.48	**13.94**	**8.34**	**11.28**	**5.24**	1.90	4.61	2.66	1.45	1.66	16.81
1.42	0.38	1.15	**0.63**	**1.44**	**-2.96**	**0.24**	0.31	1.00	1.67	0.36	1.31	0.72

...edicted, mg/m3			Unstable									
			Effective	Sigme (unstable)		Plume	NOx predicted, mg/m3					
measured	delta	k	Wind	F(theta)	Sigma z	height, ho	g2	predicted	measured	delta	Temp	Stability
3.707	13.02	4.51	1.12	2.27	1.69	0.83	1.31	7.86	3.707	-4.15	26	unstable
2.659	14.16	6.32	1.12	2.27	1.69	0.83	1.31	7.90	2.659	-5.24	29	unstable
2.243	2.86	2.27	1.19	4.61	2.24	0.75	1.55	2.65	2.243	-0.41	32	unstable
3.933	4.23	2.08	1.19	4.61	2.24	0.75	1.55	4.24	3.933	-0.31	30	unstable
3.267	1.36	1.41	1.58	1.13	1.43	0.51	1.16	2.85	3.267	0.42	32	unstable
4.765	0.52	1.11	1.58	1.13	1.43	0.51	1.16	3.26	4.765	1.51	30	unstable
2.877	3.39	2.18	1.68	1.00	1.40	0.48	1.14	4.00	2.877	-1.12	34	unstable
3.539	0.68	1.19	1.68	1.00	1.40	0.48	1.14	2.69	3.539	0.85	32	unstable
8.338	-2.61	0.69	2.43	[illegible].03	1.41	0.38	1.14	4.31	8.338	4.02	30	unstable
4.982	1.33	1.27	2.43	1.03	1.41	0.38	1.14	4.75	4.982	0.23	29	unstable
1.745	0.00	1.00	2.53	1.00	1.40	0.38	1.13	1.33	1.745	0.41	34	unstable
1.603	-0.28	0.82	2.53	1.00	1.40	0.38	1.13	1.01	1.603	0.60	32	unstable
2.017	2.56	2.27	0.94	4.61	2.24	1.30	1.45	1.69	2.017	0.33	28	unstable
1.445	4.13	3.86	0.94	4.61	2.24	1.30	1.45	2.05	1.445	-0.61	27.5	unstable
2.562	-1.84	0.28	1.43	1.00	1.40	0.57	1.14	0.42	2.562	2.15	21	unstable
1.945	-0.74	0.62	1.18	1.0[illegible]	1.40	0.75	1.14	0.58	1.945	1.36	23.5	unstable
1.886	-0.55	0.71	1.33	1.03	1.41	0.63	1.15	0.72	1.886	1.16	24.5	unstable
2.000	-0.62	0.69	1.40	1.03	1.41	0.58	1.15	0.78	2.000	1.22	25	unstable
2.057	-0.79	0.61	1.40	1.03	1.41	0.58	1.15	0.71	2.057	1.34	26	unstable
3.03	2.15	1.78	1.56	1.92	1.61	0.65	1.24	2.83	3.03	0.77		
1.65	4.47	1.57	0.53	1.48	0.34	0.27	0.15	2.26	1.65	1.19		
8.34	14.16	6.32	2.53	4.61	2.24	1.30	1.55	7.90	8.34	4.02		
1.44	-2.61	0.28	0.94	1.00	1.40	0.38	1.13	0.42	1.44	-1.12		

E.4. Pedestrian Delay Model Validation:

Plot of the values is as depicted by Figure E.3. Results of regression between measured and predicted values are as presented in Table E.7. Measured and predicted pedestrian delay as suggested by Austroads model (Austroads, 1994) are as presented in Table E.8.

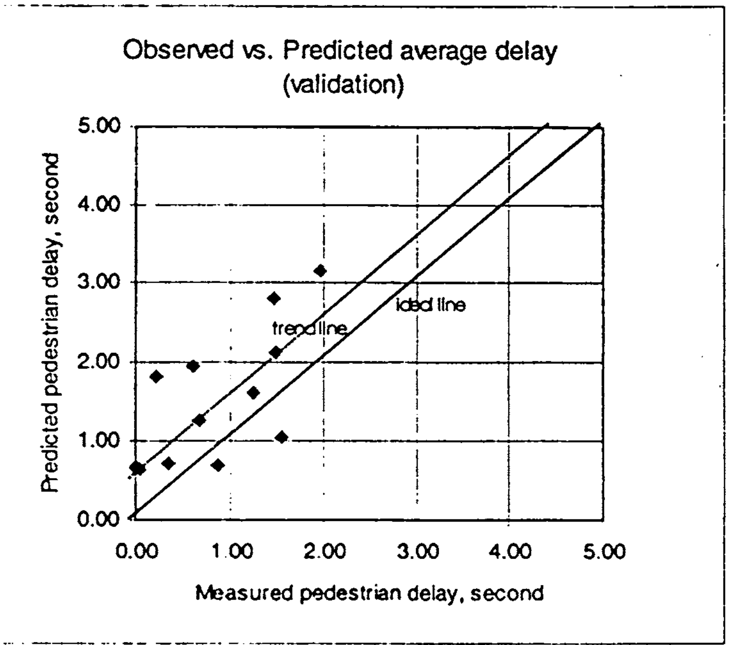

FIGURE E.3 PREDICTED VS. OBSERVED PEDESTRIAN DELAY (VALIDATION)

TABLE E.7 SUMMARY OF REGRESSION ANALYSIS OF PEDESTRIAN DELAY (VALIDATION)

Regression Statistics	
Multiple R	0.32
R Square	0.10
Adjusted R Square	0.05
Standard Error	1.98
Observations	19

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*	
Regression	1	7.693	7.693	1.953	0.180	
Residual	17	66.973	3.940			
Total	18	74.666				
Variables	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	1.660	0.636	2.610	0.018	0.318	3.001
Pedestrian Delay	0.286	0.205	1.397	0.180	-0.146	0.717

TABLE E.8 MEASURED AND PREDICTED PEDESTRIAN DELAY (VALIDATION)

Table E.8 Measured and

SiteNo	LinkName	Road Class	Type	Pavement	Road geometry and Landuse					
					Width	# lanes	Lane width	Manual	%HV	Speed
am03	Martadinata	arterial	residential	AC	7.4	2	3.7	1173	5	32
lk05	Sawah Kuning	local	commercial	CS	5	2	2.5	516	3	26
ap03	Gatot Subroto	arterial	residential	AC	10	2	5	2883	9	27
		arterial	residential	AC	10	2	5	3081	9	26
ak03	A. Yani	arterial	commercial	AC	12.8	4	3.2	2283	18	24
		arterial	commercial	AC	12.8	4	3.2	2295	17	24
		arterial	residential	AC	7.4	2	3.7	1769	5	30
kk04	Margasari	collector	commercial	CS	5	2	2.5	1370	7	31
		collector	commercial	CS	5	2	2.5	1481	7	29
km04	Tubagus Ismail	collector	residential	CS	7	2	3.5	1664	5	24
		collector	residential	CS	7	2	3.5	1234	5	27
kp04	Banteng	collector	residential	AC	6	2	3	1009	3	30
		collector	residential	AC	6	2	3	721	2	28
		local	commercial	CS	5	2	2.5	634	3	26
lm05	Imam Bonjol	local	residential	CS	5	2	2.5	188	2	32
		local	residential	CS	5	2	2.5	218	2	32
lp05	Halimun	local	residential	CS	5	2	2.5	231	4	23
		local	residential	CS	5	2	2.5	264	4	23
		local	residential	CS	5	2	2.5	264	4	23
										mean
										s.d.
										max
										min

Note: delta Pr = (measured - predicted) % delay
delta d = (measured - predicted) average delay

I Predicted Pedestrian Delay (validation)

Noise		Prediction						Predicted		Predicted		
Ave. Delay	%Delayed	veh/sec	tm	tc	theta	lambda	Pr	Pr1	d	d1	delta Pr	delta d
3.90	0.67	0.16	1.00	3.03	0.36	0.12	0.35	0.38	1.49	2.23	0.29	1.68
3.71	0.29	0.07	1.00	2.05	0.18	0.06	0.13	0.16	0.44	1.18	0.12	2.53
4.28	0.63	0.40	1.00	4.10	0.67	0.22	0.70	0.73	6.65	7.39	-0.10	-3.11
4.06	0.42	0.43	1.00	4.10	0.69	0.23	0.72	0.75	7.37	8.11	-0.33	-4.05
6.71	0.58	0.16	0.50	2.62	0.20	0.14	0.31	0.34	0.74	1.48	0.24	5.23
7.81	0.78	0.16	0.50	2.62	0.20	0.14	0.32	0.35	0.74	1.48	0.43	6.33
1.95	0.67	0.25	1.00	3.03	0.49	0.17	0.46	0.49	2.38	3.12	0.18	-1.17
0.22	0.06	0.19	1.00	2.05	0.41	0.14	0.30	0.33	1.24	1.98	-0.27	-1.77
0.62	0.19	0.21	1.00	2.05	0.43	0.15	0.32	0.35	1.36	2.10	-0.16	-1.49
1.45	0.79	0.23	1.00	2.87	0.47	0.16	0.43	0.46	2.09	2.83	0.33	-1.38
1.47	0.81	0.17	1.00	2.87	0.38	0.13	0.35	0.38	1.48	2.22	0.43	-0.75
1.24	0.48	0.14	1.00	2.46	0.32	0.11	0.27	0.30	1.03	1.77	0.18	-0.53
0.67	0.50	0.10	1.00	2.46	0.24	0.08	0.20	0.23	0.72	1.46	0.27	-0.79
1.53	0.07	0.09	1.00	2.05	0.22	0.08	0.16	0.19	0.54	1.28	-0.12	0.25
0.03	0.02	0.03	1.00	2.05	0.07	0.02	0.05	0.08	0.16	0.90	-0.06	-0.87
0.00	0.00	0.03	1.00	2.05	0.08	0.03	0.06	0.09	0.18	0.92	-0.09	-0.92
0.88	0.50	0.03	1.00	2.05	0.08	0.03	0.06	0.09	0.20	0.94	0.41	-0.06
0.35	0.30	0.04	1.00	2.05	0.10	0.03	0.07	0.10	0.22	0.96	0.20	-0.61
0.35	0.30	0.04	1.00	2.05	0.10	0.03	0.07	0.10	0.22	0.96	0.20	-0.61
0.83	0.36						0.22	0.25	0.91	1.65	0.11	-0.82
0.64	0.29						0.15	0.15	0.76	0.76	0.23	0.55
7.81	0.81						0.46	0.49	2.38	3.12	0.43	0.25
0.00	0.00						0.05	0.08	0.16	0.90	-0.27	-1.77

E.5. Accident Rate Model Validation:

Plot of the values is as depicted by Figure E.4. Results of regression between measured and predicted values are as presented in Table E.9. Measured and predicted accident rates as suggested by Zeeger (1978) are as presented in Table E.10.

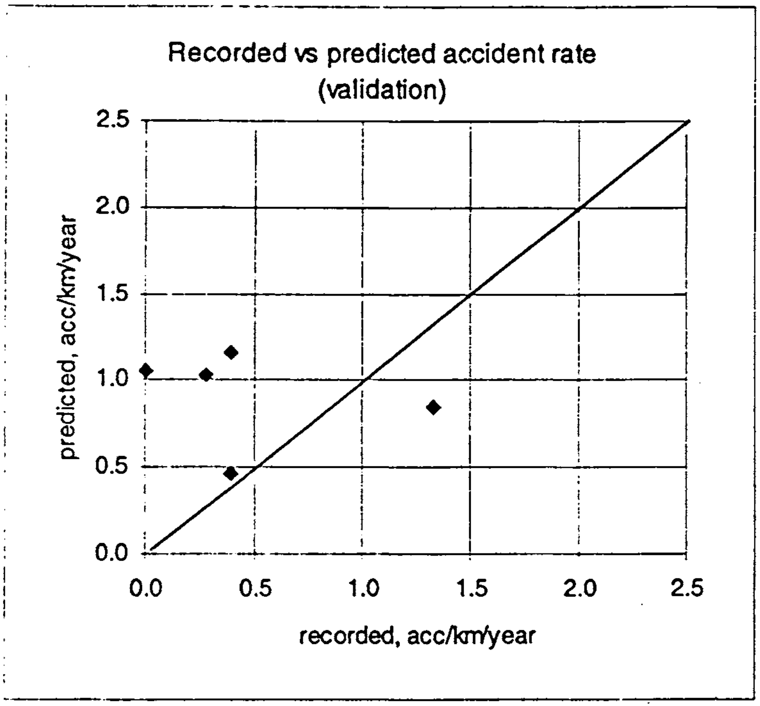

FIGURE E.4 PREDICTED VS. OBSERVED ACCIDENT RATE (VALIDATION)

TABLE E.9 SUMMARY OF REGRESSION ANALYSIS OF ACCIDENT RATE (VALIDATION)

Regression Statistics	
Multiple R	0.26
R Square	0.07
Adjusted R Square	-0.17
Standard Error	0.54
Observations	6

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.081	0.081	0.280	0.625
Residual	4	1.155	0.289		
Total	5	1.236			

Variables	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.945	0.350	2.702	0.054	-0.026	1.915
Predicted Acc.rate	0.257	0.485	0.529	0.625	-1.090	1.603

TABLE E.10 RECORDED AND PREDICTED ACCIDENT RATE (VALIDATION)

SiteNo	LinkName	Road Class	Pavement	Road geometry				Landuse	Traffic	
				Width	Grad.	# lanes	Lane width	type	Volume	Speed
lk05	Sawah Kurung	local	CS	5	2	2	2.5	1	0.575	26
ak03	A. Yani	arterial	AC	12.8	4	4	3.2	1	2	24
am03	Martadinata	arterial	AC	7.4	8	2	3.7	2	1.471	31
ap03	Gatot Subroto	arterial	AC	10	4	2	5	2	2.982	26.5
kk04	Margasari	collector	CS	5	4	2	2.5	1	1.426	30
lp05	Halimun	local	CS	5	2	2	2.5	2	0.248	23

Note: length in km, width in metres; gradient in %, lane width in metres; landuse type 1=commercial, 2=residential; volume in 1000 veh/hour; speed in kph;
PA=paved shoulder in m.; UP=unpaved shoulder in m; R= accident recovery area in m wide; TER1=type of terrain 1, 1=flat, 0 otherwise; TER2=type terrai
Fatal=accident involving fatality; HI=accident involving severed injury; SI=accident involving slight injury; DO=accident involving damage only; Total=total a

Table E.10 Validation of Accident Rate Model

Paved	Unpaved	Recovery	Terrain	Terrain	Link	Number of accidents between 1993-1995					Acci
PA	UP	R	TER1	TER2	Length	Fatal	HI	SI	DO	Total	acc./yr.
0	0.5	0	1	0	0.34	0	1	0	0	1	0.33
0	2	0	1	0	3	5	2	0	5	12	4.00
0	2	5	1	0	3.02	0	0	0	0	0	0.00
0	2	5	1	0	3.45	1	0	1	2	4	1.33
0	2	10	1	0	1.2	0	0	1	0	1	0.33
0	2	2	1	0	0.86	0	1	0	0	1	0.33
										average	1.20
										s.d	1.64

in 2, 1=rolling, 0 otherwise

accidents for all categories

dent rate	Prediction Models							
acc./yr./km	model1	error1	model2	error2	model3	error3	model4	error4
0.98	**1.97**	-0.99	**0.21**	0.77	**0.70**	-0.36	**1.75**	-0.77
1.33	**0.85**	0.49	**0.62**	0.71	**2.83**	1.17	**0.99**	0.34
0.00	**1.06**	-1.06	**0.22**	-0.22	**2.14**	-2.14	**0.48**	-0.48
0.39	**1.16**	-0.77	**0.90**	-0.51	**1.99**	-0.66	**0.17**	0.22
0.28	**1.03**	-0.75	**0.55**	-0.28	**1.12**	-0.79	**0.54**	-0.26
0.39	**0.47**	-0.08	**1.06**	-0.67	**1.49**	-1.16	**0.73**	-0.34
0.48	0.91	-0.43	0.67	-0.19	1.92	-0.72	0.58	-0.10
0.50	0.27	0.63	0.33	0.54	0.65	1.20	0.31	0.36

Appendix F

ent rate	Prediction Models							
acc./yr./km	model1	error1	model2	error2	model3	error3	model4	error4
0.98	**1.97**	-0.99	**0.21**	0.77	0.70	-0.36	**1.75**	-0.77
1.33	**0.85**	0.49	**0.62**	0.71	2.83	1.17	**0.99**	0.34
0.00	**1.06**	-1.06	**0.22**	-0.22	2.14	-2.14	**0.48**	-0.48
0.39	**1.16**	-0.77	**0.90**	-0.51	**1.99**	-0.66	**0.17**	0.22
0.28	**1.03**	-0.75	**0.55**	-0.28	**1.12**	-0.79	**0.54**	-0.26
0.39	**0.47**	-0.08	1.06	-0.67	**1.49**	-1.16	**0.73**	-0.34
0.48	0.91	-0.43	0.67	-0.19	1.92	-0.72	0.58	-0.10
0.50	0.27	0.63	0.33	0.54	0.65	1.20	0.31	0.36

Appendix F

APPENDIX F:

PREFERENTIAL DATA (CALIBRATION AND VALIDATION)

F.1. Overall Database

Typical data recorded in overall database are as summarized in Table F.1. Overall database for calibration data set is as in Table F.2. Validation data set is as documented in Table F.3.

TABLE F.1 TYPICAL DATA FIELDS

Data Category	Data Field	Notes
Site Information	Site Code	As mentioned in chapter 6
	Site Type	11 – arterial com 12 – arterial mix 13 – arterial residential 21 – collector com 22 – collector mix 23 – collector residential 31 – local com 32 – local mix 33 – local residential
Ranking Data	r_noise	Noise rank, 1-4
	r_airpol	Air pollution rank, 1-4
	r_pedes	Pedestrian delay rank, 1-4
	r_accid	Accident rank, 1-4
Rating Data	noise_max	Upper noise rate, 0-100
	noise_min	Lower noise rate, 0-100
	airpol_max	Upper air pollution rate, 0-100
	airpol_min	Lower air pollution rate, 0-100
	pedes_max	Upper pedestrian delay rate, 0-100
	pedes_min	Lower pedestrian delay rate, 0-100
	accid_max	Upper accident risk rate, 0-100
	accid_min	Lower accident risk rate, 0-100
Pairwise Comparison Data	no-ap	0. Noise is as annoying as air pollution 1. noise is more annoying than air pollution 2. air pollution is more annoying than noise
	no-ap_pref	Prefrerence scale, 1-9
	no-pd	0. Noise is as annoying as pedestrian delay 1. noise is more annoying than pedestrian delay 2. pedestrian delay is more annoying than noise
	no-pd_pref	Prefrerence scale, 1-9
	no-ac	0. noise is as annoying as accident risk 1. noise is more annoying than accident risk 2. accident risk is more annoying than noise

	no-ac_pref	Prefrerence scale, 1-9
	ap-pd	0. air pollution is as annoying as pedestrian delay 1. air pollution is more annoying than pedestrian delay 2. pedestrian delay is more annoying than air pollution
	ap-pd_pref	Prefrerence scale, 1-9
	ap-ac	0. air pollution is as annoying as accident risk 1. air pollution is more annoying than accident risk 2. accident risk is more annoying than air pollution
	ap-ac_pref	Prefrerence scale, 1-9
	pd-ac	0. pedestrian delay is as annoying as accident risk 1. pedestrian delay is more annoying than accident risk 2. accident risk is more annoying than pedestrian delay
	pd-ac_pref	Prefrerence scale, 1-9
Other	Comments	Comments from respondent

	no-ac_pref	Prefrerence scale, 1-9
	ap-pd	0. air pollution is as annoying as pedestrian delay 1. air pollution is more annoying than pedestrian delay 2. pedestrian delay is more annoying than air pollution
	ap-pd_pref	Prefrerence scale, 1-9
	ap-ac	0. air pollution is as annoying as accident risk 1. air pollution is more annoying than accident risk 2. accident risk is more annoying than air pollution
	ap-ac_pref	Prefrerence scale, 1-9
	pd-ac	0. pedestrian delay is as annoying as accident risk 1. pedestrian delay is more annoying than accident risk 2. accident risk is more annoying than pedestrian delay
	pd-ac_pref	Prefrerence scale, 1-9
Other	Comments	Comments from respondent

TABLE F.2 OVERALL PREFERENTIAL DATABASE (CALIBRATION SET)

Table F.2 Stated Preference Database (Calib

sitecode	site	site2	road	landuse	type	siteno	age	edu	sex	role	noise_max	noise_min	noise
aç01	11	mç	a	com	11	1	2	3	1	1	100	60	80
ac01	11	mç	a	com	11	2	2	2	2	4	100	90	95
ac02	11	mç	a	com	11	1	2	2	1	5	80	70	75
aç02	11	mç	a	com	11	1	3	3	1	5	70	60	65
ac02	11	mç	a	com	11	2	2	3	2	5	80	70	75
ac02	11	mç	a	com	11	3	2	3	1	5	80	60	70
aç02	11	mç	a	com	11	4	2	3	1	5	70	60	65
am01	12	mr	a	mix	12	2	2	1	1	5	40	20	30
am01	12	mr	a	mix	12	3	2	1	1	5	50	20	35
am01	12	mr	a	mix	12	4	2	3	1	5	50	20	35
am01	12	mr	a	mix	12	5	2	3	1	3	60	30	45
am02	12	mr	a	mix	12	1	2	1	2	5	80	40	60
am02	12	mr	a	mix	12	2	3	1	2	2	60	40	50
am02	12	mr	a	mix	12	3	3	1	1	5	70	50	60
am02	12	mr	a	mix	12	4	2	1	1	5	70	30	50
am02	12	mr	a	mix	12	5	2	1	1	5	60	20	40
ar01	13	mr	a	res	12	1	2	2	1	5	90	80	85
ar01	13	mr	a	res	12	2	2	2	1	5	80	60	70
ar01	13	mr	a	res	12	3	3	3	1	5	80	60	70
ar01	13	mr	a	res	12	4	2	2	1	5	70	50	60
ar01	13	mr	a	res	12	5	2	2	2	4	70	50	60
ar02	13	mr	a	res	12	1	2	2	2	5	90	70	80
ar02	13	mr	a	res	12	2	2	1	1	4	70	60	65
ar02	13	mr	a	res	12	3	2	1	1	5	80	60	70
ar02	13	mr	a	res	12	4	2	1	1	5	90	70	80
ar02	13	mr	a	res	12	5	3	1	1	5	80	60	70
ar02	13	mr	a	res	12	6	2	2	1	4	70	60	65
cc01	21	mc	c	com	11	2	3	1	1	1	80	60	70
cc01	21	mc	c	com	11	3	2	1	2	2	70	50	60
cc02	21	mc	c	com	11	1	3	1	1	1	80	60	70
cc02	21	mc	c	com	11	2	3	1	1	5	70	60	65
cc02	21	mc	c	com	11	3	2	3	1	5	60	20	40
cc02	21	mç	c	com	11	4	2	2	2	4	80	60	70
cc03	21	mc	c	com	11	1	2	1	2	2	70	40	55
cc03	21	mc	c	com	11	2	2	1	1	1	80	50	65
cc03	21	mc	c	com	11	3	3	1	1	1	70	50	60
cc03	21	mc	c	com	11	4	3	1	1	1	60	40	50
cm01	22	mr	c	mix	12	1	2	3	1	5	70	60	65
cm01	22	mr	c	mix	12	2	2	3	1	5	90	60	75
cm01	22	mr	c	mix	12	3	2	3	2	5	90	80	85
cm02	22	mr	c	mix	12	1	2	1	1	5	70	50	60
cm02	22	mr	c	mix	12	2	2	1	1	1	80	70	75
cm02	22	mr	c	mix	12	3	3	2	1	5	70	40	55
cm02	22	mr	c	mix	12	4	2	1	1	5	60	40	50
cm03	22	mr	c	mix	12	1	2	2	1	5	60	50	55
cm03	22	mr	c	mix	12	2	2	3	2	5	75	60	68
cm03	22	mr	c	mix	12	3	2	2	1	5	50	40	45
cm03	22	mr	c	mix	12	4	2	1	1	5	60	40	50
cr01	23	mr	c	res	12	1	2	1	1	5	70	30	50
cr01	23	mr	c	res	12	2	2	1	2	5	60	50	55
cr01	23	mr	c	res	12	3	3	1	1	5	70	30	50
cr01	23	mr	c	res	12	4	3	2	1	1	60	40	50
cr02	23	mr	c	res	12	1	3	1	1	5	40	20	30
cr02	23	mr	c	res	12	2	3	3	1	1	70	40	55
cr02	23	mr	c	res	12	3	2	1	1	3	60	20	40
cr02	23	mr	c	res	12	4	2	2	2	5	60	30	45
cr03	23	mr	c	res	12	1	2	2	2	5	60	40	50
cr03	23	mr	c	res	12	2	3	1	1	1	70	60	65
cr03	23	mr	c	res	12	3	2	1	1	5	80	70	75
lc01	31	lc	l	com	21	1	2	1	2	5	80	60	70
lc01	31	lc	l	com	21	2	2	1	1	5	70	40	55
lc01	31	lc	l	com	21	3	3	1	1	1	60	40	50
lc01	31	lc	l	com	21	4	2	1	1	5	70	40	55
lc01	31	lc	l	com	21	5	2	2	1	5	80	40	60
lc02	31	lc	l	com	21	1	3	1	2	2	70	40	55
lc02	31	lc	l	com	21	2	2	2	1	5	60	40	50
lc02	31	lc	l	com	21	3	2	2	1	5	40	20	30
lc02	31	lc	l	com	21	4	2	1	2	5	70	60	65
lc03	31	lc	l	com	21	1	2	1	1	5	70	50	60
lc03	31	lc	l	com	21	2	3	1	2	2	60	30	45
lc03	31	lc	l	com	21	3	2	2	1	4	70	50	60
lc03	31	lc	l	com	21	4	3	2	1	5	70	50	60

sitecode	site	site2	road	landuse	type	siteno	age	edu	sex	role	noise max	noise min	noise
lc04	31	lc	l	com	21	1	2	2	1	5	50	40	45
lc04	31	lc	l	com	21	2	2	1	2	5	70	50	60
lc04	31	lc	l	com	21	3	2	1	1	1	60	40	50
lc04	31	lc	l	com	21	4	3	2	1	1	70	60	65
lm01	32	lr	l	mix	22	1	2	1	1	1	60	40	50
lm01	32	lr	l	mix	22	2	2	1	1	5	80	70	75
lm01	32	lr	l	mix	22	3	3	1	1	1	80	60	70
lm01	32	lr	l	mix	22	4	2	2	2	4	80	60	70
lm01	32	lr	l	mix	22	5	2	1	1	4	80	40	60
lm01	32	lr	l	mix	22	6	3	2	1	4	60	50	55
lm02	32	lr	l	mix	22	1	3	3	1	5	40	10	25
lm02	32	lr	l	mix	22	2	3	3	1	5	50	40	45
lm02	32	lr	l	mix	22	3	2	3	1	1	80	20	50
lm03	32	lr	l	mix	22	2	3	3	1	5	70	40	55
lm03	32	lr	l	mix	22	3	2	1	1	5	60	20	40
lm03	32	lr	l	mix	22	4	2	3	1	5	60	50	55
lm04	32	lr	l	mix	22	1	3	2	2	2	80	60	70
lm04	32	lr	l	mix	22	2	3	1	2	1	60	50	55
lm04	32	lr	l	mix	22	4	2	3	1	1	70	50	60
lr01	33	lr	l	res	22	1	2	1	1	4	60	40	50
lr01	33	lr	l	res	22	2	2	2	2	5	60	50	55
lr01	33	lr	l	res	22	3	2	1	1	4	50	40	45
lr01	33	lr	l	res	22	4	2	1	1	4	60	40	50
lr02	33	lr	l	res	22	1	2	1	2	5	50	30	40
lr02	33	lr	l	res	22	2	2	2	2	5	70	50	60
lr02	33	lr	l	res	22	3	2	1	1	5	60	40	50
lr03	33	lr	l	res	22	1	2	3	1	5	80	60	70
lr03	33	lr	l	res	22	2	2	3	2	5	50	20	35
lr03	33	lr	l	res	22	3	2	3	2	5	50	30	40
lr04	33	lr	l	res	22	1	3	1	1	1	80	60	70
lr04	33	lr	l	res	22	2	3	2	1	5	70	60	65
lr04	33	lr	l	res	22	3	3	1	2	2	70	50	60

sitecode	site	site2	road	landuse	type	siteno	age	edu	sex	role	noise_max	noise_min	noise
lc04	31	lc	l	com	21	1	2	2	1	5	50	40	45
lc04	31	lc	l	com	21	2	2	1	2	5	70	50	60
lc04	31	lc	l	com	21	3	2	1	1	1	60	40	50
lc04	31	lc	l	com	21	4	3	2	1	1	70	60	65
lm01	32	lr	l	mix	22	1	2	1	1	1	60	40	50
lm01	32	lr	l	mix	22	2	2	1	1	5	80	70	75
lm01	32	lr	l	mix	22	3	3	1	1	1	80	60	70
lm01	32	lr	l	mix	22	4	2	2	2	4	80	60	70
lm01	32	lr	l	mix	22	5	2	1	1	4	80	40	60
lm01	32	lr	l	mix	22	6	3	2	1	4	60	50	55
lm02	32	lr	l	mix	22	1	3	3	1	5	40	10	25
lm02	32	lr	l	mix	22	2	3	3	1	5	50	40	45
lm02	32	lr	l	mix	22	3	2	3	1	1	80	20	50
lm03	32	lr	l	mix	22	2	3	3	1	5	70	40	55
lm03	32	lr	l	mix	22	3	2	1	1	5	60	20	40
lm03	32	lr	l	mix	22	4	2	3	1	5	60	50	55
lm04	32	lr	l	mix	22	1	3	2	2	2	80	60	70
lm04	32	lr	l	mix	22	2	3	1	2	1	60	50	55
lm04	32	lr	l	mix	22	4	2	3	1	1	70	50	60
lr01	33	lr	l	res	22	1	2	1	1	4	60	40	50
lr01	33	lr	l	res	22	2	2	2	2	5	60	50	55
lr01	33	lr	l	res	22	3	2	1	1	4	50	40	45
lr01	33	lr	l	res	22	4	2	1	1	4	60	40	50
lr02	33	lr	l	res	22	1	2	1	2	5	50	30	40
lr02	33	lr	l	res	22	2	2	2	2	5	70	50	60
lr02	33	lr	l	res	22	3	2	1	1	5	60	40	50
lr03	33	lr	l	res	22	1	2	3	1	5	80	60	70
lr03	33	lr	l	res	22	2	2	3	2	5	50	20	35
lr03	33	lr	l	res	22	3	2	3	2	5	50	30	40
lr04	33	lr	l	res	22	1	3	1	1	1	80	60	70
lr04	33	lr	l	res	22	2	3	2	1	5	70	60	65
lr04	33	lr	l	res	22	3	3	1	2	2	70	50	60

airpol_max	airpol_min	airpol	pedes_max	pedes_min	pedes	accid_max	accid_min	accid
50	30	40	30	20	25	30	10	20
60	40	50	30	20	25	30	20	25
50	40	45	30	10	20	10	5	8
60	50	55	50	30	40	30	10	20
70	50	60	40	30	35	30	20	25
60	40	50	50	40	45	20	10	15
60	50	55	60	40	50	30	20	25
70	50	60	40	30	35	20	10	15
60	30	45	70	40	55	20	10	15
70	60	65	40	20	30	20	10	15
40	10	25	10	0	5	10	0	5
40	30	35	70	60	65	20	10	15
80	50	65	60	0	30	50	0	25
50	50	50	20	10	15	40	10	25
30	10	20	10	0	5	10	0	5
40	30	35	40	30	35	20	20	20
60	20	40	50	30	40	60	20	40
30	20	25	40	20	30	70	40	55
40	20	30	60	50	55	40	10	25
50	40	45	30	20	25	20	10	15
50	40	45	20	10	15	20	10	15
40	30	35	30	20	25	20	10	15
60	50	55	30	20	25	30	10	20
30	20	25	20	10	15	20	10	15
50	30	40	20	0	10	50	50	50
10	0	5	10	0	5	10	0	5
30	20	25	50	30	40	50	40	45
70	40	55	30	10	20	20	0	10
80	50	65	50	40	45	40	20	30
60	40	50	60	40	50	30	20	25
40	20	30	60	40	50	20	10	15
40	30	35	40	30	35	20	10	15

TABLE F.3 OVERALL PREFERENTIAL DATABASE (VALIDATION SET)

Table F.3 Stated Preference Database (Validation

site code	site type	site_no	age	edu	sex	role	r_noise	r_airpol	r_pedes	r_accid	noise_max	noise_min
ac03	11	1	2	2	2	5	1	2	3	4	30	10
ac03	11	2	2	1	1	5	1	2	3	4	50	40
ac03	11	3	2	1			1	2	3	4	60	40
ac03	11	4	3	1	1	5	1	2	3	4	70	30
am03	12	1	2	2	1	5	1	2	4	3	70	50
am03	12	2	3	3	1	1	1	2	4	3	70	60
am03	12	3	2	1	1	5	3	4	2	1	30	20
am03	12	4	2	1	2	5	1	2	3	4	70	60
am03	12	5	3	2	1	5	4	3	2	1	20	10
am03	12	6	2	1	1	1	1	2	3	4	0	0
ar03	13	5	2	1	1	5	1	3	2	4	90	80
ar03	13	4	2	2	2	4	1	2	3	4	90	70
ar03	13	3	3	1	1	5	1	3	2	4	80	70
ar03	13	2	3	1	1	1	1	3	2	4	70	60
ar03	13	1	2	2	1	4	1	4	2	3	90	80
cc04	21	1	2	1	1	5	1	3	2	4	70	40
cc04	21	2	2	1	2	5	1	2	3	4	70	40
cc04	21	3	3	2	1	5	1	4	2	3	75	50
cc04	21	4	2	1	1	5	1	2	3	4	6	40
cm04	22	1	3	2	1	1	2	1	3	4	70	50
cm04	22	2	3	1	2	2	1	2	3	4	65	40
cm04	22	3	2	3	1	1	2	1	3	4	60	50
cm04	22	4	3	2	1	1	2	1	3	4	60	40
cm04	22	5	3	2	1	1	1	2	3	4	60	50
cr04	23	1	3	2	1	5	1	2	3	4	60	30
cr04	23	2	2	3	2	5	1	2	3	4	60	30
cr04	23	3	3	1	1	5	1	2	3	4	60	0
cr04	23	4	2	3	1	5	1	2	3	4	50	30
lc05	31	1	2	2	1	5	1	2	3	4	50	40
lc05	31	2	2	1	2	5	1	2	3	4	70	50
lc05	31	3	2	1	1	1	1	2	3	4	60	40
lc05	31	4	3	2	1	1	1	2	3	4	70	60
lc05	31	1	2	1	2	5	1	2	3	4	70	40
lc05	31	2	2	3	2	5	1	2	3	4	70	30
lc05	31	3	3	3	1	1	1	2	3	4	50	30
lc05	31	4	2	3	1	1	1	2	3	4	60	30
lm05	32	1	2	2	1	5	1	2	3	4	40	20
lm05	32	2	3	1	1	5	1	2	3	4	50	40
lm05	32	3	2	1	1	5	1	2	3	4	40	30
lm05	32	4	3	1	1	1	1	3	2	4	50	30
lr05	33	1	2	3	1	1	2	1	3	4	30	20
lr05	33	2	2	2	2	5	3	1	4	2	40	20
lr05	33	3	3	1	2	2	2	3	1	4	60	40

Set)

airpol_max	airpol_min	pedes_max	pedes_min	accid_max	accid_min	no-ap	no-ap_pref	no-pd	no-pd_pref	no-ac	no-ac_pref	ap-pd
40	30	50	30	30	10	2	5	2	5	2	4	2
60	30	30	20	30	20	2	3	1	3	1	6	1
80	50	60	30	40	20	2	2	1	3	1	5	1
80	40	40	10	20	10	2	2	1	3	1	3	1
60	50	40	30	50	40	1	3	1	3	1	3	1
70	60	20	10	40	30	1	2	1	3	1	5	1
20	10	70	60	50	40	1	2	2	3	2	4	2
40	30	60	50	40	30	1	4	1	3	1	4	2
30	10	40	20	80	50	0	2	2	2	2	6	2
0	0	0	0	0	0	0	0	0	0	0	0	0
50	30	60	40	30	20	1	5	1	4	1	5	2
80	60	60	40	50	40	1	2	1	3	1	4	1
50	30	70	60	30	20	1	4	1	3	1	4	1
40	20	50	40	30	20	1	4	1	2	1	4	2
30	20	70	60	50	40	1	5	1	3	1	4	2
40	30	50	30	30	10	1	3	1	4	1	5	2
60	40	50	40	30	20	1	3	1	3	1	4	1
30	10	60	40	50	40	1	6	1	3	1	3	2
60	30	40	20	30	20	1	2	1	3	1	4	1
75	65	40	30	30	20	2	2	1	5	1	5	1
30	20	30	10	20	10	1	4	1	3	1	5	1
70	60	20	10	10	0	1	2	1	3	1	4	1
60	50	30	20	30	15	2	2	1	3	1	4	1
50	30	30	20	20	10	1	3	1	3	1	4	1
60	30	60	50	40	30	1	3	2	3	1	7	1
50	30	70	30	20	10	2	5	2	3	1	7	2
80	50	90	40	80	40	2	2	2	5	2	5	2
20	10	80	50	30	20	0	0	2	3	2	2	2
50	30	30	20	30	10	1	2	1	3	1	5	1
60	40	30	20	30	20	1	2	1	3	1	6	1
50	40	30	10	10	5	1	3	1	4	1	5	1
60	50	50	30	30	10	1	3	1	3	1	3	1
50	30	40	20	30	20	1	3	1	7	1	7	1
70	30	60	50	50	10	1	3	1	5	1	7	1
50	20	75	50	10	0	1	3	2	5	1	5	2
40	30	20	10	40	30	1	3	1	3	1	3	1
30	20	30	10	10	5	1	2	1	2	1	3	1
30	20	20	10	10	0	1	3	1	4	1	4	1
30	20	20	10	10	0	1	2	1	3	1	4	1
30	20	30	25	20	10	1	3	1	2	1	3	2
40	30	10	10	10	10	2	3	1	5	1	3	1
60	50	30	10	40	10	2	3	1	3	1	3	1
50	40	70	40	40	30	1	3	2	2	1	3	2

ap-pd_pref	ap-ac	ap-ac_pref	pd-ac	pd-ac_pref	comments
2	2	5	2	5	need traffic light and zebra cross
2	1	5	0	3	need trees along the pedestrian path and more crossing
3	1	7	1	3	need parking space and regulate roadside traders
5	1	4	2	3	no comment
3	1	5	2	2	no comment
5	0	5	1	2	no comment
3	2	3	1	3	need zebra cross
5	1	2	1	5	campaigning towards angkot's drivers
2	2	3	1	3	need parking, trees and lighting
0	0	0	0	0	no comment
3	1	3	1	4	no comment
3	1	3	1	3	need road widening and road trees
3	1	2	1	3	need road widening and reduce traffic
2	1	3	1	3	need pedestrian pathway and zebra cross
3	2	3	1	3	need pedestrian pathway and reduce angkot
3	1	2	1	3	need pedestrian pathway, reduce angkot
3	1	3	1	3	need zebra cross, pedestrian pathway, drainage and reduce vibration
3	2	3	1	3	need pedestrian pathway and reduce heavy vehicles vibration
3	1	3	1	2	need pedestrian pathway, reduce vibration and angkot
4	1	6	1	2	no more traffic and no public transit
3	1	4	1	3	need zebra cross and pedestrian pathway in front of Muhammadiyah hospital
5	1	6	1	2	do not cut trees to reduce noise, improve road pavement to reduce dust
4	1	5	1	2	no one way traffic
3	1	3	1	2	need zebra cross and pedestrian pathway in front of Muhammadiyah hospital
5	1	7	1	3	no comment
4	1	7	1	7	need crossing bridge
6	2	5	1	2	need crossing bridge
7	2	2	1	4	no comment
3	1	4	1	2	no comment
4	1	5	1	3	no comment
3	1	3	1	3	need pedestrian pathway
4	1	3	1	2	no more new angkot and improve street lighting
5	1	7	1	5	parking
3	1	7	1	3	need road widening
3	1	7	1	5	limit speed
3	1	5	0	2	need road signs
2	1	3	1	2	need pedestrian pathway
2	1	3	1	2	no comment
2	1	3	1	2	no comment
2	1	2	1	3	no public transit (angkot)
4	1	3	1	2	need overlaying and road widening
4	1	5	1	2	need pedestrian pathway and garbage bins
3	1	3	1	3	vehicle vibration need attention

ap-pd_pref	ap-ac	ap-ac_pref	pd-ac	pd-ac_pref	comments
2	2	5	2	5	need traffic light and zebra cross
2	1	5	0	3	need trees along the pedestrian path and more crossing
3	1	7	1	3	need parking space and regulate roadside traders
5	1	4	2	3	no comment
3	1	5	2	2	no comment
5	0	5	1	2	no comment
3	2	3	1	3	need zebra cross
5	1	2	1	5	campaigning towards angkot's drivers
2	2	3	1	3	need parking, trees and lighting
0	0	0	0	0	no comment
3	1	3	1	4	no comment
3	1	3	1	3	need road widening and road trees
3	1	2	1	3	need road widening and reduce traffic
2	1	3	1	3	need pedestrian pathway and zebra cross
3	2	3	1	3	need pedestrian pathway and reduce angkot
3	1	2	1	3	need pedestrian pathway, reduce angkot
3	1	3	1	3	need zebra cross, pedestrian pathway, drainage and reduce vibration
3	2	3	1	3	need pedestrian pathway and reduce heavy vehicles vibration
3	1	3	1	2	need pedestrian pathway, reduce vibration and angkot
4	1	6	1	2	no more traffic and no public transit
3	1	4	1	3	need zebra cross and pedestrian pathway in front of Muhammadiyah hospital
5	1	6	1	2	do not cut trees to reduce noise, improve road pavement to reduce dust
4	1	5	1	2	no one way traffic
3	1	3	1	2	need zebra cross and pedestrian pathway in front of Muhammadiyah hospital
5	1	7	1	3	no comment
4	1	7	1	7	need crossing bridge
6	2	5	1	2	need crossing bridge
7	2	2	1	4	no comment
3	1	4	1	2	no comment
4	1	5	1	3	no comment
3	1	3	1	3	need pedestrian pathway
4	1	3	1	2	no more new angkot and improve street lighting
5	1	7	1	5	parking
3	1	7	1	3	need road widening
3	1	7	1	5	limit speed
3	1	5	0	2	need road signs
2	1	3	1	2	need pedestrian pathway
2	1	3	1	2	no comment
2	1	3	1	2	no comment
2	1	2	1	3	no public transit (angkot)
4	1	3	1	2	need overlaying and road widening
4	1	5	1	2	need pedestrian pathway and garbage bins
3	1	3	1	3	vehicle vibration need attention

TABLE F.4 EXPERTS DATA SET

Table F.4 Stated Preferential (I

No.	Cat.	r-noise	r-airpol	r-pedes	r-accid	r-other	no-ap	p1	no-pd	p2	no-ac	p3	ap-pd	p4	ap-ac	p5	pd-ac	p6
1	5	2	1	3	4	5	2	2	1	1	1	2	1	2	1	3	1	2
2	3	1	1	1	1	5	2	1	1	1	1	1	1	1	1	1	1	1
3	2	4	3	2	2	5	2	4	2	4	2	4	2	4	2	3	2	2
4	2	4	3	2	1	5	2	4	2	5	2	7	2	5	2	7	2	3
5	1	2	1	3	4	5	2	3	1	4	1	5	1	4	1	6	1	3
6	1	4	1	3	2	5	2	4	2	3	1	2	1	4	1	2	1	2
7	2	3	2	4	1	5	2	4	1	3	2	7	1	5	2	5	2	7
8	5	2	1	3	4	5	2	2	1	3	1	3	1	3	1	3	1	2
9	4	1	2	3	4	5	1	4	1	5	1	5	1	3	1	3	1	3
10	2	4	1	3	2	5	2	7	2	7	2	7	2	2	1	2	2	2
11	4	4	3	1	2	5	2	5	2	8	2	8	2	7	2	7	1	5
12	2	3	2	1	4	5	2	4	2	5	1	4	2	5	1	4	1	5
13	3	4	2	3	1	5	2	5	2	4	2	7	1	3	2	4	2	5
14	5	1	2	3	4	5	2	4	2	4	2	3	2	4	2	4	2	2
15	3	4	2	3	1	5	2	5	2	6	2	8	1	3	2	5	2	5
16	3	2	1	3	4	5	2	4	1	4	1	3	1	5	1	6	1	3
17	3	5	2	3	1	4	2	7	2	4	2	9	1	7	2	9	2	9
18	4	4	3	1	2	5	2	3	2	3	2	4	2	4	2	4	1	4
19	2	2	4	3	1	5	1	4	1	2	2	4	2	4	2	4	2	4
20	2	4	1	2	3	5	2	5	2	3	2	3	1	5	1	2	1	2
21	2	4	3	1	2	5	2	4	2	5	2	5	2	5	2	4	1	5
22	3	1	2	3	4	5	2	2	2	5	2	6	2	7	2	6	2	2
23	2	1	2	3	4	5	1	4	1	3	1	3	2	3	2	3	1	3
24	5	1	2	3	4	5	2	3	2	4	2	5	2	5	2	5	1	3
25	4	1	2	3	4	5	2	4	2	3	2	3	1	5	1	3	2	5
																	average	

Experts Data Set)

noise-max	noise-min	noise	airpol-max	airpol-min	airpol	pedes-max	pedes-min	pedes	accid-max	accid-min	accid
60	40	50	80	60	70	60	40	50	40	20	30
100	70	85	100	100	100	100	80	90	100	60	80
70	50	60	85	50	67.5	85	50	67.5	85	50	67.5
60	50	55	70	60	65	80	70	75	90	80	85
70	55	62.5	85	65	75	45	30	37.5	35	20	27.5
55	30	42.5	75	50	62.5	60	30	45	70	30	50
45	55	50	70	30	50	25	75	50	80	20	50
90	70	80	100	90	95	60	40	50	50	30	40
70	40	55	65	40	52.5	60	40	50	50	40	45
30	10	20	90	60	75	80	55	67.5	85	50	67.5
80	60	70	90	70	80	95	75	85	90	75	82.5
60	30	45	65	30	47.5	70	30	50	50	25	37.5
40	20	30	80	60	70	60	40	50	100	80	90
60	40	50	100	80	90	80	60	70	80	60	70
40	10	25	80	40	60	50	30	40	90	70	80
70	20	45	80	30	55	60	10	35	55	10	32.5
50	40	45	70	60	65	60	50	55	90	80	85
55	0	27.5	60	0	30	55	0	27.5	0	40	20
80	60	70	70	60	65	80	60	70	80	60	70
60	35	47.5	90	50	70	75	40	57.5	70	40	55
50	25	37.5	60	30	45	75	50	62.5	70	45	57.5
40	20	30	60	40	50	80	50	65	90	60	75
70	30	50	50	30	40	70	40	55	60	40	50
50	45	47.5	60	50	55	70	60	65	75	65	70
70	40	55	100	70	85	70	40	55	100	70	85
61	37.8	49.40	77.4	52.2	64.80	68.2	45.8	57.00	71.4	48.8	60.10

F.2. Rating Method

Summary results of rating method are as presented in Tables F.5, F.6 and F.7. Validation results are as presented in Tables F.8 and F.9.

TABLE F.5 SUMMARY STATISTICS OF RATING VALUES (CALIBRATION)

Combination of		noise		air pol		pedest		accident	
Categories	N	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Arterial-Commercial	7	75.00	10.41	58.21	14.34	60.00	15.75	46.07	15.27
Arterial-Mix	9	45.00	10.90	40.28	17.61	35.00	10.00	31.11	20.73
Arterial-Residential	11	70.45	8.20	46.36	13.62	50.45	9.86	25.91	8.31
Collector-Commercial	10	60.50	9.85	53.00	13.37	49.50	10.66	37.00	19.03
Collector-Mix	11	62.05	12.59	46.82	17.65	42.27	14.89	34.09	12.21
Collector-Residential	11	51.36	11.85	41.82	6.81	30.00	16.28	26.82	12.10
Local-Commercial	17	55.00	9.52	47.94	9.20	35.00	11.99	25.15	8.12
Local-Mix	15	55.67	13.07	44.00	15.26	35.33	17.57	21.67	12.77
Local-Residential	13	53.08	11.46	39.23	15.92	27.69	15.09	21.15	13.25
Arterials	27	63.15	16.18	47.41	16.24	47.78	15.01	32.87	16.77
Collectors	32	57.89	12.17	47.03	13.73	40.31	16.01	32.50	14.81
Locals	45	54.67	11.15	44.11	13.66	33.00	14.98	22.83	11.28
Commercial	34	60.74	12.26	51.54	12.00	44.41	15.84	32.94	15.68
Mix	35	54.93	13.70	43.93	16.33	37.43	15.07	28.00	15.63
Residential	35	58.00	13.46	42.29	12.91	35.57	17.10	24.43	11.49
Major-Commercial	17.00	66.47	12.22	55.15	13.59	53.82	13.61	40.74	17.67
Major-Residential	42.00	57.80	14.40	43.99	14.18	39.64	15.00	29.40	13.58
Local-Commercial	17.00	55.00	9.52	47.94	9.20	35.00	11.99	25.15	8.12
Local-Residential	28.00	54.46	12.20	41.79	15.47	31.79	16.62	21.43	12.76
All community	104	57.86	13.25	45.87	14.33	39.09	16.32	28.41	14.67
Experts	25	49.40	16.30	64.80	17.14	57.00	14.98	60.10	20.91

TABLE F.6 WEIGHTS OF ENVIRONMENTAL FACTORS (RATING METHOD – CALIBRATION)

Combination of	normalised			
Categories	noise	airpol	pedest	accid.
Arterial-Commercial	0.31	0.24	0.25	0.19
Arterial-Mix	0.30	0.27	0.23	0.21
Arterial-Residential	0.36	0.24	0.26	0.13
Collector-Commercial	0.30	0.27	0.25	0.19
Collector-Mix	0.33	0.25	0.23	0.18
Collector-Residential	0.34	0.28	0.20	0.18
Local-Commercial	0.34	0.29	0.21	0.15
Local-Mix	0.36	0.28	0.23	0.14
Local-Residential	0.38	0.28	0.20	0.15
Arterials	0.33	0.25	0.25	0.17
Collectors	0.33	0.26	0.23	0.18
Locals	0.35	0.29	0.21	0.15
Commercial	0.32	0.27	0.23	0.17
Mix	0.33	0.27	0.23	0.17
Residential	0.36	0.26	0.22	0.15
Major-Commercial	0.31	0.26	0.25	0.19
Major-Residential	0.34	0.26	0.23	0.17
Local-Commercial	0.34	0.29	0.21	0.15
Local-Residential	0.36	0.28	0.21	0.14
All community	0.34	0.27	0.23	0.17
Experts	0.21	0.28	0.25	0.26

TABLE F.7 STUDENT T TESTS BETWEEN PAIR OF CATEGORIES (RATING METHOD – CALIBRATION)

	Student-t					
Pair of categories	Noise	Airpol	Pedest	Accid	d.o.f	t-0.975
Arterial – Collector	1.40	0.09	1.80	0.09	57.00	2.00
Arterial – Local	2.59	0.91	3.99	2.99	70.00	1.99
Collector – Local	1.19	0.91	2.02	3.21	75.00	1.99
Commercial – Mix	1.83	2.17	1.85	1.29	67.00	2.00
Commercial – Resid.	0.87	3.04	2.19	2.54	67.00	2.00
Mix – Residential	-0.93	0.46	0.48	1.07	68.00	2.00
All Community – Experts	-2.71	5.65	4.97	8.78	127.00	1.98

TABLE F.8 SUMMARY STATISTICS OF RATING VALUES (VALIDATION)

Combination of		noise		air pol		Pedest		accident	
Categories	N	Mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Major-Commercial	12	43.38	13.09	43.33	15.86	44.58	13.56	28.33	13.03
Major-Residential	20	57.13	21.99	45.00	20.96	41.63	20.17	32.88	17.27
Local-Commercial	4	47.50	6.45	40.00	7.07	40.63	22.02	23.75	13.15
Local-Residential	7	36.43	9.00	33.57	12.15	23.21	15.05	14.64	11.40
All community	43	49.02	18.58	42.21	17.50	39.36	18.79	27.79	15.91

TABLE F.9 WEIGHTS OF ENVIRONMENTAL FACTORS (RATING METHOD – VALIDATION)

Major-Commercial	0.27	0.27	0.28	0.18
Major-Residential	0.32	0.25	0.24	0.19
Local-Commercial	0.31	0.26	0.27	0.16
Local-Residential	0.34	0.31	0.22	0.14
All community	0.31	0.27	0.25	0.18

F.3. Ranking Method

Summary results of rating method are as presented in Tables F.10 and F.11. Validation results are as presented in Tables F.12 and F.13. Figures F.1 through F.8 show the distribution of ranks amongst categories for each factor for calibration and validation. Figure F.9 depicts the ranks as given by experts.

TABLE F.10 SUMMARY OF RANKING OF FACTORS BY CATEGORIES (CALIBRATION)

Categories	N	Noise	Air Pollution	Pedestrian	Accident Risk	W	chi-sq	rank order
Arterial-Commercial	7	7	14	21	28	1.00	21.00	1234
Arterial-Mix	10	10	20	30	40	1.00	30.00	1234
Arterial-Residential	11	11	29	28	42	0.80	26.45	1324
Collector-Commercial	11	14	30	27	39	0.53	17.51	1324
Collector-Mix	7	9	12	23	26	0.84	17.57	1234
Collector-Residential	11	11	29	34	36	0.64	21.22	1234
Local-Commercial	17	18	35	50	67	0.91	46.34	1234
Local-Mix	21	24	42	58	66	0.47	29.57	1234
Local-Residential	13	17	28	35	50	0.68	26.45	1234
Arterials	28	28	63	79	110	0.89	74.87	1234
Collectors	33	40	79	98	113	0.55	54.35	1234
Locals	47	53	97	129	171	0.68	95.43	1234
Commercial	35	39	79	98	134	0.77	80.52	1234
Mix	38	41	77	111	131	0.65	74.08	1234
Residential	35	41	83	97	129	0.65	68.49	1234
Major-Commercial	18	21	44	48	67	0.66	35.67	1234
Major-Residential	43	47	98	129	156	0.71	91.60	1234
Local-Commercial	17	18	35	50	67	0.91	46.34	1234
Local-Residential	30	35	62	79	104	0.56	50.52	1234
All community	108	121	239	306	394	0.68	220.74	1234

TABLE F.11 WEIGHTS OF ENVIRONMENTAL FACTORS (RANKING METHOD – CALIBRATION)

Categories	noise	airpol	pedest	accid
Arterial-Commercial	0.52	0.27	0.15	0.06
Arterial-Mix	0.52	0.27	0.15	0.06
Arterial-Residential	0.52	0.15	0.27	0.06
Collector-Commercial	0.52	0.15	0.27	0.06
Collector-Mix	0.52	0.27	0.15	0.06
Collector-Residential	0.52	0.27	0.15	0.06
Local-Commercial	0.52	0.27	0.15	0.06
Local-Mix	0.52	0.27	0.15	0.06
Local-Residential	0.52	0.27	0.15	0.06
Arterials	0.52	0.27	0.15	0.06
Collectors	0.52	0.27	0.15	0.06
Locals	0.52	0.27	0.15	0.06
Commercial	0.52	0.27	0.15	0.06
Mix	0.52	0.27	0.15	0.06
Residential	0.52	0.27	0.15	0.06
Major-Commercial	0.52	0.27	0.15	0.06
Major-Residential	0.52	0.27	0.15	0.06
Local-Commercial	0.52	0.27	0.15	0.06
Local-Residential	0.52	0.27	0.15	0.06
All community	0.52	0.27	0.15	0.06

TABLE F.12 SUMMARY OF RANKING OF FACTORS BY CATEGORIES (VALIDATION)

Categories	N	Noise	Air Pollution	Pedestrian	Accident Risk	W	chi-sq	rank order
Arterial-Commercial	8	8	16	24	32	1.00	24.00	1234
Arterial-Mix	6	11	15	18	16	0.14	2.60	1243
Arterial-Residential	5	5	15	11	19	0.86	12.84	1324
Collector-Commercial	4	4	11	10	15	0.78	9.30	1324
Collector-Mix	4	7	7	10	16	0.68	8.10	1234
Collector-Residential	5	8	7	15	20	0.90	13.56	2134
Local-Commercial	4	4	8	12	16	1.00	12.00	1234
Local-Mix	4	4	9	11	16	0.93	11.10	1234
Local-Residential	3	7	5	8	10	0.29	2.60	2134
Arterials	19	24	46	53	67	0.53	30.47	1234
Collectors	13	19	25	35	51	0.69	27.09	1234
Locals	11	15	22	31	42	0.68	22.31	1234
Commercial	16	16	35	46	63	0.91	43.73	1234
Mix	14	22	31	39	48	0.38	15.86	1234
Residential	13	20	27	34	49	0.55	21.28	1234
Major-Commercial	12	12	27	34	47	0.89	31.90	1234
Major-Residential	20	31	44	54	71	0.43	25.62	1234
Local-Commercial	4	4	8	12	16	1.00	12.00	1234
Local-Residential	7	11	14	19	26	0.53	11.06	1234
All community	43	58	93	119	160	0.60	77.43	1234
Experts	18	68	49	63	66	0.54	553.3	4123

TABLE F.13 WEIGHTS OF ENVIRONMENTAL FACTORS (RANKING METHOD – VALIDATION)

Categories	noise	airpol	pedest	accid
Arterial-Commercial	0.52	0.27	0.15	0.06
Arterial-Mix	0.52	0.27	0.06	0.15
Arterial-Residential	0.52	0.15	0.27	0.06
Collector-Commercial	0.52	0.15	0.27	0.06
Collector-Mix	0.52	0.27	0.15	0.06
Collector-Residential	0.27	0.52	0.15	0.06
Local-Commercial	0.52	0.27	0.15	0.06
Local-Mix	0.52	0.27	0.15	0.06
Local-Residential	0.27	0.52	0.15	0.06
Arterials	0.52	0.27	0.15	0.06
Collectors	0.52	0.27	0.15	0.06
Locals	0.52	0.27	0.15	0.06
Commercial	0.52	0.27	0.15	0.06
Mix	0.52	0.27	0.15	0.06
Residential	0.52	0.27	0.15	0.06
Major-Commercial	0.52	0.27	0.15	0.06
Major-Residential	0.52	0.27	0.15	0.06
Local-Commercial	0.52	0.27	0.15	0.06
Local-Residential	0.52	0.27	0.15	0.06
All community	0.52	0.27	0.15	0.06
Experts	0.06	0.52	0.27	0.15

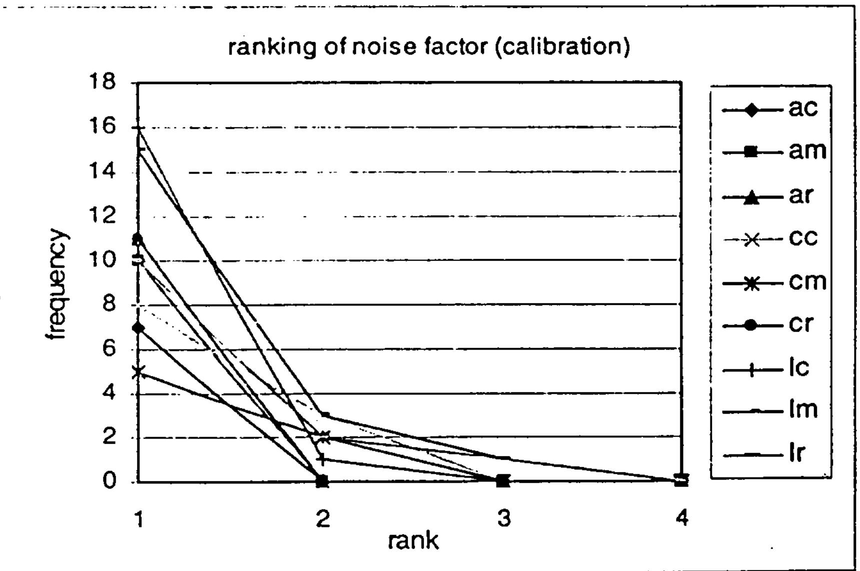

FIGURE F.1 DISTRIBUTION OF NOISE RANKS BY CATEGORIES (CALIBRATION)

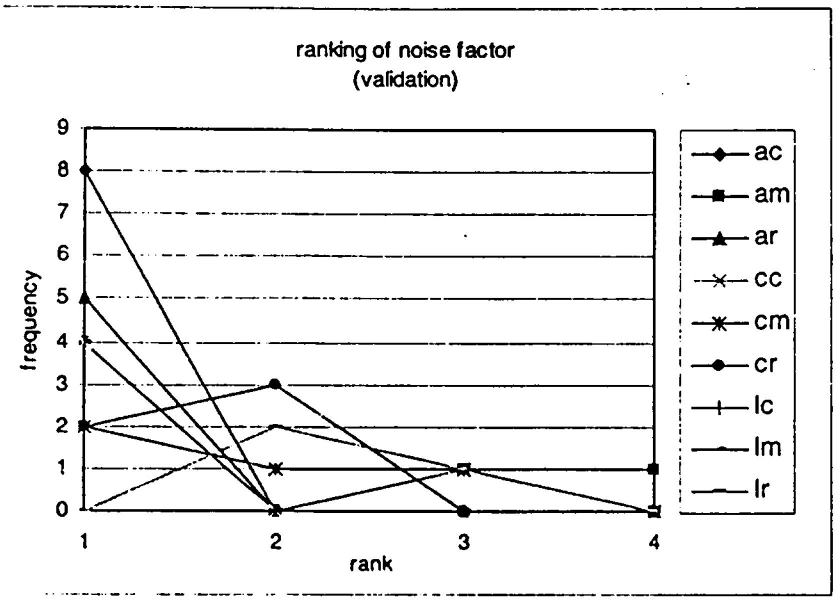

FIGURE F.2 DISTRIBUTION OF NOISE RANKS BY CATEGORIES (VALIDATION)

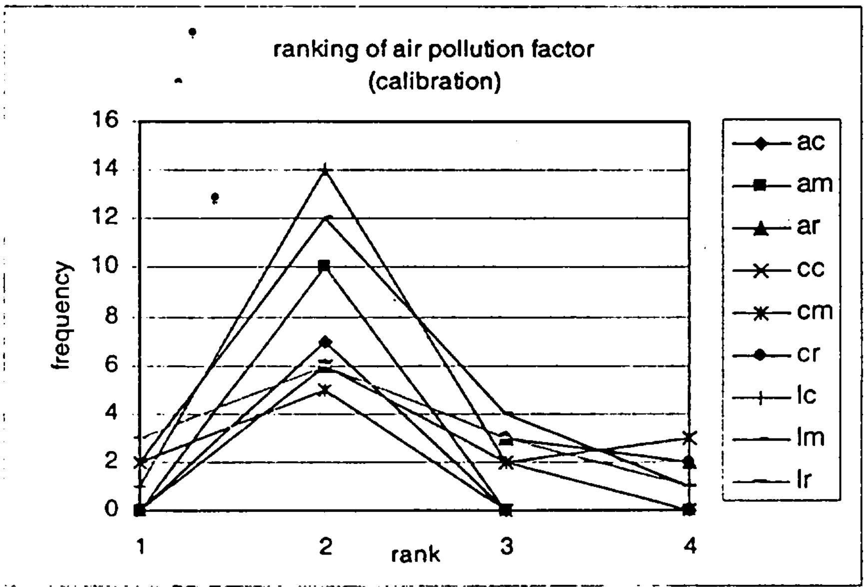

FIGURE F.3 DISTRIBUTION OF AIR POLLUTION RANKS BY CATEGORIES (CALIBRATION)

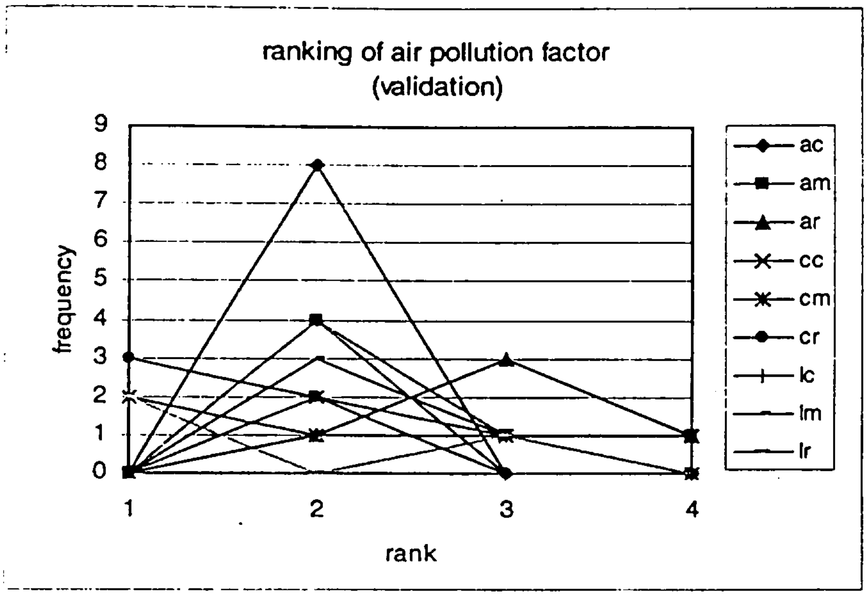

FIGURE F.4 DISTRIBUTION OF AIR POLLUTION RANKS BY CATEGORIES (VALIDATION)

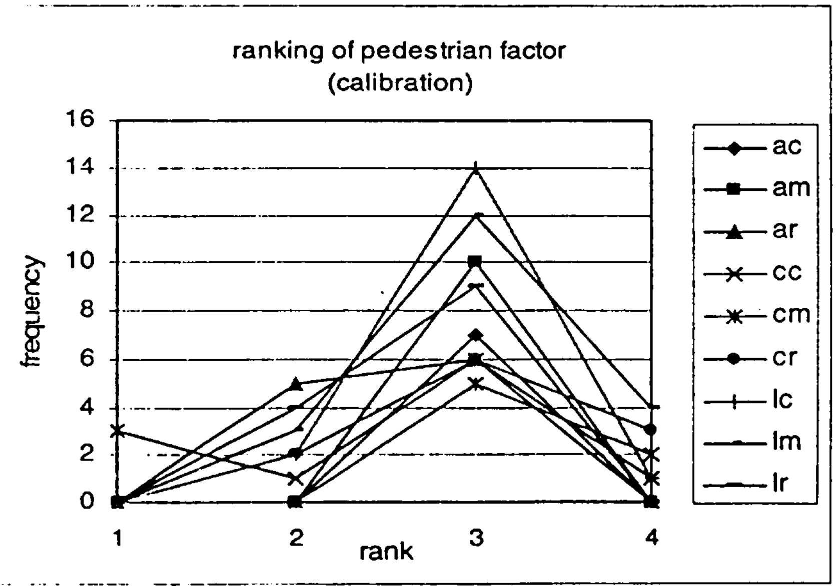

FIGURE F.5 DISTRIBUTION OF PEDESTRIAN DELAY RANKS BY CATEGORIES (CALIBRATION)

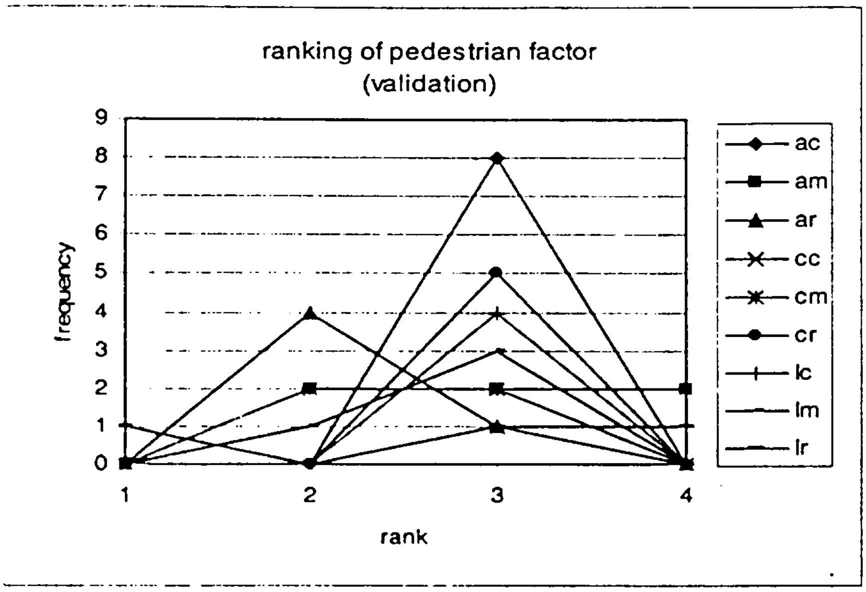

FIGURE F.6 DISTRIBUTION OF PEDESTRIAN DELAY RANKS BY CATEGORIES (VALIDATION)

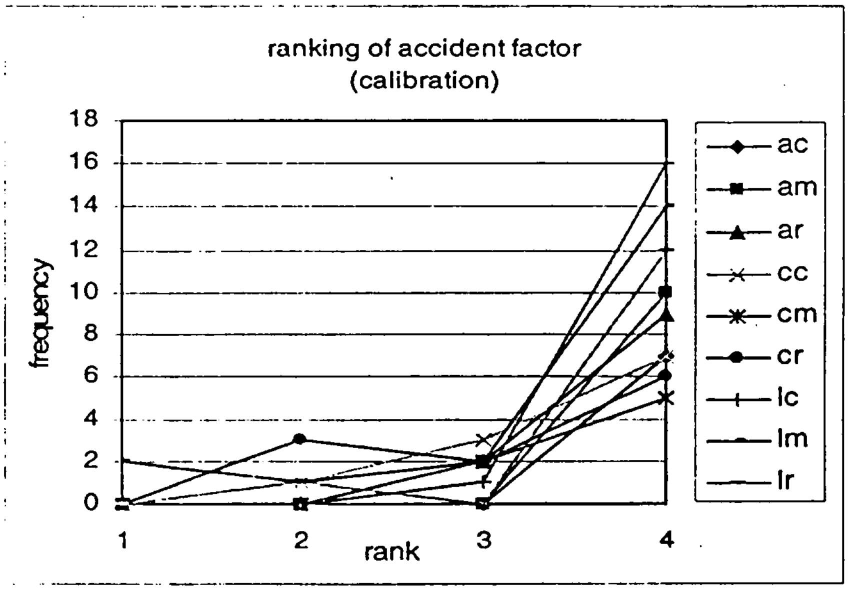

FIGURE F.7 DISTRIBUTION OF ACCIDENT RISKS RANKS BY CATEGORIES (CALIBRATION)

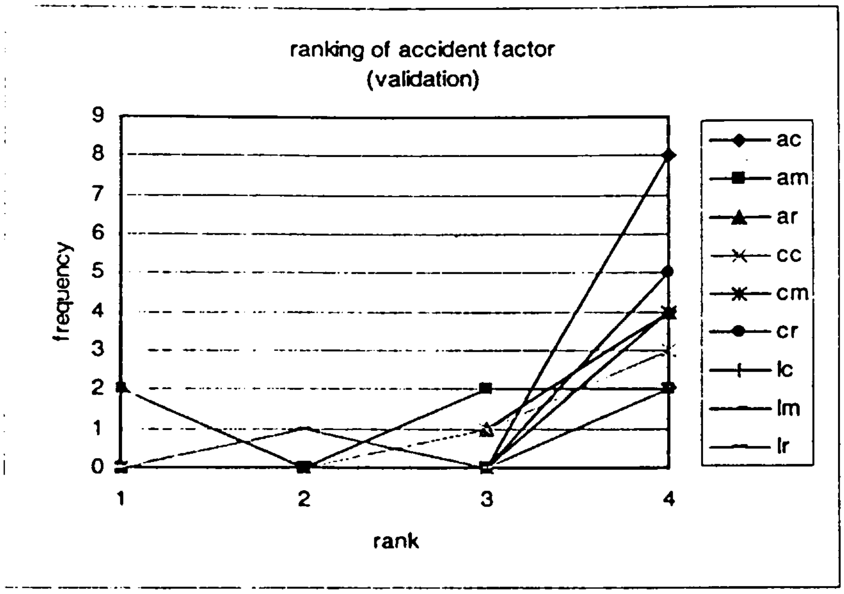

FIGURE F.8 DISTRIBUTION OF ACCIDENT RISKS RANKS BY CATEGORIES (VALIDATION)

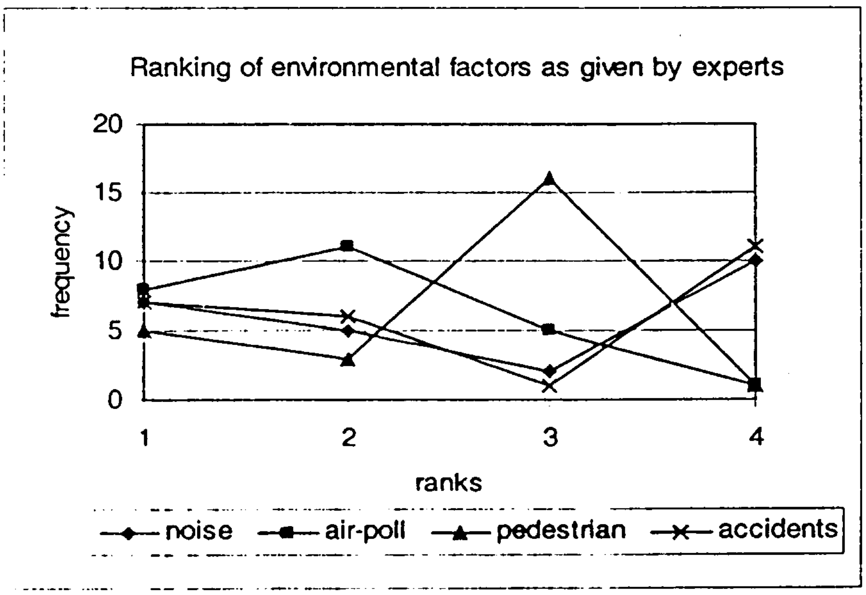

FIGURE F.9 DISTRIBUTION OF RANKS BY ENVIRONMENTAL FACTORS (EXPERTS)

F.4. Pairwise Comparison (Analytical Hierarchy Process)

Table F.14 and Figure F.10 show weight coefficients of environmental factors using AHP method of calibration data set. Table F.15 and Figure F.11 show the result of validation.

TABLE F. 14 WEIGHT COEFFICIENTS OF ENVIRONMENTAL FACTORS USING AHP (CALIBRATION)

Categories	Noise	airpol	pedes	accid	λ-max	ci	cr
Arterial-Commercial	0.47	0.19	0.23	0.10	4.054	0.018	0.020
Arterial-Mix	0.42	0.27	0.20	0.11	4.029	0.010	0.011
Arterial-Residential	0.55	0.17	0.20	0.08	4.103	0.034	0.038
Collector-Commercial	0.46	0.25	0.18	0.11	4.020	0.007	0.007
Collector-Mix	0.50	0.22	0.17	0.11	4.006	0.002	0.002
Collector-Residential	0.47	0.25	0.17	0.12	4.032	0.011	0.012
Local-Commercial	0.44	0.32	0.15	0.09	4.040	0.013	0.015
Local-Mix	0.43	0.27	0.19	0.12	4.006	0.002	0.002
Local-Residential	0.47	0.26	0.16	0.11	4.028	0.009	0.010
Arterials	0.49	0.21	0.21	0.10	4.039	0.013	0.014
Collectors	0.48	0.24	0.17	0.11	4.008	0.003	0.003
Locals	0.45	0.29	0.17	0.10	4.018	0.006	0.007
Commercial	0.45	0.27	0.18	0.10	4.019	0.006	0.007
Mix	0.46	0.26	0.17	0.11	4.010	0.003	0.004
Residential	0.50	0.23	0.17	0.10	4.040	0.013	0.015
Major-Commercial	0.48	0.20	0.20	0.12	4.014	0.005	0.005
Major-Residential	0.48	0.25	0.18	0.09	4.052	0.017	0.019
Local-Commercial	0.41	0.32	0.17	0.10	4.016	0.005	0.006
Local-Residential	0.49	0.24	0.15	0.11	4.024	0.008	0.009
All community	0.47	0.25	0.18	0.10	4.016	0.005	0.006
Experts	0.14	0.27	0.28	0.31	4.049	0.016	0.018

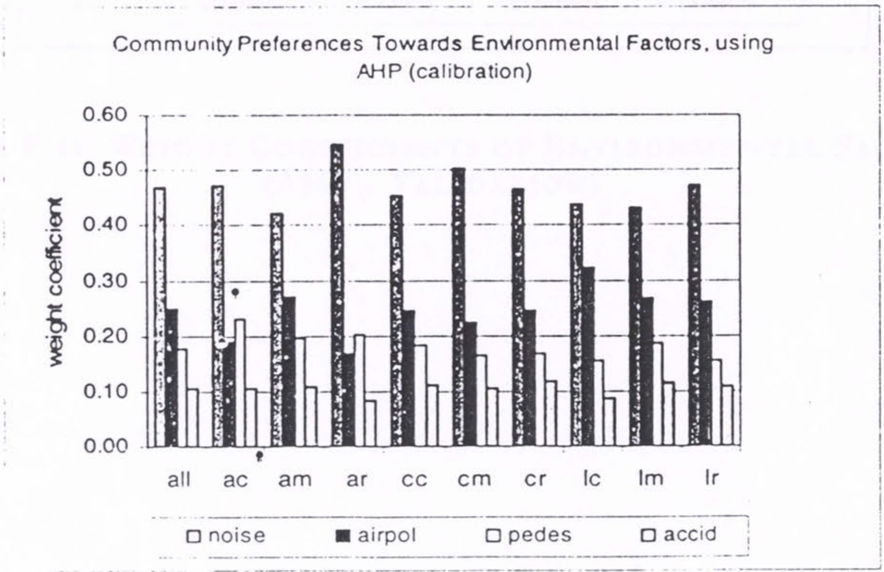

FIGURE F.10 WEIGHT COEFFICIENTS OF ENVIRONMENTAL FACTORS (AHP - CALIBRATION)

TABLE F.15 WEIGHT COEFFICIENTS OF ENVIRONMENTAL FACTORS (AHP - VALIDATION)

Categories	noise	airpol	pedes	accid
Arterial-Commercial	0.21	0.32	0.31	0.15
Arterial-Mix	0.34	0.20	0.28	0.18
Arterial-Residential	0.35	0.29	0.28	0.08
Collector-Commercial	0.52	0.17	0.20	0.10
Collector-Mix	0.38	0.30	0.22	0.09
Collector-Residential	0.42	0.37	0.13	0.08
Local-Commercial	0.47	0.29	0.19	0.06
Local-Mix	0.47	0.24	0.19	0.10
Local-Residential	0.32	0.38	0.20	0.10
All	0.39	0.27	0.23	0.11

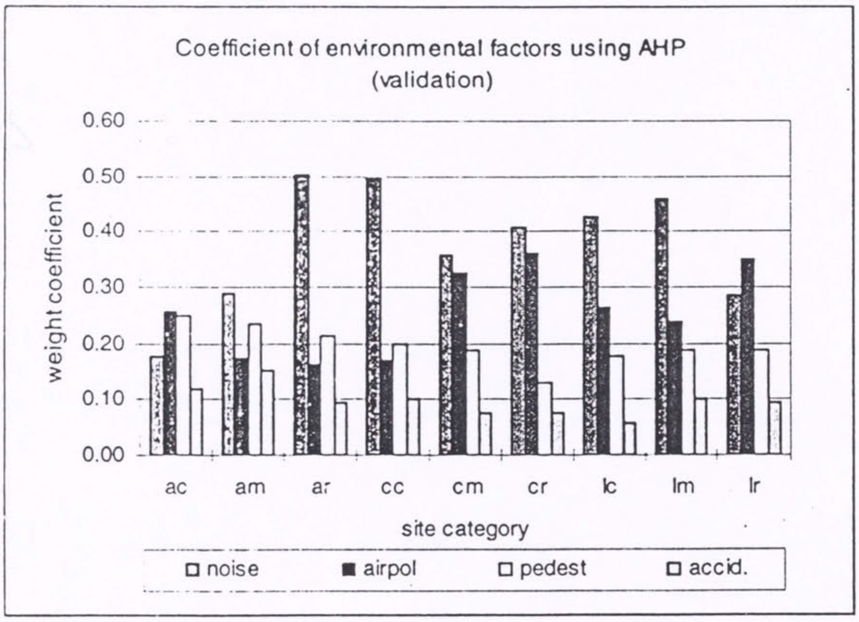

FIGURE F.11 WEIGHT COEFFICIENTS OF ENVIRONMENTAL FACTORS (AHP - VALIDATION)

F.5. EUV Model

Calibration and validation data sets for EUV model are as presented in Tables F.15 and F.16 respectively. Results of calibration and validation analyses of the data are as shown in Tables F.17 – F.20 and Figures F.12 and F.13. The subsequent sections explain on how the models have been developed for each 4 suggested categories.

TABLE F.15 EUV MODEL CALIBRATION DATABASE

Table F.15 EUV Model Calibration Database

		Road geometry and Landuse								
SiteNo	Road Class	Landuse type	%MC	# lanes	WindDir	Direction	Width	Grad(%)	Lane width	WindDir1
kk02	major	commercial	29%	4	5	5	12	1.5	3	101.25
kk02	major	commercial	29%	4	10	5	12	1.5	3	213.75
kk02	major	commercial	29%	4	1	5	12	1.5	3	11.25
ak02	major	commercial	39%	2	4	90	8	1.7	4	78.75
ak02	major	commercial	38%	2	5	90	8	1.7	4	101.25
ak01	major	commercial	25%	4	5	7	13	25	3.25	101.25
ak01	major	commercial	21%	4	5	7	13	25	3.25	101.25
am01*	major	residential	28%	4	5	6.5	12.6	15	3	101.25
am01*	major	residential	25%	4	5	6.5	12.6	15	3	101.25
am01*	major	residential	24%	4	5	6.5	12.6	15	3	101.25
am02	major	residential	30%	2	15	50	10.2	1.5	5.1	326.25
am02	major	residential	34%	2	15	50	10.2	1.5	5.1	326.25
ap01	major	residential	25%	2	9	177	8.4	15	4.2	191.25
ap01	major	residential	27%	2	9	177	8.4	15	4.2	191.25
ap02	major	residential	24%	2	15	5	8.4	15	4.2	326.25
ap02	major	residential	25%	2	14	5	8.4	15	4.2	303.75
kk01*	major	commercial	26%	2	2	110	6.6	1.5	3.3	33.75
kk01*	major	commercial	29%	2	2	110	6.6	1.5	3.3	33.75
kk03*	major	commercial	48%	2	4	93	7	1.5	3.5	78.75
kk03*	major	commercial	49%	2	4	93	7	1.5	3.5	78.75
km01	major	residential	28%	2	16	152	8.5	15	4.25	348.75
km01	major	residential	32%	2	16	152	8.5	15	4.25	348.75
km02	major	residential	41%	2	15	14	6.5	1.5	3.25	326.25
km02	major	residential	44%	2	15	14	6.5	1.5	3.25	326.25
km03	major	residential	25%	2	11	10	10	1.5	5	236.25
km03	major	residential	25%	2	11	10	10	1.5	5	236.25
kp01*	major	residential	30%	2	1	120	5	1	2.5	11.25
kp01*	major	residential	31%	2	1	120	5	1	2.5	11.25
kp02	major	residential	29%	2	10	12.5	6.5	1	3.25	213.75
kp02	major	residential	26%	2	10	12.5	6.5	1	3.25	213.75
kp03*	major	residential	31%	2	2	0	7	1	3.5	33.75
kp03*	major	residential	34%	2	2	0	7	1	3.5	33.75
lk01	local	commercial	42%	2	16	140	6.4	2	3.2	348.75
lk01	local	commercial	42%	2	16	140	6.4	2	3.2	348.75
lk01	local	commercial	43%	2	16	140	6.4	2	3.2	348.75
lk02*	local	commercial	48%	2	5	95	8	1	4	101.25
lk02*	local	commercial	47%	2	5	95	8	1	4	101.25
lk03	local	commercial	36%	2	5	20	6	1	3	101.25
lk03	local	commercial	33%	2	5	20	6	1	3	101.25
lk04	local	commercial	34%	3	16	166.5	12	1	4	348.75
lk04	local	commercial	34%	3	16	166.5	12	1	4	348.75
lm01*	local	residential	37%	2	5	25	6.5	14	3.25	101.25
lm01*	local	residential	28%	2	5	25	6.5	14	3.25	101.25
lm02*	local	residential	29%	2	4	10	6.6	1	3.3	78.75
lm02*	local	residential	27%	2	4	10	6.6	1	3.3	78.75
lm03*	local	residential	33%	2	4	15	4	1	2	78.75
lm03*	local	residential	31%	2	4	15	4	1	2	78.75
lm04*	local	residential	41%	2	7	17.5	5	1	2.5	146.25
lm04*	local	residential	45%	2	7	17.5	5	1	2.5	146.25
lp01*	local	residential	35%	2	7	24	5.4	5	2.7	146.25
lp01*	local	residential	42%	2	7	24	5.4	5	2.7	146.25
lp02*	local	residential	42%	2	8	50	6.7	1	3.35	168.75
lp02*	local	residential	44%	2	8	50	6.7	1	3.35	168.75
lp03*	local	residential	28%	2	3	81	7	1	3.5	56.25
lp03*	local	residential	28%	2	3	81	7	1	3.5	56.25
lp04*	local	residential	25%	2	8	104	6.4	2	3.2	168.75
lp04*	local	residential	29%	2	8	104	6.4	2	3.2	168.75
Note		mean	0.3	2.2	8.0	60.7	7.7	5.2	3.4	168.8
*	manual counting	st dev	0.1	0.6	4.9	57.8	2.4	6.8	0.7	111.3
**	automatic count	max	0.5	4.0	16.0	177.0	13.0	25.0	5.1	348.8
		min	0.2	2.0	1.0	0.0	4.0	1.0	2.0	11.3
		range	0.3	2.0	15.0	177.0	9.0	24.0	3.1	337.5

Meteorological Data			Traffic Volume and Speed			Noise (dBA)		Air Pollution (ppm)			Ped
WindSpd	WS1	Temp.	Volume	%HV	Speed	L10-1hr	Leq	NOx	CO	HC	Ave. Delay
1	0.84	32.00	3224	3.00	25	75.9	73.5	0.212	6.046	4.745	2.44
0	0	30.00	3280	3.00	25	75.5	73.0	0.179	5.724	4.888	2.44
0	0	29.00	2322	3.00	25	76.5	73.6	0.130	5.999	3.879	1.73
4	3.35	31.00	2138	1.67	22	76.0	73.4	0.039	1.415	2.503	5.27
8	6.70	31.00	1996	1.32	24	75.3	72.6	0.029	1.067	2.503	3.54
3	2.51	27.00	5582	4.03	26	77.6	75.0	0.111	4.041	3.630	5.04
3	2.51	25.00	4962	2.76	27	77.6	76.0	0.128	4.350	3.017	0.86
0.525	0.525	24.00	4326	0.74	24	77.2	74.5	0.156	4.970	2.795	13.71
0.5	0.5	25.00	3161	0.85	46	76.9	74.3	0.053	2.135	3.493	11.67
0.66	0.66	26.00	3162	0.89	45	76.7	74.2	0.138	4.177	3.633	12.18
8	6.70	33.00	1722	3.37	34	71.9	69.1	0.074	3.228	4.435	6.89
8	6.70	31.00	1835	3.32	32	70.7	67.8	0.087	4.051	4.078	1.77
2	1.67	30.00	1587	1.32	40	77.6	74.4	0.014	3.431	4.002	3.53
2	1.67	28.00	1858	1.72	38	77.3	74.2	0.014	2.006	3.181	5.68
1	0.84	31.00	2193	1.73	40	76.6	73.6	0.249	6.300	5.069	5.98
2	1.67	29.00	2168	1.94	38	76.7	73.9	0.221	6.177	4.061	5.47
0.5	0.5	25.00	1514	1.32	25	75.4	72.1	0.093	3.310		1.62
0.5	0.5	26.00	1532	1.04	19	74.8	72.2	0.055	3.493		1.44
0.5	0.5	22.50	1655	1.03	28	75.4	72.3	0.085	3.093	3.493	1.86
0.5	0.5	25.00	1800	1.44	29	74.5	71.6	0.047	3.310	4.891	2.44
1	0.84	30.00	2148	1.07	32	76.5	73.7	0.124	4.646	4.130	2.44
1	0.84	28.00	2403	1.17	34	76.8	74.0	0.100	4.690	3.384	1.73
1	0.84	32.00	980	0.51	32	71.7	70.7	0.047	2.296		0.48
1	0.84	32.00	901	0.55	32	71.2	68.9	0.055	3.230	2.534	3.71
1	0.84	30.00	1894	1.16	31	74.4	72.0	0.025	1.054	2.777	0.02
1	0.84	30.00	2028	0.49	31	74.3	72.1	0.038	2.237	2.327	2.12
1.25	1.25	25.00	1236	1.46	32	74.5	71.8	0.070	3.140	3.074	1.46
1	1	26.00	1265	1.03	32	74.0	71.5	0.024	2.270	2.124	1.92
1	0.84	31.00	455	0.66	26	67.1	64.8	0.044	1.268	2.651	0.78
1	0.84	30.00	470	0.85	30	68.3	65.7	0.044	1.381	2.319	1.00
0.83	0.83	23.00	1049	2.00	32	70.2	67.4	0.081	2.840	2.515	3.05
0.25	0.25	25.00	1196	2.01	28	70.5	67.4	0.057	2.602	3.354	3.17
2	1.67	34.00	917	0.76	37	72.5	70.6	0.695	4.510	5.070	0.95
2	1.67	33.00	989	0.81	36	73.9	72.1	0.239	6.351	5.069	1.05
2	1.67	31.00	868	0.58	36	73.8	71.3	0.058	5.156	5.052	0.09
0.58	0.58	23.00	400	0.25	24	66.8	63.2	0.072	2.950		0.50
0.75	0.75	24.00	470	0.43	21	66.8	63.2	0.072	2.950	3.521	0.00
2	1.67	31.00	610	0.16	24	69.1	65.9	0.023	1.558	3.144	0.27
2	1.67	30.00	534	0.37	25	69.0	65.8	0.026	2.044	2.672	0.56
0	0	31.00	354	0.85	31	68.7	67.5	0.034	1.603	5.070	0.20
0	0	30.00	346	1.16	29	69.9	67.1	0.026	2.526	1.975	0.00
0.6	0.6	25	478	2.72	27	71.8	68.7	0.031	1.616		0.09
0.5	0.5	26	670	2.24	25	71.4	68.7	0.031	1.616		1.35
0.75	0.75	23	1003	0.30	31	72.3	70.4	0.097	3.418	2.655	1.88
0.55	0.55	27	998	0.00	31	71.8	68.9	0.083	2.844	2.306	1.53
2	2	26	241	0.00	28	66.4	63.4	0.015	2.663	3.186	0.00
2	2	26	185	1.08	28	66.6	64.1	0.027	1.200	3.074	0.00
0.8	0.8	23	517	0.58	30	74.1	71.0	0.263	2.840	3.130	1.19
0.5	0.5	24	449	0.22	31	73.5	71.2	0.050	2.467	3.689	2.95
0.5	0.5	25	249	0.80	24	66.8	64.0	0.110	3.078	3.074	0.11
0.5	0.5	26	207	0.48	26	65.8	64.0	0.110	3.078	3.074	0.05
0.4	0.4	23	292	0.00	28	65.1	64.2	0.067	2.043	2.096	0.76
1	1	25	401	0.50	29	66.5	64.3	0.087	2.694	2.515	0.37
0.5	0.5	23	274	1.09	35	65.8	61.7	0.034	2.368	3.913	0.50
0.58	0.58	25	316	0.00	36	67.8	64.8	0.036	1.875	3.507	0.00
0.58	0.58	23	680	0.44	32	69.4	65.5	0.050	1.585	1.956	1.27
1.75	1.75	23.5	646	0.62	32	69.5	65.9	0.037	1.803	3.353	1.63
1.3	1.2	27.1	1339.1	1.1	30.8	72.0	69.3	0.1	3.0	3.3	2.3
1.5	1.3	3.3	1174.3	0.9	5.4	3.9	3.9	0.1	1.3	0.9	3.1
8.0	6.7	34.0	5581.5	4.0	46.0	77.6	76.0	0.7	6.4	5.1	13.7
0.0	0.0	22.5	185.0	0.0	19.0	65.1	61.7	0.0	1.1	2.0	0.0
8.0	6.7	11.5	5396.5	4.0	27.0	12.5	14.3	0.7	5.3	3.1	13.7

estrian	Accidents	Normalised Value				EUV		
%Ped Delayed	acc./km/yr.	Noise	Airpol_CO	Pedest.	Accid.	Measured	Predicted	M-P
0.69	0.48	86	94	73	18	72.25	50.4	21.83
0.69	0.48	83	88	73	18	69.68	51.2	18.46
0.63	0.48	91	93	66	18	71.80	37.8	33.96
0.60	0.51	87	7	63	18	47.54	48.1	-0.58
0.50	0.51	82	0	53	18	41.56	46.5	-4.98
0.54	2.73	100	56	57	100	78.32	78.0	0.28
0.18	2.73	100	62	19	100	70.79	70.8	0.03
0.71	0.48	97	74	76	17	73.03	[redacted]	10.83
0.79	0.48	94	20	84	17	55.64		-8.38
0.91	0.48	93	59	96	17	72.36		5.77
0.56	0.82	54	41	59	30	[illegible]		13.63
0.38	0.82	45	57	41	30	[illegible]		10.78
0.42	0.00	100	45	44	0	55.29		4.29
0.42	0.00	98	18	45	0	[illegible]		-6.85
0.55	0.67	92	99	58	24	75.32		9.68
0.62	0.67	93	97	66	24	76.06		14.49
0.16	0.16	82	43	17	6	41.84	43.9	-2.02
0.25	0.16	78	46	26	6	43.47	40.1	3.34
0.29	1.01	82	38	30	37	49.82	47.1	2.70
0.44	1.01	75	43	46	37	52.51	51.3	1.22
0.69	0.48	91	68	73	17	68.99	[redacted]	16.68
0.63	0.48	94	69	66	17	68.39		7.43
0.19	0.41	53	23	20	15	31.29		-8.13
0.47	0.41	49	41	50	15	[illegible]		3.86
0.02	0.00	74	0	3	0	[illegible]		-9.22
0.19	0.00	74	22	20	0	[illegible]		-2.38
0.80	0.00	75	39	85	0	[illegible]		0.42
0.95	0.00	71	23	100	0	[illegible]		-2.48
0.12	0.00	16	4	13	0	20.50		-9.38
0.19	0.00	26	6	20	0	[illegible]		-10.11
0.32	0.00	41	34	33	0	[illegible]		-6.98
0.39	0.00	43	29	41	0	[illegible]		-3.08
0.09	0.00	59	65	9	0	[illegible]	53	-11.49
0.08	0.00	70	100	9	0	[illegible]	55	1.28
0.04	0.00	70	77	5	0	[illegible]	50	-1.98
0.09	0.00	14	36	10	0	[illegible]	18	-0.39
0.00	0.00	14	36	0	0	[illegible]	20	-5.02
0.09	0.00	32	10	10	0	[illegible]	20	-7.81
0.11	0.00	31	19	12	0	[illegible]	21	-3.38
0.14	0.00	29	10	14	0	[illegible]	22	-5.89
0.00	0.00	38	28	0	0	[illegible]	19	2.24
0.04	0.00	54	11	5	0	24.04	19	4.77
0.16	0.00	50	11	17	0	25.32	27	-1.81
0.40	0.67	58	45	42	24	45.85	44	1.78
0.26	0.67	54	34	28	24	38.65	44	-5.19
0.00	0.00	10	30	0	0	11.85	19	-7.19
0.00	0.00	12	3	0	0	5.28	17	-11.24
0.19	0.00	72	34	20	0	40.19	28	11.96
0.32	0.00	67	27	34	0	39.33	26	13.77
0.06	0.00	14	38	7	0	16.44	12	4.23
0.05	0.00	6	38	6	0	13.18	11	2.07
0.10	0.00	0	19	11	0	6.97	10	-3.52
0.05	0.00	11	31	6	0	13.43	16	-2.36
0.26	0.00	6	25	28	0	14.14	11	2.91
0.00	0.00	22	15	0	0	12.24	14	-1.27
0.33	0.00	34	10	35	0	22.73	31	-8.00
0.38	0.00	35	14	40	0	24.98	29	-4.22
0.3	0.3	54.8	30	30	30	37.8	37.8	0.01
0.3	0.6	30.9	30	30	30	21.2	18.4	7.21
0.9	2.7	100.0	30	30	30	78.3	78.0	16.68
0.0	0.0	0.0	30	30	30	5.3	10.5	-11.49
0.9	2.7	100.0						

lestrian	Accidents	Normalised Value				EUV		
%Ped Delayed	acc./km/yr.	Noise	Airpol_CO	Pedest.	Accid.	Measured	Predicted	M-P
0.69	0.48	86	94	73	[illegible]	72.25	50.4	21.83
0.69	0.48	83	88	73	[illegible]	69.68	51.2	18.46
0.63	0.48	91	93	66	[illegible]	71.80	37.8	[illegible]
0.60	0.51	87	7	63	[illegible]	47.54	48.1	-0.58
0.50	0.51	82	0	53	15	41.56	46.5	-4.98
0.54	2.73	100	56	57	[illegible]	78.32	78.0	0.28
0.18	2.73	100	62	[illegible]	[illegible]	70.79	70.8	0.03
0.71	0.48	97	74	76	17	73.05	[redacted]	10.83
0.79	0.48	94	20	34	17	59.64	[redacted]	-8.38
0.91	0.48	93	59	[illegible]	17	72.56	[redacted]	5.77
0.56	0.82	54	41	[illegible]	3	47.88	[redacted]	13.63
0.38	0.82	45	57	41	30	44.66	[redacted]	10.78
0.42	0.00	100	45	44	0	56.29	[redacted]	4.29
0.42	0.00	98	18	45	0	48.54	[redacted]	-6.85
0.55	0.67	92	99	58	24	75.32	[redacted]	9.68
0.62	0.67	93	97	66	24	76.66	[redacted]	14.49
0.16	0.16	82	43	17	6	41.84	43.9	-2.02
0.25	0.16	78	46	26	6	43.47	40.1	3.34
0.29	1.01	82	38	30	37	49.82	47.1	2.70
0.44	1.01	75	43	46	37	52.51	51.3	1.22
0.69	0.48	91	68	73	17	68.99	[redacted]	16.68
0.63	0.48	94	69	66	17	68.39	[redacted]	7.43
0.19	0.41	53	23	20	15	31.29	[redacted]	-8.13
0.47	0.41	49	41	50	15	41.51	[redacted]	3.86
0.02	0.00	74	0	3	0	25.87	[redacted]	-9.22
0.19	0.00	74	22	20	0	35.73	[redacted]	-2.38
0.80	0.00	75	39	85	0	55.65	[redacted]	0.42
0.95	0.00	71	23	100	0	53.41	[redacted]	-2.48
0.12	0.00	16	4	13	0	9.50	[redacted]	-9.38
0.19	[illegible]	26	6	[illegible]	0	14.93	[redacted]	-10.11
0.32	[illegible]	41	34	33	0	30.65	[redacted]	6.98
0.39	[illegible]	43	29	41	[illegible]	52.05	[redacted]	3.08
0.09	[illegible]	59	65	[illegible]	0	41.72	53	11.49
0.08	[illegible]	70	100	[illegible]	0	55.82	55	1.28
[illegible]	[illegible]	70	77	5	0	47.91	50	1.98
[illegible]	[illegible]	14	36	10	0	17.48	18	0.39
0.30	[illegible]	14	36	0	0	15.56	20	5.02
[illegible]	[illegible]	32	10	10	0	15.85	24	-7.81
[illegible]	[illegible]	31	19	12	0	18.80	22	-3.38
[illegible]	[illegible]	29	10	14	0	16.07	22	-5.89
[illegible]	[illegible]	38	28	0	0	21.39	19	2.24
[illegible]	[illegible]	54	11	5	0	24.04	19	4.77
[illegible]	[illegible]	50	11	17	0	25.32	27	-1.81
[illegible]	[illegible]	58	45	42	24	45.85	44	1.78
[illegible]	[illegible]	54	34	28	24	38.65	44	-5.19
0.00	[illegible]	10	30	0	0	11.85	19	-7.19
0.00	[illegible]	12	3	0	0	5.28	17	-11.24
0.19	[illegible]	72	34	20	0	40.19	28	11.96
0.32	0.00	67	27	34	0	39.33	26	13.77
0.06	0.00	14	38	7	0	16.44	12	4.23
0.05	0.00	6	38	6	0	13.18	11	2.07
0.10	0.00	0	19	11	0	6.97	10	-3.52
0.05	0.00	11	31	6	0	13.43	16	-2.36
0.26	0.00	6	25	28	0	14.14	11	2.91
0.00	0.00	22	15	9	0	12.24	14	-1.27
0.33	0.00	34	10	35	[illegible]	22.73	31	-8.00
0.38	[illegible]	35	24	[illegible]	[illegible]	24.98	29	-4.22
0.3	[illegible]	54.8	30	[illegible]		37.8	37.8	0.01
0.3		30.9	30	[illegible]		[illegible]	18.4	7.21
0.9		100.0	30	[illegible]		[illegible]	78.0	15.68
[illegible]		0.0	30	[illegible]		[illegible]	10.5	11.49
[illegible]		100.0						

TABLE F.16 EUV MODEL VALIDATION DATABASE

Table F.16 EUV Model Validation Database

		Road geometry and Landuse					Meteorological D		
SiteNo	Road Class	Landuse type	Direction	Width	Grad.	# lanes	Lane width	WindDir	WindDir1	WindSpd
ap03	major	residential	103	10	4	2	5	2	33.75	2
ap03	major	residential	103	10	4	2	5	2	33.75	2
ak03	major	commercial	65	12.8	4	4	3.2	2	33.75	0.5
ak03	major	commercial	65	12.8	4	4	3.2	2	33.75	0.5
am03	major	residential	90	7.4	8	2	3.7	4	78.75	2
am03	major	residential	90	7.4	8	2	3.7	4	78.75	2
kk04	major	commercial	110	5	4	2	2.5	8	168.75	1
kk04	major	commercial	110	5	4	2	2.5	8	168.75	1
km04	major	residential	90	7	4	2	3.5	9	191.25	1
km04	major	residential	90	7	4	2	3.5	9	191.25	1
kp04	major	residential	105	6	2	2	3	1	11.25	2
kp04	major	residential	105	6	2	2	3	1	11.25	2
lk05	local	commercial	0	5	2	2	2.5	1	11.25	0.4
lk05	local	commercial	0	5	2	2	2.5	1	11.25	0.4
lm05	local	residential	0	5	10	2	2.5	5	101.25	0.58
lm05	local	residential	0	5	10	2	2.5	5	101.25	0.33
lp05	local	residential	100	5	2	2	2.5	8	168.75	0.5
lp05	local	residential	100	5	2	2	2.5	8	168.75	0.58
lp05	local	residential	100	5	2	2	2.5	8	168.75	0.58
		mean	71.76	6.55	4.35	2.24	2.90	4.94	99.93	0.96
		st Dev	42.97	2.53	2.85	0.66	0.48	3.17	71.36	0.63
		max	110.00	12.80	10.00	4.00	3.70	9.00	191.25	2.00
		min	0.00	5.00	2.00	2.00	2.50	1.00	11.25	0.33

ata		Traffic Volume and Speed				Noise		Air Pollution		
WS1	Temp	Volume	%HV	%MC	Speed	L10-1hr	Leq	NOx	CO	HC
1.67	30	2883	0.90	36%	27	74.3	71.0	0.093	2.859	3.195
1.67	29	3081	0.65	36%	26	74.3	71.9	0.120	4.169	3.091
0.5	26	2283	1.00	30%	24	72.7	70.1	0.063	3.243	4.304
0.5	29	2295	1.00	31%	24	73.1	71.0	0.027	2.327	4.304
1.67	32	1173	0.51	29%	32	74.4	71.4	0.046	1.963	3.147
1.67	30	1769	1.02	30%	30	74.4	71.4	0.080	3.441	2.897
0.84	32	1370	2.48	32%	31	77.0	74.4	0.077	2.517	4.37
0.84	30	1481	2.36	33%	29	77.9	74.5	0.080	3.097	3.413
0.84	34	1664	1.38	33%	24	72.1	69.3	0.220	7.296	4.002
0.84	32	1234	1.78	31%	27	72.1	70.1	0.134	4.359	3.158
1.67	34	1009	1.68	24%	30	69.0	67.1	0.048	1.527	2.065
1.67	32	721	1.39	25%	28	69.3	66.3	0.045	1.403	2.269
0.4	28	516	3.10	44%	26	71.4	68.3	0.046	1.765	3.857
0.4	27.5	634	1.89	39%	26	71.1	67.8	0.059	1.264	3.326
0.58	21	188	1.00	18%	32	64.2	61.6	0.055	2.242	1.677
0.33	23.5	218	1.00	16%	32	63.3	58.4	0.040	1.702	2.18
0.5	24.5	231	0.00	36%	23	63.5	60.5	0.026	1.650	3.354
0.58	25	264	0.00	33%	23	64.0	61.3	0.027	1.750	2.500
0.58	26	250	0.00	30%	24	62.9	61.0	0.023	1.800	3.100
	28.62	1017.65	1.27	0.30	27.35	70.14	67.32	0.06	2.55	3.17
	3.85	716.58	0.89	0.07	3.37	4.92	5.03	0.05	1.48	0.83
	34.00	2295.34	3.10	0.44	32.00	77.90	74.50	0.22	7.296	4.37
	21.00	188.00	0.00	0.16	23.00	62.90	58.40	0.02	1.05	1.68

Pedestrian		Accidents	Normalised Value				EUV		
Ave. Delay	%Delayed	acc./km	Noise	Airpol_CO	Pedest.	Accid.	Measured	Predicted	M-P
4.28	0.63	0.39	76	29	44	12	[illegible]	[illegible]	-43.02
4.06	0.42	0.39	41	50	50	12	[illegible]	[illegible]	-56.59
6.71	0.58	3.33	65	35	82	100	68.95	65.52	3.42
7.81	0.78	3.33	77	20	70	100	65.71	65.84	-0.13
3.90	0.67	0.00	77	15	70	0	[illegible]	[illegible]	4.95
1.95	0.67	0.00	94	38	7	0	[illegible]	[illegible]	-14.60
0.22	0.06	0.06	100	23	20	2	42.50	42.72	-0.21
0.62	0.19	0.06	61	33	83	2	48.72	45.49	3.23
1.45	0.79	0.00	61	100	86	0	[illegible]	[illegible]	8.60
1.47	0.81	0.00	76	53	66	0	[illegible]	[illegible]	13.28
1.24	0.48	0.00	43	8	53	0	[illegible]	[illegible]	-14.08
0.67	0.50	0.00	57	6	30	0	[illegible]	[illegible]	-2.49
3.71	0.29	0.98	55	11	7	29	27.79	15.65	12.14
1.53	0.07	0.98	9	3	2	29	8.71	22.61	-13.90
0.03	0.02	0.00	3	19	0	0	6.29	14.21	-7.92
0.00	0.06	0.00	4	10	53	0	15.45	15.56	-0.11
0.88	0.50	0.39	7	10	32	12	13.60	12.61	0.99
0.35	0.30	0.39	0	11	32	12	11.41	14.10	-2.69
0.35	0.30	0.39	48	12	44	12	31.49	13.86	17.63
1.93	0.41	0.58					34.75	34.27	0.48
2.31	0.28	1.08					20.89	19.19	9.46
13.71	0.95	3.33					68.95	65.84	17.63
0.00	0.00	0.09					6.29	12.61	-14.60

Calibration:

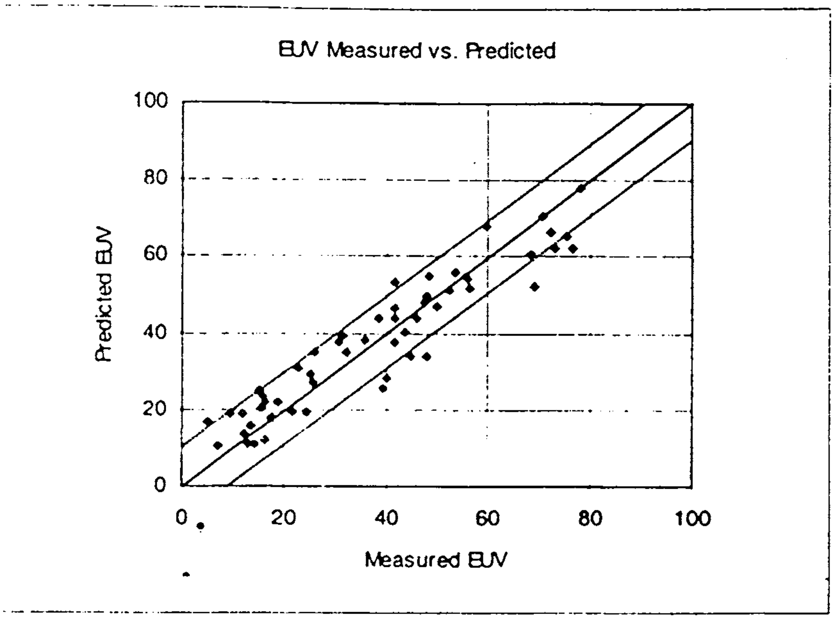

FIGURE F.12 SCATTER PLOT BETWEEN MEASURED AND PREDICTED EUV (CALIBRATION)

TABLE F.17 SUMMARY OF REGRESSION ANALYSIS BETWEEN MEASURED AND PREDICTED EUV (CALIBRATION)

Regression Statistics	
Multiple R	0.97
R Square	0.94
Adjusted R Square	0.94
Standard Error	4.89
Observations	57

ANOVA	*Df*	*SS*	*MS*	*F*	*Significance F*	
Regression	1	21980.25	21980.25	920.199	5.03E-36	
Residual	55	1313.75	23.88			
Total	56	23294.01				
Variables	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.895	1.379	0.649	0.518	-1.868	3.659
Measured	0.979	0.032	30.334	5.03E-36	0.914	1.043

TABLE F.18 SUMMARY STATISTICS OF EUV MODEL PERFORMANCE (CALIBRATION)

EUV	Mean	St. Deviation
Measured	37.77	21.22
Predicted	37.76	18.35
Residual (M-P)	0.01	7.21

Validation:

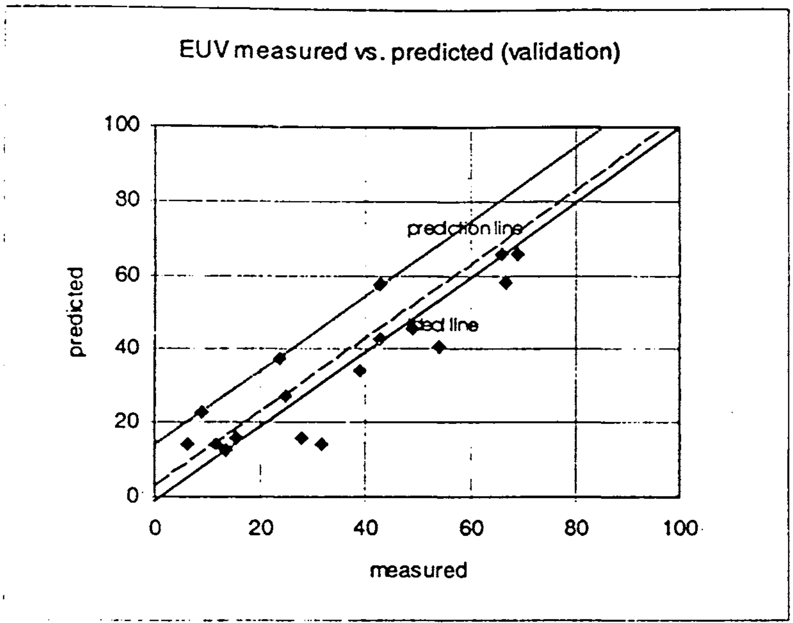

FIGURE F.13 SCATTER PLOT BETWEEN MEASURED AND PREDICTED EUV (VALIDATION)

TABLE F.19 SUMMARY OF REGRESSION ANALYSIS BETWEEN MEASURED AND PREDICTED EUV (VALIDATION)

Regression Statistics						
Multiple R	0.87					
R Square	0.75					
Adjusted R Square	0.73					
Standard Error	10.79					
Observations	17					
ANOVA	*Df*	*SS*	*MS*	*F*	*Significance F*	
Regression	1	5235.82	5235.82	45.00	0.00	
Residual	15	1745.09	116.34			
Total	16	6980.90				
Variables	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-7.03	6.75	-1.04	0.31	-21.43	7.37
Predicted EUV	1.09	0.16	6.71	0.00	0.74	1.43

TABLE F.20 SUMMARY STATISTICS OF EUV MODEL PERFORMANCE (VALIDATION)

EUV	Mean	St. Deviation
Measured	34.75	20.89
Predicted	34.27	19.19
Residual (M-P)	0.48	9.46

Major-Commercial:

TABLE F.21 CORRELATION COEFFICIENTS BETWEEN PARAMETERS (MAJOR-COMMERCIAL)

	Grad(%)	*WindSpd*	*Width*	*Volume*	*%HV*	*Speed*	*EUV*
Grad(%)	1.000						
WindSpd	0.236	1.000					
Width	0.609	-0.034	1.000				
Volume	0.537	0.650	0.631	1.000			
%HV	0.593	-0.097	0.950	0.575	1.000		
Speed	0.262	-0.156	0.214	0.003	0.204	1.000	
EUV	0.550	-0.254	0.952	0.459	0.953	0.337	1.000

	Width	*Volume*	*Speed*	*V/W*	*EUV*
Width	1				
Volume	0.992	1			
Speed	0.259	0.266	1		
V/W	0.978	0.995	0.276	1	
EUV	0.929	0.958	0.420	0.968	1

TABLE F.22 SUMMARY OF REGRESSION ANALYSIS OF EUV MODEL FOR MAJOR-COMMERCIAL CATEGORY

Regression Statistics	
Multiple R	0.85
R Square	0.72
Adjusted R Square	0.62
Standard Error	8.85
Observations	9

ANOVA	*Df*	*SS*	*MS*	*F*	*Significance F*	
Regression	2	1195.665	597.832	7.633	0.022	
Residual	6	469.898	78.316			
Total	8	1665.563				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-8.49	26.15	-0.324	0.756	-72.498	55.514
Speed	0.75	1.055	0.711	0.503	-1.833	3.334
V/W	0.159	0.045	3.497	0.012	0.047	0.270

Major-Residential

TABLE F.23 CORRELATION COEFFICIENTS BETWEEN PARAMETERS (MAJOR-RESIDENTIAL)

	Grad(%)	Temp.	Width	WindSpd	%HV	Speed	Volume	EUV
Grad(%)	1.000							
Temp.	-0.208	1.000						
Width	0.491	-0.107	1.000					
WindSpd	-0.237	0.430	0.183	1.000				
%HV	-0.116	0.106	0.082	0.824	1.000			
Speed	0.578	-0.040	0.376	0.014	0.075	1.000		
Volume	0.723	-0.258	0.828	0.004	0.036	0.616	1.000	
EUV	0.789	-0.232	0.415	0.001	0.098	0.514	0.764	1.000

TABLE F.24 SUMMARY OF REGRESSION ANALYSIS OF EUV MODEL FOR MAJOR-RESIDENTIAL CATEGORY

Regression Statistics	
Multiple R	0.87
R Square	0.76
Adjusted R Square	0.72
Standard Error	10.64
Observations	21

ANOVA	*Df*	*SS*	*MS*	*F*	*Significance F*	
Regression	3	6106.891	2035.63	17.982	1.618E-05	
Residual	17	1924.426	113.201			
Total	20	8031.317				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	14.322	21.457	0.667	0.513	-30.948	59.592
Volume	0.022	0.006	3.793	0.001	0.009	0.035
Speed	1.456	0.733	1.986	0.063	-0.090	3.003
Width	-6.698	1.951	-3.434	0.003	-10.813	-2.582

Local Commercial:

TABLE F.25 CORRELATION COEFFICIENTS BETWEEN PARAMETERS (LOCAL-COMMERCIAL)

	Temp.	*Grad(%)*	*Width*	*WindSpd*	*Volume*	*%HV*	*Speed*	*EUV*
Temp.	1							
Grad(%)	0.601	1.000						
Width	0.152	-0.465	1.000					
WindSpd	0.533	0.618	-0.910	1.000				
Volume	0.619	0.936	-0.698	0.827	1.000			
%HV	0.471	0.278	0.631	-0.348	0.043	1.000		
Speed	0.733	0.902	-0.080	0.345	0.743	0.605	1.000	
EUV	0.595	0.969	-0.415	0.582	0.910	0.346	0.880	1

TABLE F.26 SUMMARY OF REGRESSION ANALYSIS OF EUV MODEL FOR LOCAL-COMMERCIAL CATEGORY

Regression Statistics	
Multiple R	0.957
R Square	0.916
Adjusted R Square	0.888
Standard Error	4.796
Observations	13.000

ANOVA	*Df*	*SS*	*MS*	*F*	*Significance F*
Regression	3.000	2263.614	754.538	32.798	0.000
Residual	9.000	207.050	23.006		
Total	12.000	2470.664			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-36.183	18.630	-1.942	0.084	-78.328	5.962
Volume	0.036	0.009	3.799	0.004	0.014	0.057
Width	0.737	2.337	0.315	0.760	-4.550	6.024
Speed	1.265	0.398	3.179	0.011	0.365	2.165

Local-Residential:

TABLE F.27 CORRELATION COEFFICIENTS BETWEEN PARAMETERS (LOCAL-RESIDENTIAL)

	Temp.	*Grad(%)*	*Width*	*WindSpd*	*Volume*	*%HV*	*Speed*	*EUV*
Temp.	1.000							
Grad(%)	0.299	1.000						
Width	-0.299	0.207	1.000					
WindSpd	0.209	-0.288	-0.586	1.000				
Volume	-0.103	0.101	0.422	-0.192	1.000			
%HV	0.143	0.858	0.113	-0.094	-0.022	1.000		
Speed	-0.431	-0.580	0.403	-0.027	0.209	-0.400	1.000	
EUV	-0.235	0.009	0.112	-0.273	0.798	-0.048	0.168	1.000

TABLE F.28 SUMMARY OF REGRESSION ANALYSIS OF EUV MODEL FOR LOCAL-RESIDENTIAL CATEGORY

Regression Statistics						
Multiple R	0.846					
R Square	0.715					
Adjusted R Square	0.644					
Standard Error	7.627					
Observations	16					
ANOVA	*Df*	*SS*	*MS*	*F*	*Significance F*	
Regression	3	1751.289	583.763	10.035	0.001	
Residual	12	698.069	58.172			
Total	15	2449.359				
Variables	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	13.273	18.345	0.724	0.483	-26.697	53.243
Volume	0.045	0.008	5.371	0.000	0.026	0.063
Width	-4.014	2.308	-1.739	0.108	-9.042	1.014
Speed	0.392	0.644	0.609	0.554	-1.010	1.795

Appendix G

APPENDIX G:

SITE PHOTOGRAPHS

TABLE G.1 SITE CODES AND SURVEY SCHEDULE

No	Site Code	Link Name	Road Class	Land-use	Date of Survey	Session	Remarks
1.	Ac01	Jl. Setia Budi	arterial	commercial	Mon, 22/9/97	p.m.	
2.	Ac02	Jl. Asia Afrika	arterial	commercial	Fri, 26/9/97	p.m.	Data loss
2a.	Ac02a	Jl. Hasan Mustafa (Suci)	arterial	commercial	Mon, 13/10/97	a.m.	Replacement
3.	Ac03	Jl. Ahmad Yani (Cicadas)	arterial	commercial	Tue, 30/9/97	a.m.	
4.	Am01	Jl. H. Juanda (Dago)	arterial	mix	Thu, 25/9/97	a.m.	
5.	Am02	Jl. Moh. Ramdhan	arterial	mix	Mon, 29/9/97	p.m.	
6.	Am03	Jl. Martadinata (Riau)	arterial	mix	Wed, 1/10/97	p.m.	
7.	Ar01	Jl. Sukajadi	arterial	residential	Tue, 23/9/97	p.m.	
8.	Ar02	Jl. Cipaganti	arterial	residential	Wed, 24/9/97	p.m.	
9.	Ar03	Jl. Gatot Subroto	arterial	residential	Sat, 27/9/97	p.m.	
10.	Cc01	Jl. Geger Kalong Hilir	collector	commercial	Mon, 22/9/97	a.m.	
11.	Cc02	Jl. Moh. Thaha	collector	commercial	Fri, 3/10/97	p.m.	
12.	Cc03	Jl. Pagarsih	collector	commercial	Tue, 7/10/97	a.m.	
13.	Cc04	Jl. Ciwastra	collector	commercial	Thu, 9/10/97	p.m.	
14.	Cm01	Jl. Dipati Ukur	collector	mix	Thu, 25/9/97	p.m.	
15.	Cm02	Jl. Gandapura	collector	mix	Thu, 2/10/97	p.m.	
16.	Cm03	Jl. Burangrang	collector	mix	Sat, 4/10/97	p.m.	
17.	Cm04	Jl. Tubagus Ismail	collector	mix	Fri, 10/10/97	p.m.	
18.	Cr01	Jl. Karawitan	collector	residential	Mon, 6/10/97	a.m.	
19.	Cr02	Jl. Reog	collector	residential	Wed, 8/10/97	p.m.	
20.	Cr03	Jl. Sriwijaya	collector	residential	Sat, 11/10/97	a.m.	
21.	Cr04	Jl. Banteng	collector	residential	Sat, 11/10/97	p.m.	
22.	Lc01	Jl. Purwakarta	local	commercial	Tue, 30/9/97	p.m.	
23.	Lc02	Jl. H. Kurdi	local	commercial	Fri, 3/10/97	a.m.	
24.	Lc03	Jl. Solontongan	local	commercial	Mon, 6/10/97	p.m.	
25.	Lc04	Jl. Suryani	local	commercial	Tue, 7/10/97	p.m.	
26.	Lc05	Jl. Sawah Kurung	local	commercial	Mon, 29/9/97	a.m.	
27.	Lm01	Jl. Jurang	local	mix	Tue, 23/9/97	a.m.	
28.	Lm02	Jl. Palasari	local	mix	Sat, 27/9/97	a.m.	
29.	Lm03	Jl. Kinanti	local	mix	Wed, 8/10/97	a.m.	
30.	Lm04	Jl. Logam	local	mix	Thu, 9/10/97	a.m.	
31.	Lm05	Jl. Imam Bonjol	local	mix	Fri, 10/10/97	a.m.	
32.	Lr01	Jl. Sejahtera	local	residential	Wed, 24/9/97	a.m.	
33.	Lr02	Jl. Vandeventer	local	residential	Fri, 26/9/97	a.m.	
34.	Lr03	Jl. Bahureksa	local	residential	Wed, 1/10/97	a.m.	
35.	Lr04	Jl. Patrakomala	local	residential	Thu, 2/10/97	a.m.	
36.	Lr05	Jl. Halimun	local	residential	Sat, 4/10/97	a.m.	

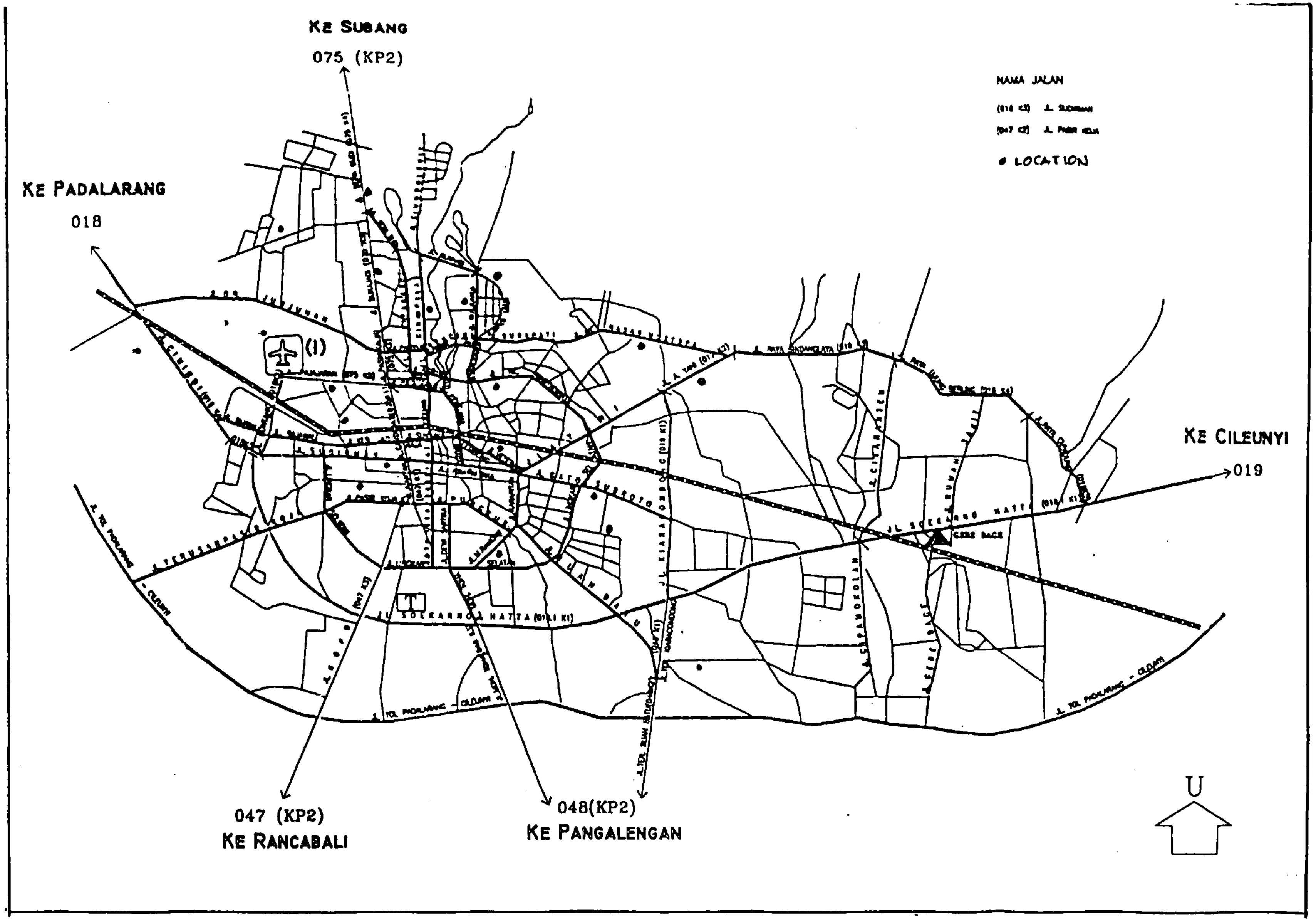

FIGURE G.1 SITE LOCATIONS IN THE STUDY AREA

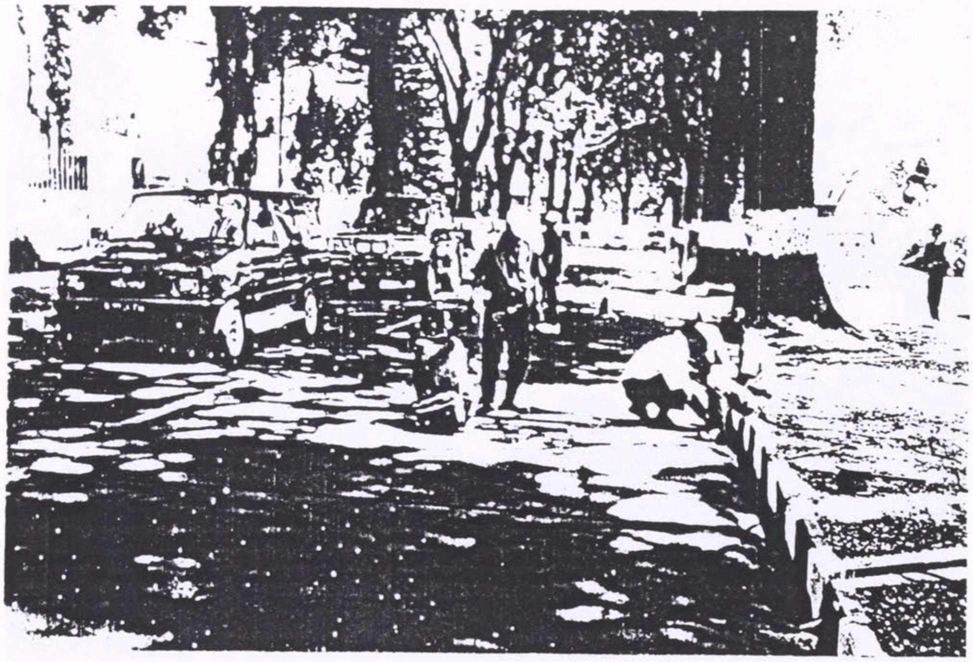

PLATE G.1 TRAFFIC SURVEY	INSTALLATION

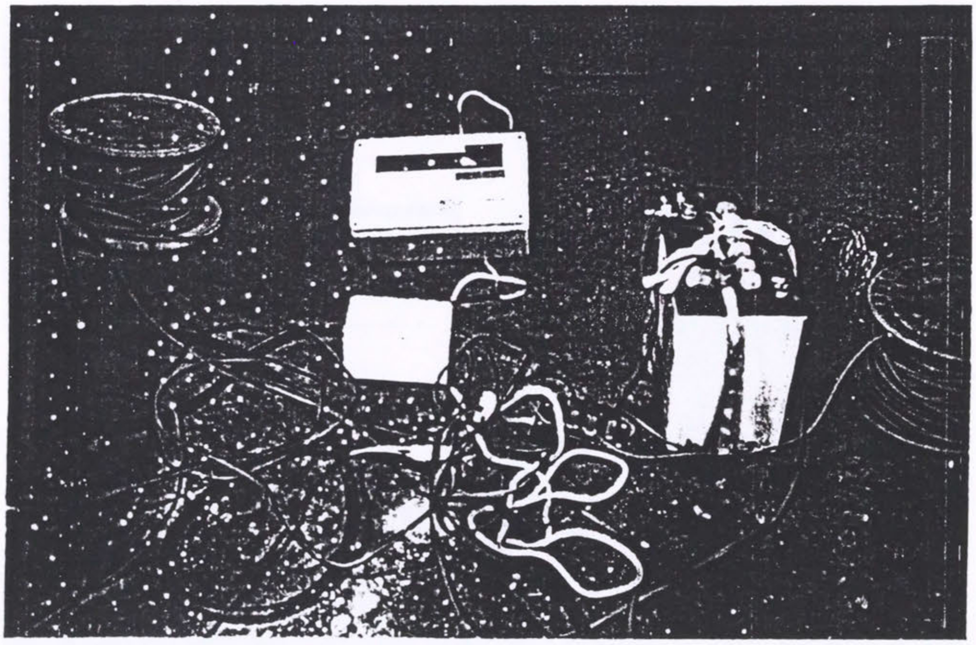

PLATE G.2 TRAFFIC SURVEY	DATA LOGGER

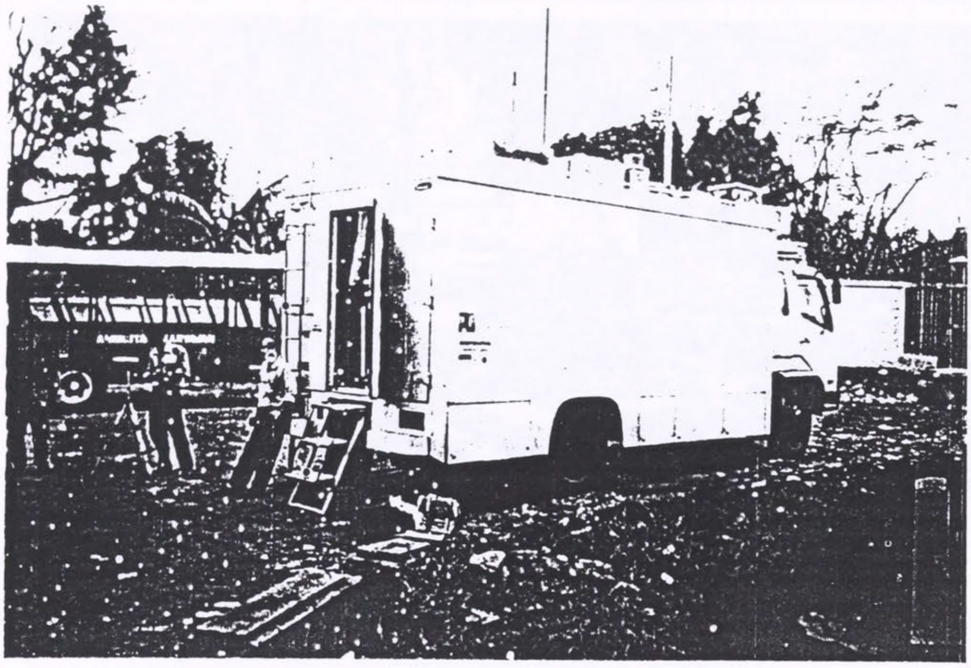

PLATE G.3 AIR POLLUTION	MOBILE LABORATORY

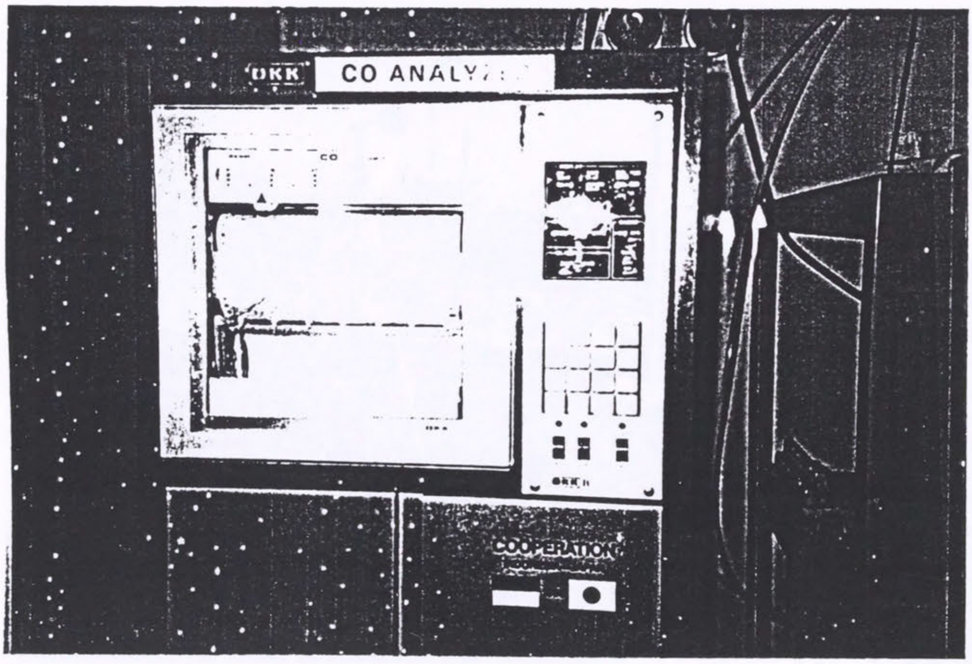

PLATE G.4 AIR POLLUTION	CO ANALYZER

PLATE G.5 NOISE	INSTALLATION

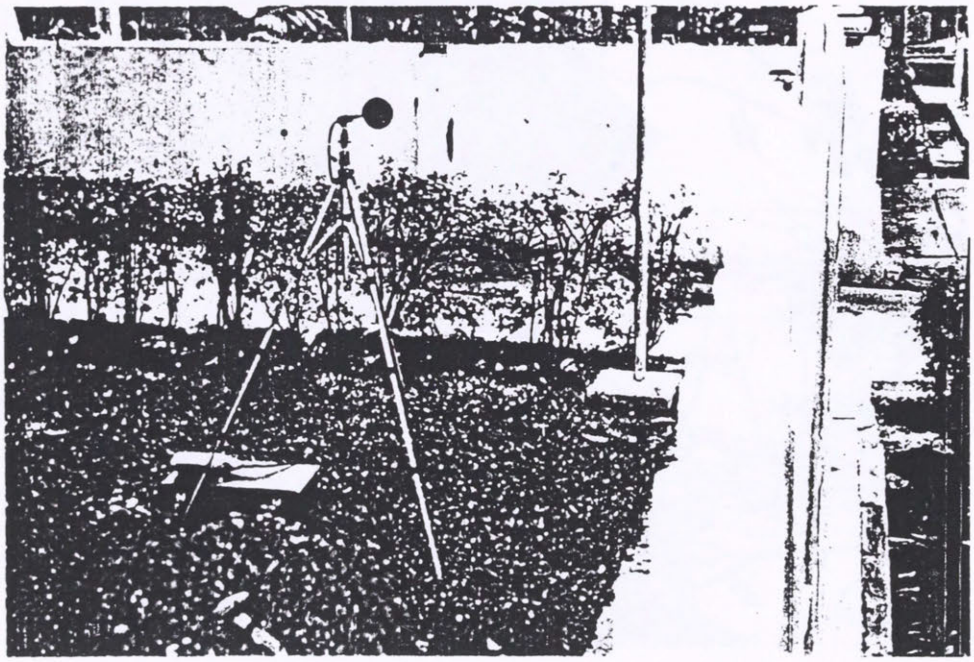

PLATE G.6 NOISE	MEASUREMENT

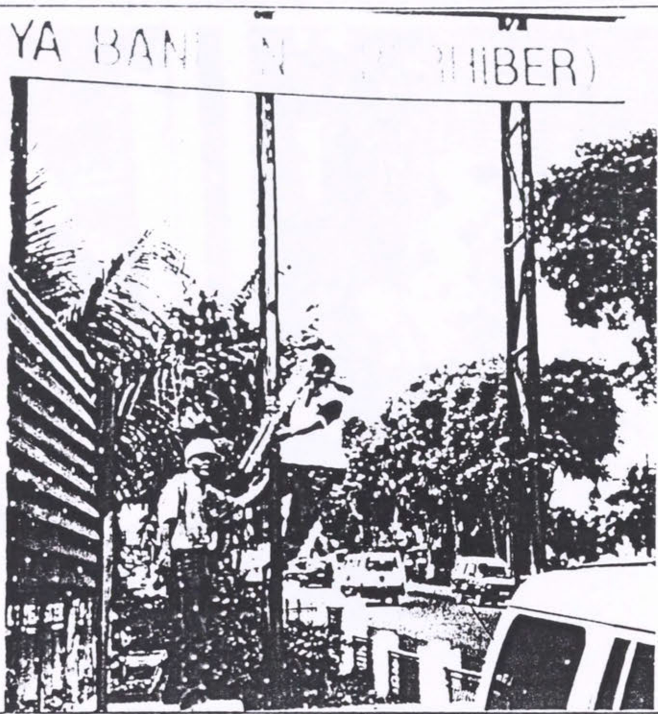

PLATE G.7 PEDESTRIAN	INSTALLATION

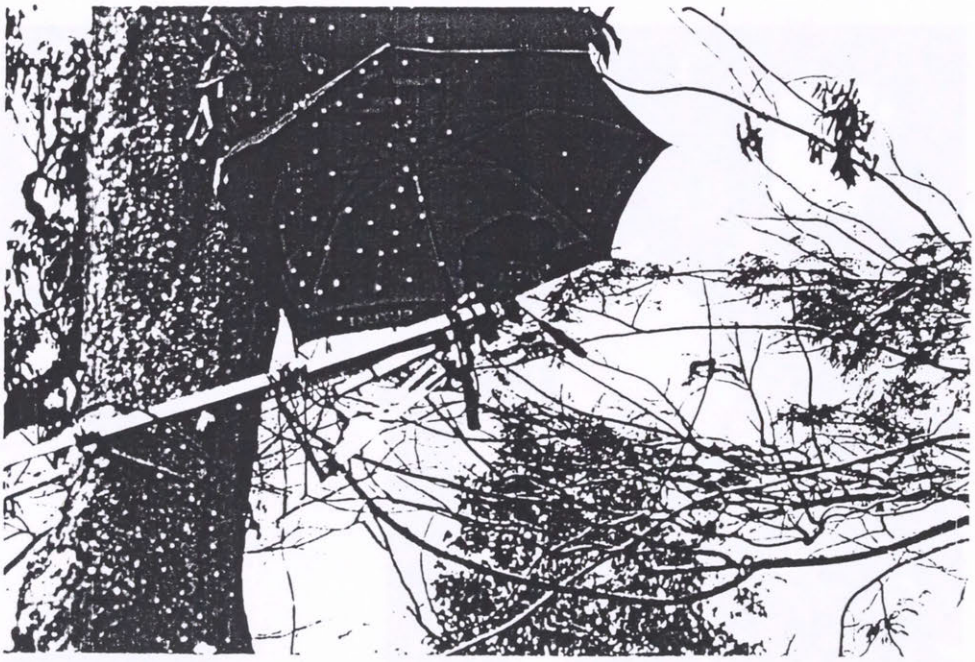

PLATE G.8 PEDESTRIAN	OBSERVATION

PLATE G.9 INTERVIEW	HOUSEHOLD

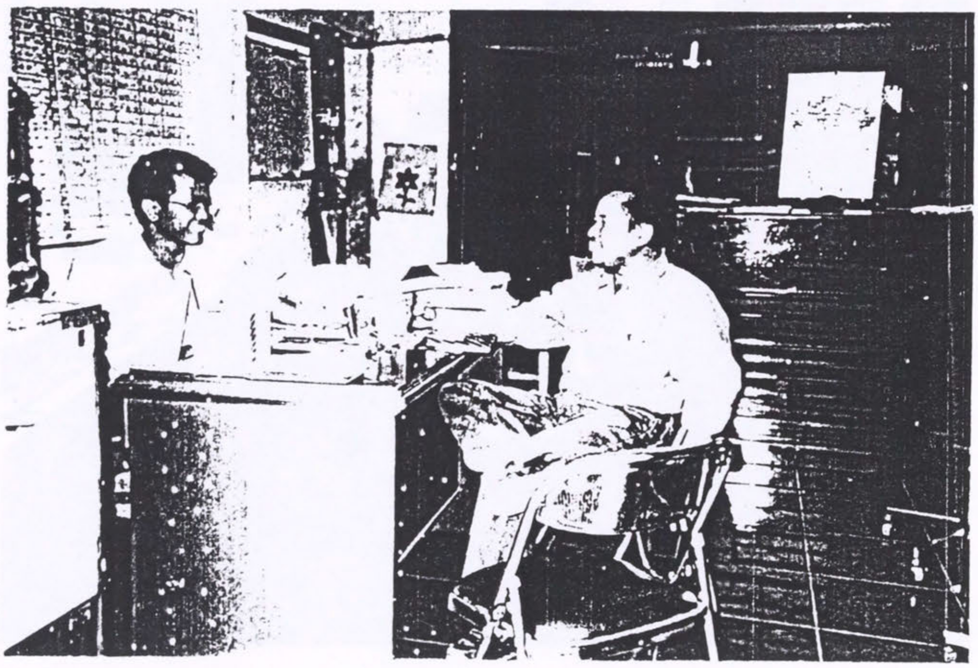

PLATE G.10 INTERVIEW	OFFICE

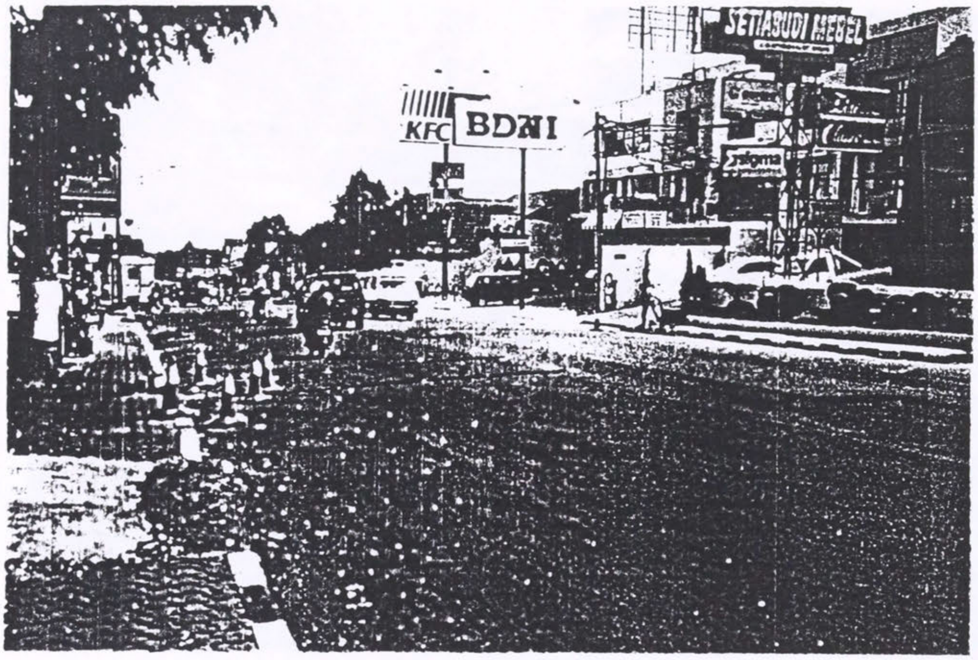

PLATE G.11 SITE AC01	JL.SETIABUDI

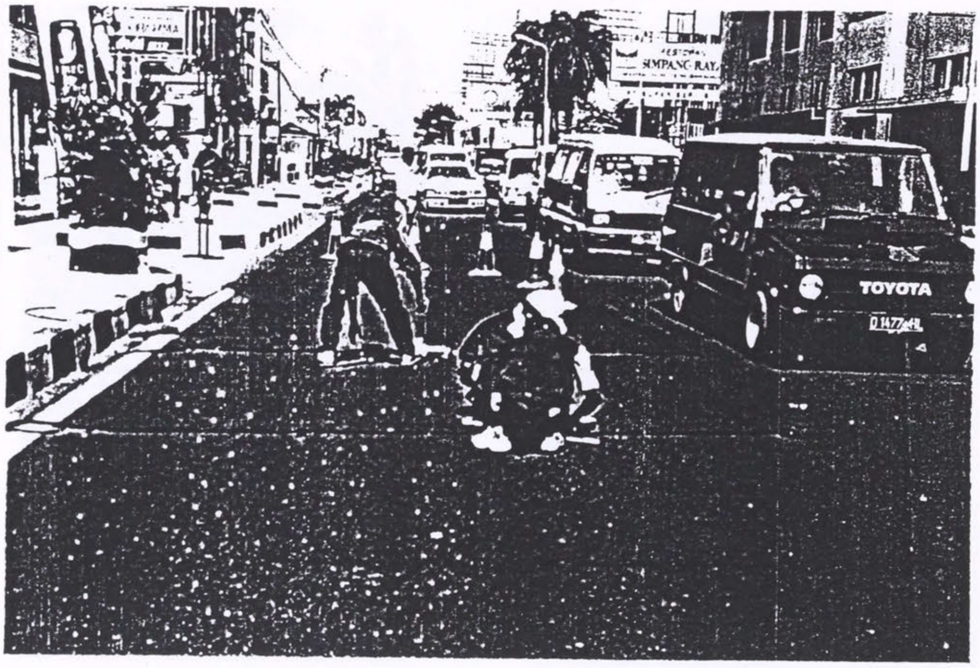

PLATE G.12 SITE AC02	JL. ASIA AFRIKA

PLATE G.13 SITE AC03	JL.A. YANI

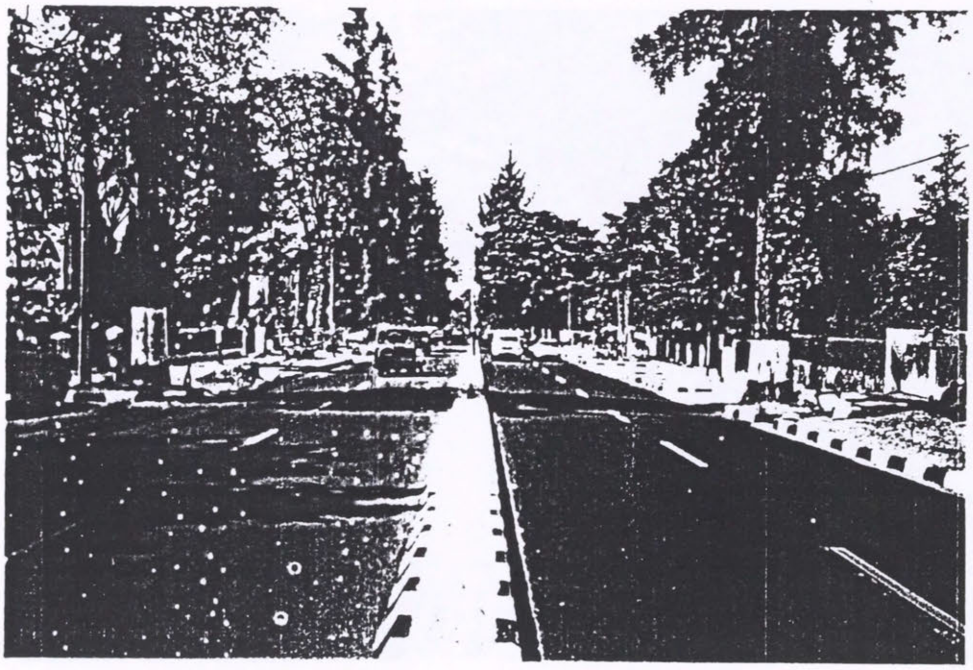

PLATE G.14 SITE AM01	JL. H. JUANDA

PLATE G.15 SITE AM02	JL. MOH. RAMDHAN

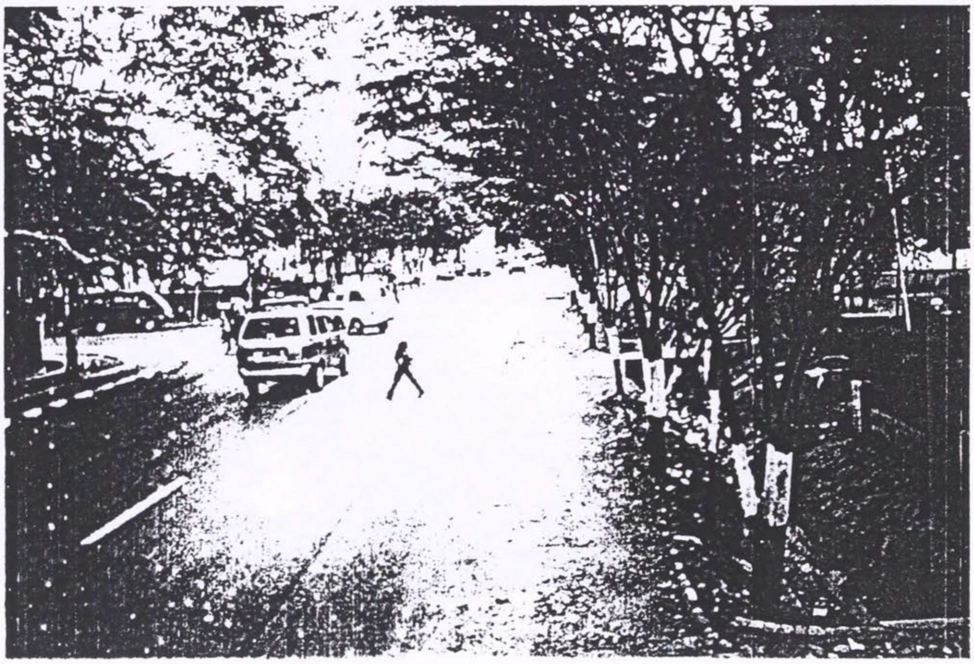

PLATE G.16 SITE AM03	JL. MARTADINATA

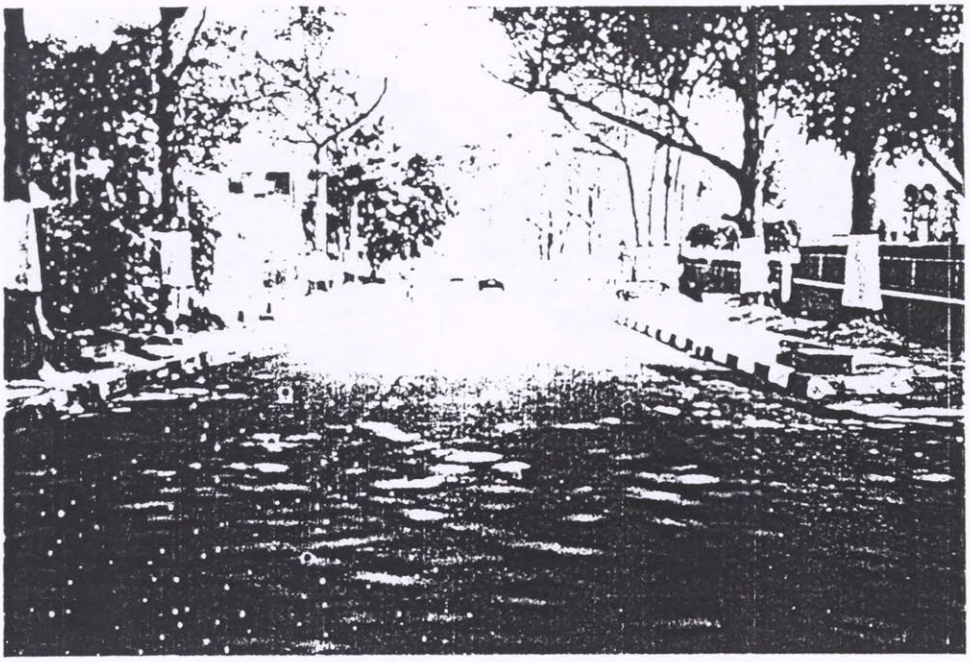

PLATE G.17 SITE AR01	JL.SUKAJADI

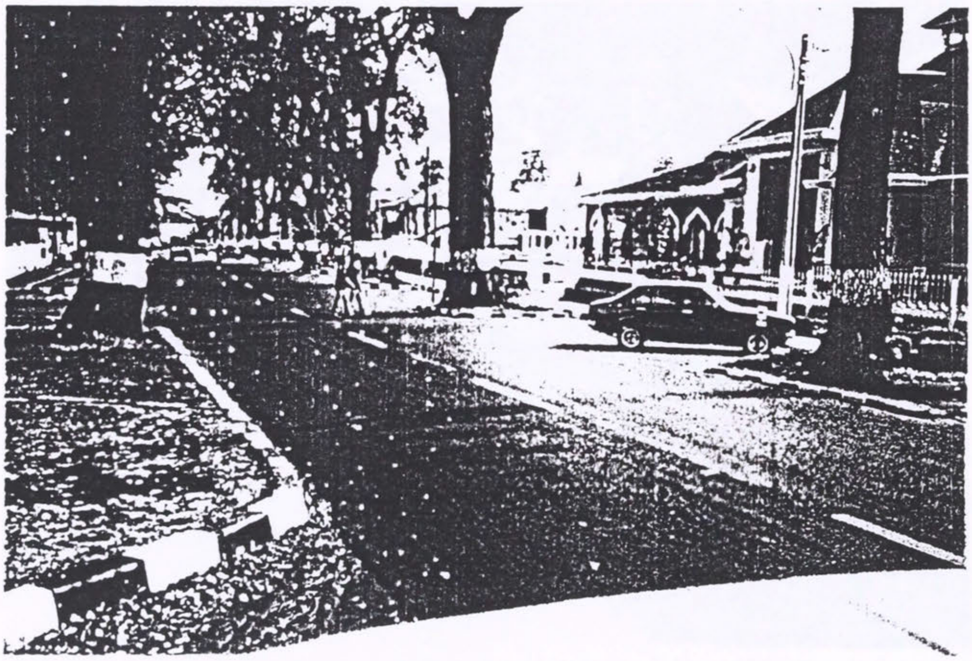

PLATE G.18 SITE AR02	JL. CIPAGANTI

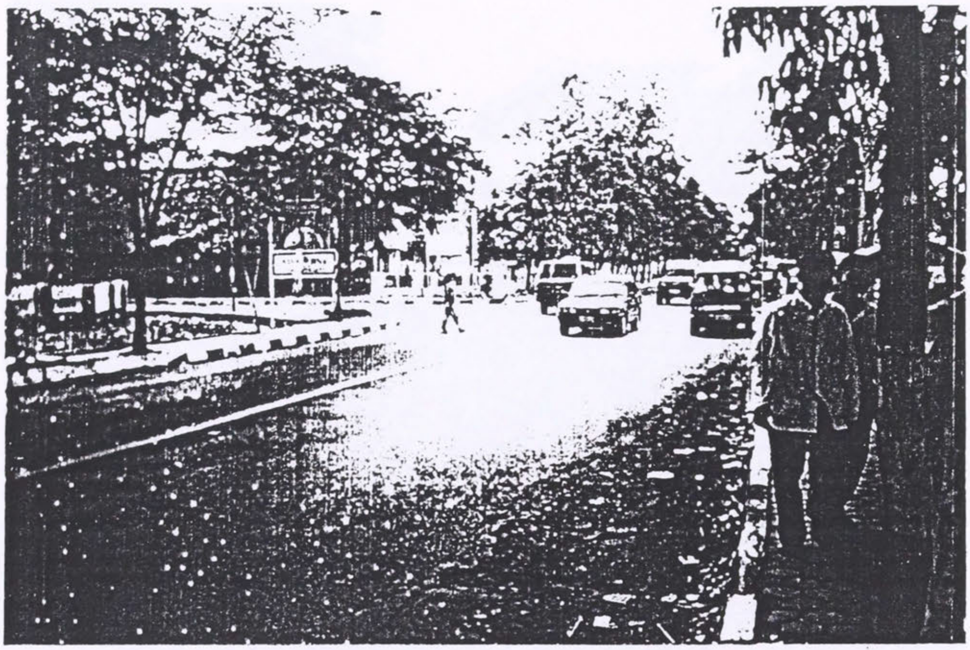

PLATE G.19 SITE AR03	JL. GATOT SUBROTO

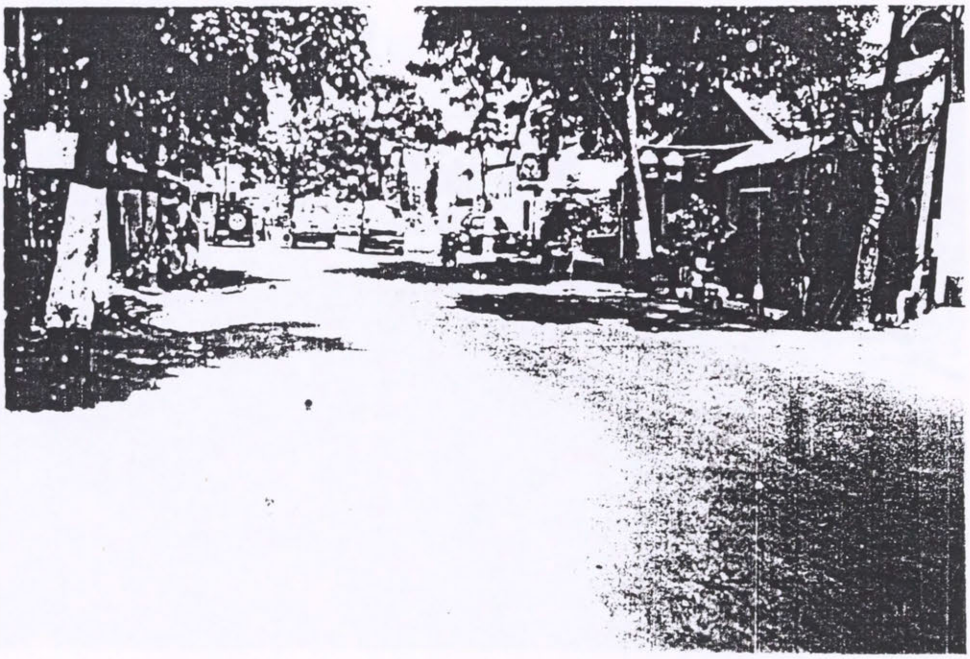

PLATE G.20 SITE CC01	JL. GEGER KALONG HILIR

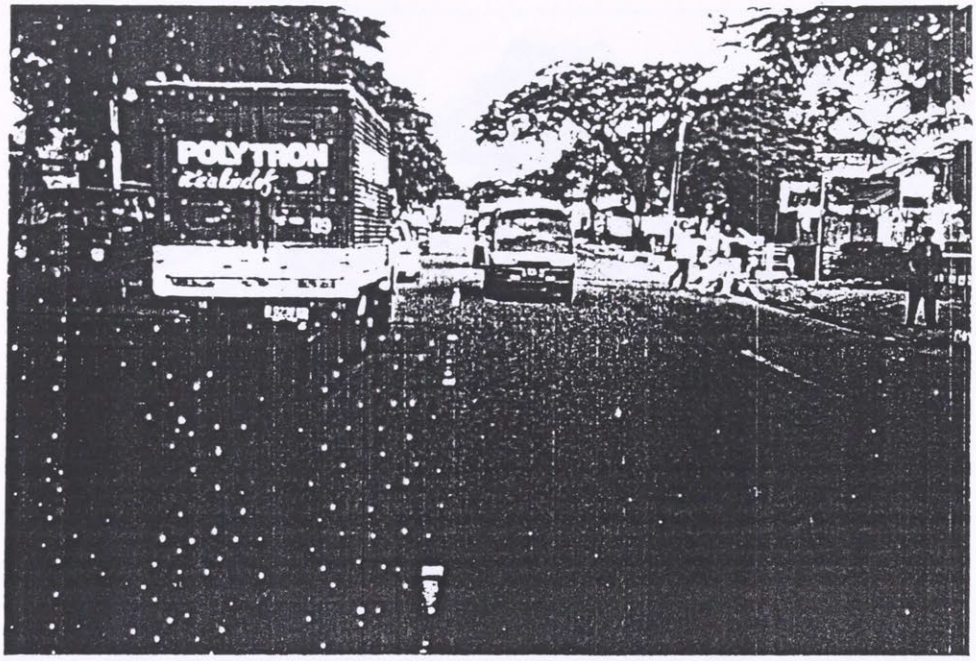

PLATE G.21 SITE Cc02	JL. MOH. THAHA

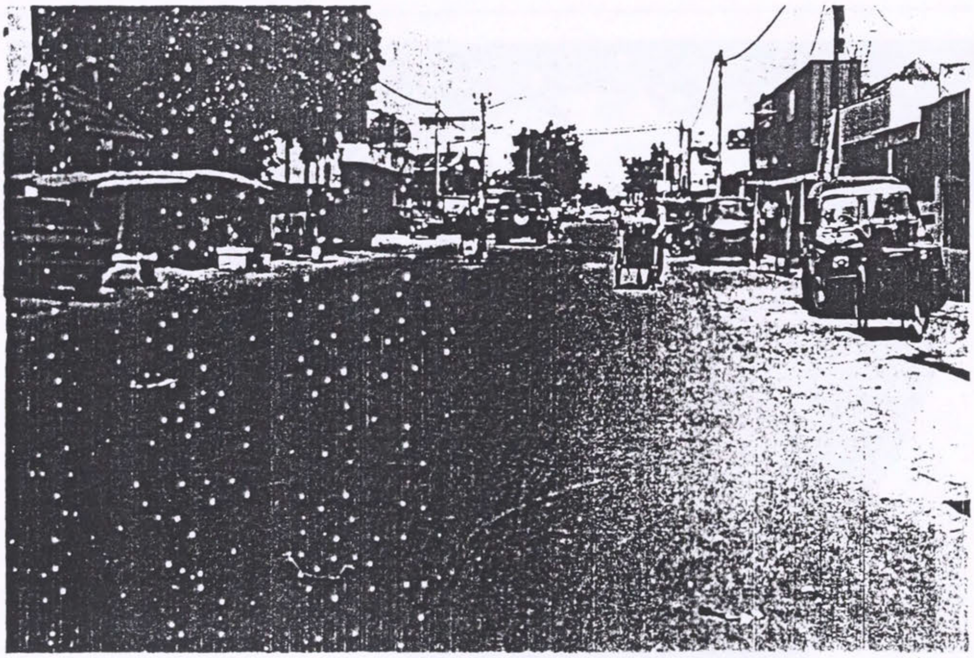

PLATE G.22 SITE Cc03	JL. PAGARSIH

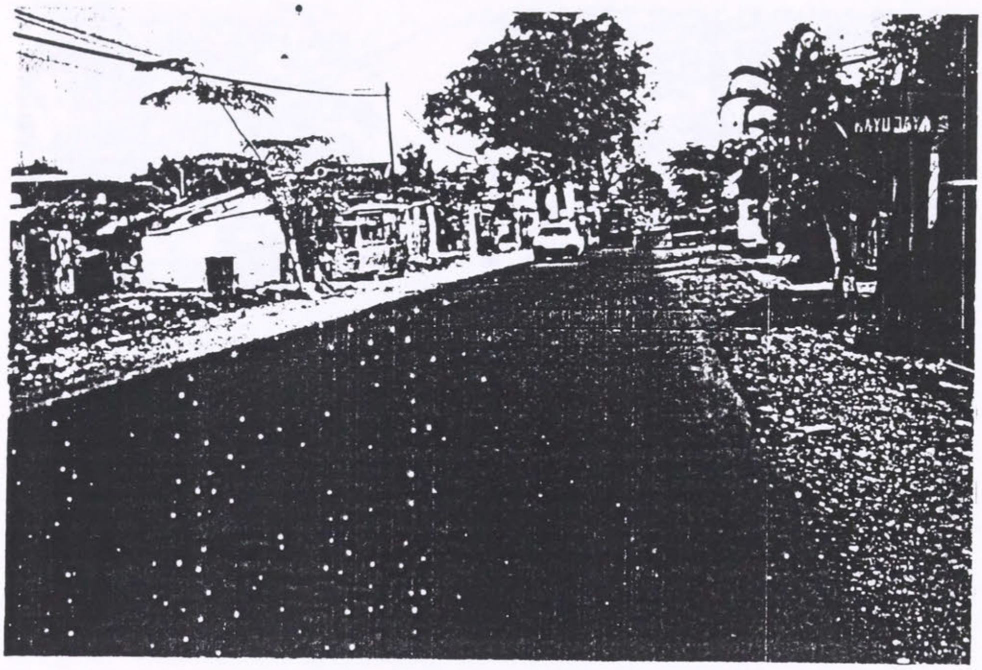

PLATE G.23 SITE Cc04	JL. CIWASTRA

PLATE G.24 SITE CM01	JL. DIPATI UKUR

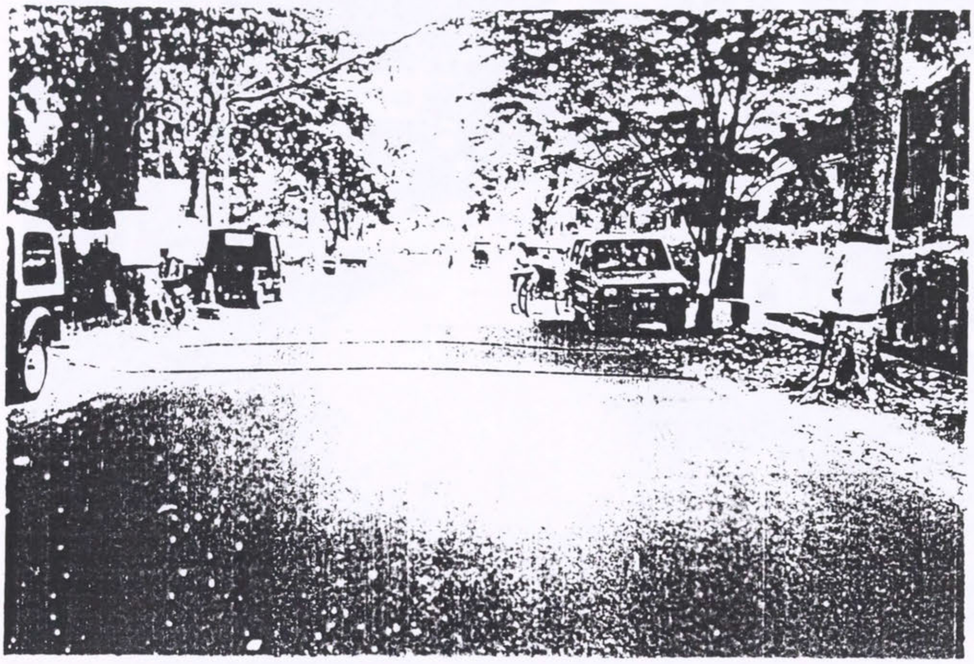

PLATE G.25 SITE CM02	JL. GANDAPURA

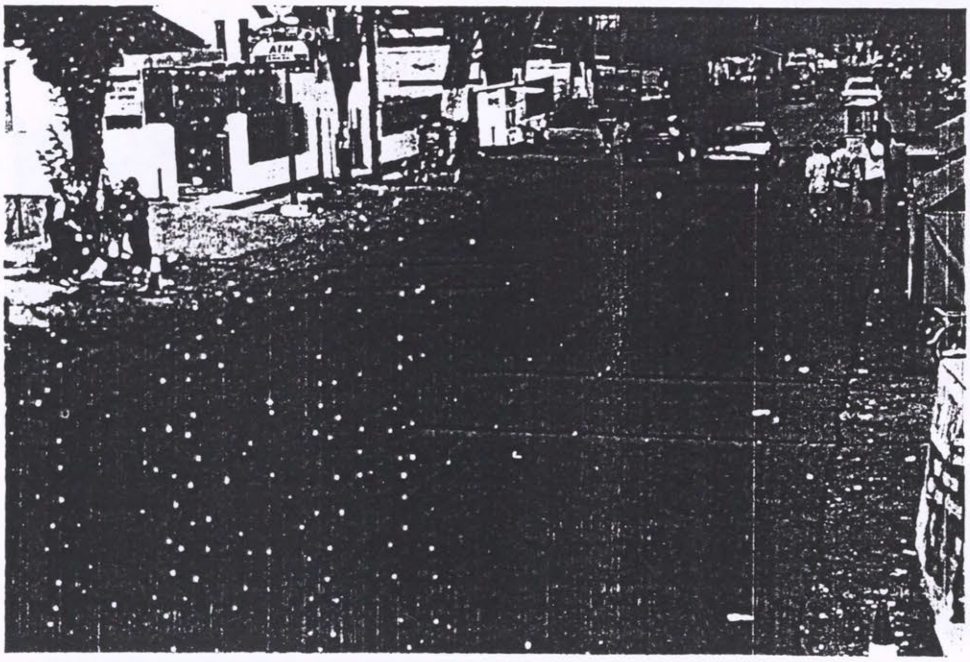

PLATE G.26 SITE CM03	JL. BURANGRANG

PLATE G.27 SITE CM04	JL. TUBAGUS ISMAIL

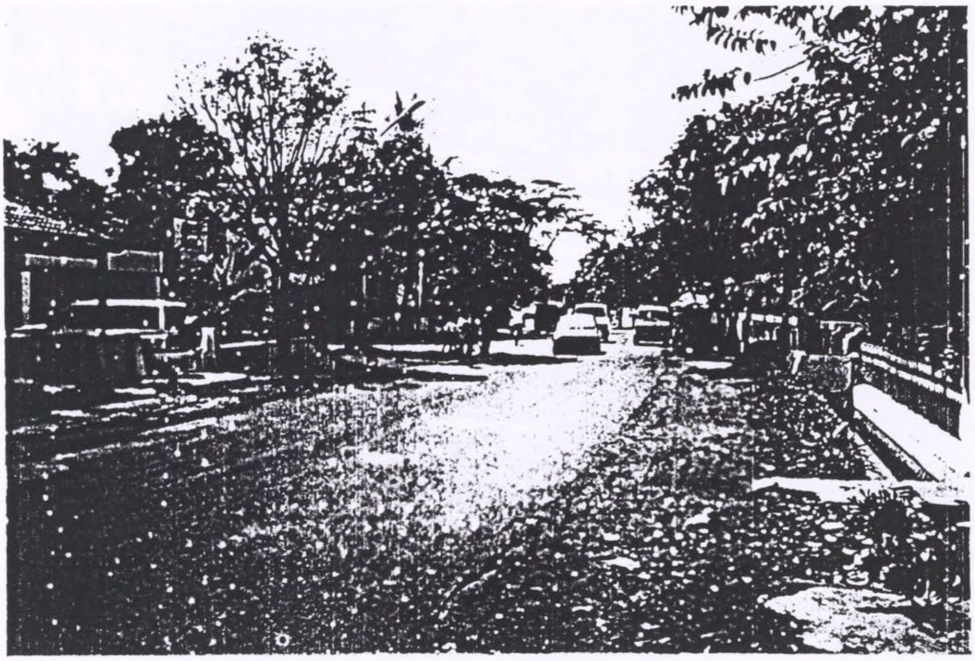

PLATE G.28 SITE CR01	JL. KARAWITAN

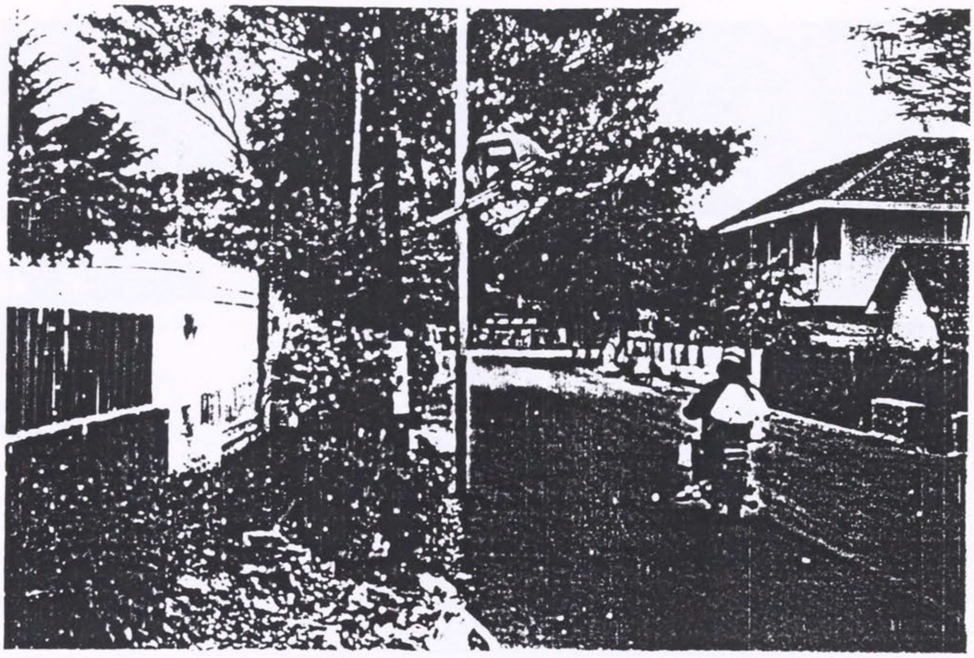

PLATE G.29 SITE CR02	JL. REOG

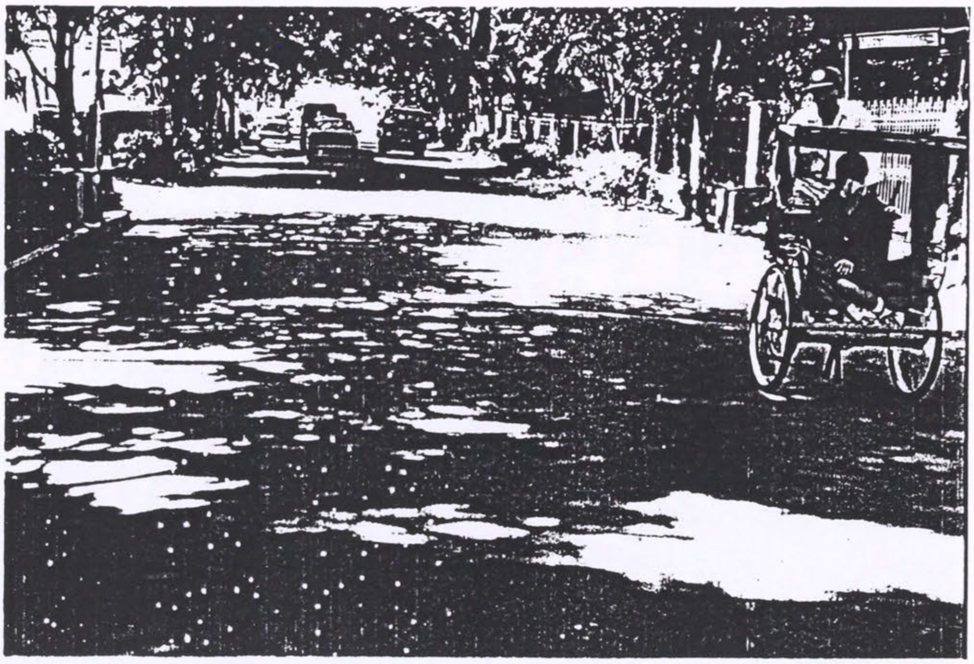

PLATE G.30 SITE CR03	JL. SRIWIJAYA

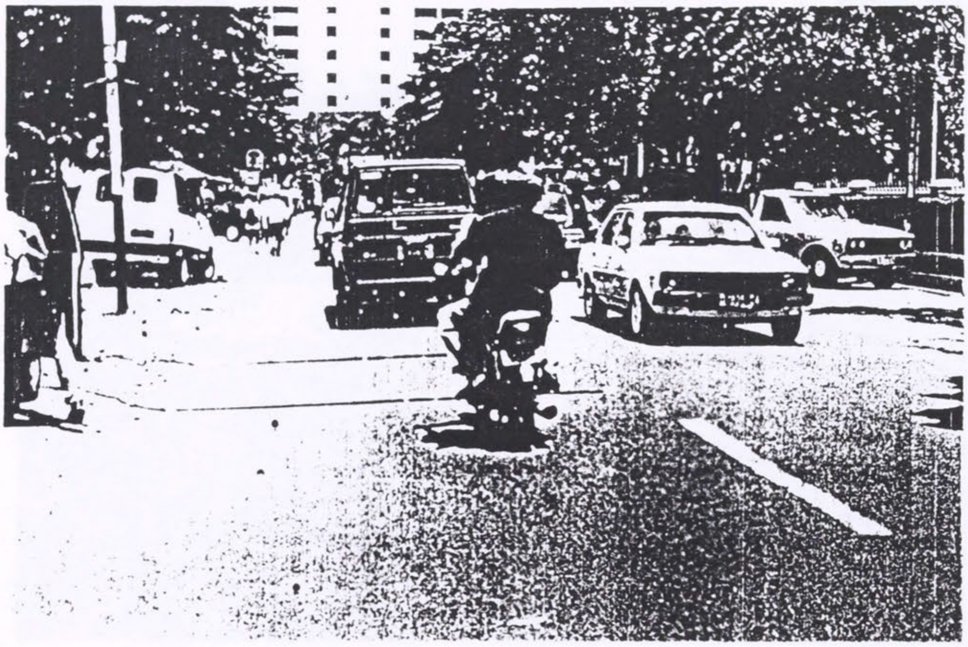

PLATE G.31 SITE CR04	JL. BANTENG

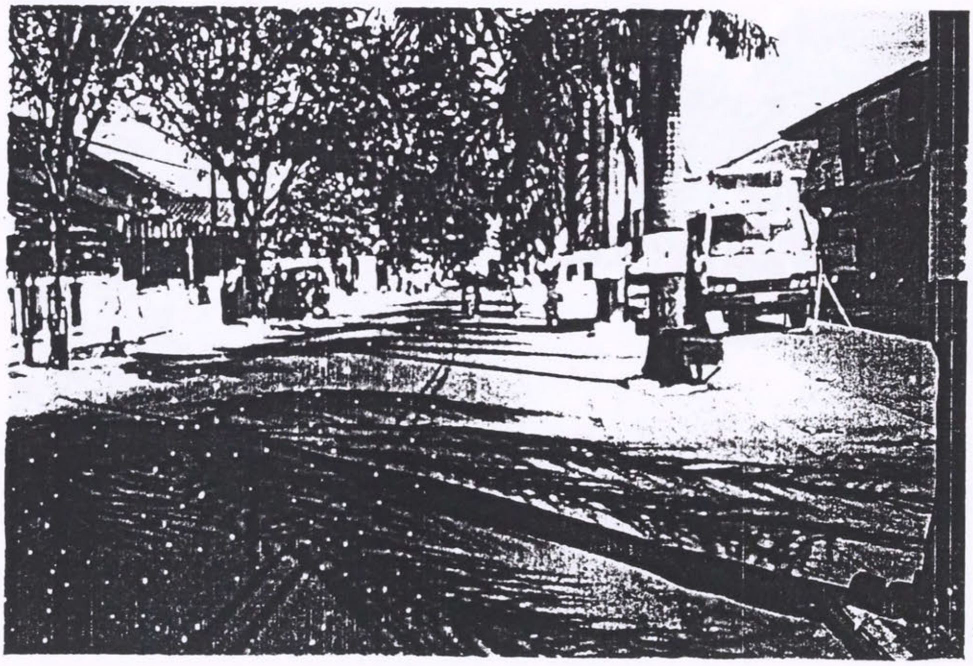

PLATE G.32 SITE LC01	JL. PURWAKARTA

PLATE G.33 SITE LC02	JL. H. KURDI

PLATE G.34 SITE LC03	JL. SOLONTONGAN

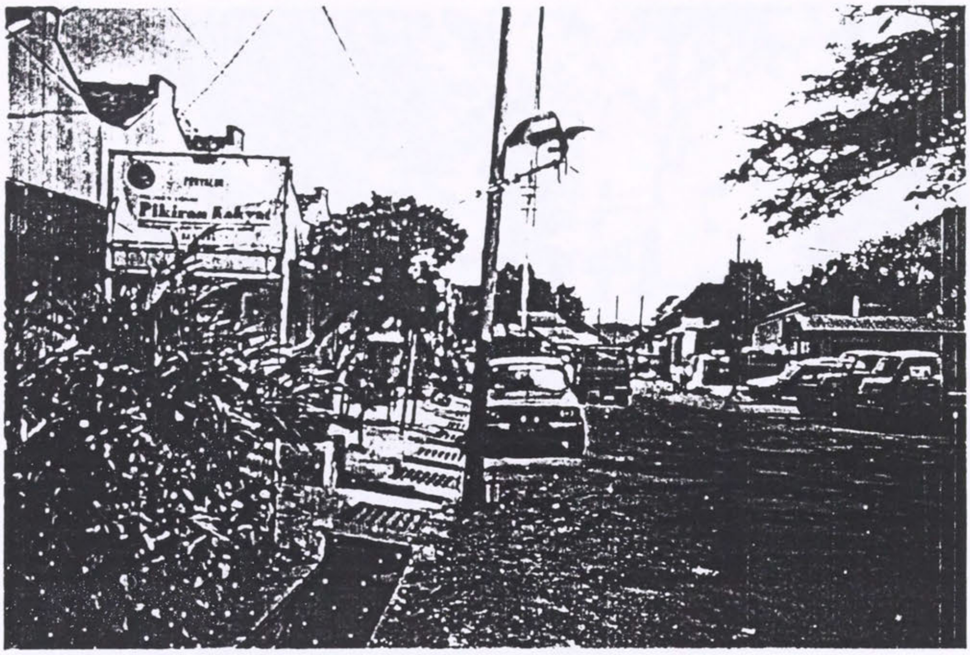

PLATE G.35 SITE LC04	JL. SURYANI

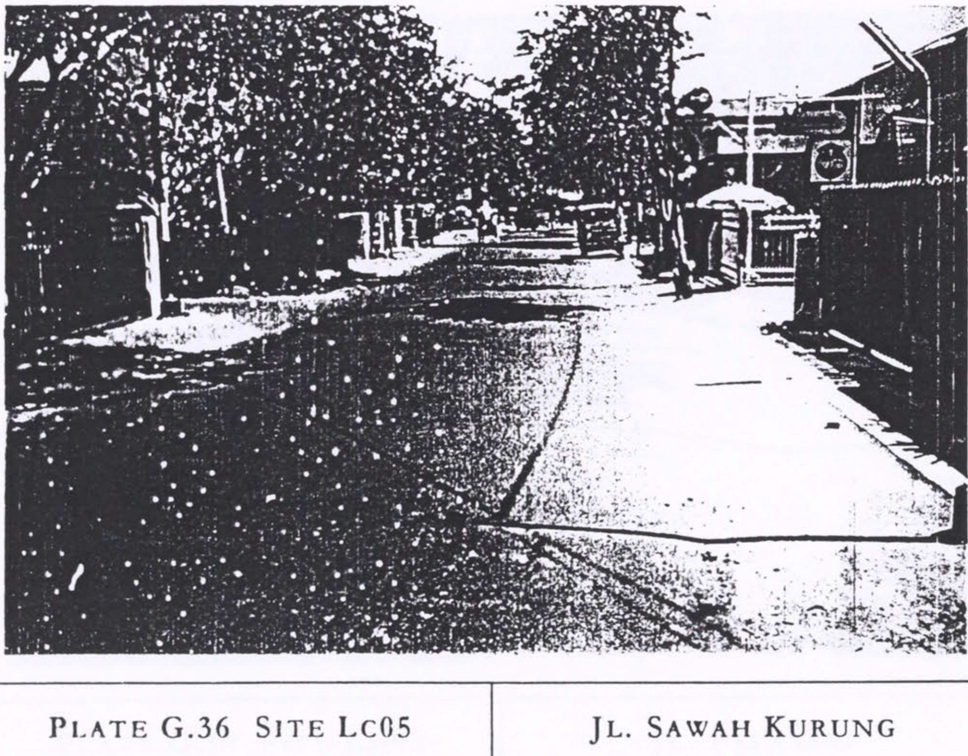

PLATE G.36 SITE LC05	JL. SAWAH KURUNG

PLATE G.37 SITE LM01	JL. JURANG

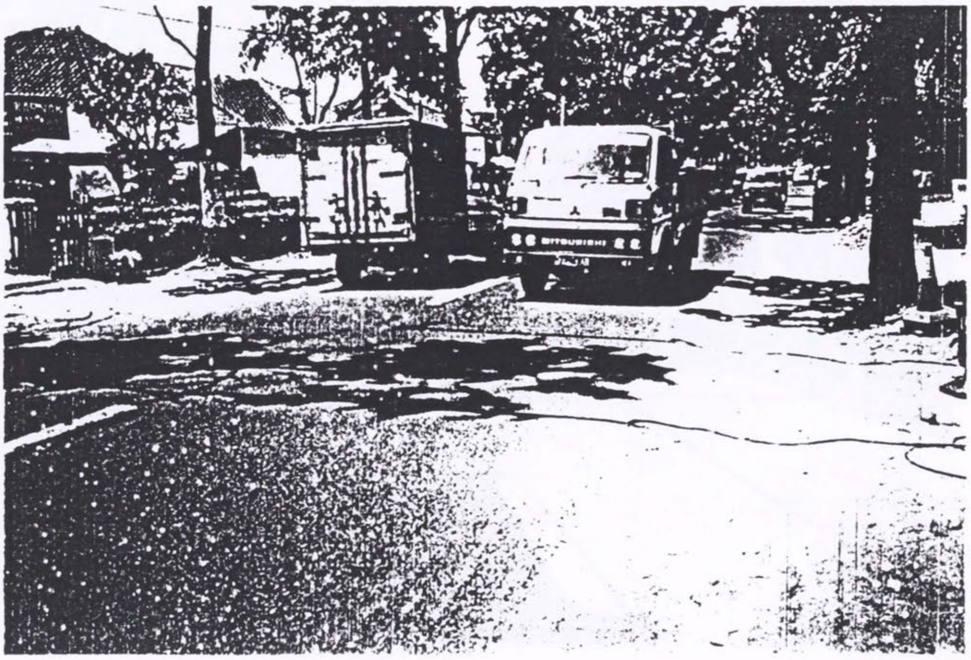

PLATE G.38 SITE LM02	JL. PALASARI

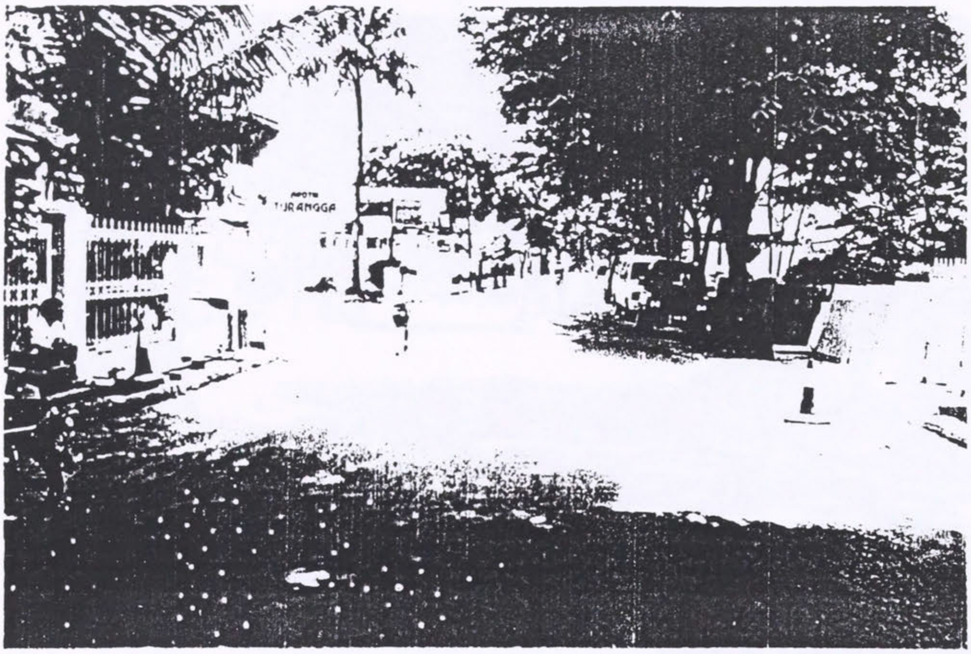

PLATE G.39 SITE LM03	JL. KINANTI

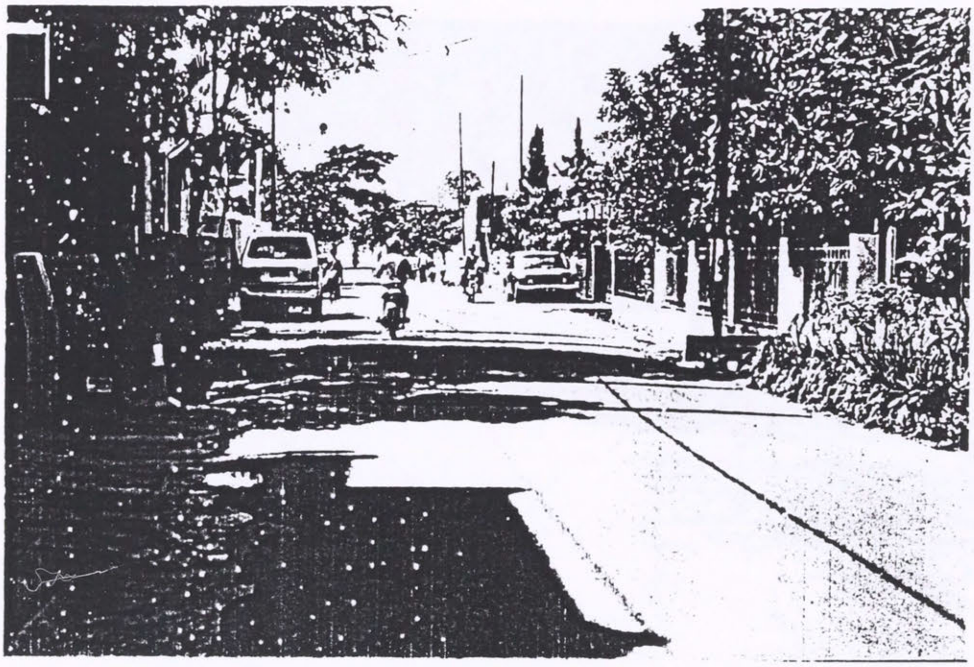

PLATE G.40 SITE LM04	JL. KINANTI

PLATE G.41 SITE LM05	JL. IMAM BONJOL

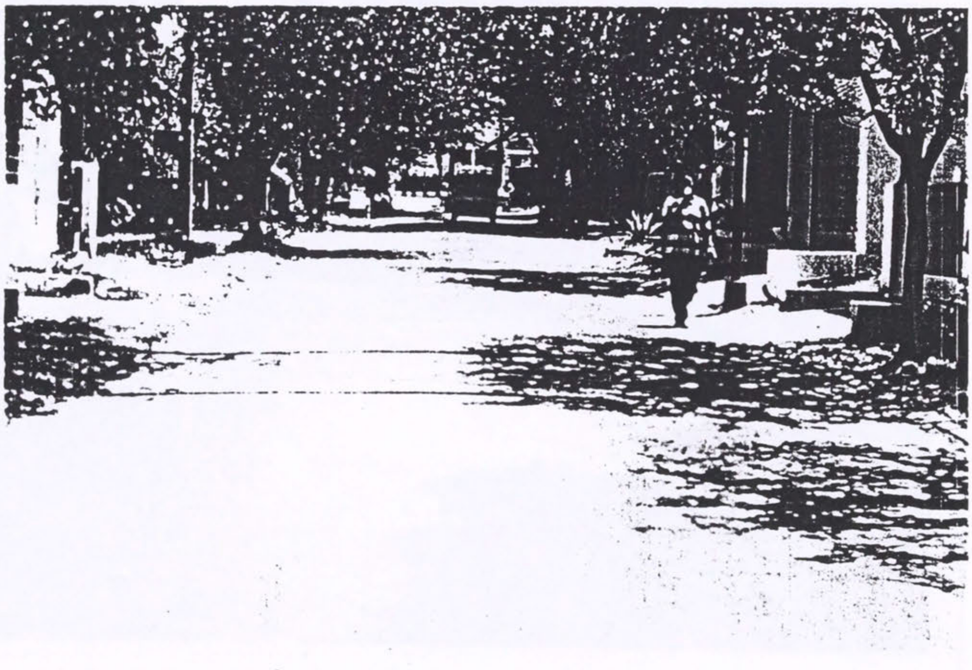

PLATE G.42 SITE LR01	JL. SEJAHTERA

PLATE G.43 SITE LR02	JL. VAN DE VENTER

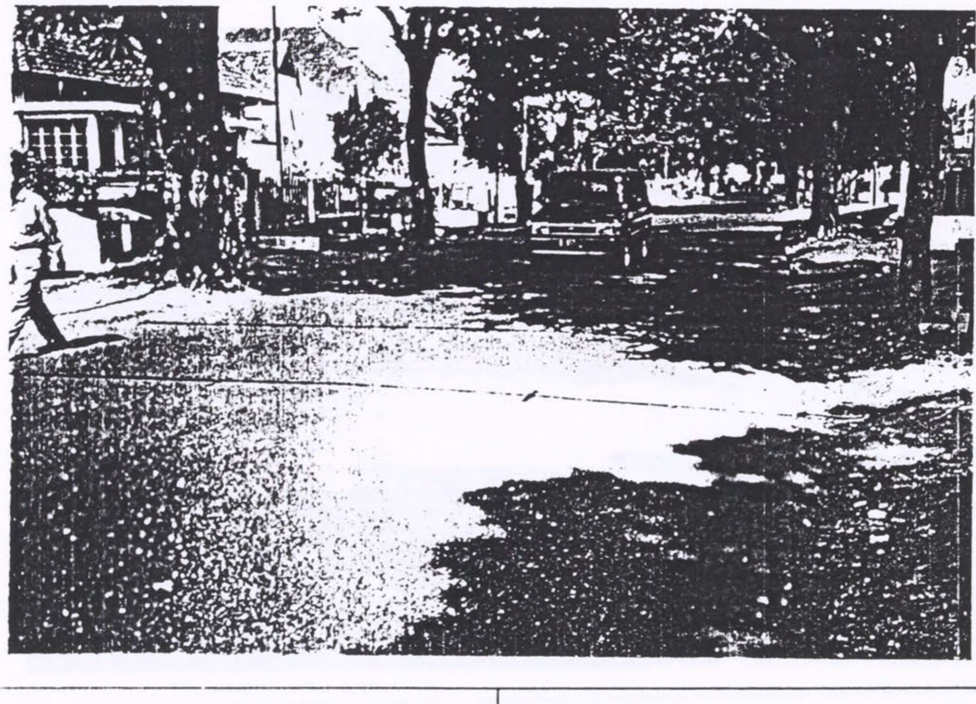

PLATE G.44 SITE LR03	JL. BAHUREKSA

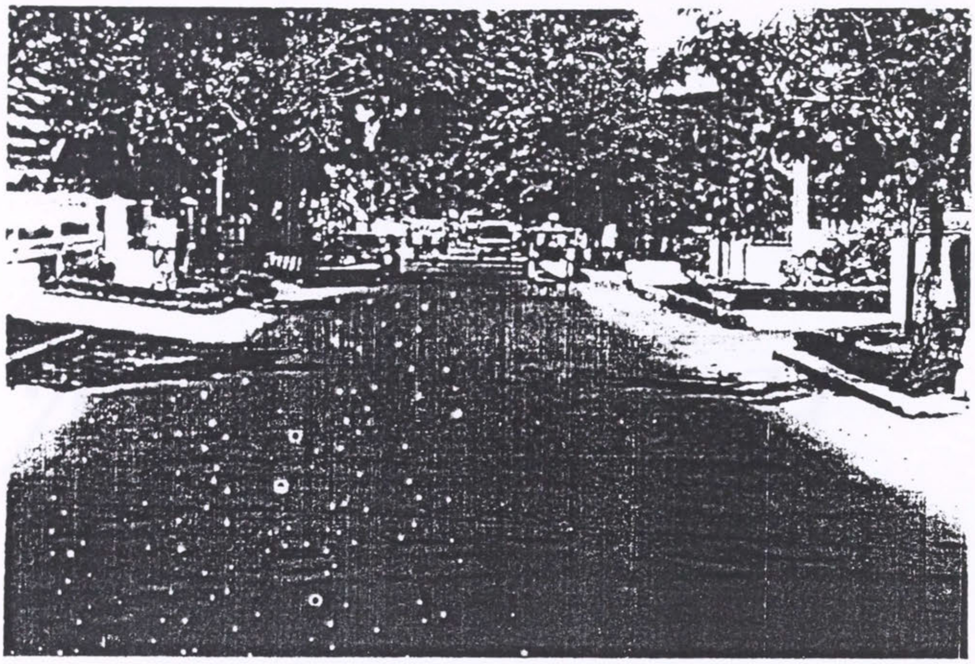

PLATE G.45 SITE LR04	JL. PATRAKOMALA

PLATE G.46 SITE LR05	JL. HALIMUN

Appendix H

APPENDIX H:

PUBLISHED PAPERS

This appendix documents papers written in regards of the materials covered in the present study. The papers were all published and presented in well-known regional and international road and transport conferences such as ARRB and REAAA in 1998. There was also one joint paper published earlier in Singapore.

Widiantono, D. and Samuels, S.E. (1998). Quantifying Community and Experts Preferences Towards Road Traffic Related Environmental Factors. *Proceedings of 19th ARRB Conference*, Sydney,7-10 December.

Widiantono, D. and Samuels, S.E. (1998). Towards A General Model of Environmental Capacity of Roads. *Proceedings of 9TH REAAA Conference*, Wellington 3-8 May.

Black, J.A, Guo, X.P., Hidas, P., Samuels, S.E., Shiran, G.R., Wdidiantono, D.J. (1998). Novel Approaches Towards the Extension and Application of the Road Traffic Environmental Capacity Concept. *Proceedings of 1st Asia Pacific Conference & Exhibition on Transport and the Environment.* Singapore 13-15 May.

TOWARDS A GENERAL MODEL FOR THE ENVIRONMENTAL CAPACITY OF ROADS

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Stephen E. Samuels was initially employed in the Australian Tyre Industry and was subsequently seconded to Monash University where he gained a M.Eng.Sci. degree for research on noise generation. Shortly after, in 1975, he joined the Australian Road Research Board where he progressed to the level of Principal Research Scientist. In 1989, he gained a Ph.D. for his work on the noise produced by traffic under interrupted flow conditions. From 1990 to 1993 he practiced as an Acoustical Consultant, maintaining his involvement in the road traffic noise field, but also dealing with the general areas of outdoor and environmental acoustics. Since 1993 he has been in an academic position in the Department of Transport Engineering in the School of Civil and Environmental Engineering at the University of New South Wales.

1. INTRODUCTION

Concerns on the sustainability of the quality of environment have encouraged the systematic identification, quantification, and evaluation of environmental impacts to be included in the modeling of transport systems. Environmental aspects as externalities in the cost-benefit evaluation of infrastructure development date back to the 1960s, but mathematical models that relate the traffic characteristics with unit of measurements of environmental factors, such as noise, air pollution, and accidents, are more recent in origin. (Burgess, 1977, 1986, DoT, 1988, Delany, 1972, HRB, 1971, Lamure, 1975, Harland, 1977, and Samuels, 1982;Taylor and Anderson, 1982, Koh and Lim, 1985, Kot and Lai 1985, Watkins, 1991, Zeeger *et. al*, 1986).

Environmental capacity (EC) was originally defined as the amount and character of traffic permissible in a street consistent with the maintenance of good environmental conditions (Buchanan, 1963). Amongst all of the road related environmental factors, noise, air pollution, and child safety were considered to be the most annoying factors (Sharpe and Maxman, 1972). It was further indicated that the EC in most residential streets would be governed primarily by public safety, while for streets with commercial and institutional landuses it would be mostly controlled by noise or air pollution issues (Buchanan, 1963; Clark and Lee, 1974, Holdworth and Singleton, 1979). A recent study on EC (Song, *et al.*, 1993) proposed accident risk to pedestrians as a primary determinant of EC. In general, previous studies were very common in their approach. They merely used a single-factor approach in estimating the EC, so the particular factor which produced the minimum EC became the controlling factor.

The methodology proposed in the present research considers several environmental factors as simultaneous contributors to the overall quality of the environment. It introduces a scoring system of environmental quality using an Environmental Utility Function, which blends the environmental factors into a single value. This value is then used as a representative score of the road in respect of environmental quality.

2. METHODOLOGY

The approach for calculating EC proposed in the present research is graphically shown in *Fig.*1. Suppose there are three main categories of data which may be described as follows.

1. Environmental data (noise, delayed pedestrian, air quality and accident risk).
2. Preferential data (data on weightings of factors).
3. Road & traffic data (traffic volume, travel speed and road geometry).

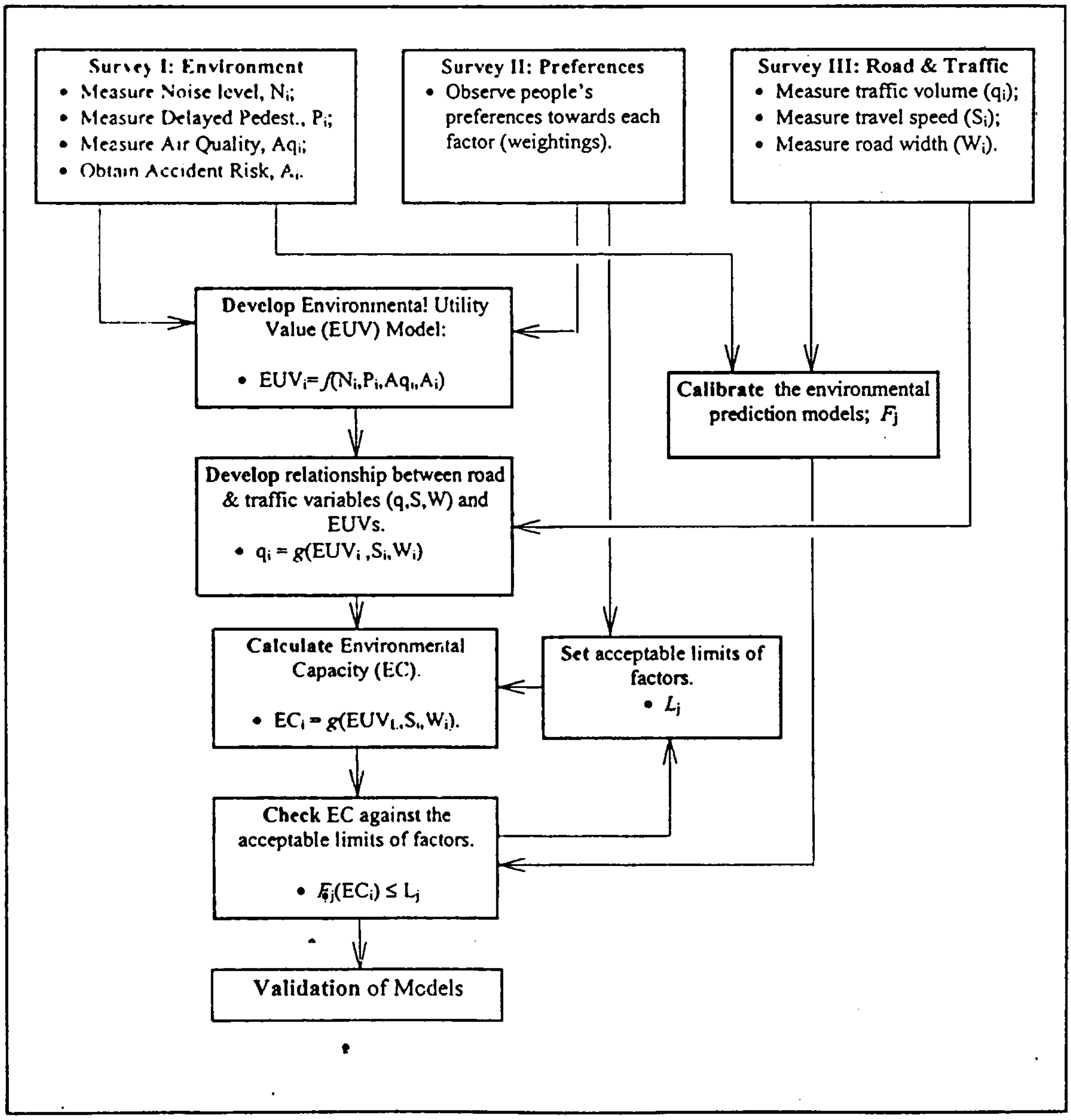
By using the first and second categories of data an Environmental Utility Function may then be developed which simply calculates the relative scores of each road. Consider a road segment with Noise level (N_i), delayed pedestrian (P_i), air quality (Aq_i), and accident risk (A_i). By applying certain weighting values on each factor, the Environmental Utility Value *(EUV)* of this road may be calculated as per the form of Eqn.(1).

$$EUV_i \approx f(n_i, p_i, aq_i, a_i) \quad (1)$$

where:

n_i, p_i, aq_i, and a_i = normalized values of N_i, P_i, Aq_i, and A_i respectively.

Figure 1: Research Methodology



If the quality of environment along the road depends primarily on traffic volume (q), travel speed (S), and road width (W), an attempt to develop a relationship between the EUVs and these variables may then be made. A regression analysis may probably be applied to obtain this relationship which might appear as Eqn.(2).

$$q_i \approx g(EUV_i, S_i, W_i) \qquad (2)$$

So, there are two functions involving EUVs. The first one, Eqn. (1), is intended to determine EUV as a representative environmental value of each site, while the second, Eqn.(2), correlates traffic volume with its associated EUV and road/traffic characteristics.

Once the model has been developed, environmental capacity (EC) may then be determined by substituting EUV with its acceptable value for that particular type of road (e.g. Local, Collector, or Arterial).

$$EC_i \approx h(EUV_L, S_i, W_i); \qquad (3)$$

where:

EUV_L = acceptable level of EUV at a certain road type.

If the value of EC produced by the method produces any excessive impact, as calculated by the prediction models F_j, it may be altered by applying different value of EUV_L, by changing one or more of the previous limit levels, until no excessive impact is produced. The value of EC that satisfies all the limit constraints may finally then be regarded as the optimum EC.

3. MODEL DEVELOPMENT

Considering the previous discussion, it is now desirable to define the variables to be included in the model. If i and j denote any nodes in the system connected by a road (route) k with road class (type) l, then q_{ijkl} can be defined as the traffic flow on road k connecting node i and node j with road type l. Similarly, S_{ijkl} can be defined as the average travel speed along the road, and W_{ijkl} as the width of the road. The level of noise of the road can also be written as N_{ijkl}, the proportion of delayed pedestrian as P_{ijkl}, the level of emission type r of the road as Aq_{ijklr}, and the expected accident risk as A_{ijkl}. Correspondingly their normalised values may be written as n_{ijkl}, p_{ijkl}, aq_{ijklr} and a_{ijkl}.

The environmental utility value of the road then may written as EUV_{ijkl}, which is a function of n_{ijkl}, p_{ijkl}, aq_{ijklr} and a_{ijkl}.

L_{sl} may be defined as the acceptable level of environmental factor s for road type l, and $F(s)$ may represent the prediction model of the factor.

Finally, the representative value of EC of road k connecting node i and node j with road type l, may be written as EC_{ijkl}. This EC_{ijkl} may be a function of EUV_{Ll}, (EUV at the limit level for road type l), S_{ijkl}, and W_{ijkl}. In summary, the variables used in the proposed model are as shown in Table 1.

As a utility function, in a simple additive form, the relationship between EUV_{ijkl} and the environmental factors may be written as shown in Eqn.(4).

$$EUV_{ijkl} = w_{1l} * n_{ijkl} + w_{2l} * p_{ijkl} + w_{3l} * aq_{ijklr} + w_{4l} * a_{ijkl} \quad (4)$$

where:

$w_{1l}, w_{2l}, w_{3l}, w_{4l}$ = weightings of the factors for road class l.

And, relationship between q_{ijkl}, EUV_{ijkl}, S_{ijkl} and W_{ijkl} may be developed. Say, the relationship is linear, then regression function may be written as shown in Eqn.(5).

$$q_{ijkl} = a_l + b_l * EUV_{ijkl} + c_l * S_{ijkl} + d_l * W_{ijkl} \quad (5)$$

where:

b_l, c_l, d_l = coefficients of regression for road class l;

a_l = constant for road class l.

From this relationship, we can then estimate the environmental capacity, EC_{ijkl}, which is simply the traffic volume when EUV is set at the acceptable limit. This may be done by substituting the EUV_{ijkl} in the Eqn.(5) by EUV_{Ll}, as shown in Eqn.(6).

$$EC_{ijkl} = a_l + b_l * EUV_{Ll} + c_l * S_{ijkl} + d_l * W_{ijkl} \quad (6)$$

This EC value may then be checked against the acceptable limit of each factor (L_s), by substituting EC_{ijkl} into the prediction model $F(s)$. Optimization of the EC value may be done by applying different values of L_s (EUV_{Ll}) untill all the constraints are satisfied.

TABLE.1 MODEL PARAMETERS

Parameter	Definition	Units
q_{ijkl}	Traffic volume on road *k* connecting node *i* and node *j* with road class *l*.	vph
S_{ijkl}	Traffic speed on road *k* connecting node *i* and node *j* with road class *l*.	km/h
W_{ijkl}	Effective width of road *k* connecting node *i* and node *j* with road class *l*.	metres
N_{ijkl}	Noise level of road *k* connecting node *i* and node *j* with road class *l*.	dB(A)
P_{ijkl}	Proportion of delayed pedestrian on road *k* connecting node *i* and node *j* with road class *l*.	%
Aq_{ijklr}	Level of emission type *r* on road *k* connecting node *i* and node *j* with road class *l*.	gr/hour
A_{ijkl}	Accident risk on road *k* connecting node *i* and node *j* with road class *l*.	accidents/km/year
n_{ijkl}	Normalized value of N_{ijkl}.	dimensionless
p_{ijkl}	Normalized value of P_{ijkl}.	dimensionless
aq_{ijklr}	Normalized value of AQ_{ijklr}.	dimensionless
a_{ijkl}	normalized value of A_{ijkl}	dimensionless
EUV_{ijkl}	Environmental utility value of road *k* connecting node *i* and node *j* with road class *l*.	dimensionless
EUV_{Ll}	*EUV* at the limit level for road type *l*.	dimensionless
EC_{ijkl}	Environmental capacity of road *k* connecting node *i* and node *j* with road class *l*.	vph
L_{ls}	Acceptable limit of environmental factor *s* for road class *l*.	
$F(s)$	Prediction model of environmental factor *s*.	

4. SIMPLE EXAMPLE

For demonstration purposes, a hypothetical case with 27 local road links as shown in Table 2, has been established. The ideal conditions of different road facilities are supposed to be as shown in Table 3.

Suppose a survey on people's preferences in regard to the quality of the environment had been undertaken and resulted in what appears in Table 4. Further suppose that the outcomes of this survey may be quantified in an environmental utility function which takes form as per Eqn.(7).

$$EUV_{ijkl} = 0.4*n_{ijkl} + 0.3*p_{ijkl} + 0.1*aq_{ijklr} + 0.2*a_{ijkl} \quad (7)$$

Subsequently by using a regression analysis, the relationship between q, EUV, S and W in this case takes form as per Eqn. (8).

$$q_{ijkl}\ (\text{local}) = 631.99 - 5.98\ EUV_{ijkl} - 1.42\ S_{ijkl} + 10.92\ W_{ijkl} \qquad (r^2 = 0.98) \quad (8)$$

TABLE 2: HYPOTHETICAL CONDITIONS OF LOCAL ROADS

Link	q	S	W	Noise	Pedestrian	CO	HC	NOx	accidents
1	100	40	6	61.0	24%	1355	145	250	0.05
2	100	40	7	60.8	26%	1355	145	250	0.04
3	100	40	8	60.6	27%	1355	145	250	0.03
4	100	50	6	61.6	24%	1100	128	250	0.05
5	100	50	7	61.4	26%	1100	128	250	0.04
6	100	50	8	61.2	27%	1100	128	250	0.03
7	100	60	6	62.3	24%	930	117	250	0.05
8	100	60	7	62.2	26%	930	117	250	0.04
9	100	60	8	62.0	27%	930	117	250	0.03
10	300	40	6	65.7	56%	4065	435	750	0.13
11	300	40	7	65.6	59%	4065	435	750	0.11
12	300	40	8	65.4	62%	4065	435	750	0.09
13	300	50	6	66.3	56%	3300	384	750	0.13
14	300	50	7	66.2	59%	3300	384	750	0.11
15	300	50	8	66.0	62%	3300	384	750	0.09
16	300	60	6	67.1	56%	2790	350	750	0.13
17	300	60	7	66.9	59%	2790	350	750	0.11
18	300	60	8	66.8	62%	2790	350	750	0.09
19	600	40	6	68.7	81%	8130	870	1500	0.24
20	600	40	7	68.6	83%	8130	870	1500	0.20
21	600	40	8	68.4	85%	8130	870	1500	0.16
22	600	50	6	69.4	81%	6600	768	1500	0.24
23	600	50	7	69.2	83%	6600	768	1500	0.20
24	600	50	8	69.0	85%	6600	768	1500	0.16
25	600	60	6	70.1	81%	5580	700	1500	0.24
26	600	60	7	70.0	83%	5580	700	1500	0.20
27	600	60	8	69.8	85%	5580	700	1500	0.16

Note q in vph; S in km/h; W in metres; Noise in dB(A); Pedestrian in % delayed; CO,HC,NOx in gr/km/hr; accidents in accidents/km/year.

TABLE 3: IDEAL CONDITIONS OF ROAD FACILITIES

Road Type	Traffic (q), vph.	Speed (S), km/h.	Width (W), m.
Local	200	50	6.0
Collector	500	60	7.5
Arterial	1000	70	15

TABLE 4: ACCEPTABLE LEVEL OF ENVIRONMENTAL IMPACTS (HYPOTHETICAL)

Road Type	Noise* L_{10},dB(A)	CO kg/hr	HC kg/hr	Nox kg/hr	Delayed Ped. %	Accident Risk acc./km/year
Local	65	7.0	0.5	1.2	60	0.15
Collector	70	8.5	1.5	1.5	75	0.20
Arterial	75	10	2.0	2.0	80	0.25

*Measured 10m from road edge.

$EUV_{l,1}$ may be calculated by substituting the normalised values of the acceptable limits into Eqn.(7), which is in this case equal to 46. Hence, the EC values may be calculated using Eqn. (8) by substituting EUV_{ijk1} with $EUV_{l,1}$. The equation may then become as per Eqn. (9):

$$EC_{ijk1} = 631.99 - 5.98\, EUV_{11.} - 1.42\, S_{ijk1} + 10.92\, W_{ijk1} \quad (9)$$

By substituting the EC values into the prediction models, it can be checked whether the EC produces any unwanted impacts. To do so, the prediction models as stated in Table 5 may be employed.

TABLE 5: LIST OF PREDICTION MODELS USED IN THE MODEL

(FOR ILLUSTRATIVE PURPOSES)

Factors (authors)	*Prediction Models*	Parameters
Noise (DoT, 1988)	$L_{10\text{-}1hour} = 10\log q + 33\log(S+40+500/S) + 10\log(1+50/S) - 10\log(((10+0.5W)^2 + 0.25)^{0.5}/13.5) - 27.6$	HV = 10% $L_{10\text{-}1hour}$ = dB(A) q = traffic volume, vph. S = speed, km/h. W = road width, m.
Delayed Pedestrian (Holdsworth and Singleton, 1979)	$P = 1\text{-}e^{-q(5+W/1.22)}$	P = proportion pedest. delayed, %. q = traffic volume, vph. W = road width, m.
Air quality (Taylor, 1982)	CO = 0.8+510/S HC = 0.6+34/S NOx = 2.5	CO = CO emision, gr/hour/veh. HC = HC emision, gr/hour/veh. NOx = NOx emission, gr/hour/veh. S = speed, km/h.
Accident Risk (Zeeger, 1986)	$A=0.00472(10q)^{0.8545}.(0.8867)^{1.639W}.(0.8922)^{3.279PA}.(0.9098)^{3.279UP}.(0.9715)^{3.279R}.(0.8182)^{TER1}.(0.2270)^{TER2}$	A = accident risk, accidents/km/year. W = road width, m. PA = paved shoulder, 1.5m. UP = unpaved shoulder, 2m. R = recovery distance, 10m. TER1= 1 for flat terrain, 0 otherwise. TER2= 1 for hilly terrain, 0 otherwise.

By substituting the figures from Tables 2, 3, and 4 into equations (8), (9) and equations in Table 5, the results shown in Table 6 are obtained. Amongst all the roads, Link 3 has an EUV of 98, which means environmentally the best. Correspondingly it has EC of 389 vph and q/EC ratio of 0.26 which also indicates a good quality of environment. At the other end, Link 25 has an EUV equal to 4 and is considered as the worst link amongst all local roads. It has an EC equal to 339 and q/EC ratio equal to 1.77 which indicates poor environmental conditions. Environmental conditions of the rest of the links lie between these two extremes, with q/EC ratios varying between 0.26 and 1.77. It may also be observed here, that although some road links have different traffic intensities, they share the same value of EC. That is simply because they have the same travel speed and road geometric characteristics, which make up the EC values.

In the right hand columns, the levels of impacts from every single factor are given. These values are the results of impacts which ensue from their associated EC. From the 9 different scenarios included in Table 6 (combination of 3 different travel speed and 3 different road width), it was apparent that in all cases the noise limit level (65 dB(A)) was exceeded by 1.5-2.6 dB(A) and the pedestrian delay limit (60%) was exceeded by 1-11%. In one case, the accident risk limit was exceeded by 0.01 accident/km/year, and in no cases in were the air pollution limits exceeded.

Using this multi-factor approach resulted in an EC for a road with 7m width and 50 km/h travel speed of 364 vph (EUV_L=46). At this value of EC, the noise level would be 67 dB(A) and pedestrian delay would be around 66%. To reduce this excessive impact, EUV_L may be altered to a higher value. For instance, if the EUV_L is set to be 60 (by lowering the noise limit to 63 dB(A) and pedestrian delay to 55%), the EC becomes 281 vph, with associated noise level and pedestrian delay are 65.9 dB(A) and 56% respectively. In comparison the value of EC in the similar condition when using the single approach method (with noise as control factor) is around 230 vph. Consequently an improvement of more than 50 vph in environmental capacity has been achieved via the new approach.

TABLE 6: RESULTS OF CALCULATED EC FOR THE LOCAL ROADS

Link	EUV	EC	q/EC	Noise	Pedestrian	CO	HC	NOx	accidents
1	97	367	0.27	66.6	64%	4972	532	917	0.16
2	97	378	0.26	66.6	68%	5120	548	945	0.13
3	98	389	0.26	66.5	71%	5268	564	972	0.11
4	94	353	0.28	67.0	62%	3880	452	882	0.15
5	95	364	0.27	67.0	66%	4001	466	909	0.13
6	96	375	0.27	67.0	70%	4121	480	937	0.11
7	91	339	0.30	67.6	61%	3149	395	846	0.15
8	92	349	0.29	67.6	65%	3250	408	874	0.12
9	93	360	0.28	67.6	69%	3352	420	901	0.10
10	49	367	0.82	66.6	64%	4972	532	917	0.16
11	51	378	0.79	66.6	68%	5120	548	945	0.13
12	52	389	0.77	66.5	71%	5268	564	972	0.11
13	47	353	0.85	67.0	62%	3880	452	882	0.15
14	49	364	0.82	67.0	66%	4001	466	909	0.13
15	50	375	0.80	67.0	70%	4121	480	937	0.11
16	44	339	0.89	67.6	61%	3149	395	846	0.15
17	46	349	0.86	67.6	65%	3250	408	874	0.12
18	47	360	0.83	67.6	69%	3352	420	901	0.10
19	8	367	1.64	66.6	64%	4972	532	917	0.16
20	12	378	1.59	66.6	68%	5120	548	945	0.13
21	15	389	1.54	66.5	71%	5268	564	972	0.11
22	7	353	1.70	67.0	62%	3880	452	882	0.15
23	10	364	1.65	67.0	66%	4001	466	909	0.13
24	13	375	1.60	67.0	70%	4121	480	937	0.11
25	4	339	1.77	67.6	61%	3149	395	846	0.15
26	8	349	1.72	67.6	65%	3250	408	874	0.12
27	11	360	1.66	67.6	69%	3352	420	901	0.10

Note: EUV, unitless, the greater the better; EC in vph, Noise in dB(A); Pedestrian in % delayed; CO,HC,NOx in gr/km/hr; accidents in accidents/km/year

Table 7 below shows how the EC reponds to changes in EUV_L. The EUV_L simply represents the percentile of sites that would be above the limit. When EUV_L is set to be 60, that means 60% of the sites concerned would be below the acceptable environmental quality. Decision in determining the EUV_L would depend on how far it is allowed to have any impact beyond the acceptable limit when traffic is at capacity level.

TABLE 7: EC VALUES TOWARDS CHANGES OF EUV_L

EUV_L	EC (50 km/h, 7m)	Noise level, dB(A) at EC	Pedestrian delay, % at EC
46	364	67	66
50	340	66.7	59
60	281	65.9	56
62	267	65.7	55
68	229	65	50

5. SENSITIVITY ANALYSIS

Sensitivity analyses are being conducted to show how the model reacts to any possible changes in model parameters, which may include speed (S) and road-width (W). For changes in the variables of the model, tests have been done against how far the changes will affect the EUVs and ECs. Results of one analysis appear in Table 8.

TABLE 8: SENSITIVITY OF THE MODEL TO CHANGES ON INDEPENDENT VARIABLES

Speed	Width	EC	EUV*
+20%	0%	-4.5%	---
-20%	0%	+5.0%	++
0%	+15%	+6.5%	+
0%	-15%	-6.5%	-
+20%	+15%	+2.0%	--
+20%	-15%	-11.0%	----
-20%	+15%	+11.5%	+++
-20%	-15%	-1.5%	++

* Changes in score, proportional to traffic volume; the greater the volume the greater the changes.

In general, the model for determining EC utilizing the multi-factor approach is very sensitive towards both travel speed and road width (Fig. 1). For local roads, increases in average speed alone by 20% may decrease the EC by 4.5%, whereas reducing speed by 20% will increase EC by 5.0%. On the other hand, the widening road by 15% will increase the EC by 6.5%, while reducing road width by 15% will reduce EC by also 6.5%. When changes against both variables are done simultaneously, the story is rather different. Changes both in speed by 20% and road width by 15% in positive ways will in fact increase the EC by only 2%. While reducing speed by 20%, but at the same time increasing road width by 15% will significantly increase EC by 11.5%.

Similar observations were made in the case of EUV. Generally, with the same traffic intensity, EUV will increase as travel speed decreases or as road width increases. Substantial positive changes in EUV were observed when speed was reduced by 20% while at the same time road width was widened by 15%. Furthermore the most negative changes happened when increasing speed by 20% as well as reducing road width by 15%.

6. CONCLUSION

In this paper an alternative approach towards estimating environmental capacity has been proposed. Conceptual methodology has been put forward, and a hypothetical example has also been given. The results show that the methodology towards developing a general model in estimating environmental capacity seems so far to be both appropriate and reasonable. In order to calibrate the model, which is the next step in the ongoing research program, considerable amount of data will need to be collected. Besides, translating peoples' preferences into figures is also not an easy task. Nevertheless, the paper shows that it is in theory generally feasible to employ a multi-factor approach in determining environmental capacity.

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QUANTIFYING COMMUNITY AND EXPERTS PREFERENCES TOWARDS ROAD TRAFFIC RELATED ENVIRONMENTAL FACTORS

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Abstract

The paper reports progress in developing a multi-factor approach for determining environmental capacity. A key feature of the approach is a model that adopts a multi-attribute utility concept in incorporating environmental factors into a single environmental utility function. This function, which accommodates the weighting of factors as perceived by the community, may be regarded as quantifying trade-offs between the environmental factors. By so doing, it is very likely that the resulting value of environmental capacity would not be the minimum one, as given by the single control factor approach, but would rather be an optimum solution. Hence, a more realistic figure of environmental capacity of a road might be obtained. Determination and quantification of the weighting of environmental factors as perceived by the community is the key element in this approach, which is the primary focus of this present paper. A brief overview of the multi-factor approach is presented and the role of environmental weighting factors outlined. From there the paper describes an extensive empirical data collection exercise, undertaken by way of a case study in the Indonesian City of Bandung, which was aimed at investigating parameters relevant to the model including the environmental weighting factors. Out comes of this process are summarised as far as the weighting factors are concerned and the implications of these outcomes discussed.

INTRODUCTION

Concerns on the sustainability of the quality of environment have encouraged the systematic identification, quantification, and evaluation of environmental impacts to be included in the modelling of transport systems. Environmental aspects as externalities in the cost-benefit evaluation of infrastructure development date back to the 1960s, but mathematical models that relate the traffic characteristics with measures of environmental factors such as noise, air pollution, and accidents, are more recent in origin. The concept of environmental capacity also originated in the early 1960s, and is based on the assumption that in order to maintain a good quality environment around a particular road, the volume of traffic allowed by a specified control factor would be chosen as the environmental capacity of the road (Buchanan 1963). This approach was applied to several environmental capacity studies conducted during 1970s with some modification to the methodology. (Sharpe and Maxman 1972; Holdworth and Singleton 1979; Song, *et. al.* 1993) Nevertheless, unlike the concept of highway capacity, application of the concept in real engineering works has been rare indeed. One of the reasons behind this is probably that the concept generally produced environmental capacity values which were far below the physical capacities of the roads concerned.

The present paper reports on progress in developing a multi-factor approach for determining environmental capacity. A key feature of the approach is a model that adopts a multi-attribute utility concept in incorporating environmental factors into a single environmental utility function. This function, which accommodates the weighting of factors as perceived by the community, may be regarded as quantifying trade-offs between the environmental factors. By so doing, it is very likely that the resulting value of environmental capacity would not be the minimum one, as given by the single control factor approach, but would rather be an optimum solution. Hence, a more realistic figure of environmental capacity of a road might be obtained (Widiantono and Samuels, 1998, Black *et.al* 1998).

Determination and quantification of the weighting of environmental factors as perceived by the community is the key element in this approach, which is the primary focus of the present paper. A brief overview of the multi-factor approach will be presented and the role of environmental weighting factors will be outlined. From there the paper will describe an extensive empirical data collection exercise, undertaken by way of a case study in the Indonesian City of Bandung, which was aimed at investigating parameters relevant to the model including the environmental weighting factors. Out comes of this process will be summarized as far as the weighting factors are concerned and the implications of these outcomes discussed.

Methodology

The approach for calculating EC proposed in the present research is graphically shown in Figure 1. Suppose there are three main categories of data which may be described as follows.

- Environmental data (noise, delayed pedestrian, air quality and accident risk).
- Preferential data (data on weightings of factors).
- Road & traffic data (traffic volume, travel speed and road geometry).

By using the first and second categories of data an Environmental Utility Function may then be developed which simply calculates the relative scores of each road. Consider a road segment with Noise level (N_i), delayed pedestrian (P_i), air quality (Aq_i), and accident risk (A_i). By applying certain weighting values on each factor, the Environmental Utility Value *(EUV)* of this road may be calculated as per the form of Eqn.(1).

$$EUV_i \approx f(n_i, p_i, aq_i, a_i) \qquad (1)$$

where:
n_i, p_i, aq_i, and a_i = normalized values of N_i, P_i, Aq_i, and A_i respectively.

If the quality of environment along the road depends primarily on traffic volume (q), travel speed (S), and road width (W), an attempt to develop a relationship between the *EUV*s and these variables may then be made. A regression analysis may probably be applied to obtain this relationship which might appear as Eqn.(2).

$q_i \approx g(EUV_i, S_i, W_i)$ (2)

So, there are two functions involving EUVs. The first one, Eqn. (1), is intended to determine EUV as a representative environmental value of each site, while the second, Eqn.(2), correlates traffic volume with its associated EUV and road/traffic characteristics.

Once the model has been developed, environmental capacity (*EC*) may then be determined by substituting *EUV* with its acceptable value for that particular type of road (e.g. Local, Collector, or Arterial).

$EC_i \approx h(EUV_L, S_i, W_i)$; (3)

where:
EUV_L = acceptable level of *EUV* at a certain road type.

If the value of EC produced by the method results in any excessive impact, as calculated by the prediction models F_j, it may be altered by applying different value of EUV_L, by changing one or more of the previous limit levels, until no excessive impact occurs. The value of EC which satisfies all the limit constraints may finally then be regarded as the optimum EC.

Considering the previous discussion, it is now desirable to define the variables to be included in the model. If *i* and *j* denote any nodes in the system connected by a road (route) *k* with road class (type) *l*, then q_{ijkl} can be defined as the traffic flow on road *k* connecting node *i* and node *j* with road type *l*. Similarly, S_{ijkl} can be defined as the average travel speed along the road, and W_{ijkl} as the width of the road. The level of noise of the road can also be written as N_{ijkl}, the proportion of delayed pedestrian as P_{ijkl}, the level of emission type *r* of the road as Aq_{ijklr}, and the expected accident risk as A_{ijkl}. Correspondingly their normalised values may be written as $n_{ijkl}, p_{ijkl}, aq_{ijklr}$ and a_{ijkl}.

The environmental utility value of the road then may written as EUV_{ijkl}, which is a function of $n_{ijkl}, p_{ijkl}, aq_{ijklr}$ and a_{ijkl}.

L_{sl} may be defined as the acceptable level of environmental factor *s* for road type *l*, and *F*(s) may represent the prediction model of the factor.

Finally, the representative value of EC of road *k* connecting node *i* and node *j* with road type *l*, may be written as EC_{ijkl}. This EC_{ijkl} may be a function of EUV_{Ll}, (*EUV* at the limit level for road type *l*), S_{ijkl}, and W_{ijkl}. In summary, the variables used in the proposed model are as shown in Table 1.

As a utility function, in a simple additive form, the relationship between EUV_{ijkl} and the environmental factors may be written as shown in Eqn.(4).

$EUV_{ijkl} = w_{1l} * n_{ijkl} + w_{2l} * p_{ijkl} + w_{3l} * aq_{ijklr} + w_{4l} * a_{ijkl}$ (4)

where:
$w_{1l}, w_{2l}, w_{3l}, w_{4l}$ = weightings of the factors for road class *l*.

And, relationship between q_{ijkl}, EUV_{ijkl}, S_{ijkl} and W_{ijkl} may be developed. Say, the relationship is linear, then regression function may be written as shown in Eqn.(5).

$q_{ijkl} = a_l + b_l * EUV_{ijkl} + c_l * S_{ijkl} + d_l * W_{ijkl}$ (5)
where:
b_l, c_l, d_l = coefficients of regression for road class *l*;
a_l = constant for road class *l*.

From this relationship, we can then estimate the environmental capacity, EC_{ijkl}, which is simply the traffic volume when *EUV* is set at the acceptable limit. This may be done by substituting the EUV_{ijkl} in the Eqn.(5) by EUV_{Ll}, as shown in Eqn.(6).

$$EC_{ijkl} = a_l + b_l^* EUV_{Ll} + c_l^* S_{ijkl} + d_l^* W_{ijkl} \qquad (6)$$

This EC value may then be checked against the acceptable limit of each factor (L_s), by substituting EC_{ijkl} into the prediction model *F*(s). Optimization of the EC value may be done by applying different values of L_s (EUV_{Ll}) until all the constraints are satisfied.

TABLE I MODEL PARAMETERS

Parameter	Definition	Units
q_{ijkl}	Traffic volume on road *k* connecting node *i* and node *j* with road class *l*.	Vph
S_{ijkl}	Traffic speed on road *k* connecting node *i* and node *j* with road class *l*.	km/h
W_{ijkl}	Effective width of road *k* connecting node *i* and node *j* with road class *l*.	Metres
N_{ijkl}	Noise level of road *k* connecting node *i* and node *j* with road class *l*.	dB(A)
P_{ijkl}	Proportion of delayed pedestrian on road *k* connecting node *i* and node *j* with road class *l*.	%
Aq_{ijklr}	Level of emission type *r* on road *k* connecting node *i* and node *j* with road class *l*.	gm/hour
A_{ijkl}	Accident risk on road *k* connecting node *i* and node *j* with road class *l*.	Accidents/km/year
n_{ijkl}	Normalized value of N_{ijkl}.	Dimensionless
p_{ijkl}	Normalized value of P_{ijkl}.	Dimensionless
aq_{ijklr}	Normalized value of AQ_{ijklr}.	Dimensionless
a_{ijkl}	normalized value of A_{ijkl}	dimensionless
EUV_{ijkl}	Environmental utility value of road *k* connecting node *i* and node *j* with road class *l*.	Dimensionless
EUV_{Ll}	*EUV* at the limit level for road type *l*.	Dimensionless
EC_{ijkl}	Environmental capacity of road *k* connecting node *i* and node *j* with road class *l*.	Vph
L_{ls}	Acceptable limit of environmental factor *s* for road class *l*.	
F(s)	Prediction model of environmental factor *s*.	

Multi-attribute Utility Theory (MAUT)

Utility function concepts were initially developed for economic analysis. That is why it is often expected to be related to financial variables although other units can be used. In this method payoff has sometimes been described as a way of taking account of the decision maker's attitude to risk (Keeney and Raifa 1976).

The multi-attribute utility theory attempts to avoid direct assessment of $u(x_1, \ldots, x_n)$. In turn, it would rather decompose a multi-attribute utility assessment into a series of single-attribute assessments. The simplest form the decomposition functions is a simple additive function:

$$u(x_1, \ldots, x_n) = \lambda_1 u_1(x_1) + \ldots + \lambda_n u_n(x_n)$$

where x_i is a measure of the attribute possessed by an alternative, u_i is the unidimensional utility function of the ith attribute, and λ_i is the measure of relative importance between attributes. This concept assumes that the attributes to be considered are independent one another.

There are many possible forms of this decomposition function. The choice of its form usually depends on the nature of the decision problem. Firstly, the assumptions of preferentially and utility independence of attributes must be tested before any unidimensional utility functions $u_i(x_i)$ are determined. In determining the decomposition form, it is necessary to insure that there is no inseparable interactions between variables, otherwise a more complicated forms such as quasipyramid, semicube, or interdependent forms must be used.

The model proposed in this paper adopts the simple weighted additive form, as this is the most appropriate and straightforward form to represent trade-offs between factors as perceived by people. This is also based on the assumption that all considered environmental factors are technically independent one another.

Determining the Attributes

Attributes are considered as measurable criteria of judgments by which a dimension of the alternatives under consideration can be characterized. There are two major approaches to determine the set of attributes, a deductive and an inductive approach (Keeney and Raiffa 1976; Nijkamp and Rietveld 1990).

In the deductive approach, a set of attributes is arrived at by starting from the general aspects of the problem. These main aspects of the problem are then broken down into several criteria or variables which are more specific in meaning. The inductive approach starts with an inventory of all possible features of the alternatives. These features are then classified into several groups which finally construct a set of attributes.

In this study, the use of deductive approach has been made. Impacts of road and traffic on the environment were firstly categorised into several different categories such as road related impacts, traffic related impacts, and administrative impacts (Lay 1984). As the first and the last categories mostly occur during the design and construction stages, they may be neglected in the operational stage. So, the model is primarily concerns with traffic related impacts. According to Department of Transport (DoT 1988), there are some considerable environmental impacts produced by road traffic, they include: noise, air pollution, visual, community severance, safety of pedestrian and cyclist, drivers stress, accidental risks and vibration. Without any intention to disregard the other factors, Sharpe and Maxman suggest that noise, air pollution and pedestrian safety are the most dominant or important impacts as long as community annoyance is concerned.

In order to have a realistic as well as comprehensive model, it was then decided to include such environmental factors as noise, air pollution, pedestrian safety and accidental risks in this study.

Determining the Weights

Weights are considered to be the reflections of the relative importance of attributes in a given situation. There are many techniques available to estimate the weights or coefficients of utility functions, either by direct or indirect methods (Nijkamp and Rietveld 1990). In the direct methods the weights are estimated based on the results of direct questionnaire survey or interviews of decision makers, while in the indirect methods estimations are made by using past statements concerning the weights (e.g. actual choices in the past, ranking of alternatives, and interactive interaction). Some of the first methods are described in the following paragraphs. The description of second methods, as they were considered not appropriate for the study, are omitted in this paper (for more information on indirect techniques, see Nijkamp and Rietveld 1990).

In direct rating method, decision makers are asked to allocate a certain value of score, say 100, among the objective criteria which reflect their relative importance. The method requires the criteria values to be standardized. As it is sometimes difficult for people to give a single value of score, instead in this study repondents were asked to give the upper and lower bounds of the acceptable score. The mid or average value was then considered as the representative score.

In ranking method the decision makers are asked to rank the criteria or decision variables in order of importance. Using the expected values of criterion weights as shown in Table II, the ranks can then be converted into weightings.

TABLE II .EXPECTED VALUES OF CRITERION WEIGHTS

No. of) Criteria (J)	Expected values of criterion weights $E(\gamma_1)$	$E(\gamma_2)$	$E(\gamma_3)$	$E(\gamma_4)$	$E(\gamma_5)$	$E(\gamma_6)$	$E(\gamma_7)$	$E(\gamma_8)$	$E(\gamma_9)$
2	.25	.75							
3	.11	.28	.61						
4	.06	.15	.27	.52					
5	.04	.09	.16	.26	.46				
6	.03	.06	.10	.16	.26	.41			
7	.02	.04	.07	.11	.16	.23	.37		
8	.02	.04	.06	.08	.11	.16	.22	.34	
9	.01	.03	.04	.06	.08	.11	.15	.20	.31

Source: Calculation based on Rietveld (1982).

When the number of criteria to be ranked is large, the respondent tends to lose the overview of the problem. Voogd (1983) then proposed a stepwise approach to overcome this problem. The approach firstly divides the set of criteria into two subsets, the important ones and less important ones. This subdivision can be repeated until the number of criteria under the subset is reasonable (say less than 9).

In Analytic Hierarchy Process (AHP), Saaty (1982) uses verbal statements and applies them for comparing pairs of criteria. For all pairs of criteria respondents are asked to determine the degree of difference in importance on a nine-point scale, from equally important up to absolutely more important. In this study instead of difference in importance, respondents were asked to state the difference in terms of annoyance between pair of environmental factors.

Multiple judgments are synthesized by using their geometric mean. The results of the interview then is used to construct a matrix of preferences B which consists of matrix elements b_{jj^*} that indicate the outcomes of the comparison for all pairs j and j^*.

$\Sigma\, b_{jj^*}\, \gamma_{j^*} = J.\gamma_j$, for all j,

In this study, emphasis was given to some extent to the first method (direct rating), while the other two methods were mainly used to check the consistency of outcomes given by the first method.

Bandung Case Study

Bandung municipality is the capital of West Java province in Indonesia. It is located at 107° East and 6°55' South. The average altitude of the city is 768 metres above sea level, with the highest level of 1,050 metres in the north and the lowest level of 675 metres in the south. Bandung was chosen as the area under study since it is considered as a typical medium sized city in Indonesia, with population around 1.8 million people and an area of 166.68 sq.km, where surveys were carried out through out the area. Average temperature as officially reported is 23.1° C, with average rainfall of 231.2 mm occuring on about 18.7 days per month. Motor cycles are the most common mode of transport with a population of 199,964 (53%) followed by cars of 114,338 (30%). Heavy vehicles including trucks and buses comprise of only around 17% of the total vehicle population or about 65,000 vehicles (Bandung Statistical Office, 1997).

Surveys were carried out through out the area for this study. Two different surveys were conducted to obtain data both on public or community and on experts' preferences towards environmental impacts of road traffic. A road environmental expert was defined as a person whom either professionally or officially deals with road and environmental design. They include people from such organizations as government bodies, universities, and consultants.
The community survey was conducted through a direct interview method, while experts were surveyed using mail-back questionnaires. Interviewees were randomly selected at various survey sites. To have more understanding on the influence of road class and land use type, locations of the community preference surveys were selected to include various combinations of road class (e.g. arterials, collectors, and locals) and land uses (e.g. commercial, mix, residential). A stratified random sampling method was employed for the survey design, and the number of sites within each category is as shown in Table III. At each site, a minimum of 3 interviewees were taken. To ensure that various parts of the city were covered, survey locations were determined based on advice from local experts. The entire survey was carried out within a three-week period between September and October 1997. Interviews were performed in two sessions in one day from Monday to Saturday.

TABLE III SUMMARY OF SURVEY SITES AND TARGET RESPONDENTS IN EACH CATEGORY

	Landuse Type		
Road Class	**Commercial**	**Mix**	**Residential**
Arterial	3 sites (9 resp.)	3 sites (9 resp.)	3 sites (9 resp.)
Collector	4 sites (12 resp)	4 sites (12 resp)	4 sites (12 resp)
Local	5 sites (15 resp)	5 sites (15 resp)	5 sites (15 resp)
Total	12 sites (36 resp.)	12 sites (36 resp.)	12 sites (36 resp.)

The experts' surveys were conducted using mail-back questionnaires and around 100 experts were chosen arbitrarily to be included in the survey. Format of the questions in the questionnaire was similar to the questions for the community interview, it differs mainly in the wording of the questions. Questions were grouped into 4 major headings, with the first group asking about the profile of the respondent/interviewee. The second group of the questions was about direct ranking. In this part, repondents were asked to rank the environmental impacts (noise, air pollution, pedestrian delay, and accident risk) according to their level of annoyance. So, the higher the rank the more annoying the factor.

In the third group, people were asked to give direct scores or ratings, in a scale of 100, towards the environmental factors. Actually they were asked to give an upper and lower bounds of the rating instead of single absolute value. The middle value between the upper and lower bound was then taken as the representative rating value of the factor. Similar to the ranks, in this case, the higher the rating the more annoying the factor. The fourth group of questions, which was considered the most complicated part of the interview/questionnaire, was pairwise comparisons. In this part people were asked to compare pairs of factors, and express the degree of the difference of annoyance. Data from the surveys were then coded and entered into spreadsheet files and subsequently then processed and analysed to obtain the required information.

Outcomes of the analyses for various categories of respondents were then compared and contrasted, and the major findings are as discussed in the following section.

Findings

Responses

About 150 people were interviewed from 36 sites, during the survey. Of these, 104 people (from 27 sites) were randomly chosen for immediate application in calibrating the model. Data from the remaining sites (9) with 42 respondents, were obtained for subsequently validating the model. A summary of the community respondents appears in Table IV. From the experts, amongst the 100 questionnaires mailed out, 25 were mailed back. All the data were used for model calibration purposes.

TABLE IV COMMUNITY RESPONDENTS

Road Class	Number of Respondents			
	Landuse Type			
	Commercial	Mix	Residential	
Arterial	15 (7)	15 (9)	16 (11)	
Collector	14 (10)	15 (11)	15 (11)	
Local	21 (17)	19 (15)	16 (13)	
Total	50 (34)	49 (35)	47 (35)	146 (104)

Note: Figures in the brackets represent number of respondents used for calibration purposes.

Rating

Average rating values as given by the community for each environmental factor are as shown in Table V below. Statistical analyses towards the data suggest that in every category, significant differences were observed between scores given to environmental factors. In other words, it can be said that there was enough evidence (at 95% level) to conclude that different scores were given to the environmental factors. Majority of categories in the community, seemed to agree to give the highest score (the most annoying factor) to noise, the second to air pollution, the third to pedestrian delay and the lowest score to accident risk.

When comparison was made of the same factor between different categories (e.g. noise as perceived by people reside along arterial and local roads), some interesting findings were observable. In general, the community's preferences towards environmental factors seemed to be independent of type of landuse. This was observable particularly within the collectors and locals categories. Within arterials, people who live in mixed landuses, tended to respond differently from the other two categories in giving scores to noise, air pollution and pedestrian delay.

The result was somewhat different when comparisons were made between landuse groups for all the data. Analyses towards these groups suggest that there were no significant differences between mixed landuse and either commercial or residential landuses in giving scores to environmental factors. But, significant differences were observed between commercial and residential landuses. Overall therefore, it might be reasonable to propose that two different types of landuses, commercial and residential, should be considered in the models.

In the meantime, comparisons between respondents in different road categories suggested that people from the arterial and collector groups were not significantly different in giving the scores. While there was enough evidence to suggest that group of locals differed significantly from the two groups, there was not sufficient evidence to conclude that the arterial group was giving significantly different opinion from the collector group. This may lead to the conclusion that two different classes of roads, major roads (arterials or collectors) and local roads, might be considered within the models.

On the other hand, result from the experts' data were quite different from what was suggested by the community. The experts tended to give indifferent scores to factors other than noise (air pollution, pedestrian delay and accident risk), but gave significantly different score to noise factor (see Table V and Figure 2). Statistical tests performed between community groups and experts, showed that there was enough evidence to conclude that preferences expressed by both of the groups were significantly different.

TABLE V AVERAGE RATING OF ENVIRONMENTAL FACTORS AS GIVEN BY COMMUNITY AND EXPERTS

		AVERAGE RATING				
Group	**Site Category**	**Noise**	**Air Pollution**	**Pedestrian Delay**	**Accident Risk**	**Order**
Community	Arterial-Commercial	75.00	58.21	60.00	46.07	1324
	Arterial-Mix	45.00	40.28	35.00	31.11	1234
	Arterial-Residential	70.45	46.36	50.45	25.91	1324
	Collector-Commercial	60.50	53.00	49.50	37.00	1234
	Collector-Mix	62.05	46.82	42.27	34.09	1234
	Collector-Residential	51.36	41.82	30.00	26.82	1234
	Local-Commercial	55.00	47.94	35.00	25.15	1234
	Local-Mix	55.67	44.00	35.33	21.67	1234
	Local-Residential	53.08	39.23	27.69	21.15	1234
	Arterials	63.15	47.41	47.78	32.87	1324
	Collectors	57.89	47.03	40.31	32.50	1234
	Locals	54.67	44.11	33.00	22.83	1234
	Commercials	60.74	51.54	44.41	32.94	1234
	Mixes	54.93	43.93	37.43	28.00	1234
	Residentials	58.00	42.29	35.57	24.43	1234
	All category	57.86	45.87	39.09	28.41	1234
Experts	All	49.40	64.80	57.00	60.10	4132

TABLE VI MULTIPLE COMPARISONS BETWEEN ARTERIAL, COLLECTOR AND LOCAL (TYPICAL) - BONFERRONI

Noise	ART	COL
COL	ns	
LOC	s	ns

Airpol	ART	COL
COL	ns	
LOC	ns	ns

Pedes	ART	COL
COL	ns	
LOC	s	s

Accid	ART	COL
COL	ns	
LOC	s	s

Note: s = the difference is significant at 5% level;

ns= the difference is not significant at 5% level.

Ranking

In general, results of the analyses of the ranking data were not quite different from those of the direct rating data. Initial analyses of the community surveys suggest that in terms of ranking, there were no major influences of site category in the community. At most of the categories, respondents agreed to assign rank one to noise, two to air pollution, three to pedestrian delay and four to accident risk. Only respondents from arterial residential and collector-commercial categories assigned slightly different orders to the factors. Instead of rank two they assigned rank three to air pollution, while rank two given to pedestrian delay factor. The outcomes have been summarised in Table VII and Figure 3.

When the order of rankings were compared to those given by the experts, some differences were apparent. Unlike the community, instead of putting noise in the first rank, experts tended to put noise in the fourth (last) rank. The first rank went to air pollution, while the second and third ranks went to pedestrian delay and accident risk respectively. Again refer to the data of Table VII.

Kendall (1975) provides a method of measuring the commonality of judgments among the respondents. The *coefficient of concordance (W)*, as a measure of agreement, will equal to unity if all of the respondents agree and become zero if they differ very much among themselves. Calculated Kendall's concordant coefficients for the community categories were ranging from 0.53 to 1.0, which indicated medium-high level of agreement. While for the experts the coefficient was 0.54, which indicated a medium level of agreement.

TABLE VII. RANK AND ORDER OF ENVIRONMENTAL FACTORS AS GIVEN BY COMMUNITY AND EXPERTS

		Rank of Environmental Factors					
Group	Site Category	Noise	Air pollution	Pedestrian Delay	Accident Risk	Kendall's coeff.	Chi sq.
Community	Arterial-Commercial	1	2	3	4	1.0	21
	Arterial-Mix	1	2	3	4	1.0	30
	Arterial-Residential	1	3	2	4	0.8	26.45
	Collector-Commercial	1	3	2	4	0.53	17.51
	Collector-Mix	1	2	3	4	0.84	17.57
	Collector-Residential	1	2	3	4	0.64	21.22
	Local-Commercial	1	2	3	4	0.91	46.34
	Local-Mix	1	2	3	4	0.57	32.68
	Local-Residential	1	2	3	4	0.68	20.45
	Arterials	1	2	3	4	0.89	74.87
	Collectors	1	2	3	4	0.58	50.26
	Locals	1	2	3	4	0.70	103.09
	Commercials	1	2	3	4	0.77	80.52
	Mixes	1	2	3	4	0.88	86.78
	Residentials	1	2	3	4	0.67	70.03
	All category	1	2	3	4	0.71	224.91
Experts	All	4	1	2	3	0.54	553

AHP

Analyses of the pairwise comparison's data suggest the following results. Noise was considered as the most annoying factor, with coefficient of weighting ranging between 0.42-0.55, followed by air pollution (0.17-0.32). Pedestrian delay was considered as the third, with the coefficient ranging between 0.15 and 0.23, while accident was the least annoying with coefficient ranging from 0.08 to 0.12. The order was slightly different according to arterial-commercial and arterial-residential categories. Instead of the second most annoying, the categories put air pollution on the third place, and put pedestrian delay as a replace (see Table VIII).

On the other hand, the experts group once again stand in a different angle as from the community. In this case they give the highest coefficient to accident risk (0.31), followed by pedestrian delay (0.28), and air pollution (0.27). The noise itself was considered as the least annoying factor and given a coefficient of 0.14 or about half of the other factors (refer to Table VIII and Figure 4).

Saaty (1982) uses Consistency Index (CI) to measure the degree of consistency, and compared with Random Consistency Index (RCI) calculated from randomly generated square matrix. The ratio between CI and RCI is called the Consistency Ratio (CR), which is considered good if less than 0.10. Calculated CR of the results showed that the respondents in every categories were quite consistent in expressing their preferences. Amongst the community, CRs were ranging between 0.002 and 0.038, while amongst the experts the CI was 0.018 which indicated very good consistency (less than 0.10).

TABLE VIII. WEIGHTING OF ENVIRONMENTAL FACTORS GIVEN BY COMMUNITY AND EXPERTS USING AHP METHOD

		WEIGHTING COEFFICIENTS (AHP)				
Group	Site Category	Noise	Air Pollution	Pedestrian Delay	Accident Risk	CR
Community	Arterial-Commercial	0.47	0.19	0.23	0.10	0.020
	Arterial-Mix	0.42	0.27	0.20	0.11	0.011
	Arterial-Residential	0.55	0.17	0.20	0.08	0.038
	Collector-Commercial	0.46	0.25	0.18	0.11	0.007
	Collector-Mix	0.50	0.22	0.17	0.11	0.002
	Collector-Residential	0.47	0.25	0.17	0.12	0.012
	Local-Commercial	0.44	0.32	0.15	0.09	0.015
	Local-Mix	0.43	0.27	0.19	0.12	0.002
	Local-Residential	0.47	0.26	0.16	0.11	0.010
	Arterials	0.49	0.21	0.21	0.10	0.014
	Collectors	0.48	0.24	0.17	0.11	0.003
	Locals	0.45	0.29	0.17	0.10	0.007
	Commercials	0.45	0.27	0.18	0.10	0.007
	Mixed	0.46	0.26	0.17	0.11	0.004
	Residentials	0.50	0.23	0.17	0.10	0.015
	All category	0.47	0.25	0.18	0.10	0.006
Experts	All	0.14	0.27	0.28	0.31	0.018

The above discussion and analyses may be summarised as follows. It suggests that two distinct classes of road, namely major and local roads, may be considered in the model. In terms of landuse, two different types of landuse, commercial and residential, may also be considered. Experts' preferences were significantly different from those of the community, suggesting that two models would be required – one for expert and one for community preferences. Based on the categorisation, weighting coefficients as shown in Table IX will be employed by the proposed models.

TABLE IX WEIGHTING COEFFICIENTS FOR SUGGESTED CATEGORIES

Category	Method	Noise	Air Pollution	Pedestrian Delay	Accident Risk
MAJOR-Commercial	Rating	0.31	0.25	0.24	0.20
	Ranking	0.52	0.27	0.15	0.06
	AHP	0.48	0.20	0.20	0.12
MAJOR-Residential	Rating	0.34	0.27	0.23	0.16
	Ranking	0.52	0.27	0.15	0.06
	AHP	0.48	0.25	0.18	0.09
LOCAL-Commercial	Rating	0.34	0.30	0.22	0.14
	Ranking	0.52	0.27	0.15	0.06
	AHP	0.41	0.32	0.17	0.10
LOCAL-Residential	Rating	0.38	0.26	0.20	0.16
	Ranking	0.52	0.27	0.15	0.06
	AHP	0.49	0.24	0.15	0.11
Experts	Rating	0.21	0.28	0.25	0.26
	Ranking	0.06	0.52	0.27	0.15
	AHP	0.14	0.27	0.28	0.31

Conclusions

Data on preferences of both community and experts towards environmental factors have been analysed and discussed. The results suggest that the community preferences were different significantly (at 95% level) from those of a group of experts, particularly in determining the most annoying factors. Noise was considered as the most annoying factor by the community, while the reverse was true according to the group of experts. Other factors such as air pollution, pedestrian delay and accidents were not considered as important as noise by the community. While the experts tended to say that the three factors are almost equally more important than noise.

In terms of road class, it was found that no significant difference was observed between arterials and collectors categories, while significant differences occurred between locals and both arterials and collectors. Similar results were also found between landuses. The analyses suggested that influences of landuse were apparent between two groups, namely commercial and residential. These outcomes will lead to the development and adoption of models considering two different classes of roads and two different types of landuses.

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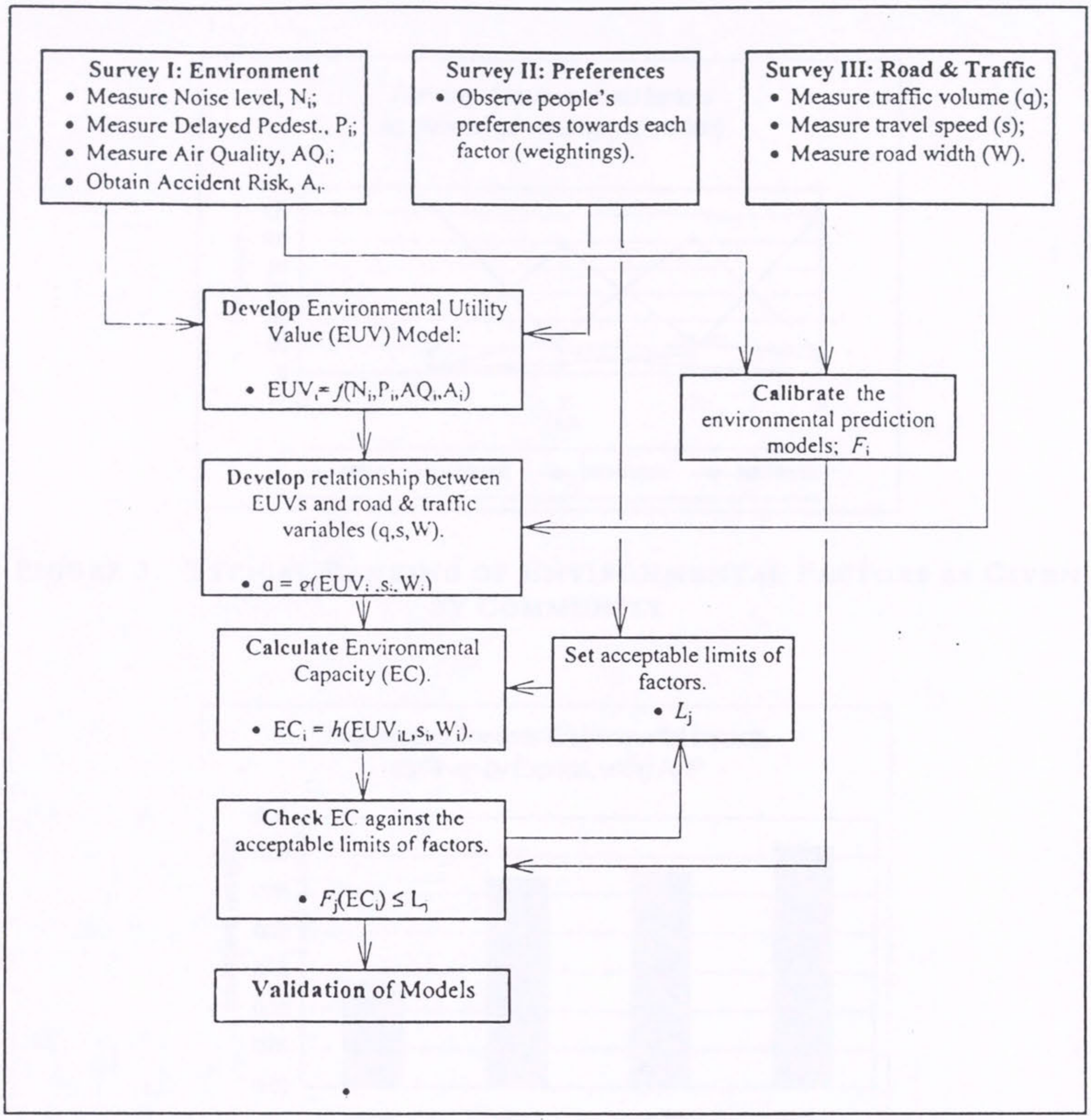

FIGURE 1. RESEARCH METHODOLOGY

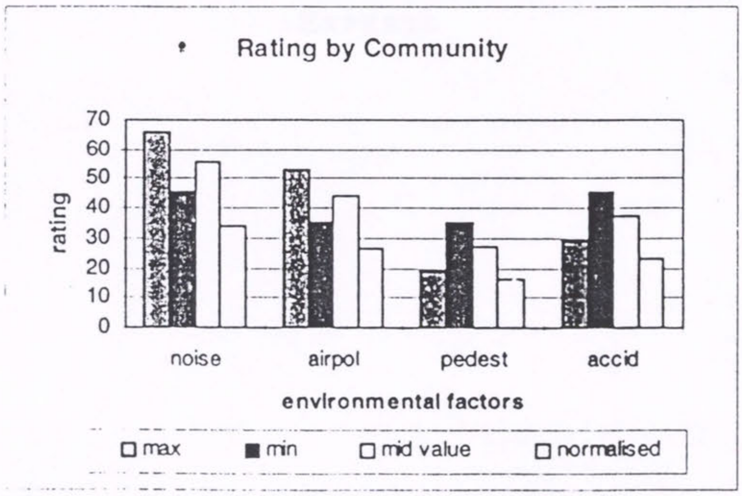

FIGURE 2. TYPICAL RATING VALUES AS GIVEN BY COMMUNITY

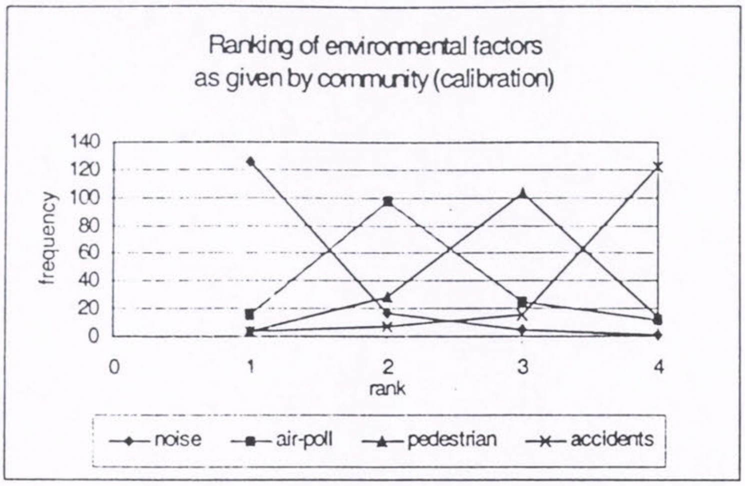

FIGURE 3. TYPICAL RANKING OF ENVIRONMENTAL FACTORS AS GIVEN BY COMMUNITY

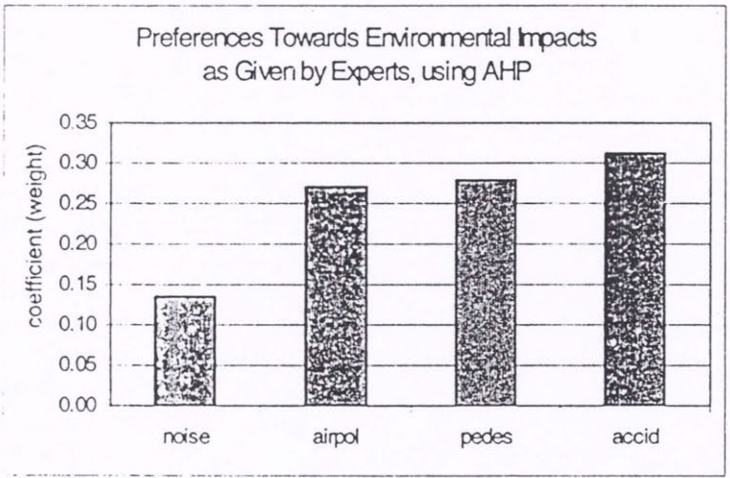

FIGURE 4. RESULT OF PAIRWISE COMPARISON (AHP) METHOD FOR EXPERTS

NOVEL APPROACHES TOWARDS THE EXTENSION AND APPLICATION OF THE ROAD TRAFFIC ENVIRONMENTAL CAPACITY CONCEPT

by

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ABSTRACT

The concept of environmental capacity, which originated in the early 1960s, is based on achieving environmental amenity through limitations of road traffic capacity. This paper synthsises results both from earlier research and from a three part ongoing research program at the University of New South Wales which is radically extending this concept and exploring a hitherto untried application. A multi-factor approach towards determining environmental capacity is being developed. A key feature of the approach is a model that adopts a multi-objective concept by which several environmental factors may be incorporated into a single environmental utility function. This function, which accommodates community preference based weighting factors, may be regarded as quantifying the trade-offs between the various environmental factors. In further pursuing the community impacts of road transport infrastructure developments, the concept of community severance is being explored and enhanced. Particular attention is being focused on the dynamic severance of vehicular traffic that impedes pedestrian movements. It is here that environmental capacity is being explored as a quantifying indicator in the assessment of dynamic severance. Finally, an extension of the classic environmental capacity concept has led to an area-wide environmental capacity (AWEC), based on air pollution criteria. AWEC models have been developed utilising an empirical/statistical approach with relevant concurrent data on factors such as traffic, meteorological, land use and air pollution conditions. The feasibility and usefulness of the AWEC concept as an evaluation tool in strategic land use and transportation planning has been examined with a case study of the inner urban area of Sydney.

INTRODUCTION

Concerns about the sustainability of the quality of the environment have encouraged the systematic identification, quantification and evaluation of environmental impacts to be included in the modelling of transport systems. Environmental capacity (EC) was originally defined as the amount and character of traffic permissible in a street consistent with the maintenance of good environmental conditions (Buchanan 1963). Amongst all of the road-related environmental factors, noise, air pollution and child safety were considered to be the most annoying factors for those living and working along major urban roads (Sharpe and Maxman 1972). Furthermore, the EC in residential streets would be governed primarily by public safety. Song (*et al* 1993) included accident risk to pedestrians as a determinant of EC in addition to pedestrian delay. For streets with commercial and institutional landuses EC would be mostly controlled by noise or air pollution issues (Buchanan 1963, Holdsworth and Singleton 1979). In general, previous studies were very common in their approach: they used a single-factor approach to estimate the EC, and the particular factor which produced the minimum EC became the controlling factor in making recommendations on traffic restraint and management.

The present paper summarises a three-part ongoing research program in the Department of Transport Engineering at the University of New South Wales which is radically extending the current concepts of EC and exploring hitherto untried applications. In the first part, a multi-factor approach towards determining environmental capacity is being developed. The department has been at the forefront of research into the optimisation of land-use/transport system (Blunden 1967; Black and Blunden 1977, Blunden and Black 1984) and its extension to embrace both multiple objective functions (Kuranami 1983) and multi-attribute decision making (Fararouri and Black 1989) is further exploited in this first part of the research program. The technique adopted here involves considering several environmental factors as simultaneous contributors to the overall quality of the environment. It introduces a scoring system of environmental quality using an environmental utility function, which blends the environmental factors into a single value. This value is then used as a representative score of the road in respect of environmental quality.

In pursuing the community impacts of road transport infrastructure developments, the concept of community severance, is being explored and enhanced in the second part of the research program. Community severance has been systematically classified into two categories - the static severance of the road infrastructure as a barrier to the community and the dynamic severance to pedestrians crossing a road induced by the flow of vehicles along the road. The nature of these impacts, along with assessment methods and mitigation measures, are being addressed for both categories. Methods of assessment of dynamic severance have been intensively reviewed and then EC as a quantifying indicator has been recommended for assessment of dynamic severance.

The third part of the research program has involved extending the environmental approach from the street level to an area basis. The Area Wide Environmental Capacity (AWEC) is defined as the maximum amount of traffic activities that may occur in a given area during a certain period of time, under fixed physical conditions, without causing environmental detriment. AWEC models have been developed by utilising an empirical-statistical approach and applied to concurrent data on traffic/transport, meteorological factors, layout and land-use conditions, and the pollution concentrations of carbon monoxide (CO) in the Sydney metropolitan region. In the face of the variability of air pollution standards in time and in space - and taking into account recent health-based studies - a new set of criteria has been introduced for use in the AWEC analysis. By way of a case study, the models have been applied Ultimo-Pyrmont (immediately to the west of the Sydney CBD) to calculate and evaluate its AWEC under a total of seven transport/traffic strategies. It demonstrates the feasibility and usefulness of the AWEC concept as an evaluation tool in strategic land use and transport planning applications.

THE MULTI-FACTOR APPROACH

A proposed multi-factor approach towards determining EC is shown in Fig 1. Suppose there are three main categories of data which may be described as follows.

1. Environmental data (noise, delayed pedestrians, air quality and accident risk).
2. Preferential data (data on weighings of factors).
3. Road and traffic data (traffic volume, travel speed and road geometry).

By using the first and second categories of data an environmental utility function is developed which simply calculates the relative scores of each road. Consider a road segment with noise level (N_i), delayed pedestrians (P_i) air quality (Aq_i), and accident risk (A_i). By applying weighting values on each factor, the environmental utility value (EUV) of this road may be calculated as per Eqn (1).

$$EUV_i = f(n_i, p_i, aq_i, a_i) \qquad (1)$$

where,

n_i, p_i, aq_i, and a_i = normalised values of N_i, P_i Aq_i, and A_i respectively.

If the quality of environment along the road depends primarily on traffic volume (q), travel speed (S), and road width (W), an attempt to develop a relationship between the EUVs and these variables may then be made. Regression analysis may be applied to obtain this relationship which might appear as Eqn (2).

$$q_i = g(EUV_i, S_i, W_i) \qquad (2)$$

Thus, there are two functions involving EUVs; Eqn (1), is intended to determine EUV as a representative environmental value of each site; Eqn (2) correlates traffic volume with its associated EUV and road/traffic characteristics. At this stage air quality is assigned to be a dependent variable for each road. However this approach will be updated in future as the outcomes of the third part of our research program (discussed subsequently in this paper) are applied to the Multi Factor Approach.

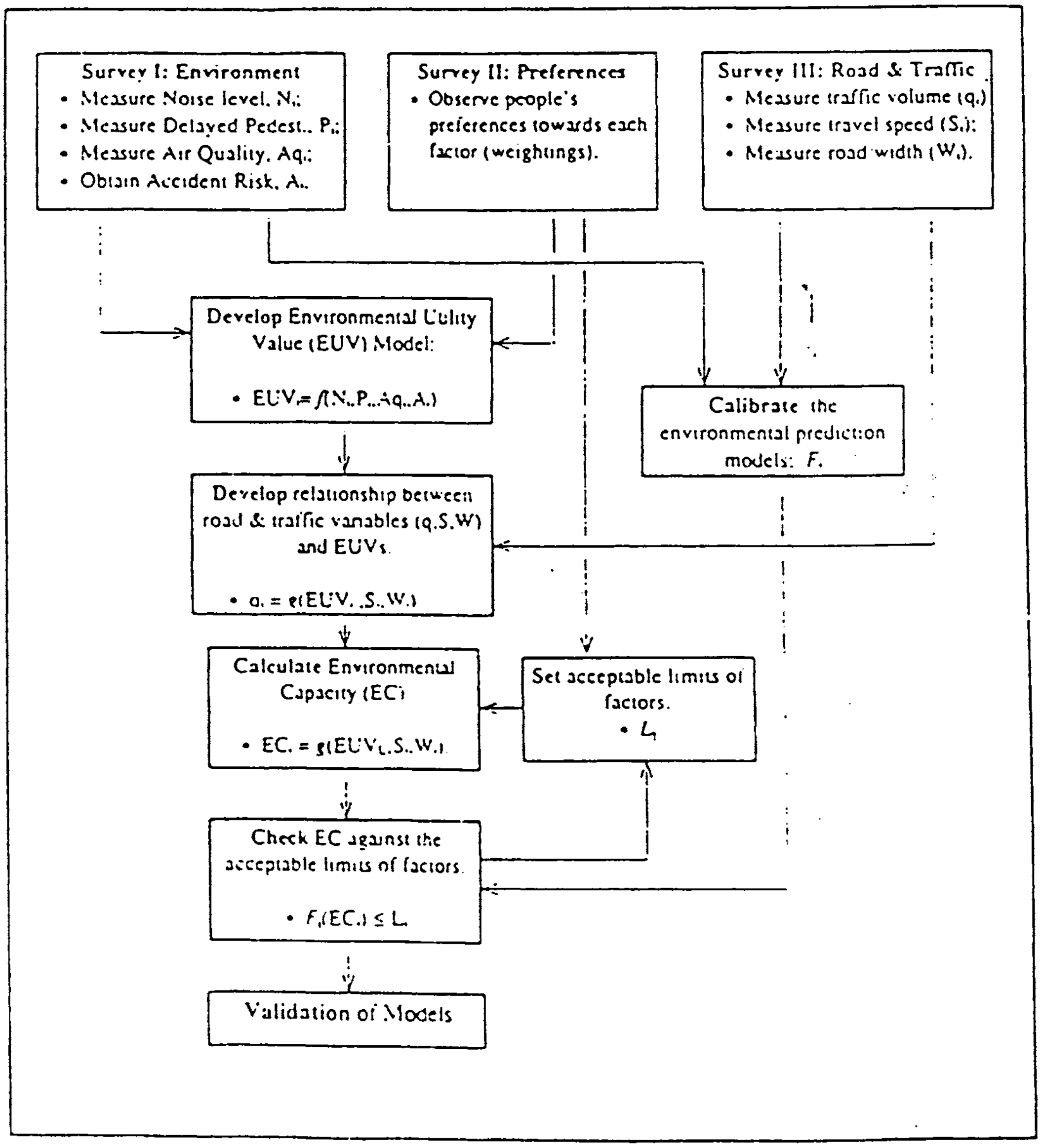


Figure 1. The multi-factor approach to environmental capacity analysis

Once the model has been developed, environmental capacity (EC) may then be determined by substituting EUV with its acceptable value for that particular type of road (for example, local, collector, or arterial) as per Eqn (3).

$$EC_i = h(EUV_L, S_i, W_i) \qquad (3)$$

where,

EUV_L = acceptable level of EUV at a certain road type.

If the value of EC produced by the method produces any excessive impact, as calculated by the prediction models, it may be altered by applying different value of EUV_L. This may be achieved by changing one or more of the previous limit levels until no excessive impact is produced. The value of EC which satisfies all the limit constraints may finally then be regarded as the optimum EC.

Further details of the model and its development are presented in Widiantono and Samuels (1998), along with some case study outcomes, and space limitations prohibit any elaboration on these matters herein. However, Table I gives results of a typical sensitivity analysis, conducted to show how the model reacts to controlled changes in model parameters such as speed (S) and road-width (W). For changes in the variables of the model, testings have been done against how far the changes will affect the EUVs in eq (1) and ECs in eq (3). In general, the model for determining EC utilising the multi-factor approach is very sensitive towards both travel speed and road width (Fig 1). For local roads, increases in average speed alone by 20% may decrease the EC by 4.5%, whereas reducing speed by 20% will increase EC by 5.0%. On the other hand, widening the road by 15% will increase the EC by 6.5%, while reducing road width by 15% will reduce EC by also 6.5%. When changes to both variables are made simultaneously, the story is rather different: changes both in speed by 20% and road width by 15% in positive ways will in fact increase the EC by only 2%. While reducing speed by 20%, but at the same time increasing road width by 15% will significantly increase EC by 11.5%.

Table I. Sensitivity of the Model to Changes in Independent Variables

Speed	Width	EC	EUV*
+20%	0%	-4.5%	---
-20%	0%	+5.0%	++
0%	+15%	+6.5%	+
0%	-15%	-6.5%	-
+20%	+15%	+2.0%	--
+20%	-15%	-11.0%	---
-20%	+15%	+11.50%	+++
-20%	-15%	-1.5%	++

* Changes in score, proportional to traffic volume; the greater the volume the greater the changes.

Similar observations were made in the case of EUV. Generally, with the same traffic intensity, EUV will increase as travel speed decreases or as road width increases. Substantial positive changes in EUV were observed when speed was reduced by 20% while at the same time road width was widened by 15%. Furthermore, the most negative changes occur by increasing speed by 20% as well as reducing road width by 15%.

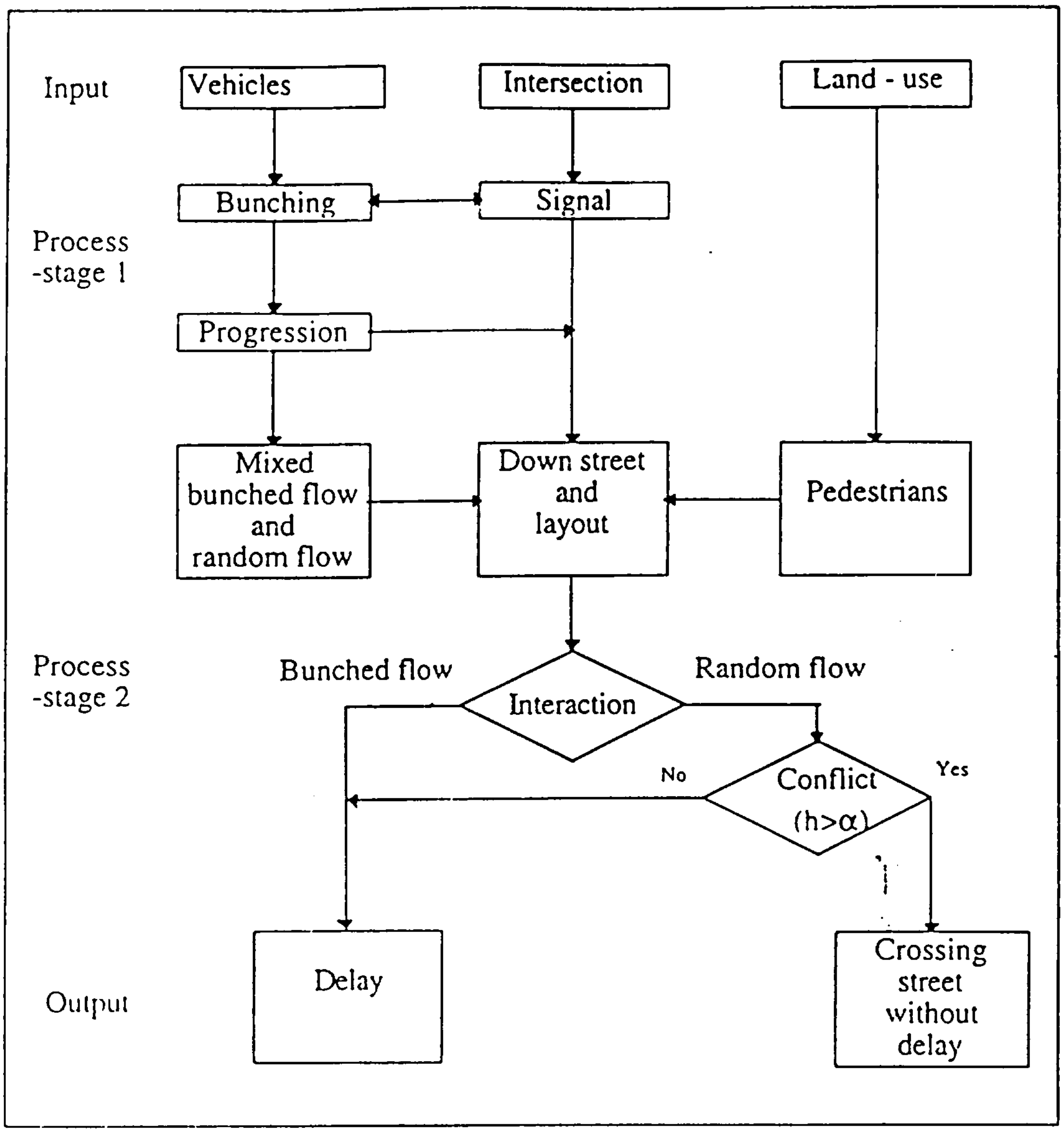
In this part of the research program an alternative approach towards estimating environmental capacity has been proposed. The conceptual approach has been outlined (Fig 1) accompanied by the results of a sensitivity analysis. This research is indicating that the methodology towards developing a general model in estimating environmental capacity seems so far to be both appropriate and reasonable. In order to calibrate the model, which is the next step in the ongoing research program, considerable amount of data will be required. Nevertheless, the indications are that, in theory, it is generally feasible to employ a multi-factor approach in determining environmental capacity.

COMMUNITY SEVERANCE

Community severance has become one of environmental factors which has been well identified in road development and traffic operations. Generally, Static Severance (SS) is a product of infrastructure which artificially divides an area into two separate parts so that it is difficult for one side to interact with the other. The direct effects of SS are trip diversion and suppression, poor accessibility and restricted personal mobility. The indirect effects may be psychological, cultural and social severance. The present research has focused on Dynamic Severance (DS). Traffic flow may be regarded as a dynamic barrier on urban streets which imposes problems for pedestrian movement. It may be defined as the time-dependent barrier effect caused by conflicting streams of pedestrian and vehicles traffic movements on a road which results in divisive impacts including physical separation and psychological impediments. Consequently, the study of DS is dealing with pedestrian/vehicle conflict including factors such as pedestrian delay, diversion to other crossing points and accident risk.

Various studies of traffic/pedestrian conflict have tried to assess the degree of severance (for example, Black *et al* 1987) but, in general, current practices do not comprehensively quantify severance effects in the environmental impact assessment of roads, and this appears to be especially so on busy urban roads where frequent traffic signals produce bunching or platooning of vehicles. The gap acceptance based approach to pedestrian delay assumes that vehicle arrivals are random which does not hold for vehicles downstream of traffic signals where bunching effects occur.

There are three inputs to our model, the first of which is vehicles arriving before the stop line at an intersection and represents the so called vehicle arrival process. The second is the intersection layout or geometric design and includes factors such as the number of approach lanes and widths. The third is the location of land-use site activities that generate pedestrian traffic and attract pedestrians to cross a street. There are two important processes within this model: vehicle bunching and dispersion and pedestrian interaction with this traffic. Vehicles bunch at the stop line and perform a progression along the street indicated as Process-Stage 1 shown in Fig. 2. This is a complex process containing three sub-processes which require the determination of the bunch size at the stop line, the bunch size immediately after the stop line; and the bunched flow dispersion downstream. The pedestrian-bunched flow interaction (Process-Stage 2 shown in Fig. 2) can be analyzed as two decision-making processes. First, the arrived pedestrians identify whether they face a bunched flow or a random flow. If it is bunched flow, they must wait until a random flow occurs to find a suitable crossing gap. If it is random flow, they start to scan for a suitable gap. Results from field observations and from simulation suggest a more accurate modelling of pedestrian delays than is the case with current models (for example, Adam's delay model) which tend to underestimate observed delays under bunched traffic flow.



h = headways; α - critical gap acceptance

Figure 2. Pedestrian-urban bunched vehicular flow interaction

AREA-WIDE ENVIRONMENTAL CAPACITY APPROACH

The basis of the AWEC model is that within a certain area and during a certain period of time there is a direct relationship between the total amount of traffic activities, measured in vehicle-kilometres of travel (VKT), and the resulting air pollution concentrations. This basic relationship is influenced by a number of traffic, meteorological and physical layout (ie. topography, land-use density and intersection density) factors. Thus, AWEC is defined as the total VKT producing a certain 'critical' air pollution concentration level (the criterion) under the prevailing traffic, meteorological and physical layout conditions unique to that sub-area. The AWEC criteria have been suggested following a comprehensive review and comparison of the air pollution standards of a number of countries (Shiran and Hidas 1995). In this paper AWEC models, based on the 'acceptable' level of carbon monoxide concentration have been applied to a Sydney case Study as the most stringent Australian, Japanese and Korean standards.

Two important factors in the AWEC model are the appropriate units of area and of time, and these have been investigated and presented in a separate paper (Shiran and Hidas, 1996a).

To simplify the inclusion of various meteorological conditions in the AWEC model, a variable called 'ventilation rate' has been introduced. The ventilation rate (VR), defined as the product of mixing height (MH) and the wind speed (WS), explains the circulation of air in both the vertical and horizontal directions in the sense of differences in meteorological conditions. Since air temperature is a prime factor in calculating the mixing height, the ventilation rate incorporates the meteorological variables of temperature, wind speed and mixing height. The AWEC analyses, reported in Shiran and Hidas (1996b), have been carried out under four meteorological scenarios, corresponding to different ranges of ventilation rate, one for peak periods: (1) VR range 0 to 300 (m^2/sec); and three others for daylight periods: (2) VR = 0-400; (3) VR = 400-850; and (4) VR = 850-1200.

Ten inner and outer suburbs of the Sydney, Newcastle and Wollongong regions (Sydney Metropolitan Region) where carbon monoxide (CO) is continuously monitored, were used to determine the AWEC model. For the statistical analysis and model building, use has been made of the data collected concurrently for the Sydney region by the Environment Protection Authority of New South Wales. These data include CO pollution concentrations, hourly wind speed and direction, and ambient air temperature, upper air information, traffic data in terms of estimated Annual Average Daily Vehicle Kilometres of Travel (VKT) for each 3x3 square kilometre grid cell and other traffic, transport and land-use information. Data were analysed from 6.00 am to 2.00pm in the winter months of 1994, because concentrations of CO are normally higher during colder months of the year, and meteorological conditions during the stated hours are more stable. Having regard to the developed spatial and temporal units, and under each meteorological grouping (or scenario), the basic relationship between traffic activities and the CO concentrations were investigated for the ten areas. The basic relationships between traffic activities and CO concetrations exhibited significant differences amongst the ten areas (Shiran and Hidas, 1996b).

From the basic relationships the numerical values of the AWEC for different areas were calculated at the 'acceptable' level of CO criterion. These were then correlated with a number of explanatory variables to which the basic relationships were thought to be sensitive. Correlation analysis was carried out under the four meteorological scenarios. The explanatory variables that were found to be strongly correlated with the AWEC (ie. those with confidence interval greater than 80%) were proportion of travel by road type (TRAVEL), density of all at-grade intersections (INTERSECTION), percentage of built-up environment (BUILT), and the angle between the predominant wind direction and the longest axis of the shape of the study area (ANGLE). Using the SPSS statistical analysis package, these variables were selected as inputs for a set of multiple linear regression models. As the generated linear models exhibited some limitations a simple transformation was carried out on the dependent variables to generate non-linear models by taking the natural logarithm of all parameters. Empirical-statistical models have been developed with the exponential models shown in Table II.

The general models in Table II have been calibrated and applied in a case study in the Ultimo-Pyrmont area of metropolitan Sydney. In the face of the sensitivity of the community to the quality of life and particularly the air quality issues resulting from traffic activities in the area, seven traffic and transport alternative plans were assessed using the AWEC models. Because of the availability of the morning peak traffic volumes, the most suitable non-linear AWEC model for these purposes will be the one for morning peak periods (ie. with ventilation rate range 0-300 m^2/sec), shown in Table II. Under the stated meteorological conditions of 0-300 m^2/sec, there are two variables for which input data were prepared: LOCALTRAVEL and ANGLE. The proportion of travel on residential/local road under each option was calculated by multiplying the link traffic volumes by their associated lengths. To approximate the predominant wind direction in the area, use was made of the 1996 data collected in neighbouring Rozelle, immediately to the west of the study area. The angle was found to be approximately 45 degrees.

Table II: Summary of the Non-linear AWEC Models, Sydney

Meteorological & Temporal Scenarios	AWEC MODELS Developed based on Acceptable level of CO Criterion
VR:0-300 m²/sec & PIN =0.05 (Peak period model)	$AWEC = 46.06\ e^{-0.156\ LOCALTRAVEL + 0.014\ ANGLE}$
VR: 0-400 m²/sec & PIN=0.05 (Daylight period model)	$AWEC = 185\ e^{-0.091\ LOCALTRAVEL}$
VR: 0-400 m²/sec & PIN=0.20 (Daylight period model)	$AWEC = 368.71\ e^{-0.078\ LOCALTRAVEL - 0.011\ BUILT}$
VR:400-850m²/sec & PIN=0.05 (Daylight period model)	$AWEC = 267.50\ e^{-0.046\ LOCALTRAVEL}$

Legend:
AWEC: The dependent variable (in 1000 VKT/km²)
LOCALTRAVEL: Travel on residential/local roads (as % of total)
ANGLE: Orientation angle measured between the longest imaginary line of development and the prevailing wind direction (degree)
BUILT: Built-up environment (as % of total)
INTERSECTION: Density of all at-grade intersections in an area
VR: Ventilation rate
PIN: Criterion used in the analyses is the probability associated with the F statistic which is called probability of F-to-enter, or simply PIN (Probability that a variable with a calculated F value can get IN the model). By default, PIN is 0.05.

The calculated AWEC values for various alternatives ranged from a low of 6234 veh/km of travel per km² to 18010 vkt/km². The Area-Wide Environmental Deficiency Index (AWEDI) is defined as the ratio of the expected travel demand (as calculated through traffic links and the link lengths) to the AWEC value for each (an AWEDI less than 1 means that the strategy/option results in no detriment to the local environment based on the acceptable criterion) was calculated to rank the strategies/options. (Hidas *et al* 1997). The superiority of a particular option was shown by the lower AWEDI of that option. The stated AWEC predictions have been made under the current state of engine technology and emission rates in the region, and no account has been given to any possible change which cuts down the overall emission rates of the future vehicle fleet. As such changes are likely to occur by the time horizon of the study, the long-term AWEC values are likely to be somewhat under-estimated and further research is required to account for this effect in the AWEC models. The AWEC approach, as shown above, is regarded as an easy-to-use evaluation tool to assess most of the transport/traffic-related control and management techniques to control the urban air pollution.

CONCLUSIONS

A three part ongoing research program has been presented which is extending the concept of environmental capacity. A multi-factor approach is being developed and preliminary results have indicated the potential of this particular technique. A Dynamic Severance (DS) component is also being explored and this work is at an initial stage. Area Wide Environmental Capacity has been presented as a powerful techniques for dealing with urban air pollution when air quality criteria are specified.

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