



UNIVERSITAS INDONESIA



Université
Lille1
Sciences et Technologies

**URBAN TRAFFIC MANAGEMENT USING
INTELLIGENT TRANSPORTATION SYSTEM (ITS)
CASE STUDY JAKARTA - INDONESIA**

THESIS

**YUSMIATI KUSUMA
0906580256**

**ENGINEERING FACULTY
POSTGRADUATE PROGRAM
UNIVERSITAS INDONESIA
DEPOK
JULI 2011**



UNIVERSITAS INDONESIA



**URBAN TRAFFIC MANAGEMENT USING
INTELLIGENT TRANSPORTATION SYSTEM (ITS)
CASE STUDY JAKARTA - INDONESIA**

THESIS

**Has been created as qualification to get
a degree Master of Engineering in Transportation**

**YUSMIATI KUSUMA
0906580256**

**ENGINEERING FACULTY
POSTGRADUATE PROGRAM
UNIVERSITAS INDONESIA
DEPOK
JULI 2011**

ii

Universitas Indonesia

DECLARATION OF ORIGINALITY

**This thesis is the work of my own, and all good source quoted
or reference I have stated correctly**

Name : Yusmiati Kusuma

Student Number : 0906580256

Signature : 

Date : 9 Juli 2011

Authentication

This Thesis is made by :

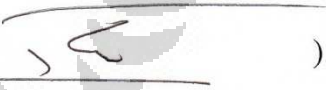
Name : Yusmiati Kusuma
NPM : 0906580256
Program Study : Civil Engineering – Transportation
Title : Urban Traffic Management using Intelligent Transportation System, Case study Jakarta - Indonesia


Has been successfully maintain in front of the judge and fulfil as one requirement to obtain Master of Engineering, Civil Engineering Department, Faculty of Engineering, University of Indonesia.

Judge

Supervisor : Rochdi MERTOUK ()

Supervisor : ()

Judge : SHAWANZ Dan ()

Judge : Harwan SADEK ()

State in : Lille
Date : 9th of July 2011

Département Licences / Masters de Polytech'Lille
Université Lille 1
Avenue Paul Langevin
F-59655 Villeneuve d'Ascq Cedex - FRANCE
Tél. : 03 28 76 74 04 - Fax : 03 28 76 73 61
E-mail : secretariat.lmd@polytech-lille.fr

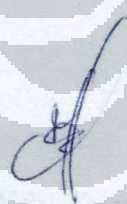

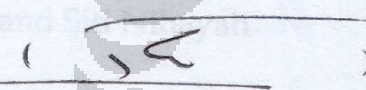
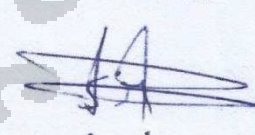
HALAMAN PENGESAHAN

Tesis ini diajukan oleh:

Nama : Yusmiati Kusuma
NPM : 0906580256
Program Studi : Transportasi
Judul Tesis : MANAJEMEN LALU LINTAS PERKOTAAN DENGAN
PENERAPAN INTELLIGENT TRANSPORTATION
SYSTEM (ITS) STUDI KASUS: JAKARTA –
INDONESIA

Telah berhasil dipertahankan dihadapan Dewan Penguji dan diterima sebagai bagian persyaratan yang diperlukan untuk memperoleh gelar Magister Teknik pada program studi kekhususan Transportasi, Program Pasca Sarjana, Universitas Indonesia.

DEWAN PENGUJI


Pembimbing : Rochdi MERZOUKI ()
Penguji : 1. SHAWANIL  ()
Maunwan SADEK ()

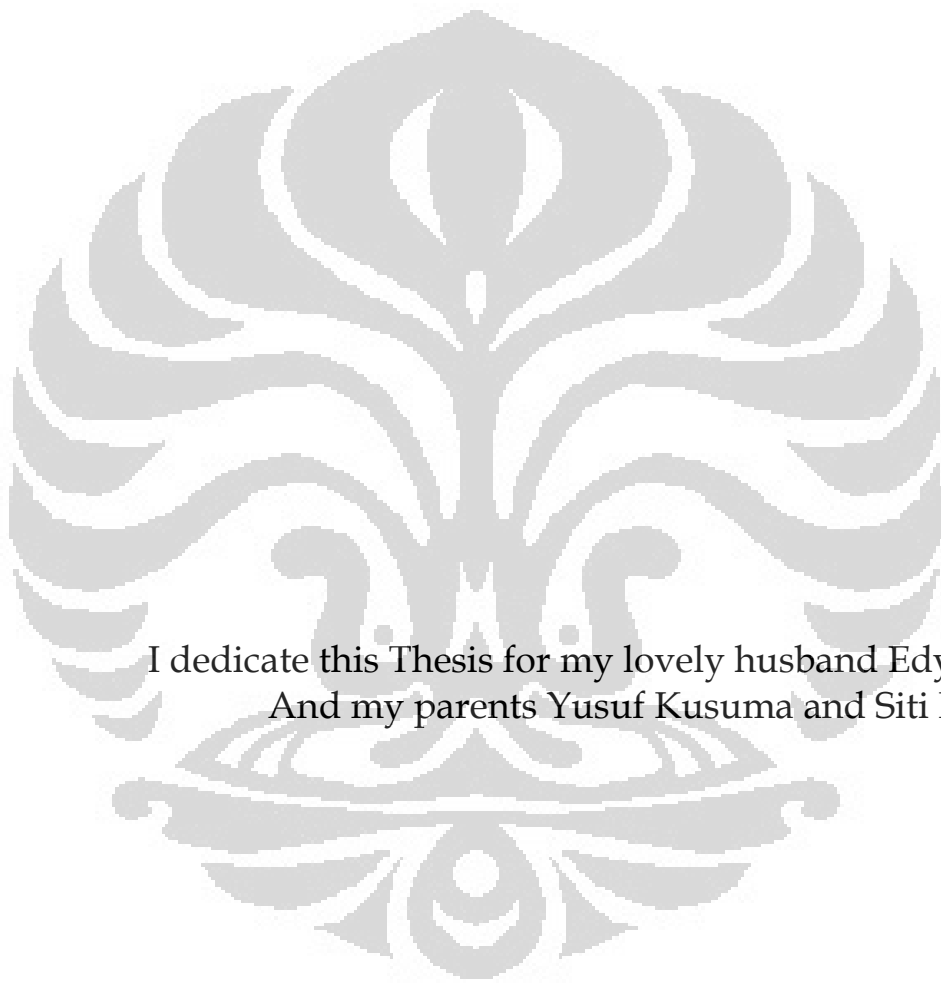
Ditetapkan di : Depok

Tanggal : 19 Agustus 2011

Mengetahui Kepala Departemen Teknik Sipil UI



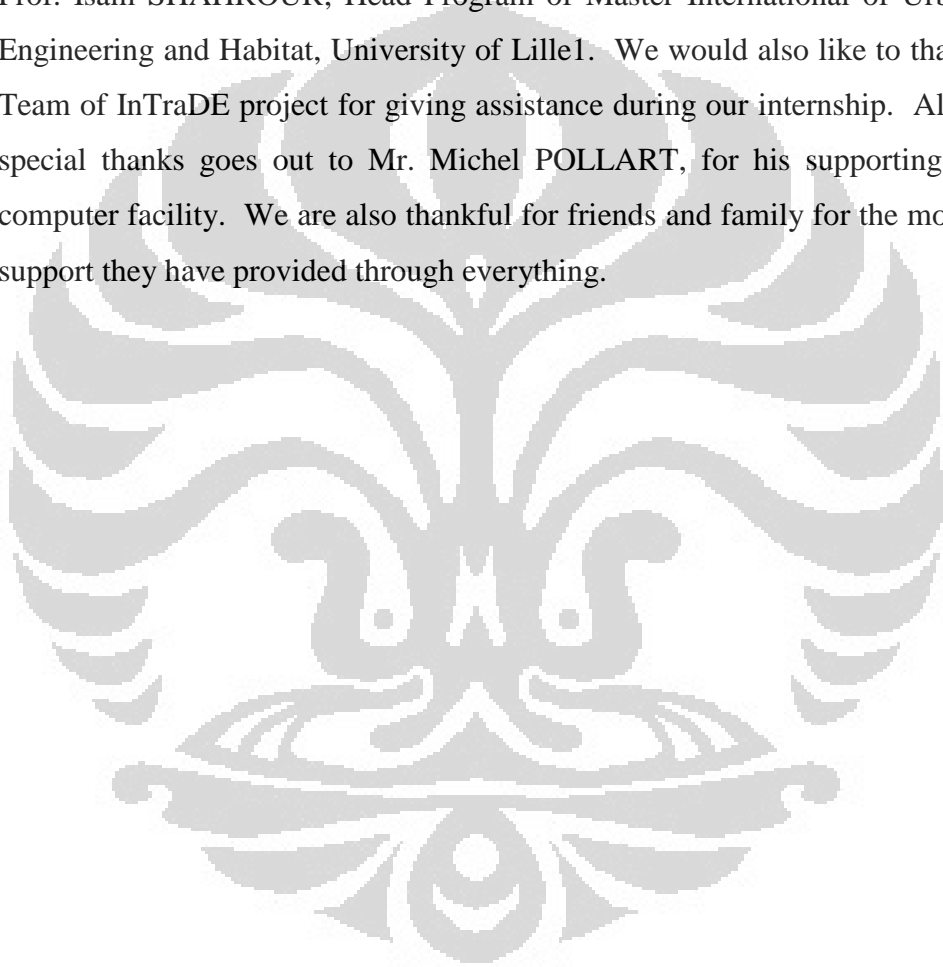

Prof. Dr. Irwan Katili, DEA



I dedicate this Thesis for my lovely husband Edy Yusran
And my parents Yusuf Kusuma and Siti Nihayah

ACKNOWLEDGMENTS

First, we would like to thank Mr. Rochdi MERZOUKI, Associate Professor of Laboratory of Automatics, Computer Engineering and Signal Processing (LAGIS) University of Lille1, for all the support and direction he has provided over the life of this internship. He has provided his instruction and the perfect balance of motivation to finish this project. A huge thanks to Prof. Isam SHAHROUR, Head Program of Master International of Urban Engineering and Habitat, University of Lille1. We would also like to thank Team of InTraDE project for giving assistance during our internship. Also, special thanks goes out to Mr. Michel POLLART, for his supporting in computer facility. We are also thankful for friends and family for the moral support they have provided through everything.



DECLARATION OF PUBLICATION APPROVAL PAGE FINAL
PROJECT ASSIGNMENT FOR ACADEMIC INTERESTS

As an academic student of University of Indonesia, I am who undersigned in below:

Name : Yusmiati Kusuma
NPM : 0906580256
Programe : Transportation
Department : Civil Engineering
Type of Assignment : Thesis

For the development of science, agreed to give University of Indonesia a **Non-Exclusive Royalty-Free Right** for my thesis with the title :

**Urban Traffic Management Using
Intelligent Transportation System (ITS)
Case study Jakarta - Indonesia**

along with existing devices (if needed). With this Non-exclusive Royalty-Free Right, University of Indonesia has a right to keep, to reform, to process in a database, to maintain and also publish my final project as long as my name as the author and the ownership stated

This statement has been quoted as correctly.

Verified in: Depok

Date: 10 August 2011

Signature



(Yusmiati Kusuma)

ABSTRACT

Name : Yusmiati Kusuma
Study program : Master of Transportation
Title : Urban Traffic Management Using Intelligent
Transportation System (ITS)
Case study Jakarta - Indonesia

The topic of this work discusses urban traffic management using intelligent transportation system. The two fluid model is a macroscopic modeling technique which provides characteristics of the performance of traffic flow on an urban road network.

The model does this by generating a relationship between trip time, stop time and running time per km. Here, we take SCBD (Sudirman Central Business District) Jakarta, Indonesia as a study area. The network was then modeled in scanner studio simulator. Data collected in 2008 and to predict the traffic volume in 2011, we use traffic growth index for Jakarta.

According to the work presented in this report, the use of IAV in urban environment can improve traffic management since it has shorter time than the use of conventional vehicle. With its ability to reconfigure itself if there is a fault, it has no impact with any other vehicle behind and congestion can be avoided. It means that if we compare parameters quality of traffic by using only IAV ($n = 0.01$ and $T_m = 2.24$) is better than using only conventional vehicles ($n = 0.03$ and $T_m = 2.37$). Average mean speed for IAV 13.61 km/h and for conventional vehicle 12.02 km/h, it means IAV can save more travel time than manual vehicle. Other benefit of using IAV is environmental friendly since it use electrical power and it can reduce pollution.

ABSTRAK

Nama : Yusmiati Kusuma
Program Studi : Master of Transportation
Judul : Manajemen Lalu Lintas Perkotaan dengan Penerapan
Intelligent Transportation System (ITS)
Studi Kasus Jakarta - Indonesia

Topik yang diangkat adalah manajemen lalu lintas perkotaan dengan menerapkan Intelligent Transportation System (ITS). Model two fluid adalah salah satu model makroskopik yang menghasilkan karakteristik arus lalu lintas pada jaringan jalan perkotaan.

Model ini menggambarkan hubungan antara waktu perjalanan, waktu berhenti dan waktu berjalan setiap km. Dalam hal ini, diambil daerah SCBD (Sudirman Central Business District) Jakarta, Indonesia sebagai area studi. Jaringan jalan dimodelkan pada program scanner studio simulator. Data diperoleh pada tahun 2008 dan untuk memprediksi tahun 2011 digunakan table indeks pertumbuhan lalu lintas Jakarta.

Hasil dari pemodelan adalah, dengan menggunakan IAV (Intelligent Autonomous Vehicle) di dalam lingkungan perkotaan dapat meningkatkan manajemen lalu lintas karena akan menghasilkan waktu perjalanan yang lebih singkat dibandingkan dengan kendaraan konvensional. Dengan kemampuannya untuk me-rekonfigurasi ketika terjadi kegagalan mesin, tidak akan berpengaruh pada kendaraan di belakangnya dan kemacetan dapat dihindari. Hal ini berarti, jika membandingkan parameter kualitas lalu lintas dengan menggunakan IAV ($n = 0.01$ dan $T_m = 2.24$) lebih baik jika dibandingkan dengan menggunakan kendaraan konvensional ($n = 0.03$ dan $T_m = 2.37$). Kecepatan rata-rata untuk IAV 13.61 km/jam dan untuk kendaraan konvensional 12.02 km/jam, ini berarti IAV dapat menghemat lebih banyak waktu perjalanan daripada kendaraan konvensional. Keuntungan lain adalah IAV bersifat ramah lingkungan karena menggunakan electrical power dan dapat mengurangi polusi.

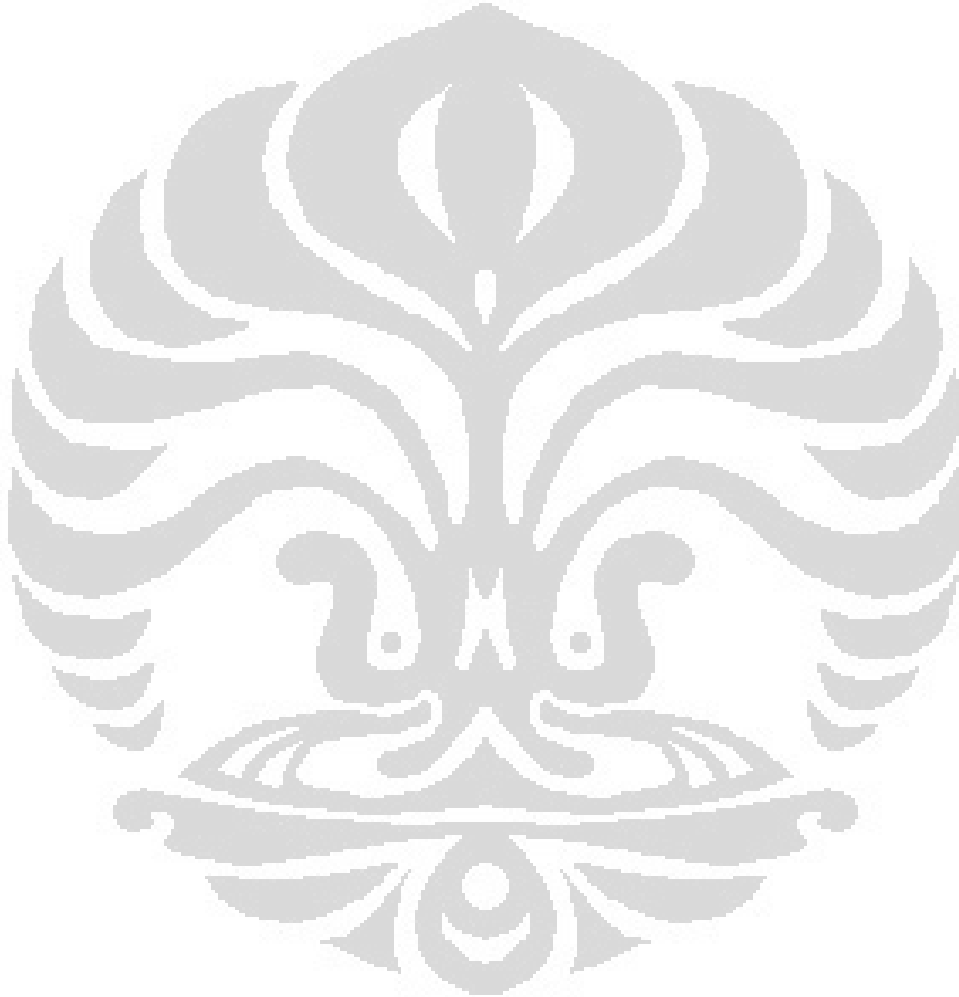
LIST OF CONTENTS

Cover	ii
Declaration of Originality	iii
Authentication	iv
Dedication	v
Acknowledgements	vi
Declaration of Publication for Academic Interest	vii
Abstract	viii
List of Contents	x
List of Tables	xii
List of Figures	xiii
List of Annexes	xv
Nomenclature	xvi
I. INTRODUCTION	
1.1. Background	1
1.2. Problem Definition	2
1.3. Goal and Hypotheses	3
1.4. The Scope of Work	3
II. LAGIS LABORATORY AND INTRADE PROJECT	
2.1. LAGIS Laboratory	4
2.2. InTraDE Project	5
III. STATE OF ART	
3.1. Introduction	8
3.2. Model Definition	8
3.3. Model Classification	9
3.4. Macroscopic Model at Urban Traffic	11

3.4.1. Two Fluid Model.....	12
3.4.2. Continuous Petri Net Model With Variable Speed.....	15
3.4.3. Platoon Dispersion Model.....	17
3.4.4. Kashani Model.....	20
3.5. Model Simulation.....	21
3.6. Conclusion.....	21
IV. CONTRIBUTION TO TRAFFIC MANAGEMENT IN URBAN ENVIRONMENT USING IAV	
4.1. Introduction	30
4.2. Methodology of work.....	30
4.3. Study Area	31
4.4. Macroscopic Model Choice.....	33
4.5. Traffic Simulation.....	34
4.6. Data Collecting	41
4.7. Data Analyzing	43
4.8. Conclusion	48
V. CONCLUSION AND PERSPECTIVES	
5.1. Conclusion.....	49
5.2. Perspectives.....	49
REFERENCES	

LIST OF TABLES

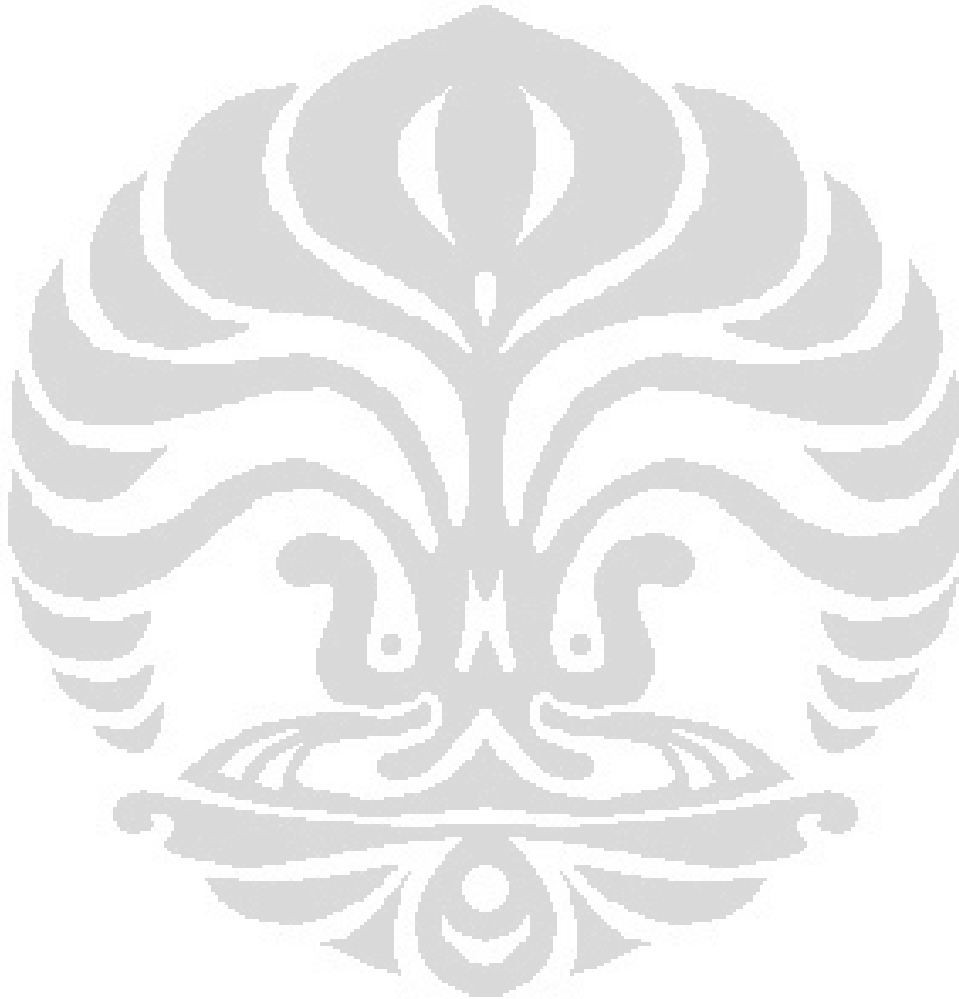
	Page
Table 3.1. The Effect of Various Network Features on Two-Fluid Model	14
Table 3.2. Macroscopic Model Choice	22



LIST OF FIGURES

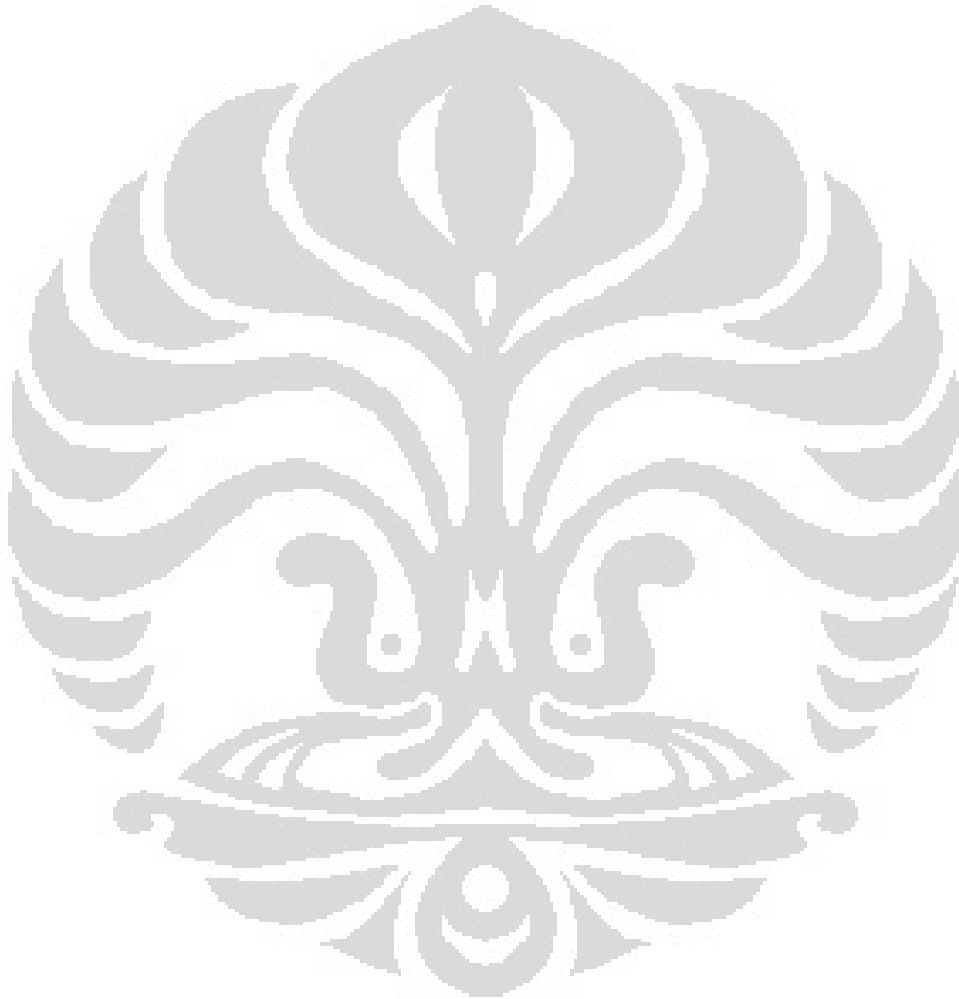
	Page
Figure 2.1	Transport Systems that Adapt to the Infrastructure 5
Figure 2.2	Heavy Intelligent Autonomous Vehicle (IAV) of InTraDE 7
Figure 2.3	Light Intelligent Autonomous Vehicle (IAV) 7
Figure 3.1	Model as a Representation of a Real World 9
Figure 3.2	Classification of Urban Traffic Model 9
Figure 3.3	Transportation Model 10
Figure 3.4	Urban Traffic Model Classification 11
Figure 3.5	Relation between Travel Time and Stop Time in One Location 14
Figure 3.6	Graphic of Petri Net 16
Figure 3.7	Illustration of Platoon Dispersion Model 19
Figure 3.8	Illustration of a Link Connecting Two Intersection 20
Figure 4.1	Flowchart of Application of Urban Traffic Modeling 31
Figure 4.2	Map of Jakarta, Indonesia 32
Figure 4.3	Study Area Image 32
Figure 4.4	Image of The Complete Terrain 34
Figure 4.5	Image of Conventional Vehicle for the First Scenario 35
Figure 4.6	Image of IAV for the Second Scenario 36
Figure 4.7	Flowchart in Fault Condition 37
Figure 4.8	Flowchart for Shuttle Bus 38
Figure 4.9	Traffic Network Simulation 39
Figure 4.10	Traffic Network Simulation in 3D view 40
Figure 4.11	Display of Data Export to Ascii File 40
Figure 4.12	Cross Section 41
Figure 4.13	Situation of SCBD Area 41
Figure 4.14	Direction way 43
Figure 4.15	Speed for All IAV 43
Figure 4.16	Graph $\ln T$ vs. $\ln T_r$ for All IAV 44
Figure 4.17	Relationship of T and T_s for All IAV 44
Figure 4.18	Speed for All Conventional Vehicle 45

	Page	
Figure 4.19	Graph $\ln T$ vs. $\ln T_r$ for All Conventional Vehicle	46
Figure 4.20	Relationship of T and T_s for All Conventional Vehicle	47
Figure 4.21	Comparison of T and T_s between IAV and Conventional Vehicle	47



LIST OF ANNEXES

- Annex 1 Description of SCANeR™studio through an Example
- Annex 2 Data of Traffic in SCBD Area
- Annex 3 Result



Nomenclature

U = speed (km/h)

U_m = speed at maximum flow (km/h)

K = density (veh/m)

K_j = jam density (veh/m)

U_f = free flow speed (km/h)

K_m = maximum density (veh/m)

m_{arr} = number of cars arriving

m_{dep} = number of cars departing

α = origin intersection

β = destination intersection

$$\delta = \text{ceil} \left(\frac{S_{\alpha, \beta} (l) L_{av}}{v_{free, \alpha, \beta}} \right)$$

$v_{free, \alpha, \beta}$ = the average speed of the traffic in link α, β in free flow condition (km/h)

L_{av} = the average vehicle link

S = available storage space of link

$\text{ceil}(r)$ with r a real number denotes the smallest integer larger than or equal to r

$VCPN = (Q, V_{max})$

$Q = (P, T, Pre, Post, M_0)$

P = place

T = transition

Pre = the weight of the arc directed from P to T

$Post$ = the weight of the arc directed from T to P

M_0 = initial marking

V_{max} = real positive vector of transitions maximal firing speeds (km/h)

v_i = firing speed of the transition t_i (km/h)

x = length of segment (continuous petri net model)

ρ = density

$v_{free i}$ = the limited maximal speed in segment i (continuous petri net model)

α : weight of the current traffic situation (bayessian model)

PS : prediction speed
 RS : vehicle speed of the real-time result
 q = traffic flow rate (veh/h)
 l = length of cell (m)
 i = cell
 t = time (s)
 T : total travel time (s)
 T_r = running time (s)
 T_m = average minimum trip time per unit distance (s)
 n = indicator of the quality of traffic service in the network (two fluid model)
 Δt = time step duration, measured in the time intervals used for q'_t (s)
 T = minimum travel time on the roadway in units of time steps, equal to $\beta \cdot T_a$
 (platoon dispersion model) (s)
 β = dimensionless travel time factor (platoon dispersion model)
 α = dimensionless platoon dispersion factor (platoon dispersion model)
 F = smoothing factor
 T_a = mean roadway travel time, measured in units of time steps (s)
 ξ = specific detector
 j = subset
 i = day
 $\hat{\sigma}_{i,j}^2$ = variance
 $\hat{\rho}_i(\tau)$ = covariance
 ρ = density
 v = space mean speed
 λ = number of lane in segment
 T = sampling time (new mixed flow model) (s)
 L_m = length of segment
 I = traffic intensity (per unit area)
 R = road density
 α and m = parameters (α -relationship model)

CHAPTER 1

INTRODUCTION

1.1. BACKGROUND

Transportation in urban areas is becoming more important nowadays. Jakarta, as a capital of Indonesia has an important role to create sustainability in urban transportation system. It means that it should includes many factors on it such as: plan, design, construct, operate, maintain, and manage in safety way, rapid, comfort, convenient, economical and environment compatible. Transportation is key of the future. It is a driver of economic and social development of development countries. Transportation impacts on sustainability include [33]:

1. Economic

Traffic congestion, mobility barriers, accident damages, transportation facility cost, consumer transportation cost, depletion of non-renewable resources.

2. Social

Inequity of impacts, mobility disadvantaged, human health impacts, community cohesion and liveability, aesthetic.

3. Environment

Air and water pollution, climate change, noise impacts, hydrologic impacts.

Jakarta has an area of approximately 662.33 km², with a total population of 9,588,198 inhabitants [46]. The city become fast developed nowadays and it will be impact to the environment and the quality of life for all citizens. Many policies have applied to improve this but still it is not solve the problem.

One of the solutions to overcome this problem is by applying Intelligent Transportation System (ITS) in urban area. This system could be applied for infrastructures, signals and vehicles. In Jakarta, it is not possible to arrange infrastructure since there is a limited area, signal will also not be make it better. Trying in experimenting new concept like using Intelligent Autonomous Vehicle in confined area in Jakarta could be interesting one with many advantages on it namely: decrease pollution (because of its stable speed), and decrease fatigue caused by queue (it could be reduce accidents), enabling a smoother traffic flow (people can work or rest while travelling), improved safety (with the ability to detect many different kinds of transportation system/dynamics object namely: walking, cycling, driving).

1.2. PROBLEM DEFINITION

The problem with urban city transportation especially traffic in Jakarta is getting worse, the traffic environment and control system are getting more and more complex. In addition with increase of the number of accident and pollution will make it worst. In order to improve the quality of transportation and safety infrastructure, by not produce new infrastructure, we want to test the feasibility of introducing the Intelligent Autonomous Vehicle (IAV) for routing operations in the context of Jakarta. This study encloses modeling of traffic and simulate by using the real traffic measurements. One of the advantages of using the IAV in urban environment is that the infrastructure should not get modified, due to the new technologies capabilities.

1.3. GOAL AND HYPOTHESES

The goal of this project is to improve the traffic management and space optimization using IAV by scoping and describing traffic flow in macroscopic level.

1.4. THE SCOPE OF WORK

This project is focused in Central Business District (CBD) area in Jakarta and limited with:

- Macroscopic traffic flow study in unsignalized confined area
- Modeling existing traffic flow in unsignalized confined area
- Using simulation software to apply the appropriate model
- No external perturbation (weather, accident, pedestrian crossing)
- Considering macroscopic parameter only (flow, speed, density)
- Homogenous vehicle (all IAV or all conventional vehicle)

CHAPTER 2

LAGIS LABORATORY AND INTRADE PROJECT

2.1. LAGIS LABORATORY

This internship takes place at Laboratoire d'Automatique, Genie Informatique et Signal (LAGIS) university of Lille 1. The Laboratory of Automatics, Computer Engineering and Signal Processing (LAGIS) is a joint research unit of the University of Lille 1, the Ecole Centrale de Lille (Higher School of Engineering independent of the University) and the National Scientific Research Centre (CNRS). LAGIS is composed of 64 permanent researchers from the CNRS and the associated institutions, 19 engineers, technicians and administrative employees, and 66 PhD students and Post-Does [22].

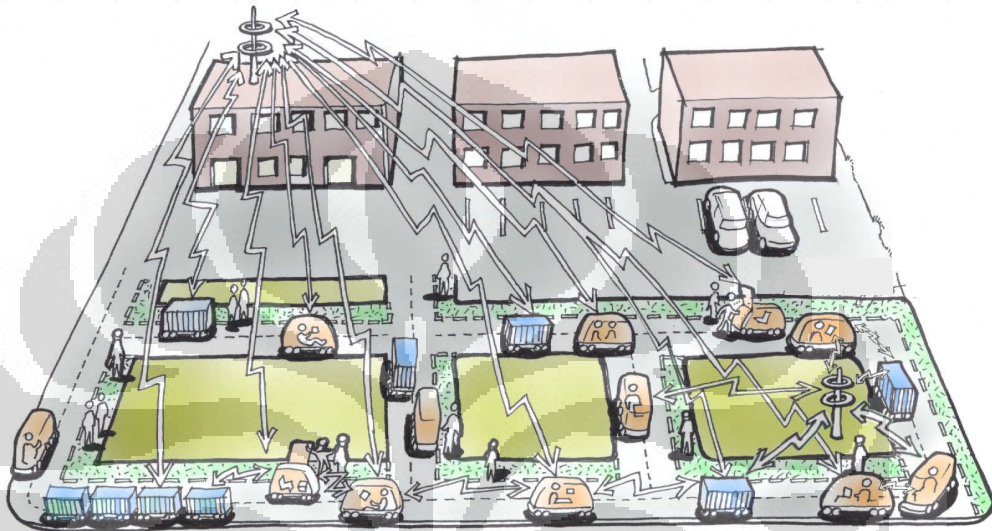
The LAGIS research objectives concern the development of fundamental, methodological, and technological research in the fields of automatic control, computer engineering and signal processing. The LAGIS research teams are active in [22]:

- Integrated design of multi physical systems
- Nonlinear and time-delay systems
- Optimization of logistic systems
- Fault tolerant systems
- Signal and image processing

LAGIS Research in Intelligent Transportation Systems (ITS) includes:

- Control and supervision of intelligent autonomous vehicles
- Virtual and dynamic simulation

Figure 2.1 represents that ITS system is able to connect and control the infrastructure of transportation with automobile. This system could be controlled by a center station. For example center station can detect position of vehicles and get information of traffic. It can send the information to the vehicles in real-time condition.



Source: [23]

Figure 2.1 Transport Systems that Adapt to the Infrastructure

2.2. INTRADE PROJECT

Our internship theme is based on project research that has been doing at LAGIS laboratory (InTraDE project). InTraDE (Intelligent Transportation for Dynamic Environment) is a multi disciplinary project with many benefits. The description of the project objectives and its partnership is given in [45], where the following text is taken:

- Universite Lille1 – LAGIS (Project leader)

LAGIS is the leader partner and thus, manages the project from an overall perspective. It collaborates with Port of Oostende, NITL (Dublin Institute of Technology (DIT) and CRITT for coordination and administrative tasks.

- Institut National de Recherche et Informatique et Automatique (INRIA – Loria)
- South East England Development Agency (SEEDA)
- Centre Regional d’Innovation et de Transfert de Technologie Transport et Logistic (CRITT TL)
- AG Port of Oostende (AGHO)
- National Institute for Transport and Logistics, Dublin Institute of Technology (DIT)
- Liverpool John Moores University

The main objectives of this project are:

1. To study traffic flow within confined spaces of container terminals and develop an insight into the factors influencing the overall productivity of such facilities, and to investigate existing traffic control methods and develop new methods where necessary to improve efficiency whilst ensuring safety.
2. To identify automatic navigation methods and develop new algorithms for robust supervision, and to investigate practical issues in implementing automatic navigation system in container terminals.
3. To develop an automatic traffic time-domain simulator for autonomous and human driven-vehicles within the terminals and to carry out a design case study of terminal layout using the simulator.
4. To design, test and validate intelligent transport vehicles prototype with dynamic environments inside confined spaces or combined urban-confined spaces.

InTraDE project contributes to improve the traffic management and space optimisation inside confined space by developing a clean and safe, intelligent transportation system. This system would adapt to the specific environment requirements, and could be transferred to different sizes of ports and terminals. The transportation system operates in parallel with virtual simulation software using SCANeR™studio interface of the

automated site [45], allowing a robust and real-time supervision of the goods handling operation. Hence, no infrastructure requirements and investment, while the project took a port as an area study, we take confined urban area in Jakarta, Indonesia with the same vehicle and simulator.

Figure 2.2 shows the Heavy IAV of InTraDE. This IAV called Robutainer has specification:

- Weight without load : 3000 kg
- Payload : 7000 kg
- Dimension : 7×2.5×1.2m (l×w×h)
- Maximum speed : 25 km/h

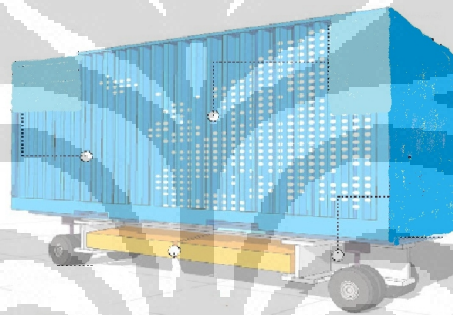


Figure 2.2 Heavy Intelligent Autonomous Vehicle (IAV) of InTraDE

While Figure 2.3 shows the light vehicle type of IAV.



Figure 2.3 Light Intelligent Autonomous Vehicle (IAV)

CHAPTER 3

STATE OF ART

3.1. INTRODUCTION

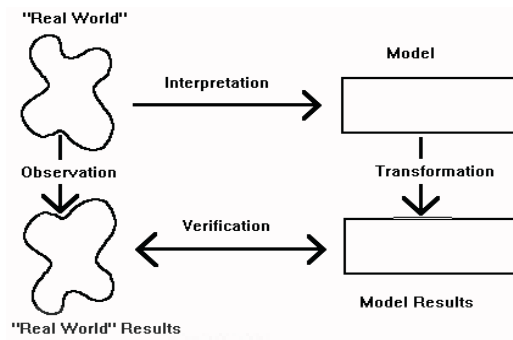
The aim of this chapter is to do literature study of modeling of urban traffic at macroscopic levels and make comparison between different models according to performances and objectives.

3.2. MODEL DEFINITION

Model is a real representation containing the essential structure of some object or event in the real world. The representation may take two major forms:

1. Physical, as in a model vehicle.
2. Symbolic, as in a natural language, a computer program, or a set of mathematical equations.

The scientific method is a procedure for the construction and verification of models. After a problem is formulated, the process consists of four stages. These four stages and their relationship to one another are illustrated in Figure 3.1. It shows interpretation of a real system to the simple system (model) then after model result obtained; compare it with the data from observation.



Source: [12]

Figure 3.1. Model as a Representation of a Real World

3.3. MODEL CLASSIFICATION

Many mathematical and simulation transportation models have been developed and can be categorized as macroscopic, mesoscopic and microscopic models. The explanation of these models can be seen in Figure 3.2.

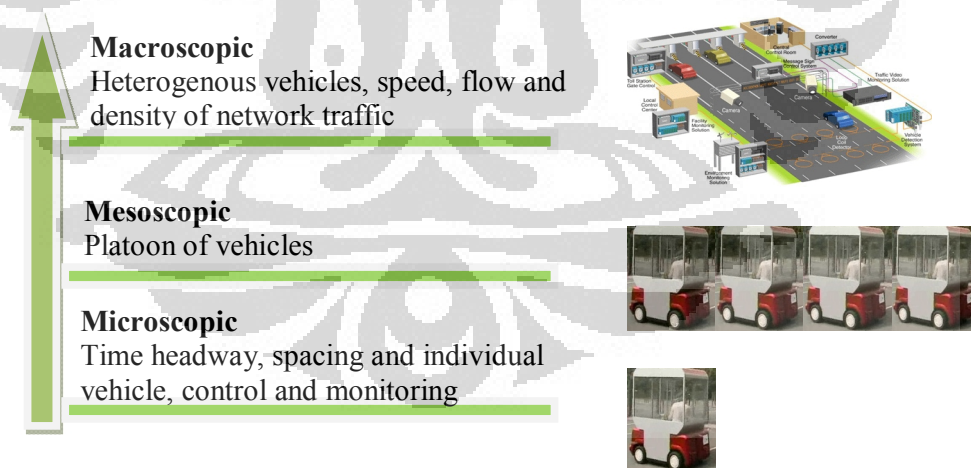


Figure 3.2. Classification of Urban Traffic Model

From Figure 3.2, it can be seen that macroscopic model describe traffic flow, taking into consideration cumulative traffic stream

characteristics (speed, flow and density). Microscopic model takes an individual vehicle movement within transportation network according to the physical characteristic of vehicle (length, time headway, spacing, etc). Mesoscopic focuses on characteristics of platoon vehicle in the network.

Macroscopic should be used when the available model developed time and resources are too limited for development of microscopic model. In some occasions macro approaches provide better result, the number of parameters is relatively small and more important, easy to observe and measure [33]. Macroscopic model is very suitable for model based on estimation, prediction and control of traffic flow.

Transportation models generally divided by four models, given in [3], as can be seen in Figure 3.3.

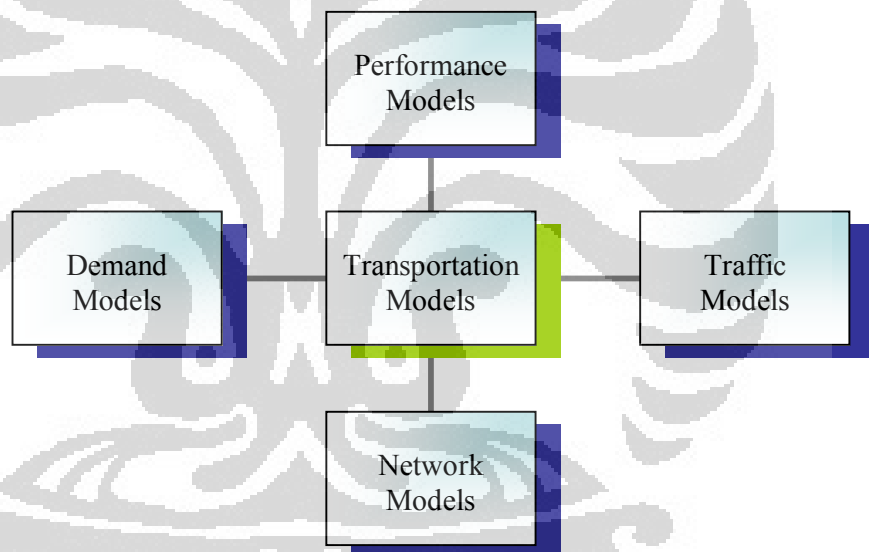


Figure 3.3. Transportation Model

Figure 3.3 shows that transportation models in macroscopic level have four models, each model has its characteristics, such as:

1. Demand models: econometric, short-term traffic prediction, traffic generation.
2. Network models: modal split, traffic assignment, scheduling.
3. Traffic models: advanced traffic and control representation, interaction between vehicles.

4. Performance models: traffic quality perception, safety performance models, fuel consumption, air-pollution generation, noise generation, signal optimization.

3.4. MACROSCOPIC MODEL AT URBAN TRAFFIC

In this project, we only focus on macroscopic model at urban traffic. Figure 3.4 shows the different type of urban traffic model. Descriptive model used for describe the characteristics of traffic, while predictive model used for predict the future traffic. The use of stochastic model in the form of ility distribution, while in deterministic model has precisely determined distribution.

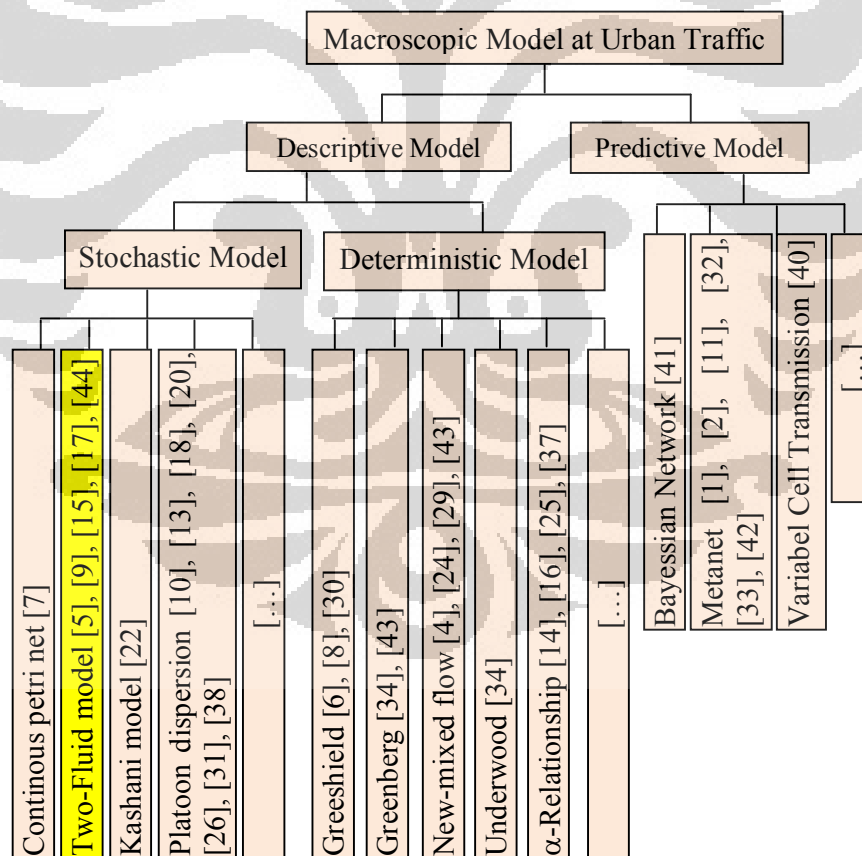


Figure 3.4. Urban Traffic Model Classification

From Figure 3.4, it can be concluded that based on the definition and the use of urban traffic model, the appropriate model for the IAV is stochastic model, because the traffic parameters are not usually deterministic in terms of density, flow and speed. These models are: continuous petri net model, Two-Fluid model, kashani model and platoon dispersion model. Here, we only take Two-Fluid model as an example.

3.4.1. TWO FLUID MODEL

This model describes traffic as a fluid. In this model there is 2 fraction of vehicle, namely: moving vehicles and stopped vehicles [28]. This model was constructed between the average travel time per km (T) versus the average running time per km (T_r) using regression as shown in equation (3.1). The parameters (n, T_m) determined from the regression model are indicative of the quality of service of the networks. This also translates to the relationship between stopped time and travel time per km shown in equation (3.2).

$$T_r = T_m \frac{1}{n+1} T^{\frac{n}{n+1}} \quad (3.1)$$

$$T_s = T - T_m \frac{1}{n+1} T^{\frac{n}{n+1}} \quad (3.2)$$

where:

T_m = average minimum travel time per unit distance (min/km)

T = total travel time (min/km)

T_r = running time (min/km)

n = quality of traffic service in the network

T_s = stop time (min/km)

T_m translates to the free flow travel time per km and n determines how rapidly the travel time will increase as the stop time increases.

Therefore, larger values of both T_m and n indicate worse network performance. If $n = 0$, T_r is constant, and travel time would increase at the same rate as the stop time. If $n > 0$, travel time increases at a faster rate than the stop time, meaning that running time is also increasing. In other words, n is a measure of the resistance of the network to degraded operation with increasing demand [5].

A quick and simple way of calculating T_m and n by restarting equation (3.1) as follows [17]:

$$\ln T_r = \frac{1}{n+1} \ln T_m + \frac{1}{n+1} \ln T \quad (3.3)$$

Or
$$\ln T_r = A + B \ln T \quad (3.4)$$

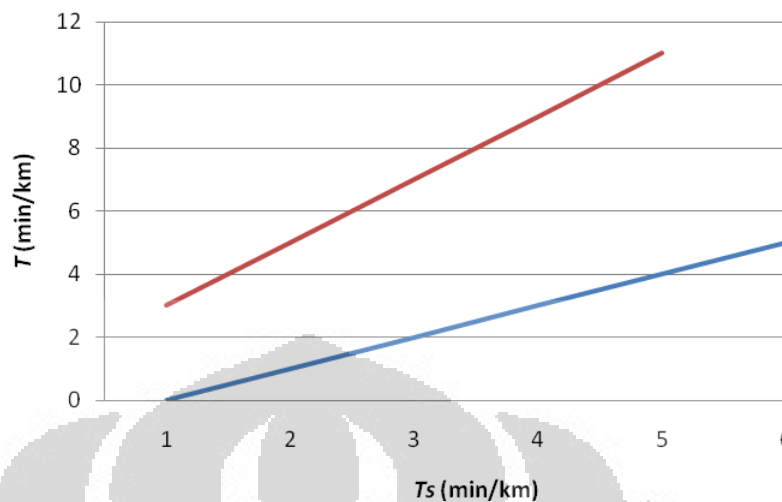
Where:

$$n = \frac{B}{1-B} \quad (3.5)$$

$$T_m = e^{\frac{A}{1-B}} \quad (3.6)$$

All that is needed at this point is a means of finding A and B . Once the data for T and T_r are collected, $\ln T$ is plotted vs. $\ln T_r$. The regression line of this plot is in the form equation [3.4].

Finally we can describe the relation of travel time and stop time as seen in Figure 3.5.



Source: [17]

Figure 3.5. Relation between Travel time and Stop Time in One Location

Table 3.1 summarizes the effects on the two parameters of the Two-Fluid model. The '+' and '-' signs indicate positive and negative effects respectively on T_m and n as the associated factor increases. For example, an increase in signal density would increase T_m (depicted with a '+' sign) and decrease n (depicted with a '-' sign). In other words, an increase in the signal density would result in worse network performance during free flow conditions and better performance during congested conditions.

Table 3.1. The Effect of Various Network Features on Two-Fluid Model

Factor	T_m	n
Signal Density	+	-
Average Speed Limit	-	
Fraction of approaches with signal progression	-	
Average Number of Lanes per Street		-
Fraction of one way streets		+
Fraction with Actuated Signals		-
Average Block Lengths		+
Average Speed Limit	-	
Average Cycle Length	-	+

Source: [17]

3.4.2. CONTINUOUS PETRI NET MODEL WITH VARIABLE SPEED

Petri nets are a graphical and mathematical modelling tool applicable to many systems. They are a promising tool for describing and studying information processing systems that are characterized as being concurrent, asynchronous, distributed, parallel, nondeterministic and/or stochastic [36].

Petri nets have been used extensively for modelling, analysis and synthesis of dynamic system. The basic idea is to consider the marking of the places as a positive real number instead of an integer one and the firing of transitions as a continuous process instead of a discrete event one. Concerning the domain of transportation, continuous Petri net (PN) have been done some works either to represent the traffic flow in motorway corridors or in complex road junction. Several models of continuous PN have been defined with constant speeds, with variable speeds and with nonlinear firing speeds. The Continuous Petri Nets with Variable Speed (VCPN) is suitable to model the traffic flow with a modular spatial discretization.

As a graphical model A VCPN is a couple (Q, V_{\max}) in which Q is a marked ordinary PN and V_{\max} is the real positive vector of transitions maximal firing speeds. Formally, a marked ordinary PN is a quintuplet $Q = (P, T, Pre, Post, M_0)$,

where :

$P = \{P_1, P_2, \dots, P_L\}$ is a finite, nonempty set of places

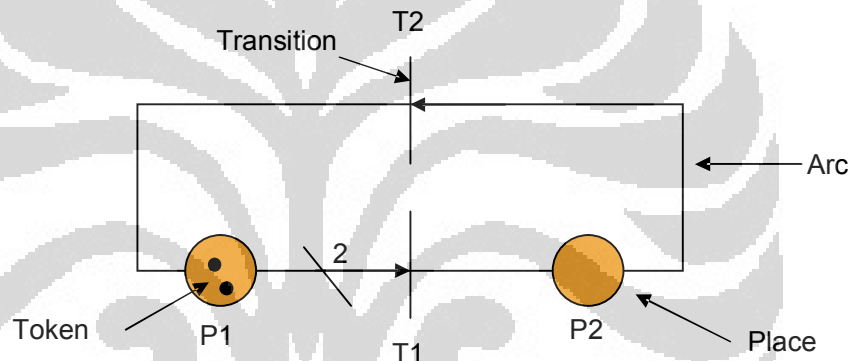
$T = \{T_1, T_2, \dots, T_n\}$ is a finite, nonempty set of transitions

$P \cap T = \emptyset$ (i.e., the sets P and T are disjoint)

$Pre = P \times T \rightarrow \{0,1\}$ is the input incidence function such that $Pre(P_i, T_j)$ is the weight of the arc directed from place P_i to transition T_j

$\text{Post} = PxT \rightarrow \{0,1\}$ is the output incidence function such that
 $\text{Post}(P_i, T_j)$ is the weight of the arc directed from
 transition T_j to place P_i
 M_o = an initial marking that associates zero or more tokens to
 each place

Figure 3.6 represents movement of token that indicated of vehicle.
 For moving, number of token must equal or more than weight of the
 arc that defined 2 according to the figure. As a mathematical model
 VCPN model is inspired from the hydrodynamic theory and consider
 the flow as a compressible fluid [21].



Source: [35]

Figure 3.6. Graphic of Petri Net

In VCPN models each place P_i corresponds to the road
 segment i , $i = 1, \dots, L$, and each transition T_i stands for the separation
 between the segments P_i and P_{i+1} . By using equation (3.7) and (3.8)
 we can get average density and speed for each segment.

$$K_i(t) = \frac{m_i(t)}{x_i} \quad (3.7)$$

$$U_i(t) = \frac{v_i(t)x_i}{m_i(t)} \quad (3.8)$$

Where:

$K_i(t)$ = average density for segment i

$U_i(t)$ = average speed for segment i

$m_i(t)$ = number of vehicles

x_i = length of segment

$v_i(t)$ = transition firing speed

3.4.3. PLATOON DISPERSION MODEL

Simulation is performed under the full-actuated control scheme, data manually survey. Simple matrix equations can formulate all of the intersection regardless of its geometry. An embedded traffic is represented as platoon dispersion; this model has linear constants (based on microscopic simulation). Urban vehicles involved in platooning applications are supposed to move at a quite low speed.

The parameter that best describes the characteristics of traffic streams is the 'arrival type' which should be determined as accurately as possible because it will have a significant impact on delay estimates and level of service determination, platoon ration is a useful measure to quantify arrival types. A platoon of road traffic is a set of vehicle travelling together as a group. It will have dispersion if they get segregated as they move over the distance towards the downstream signal. We should know the platoon character, platoon effect (when design signal timing or stopped immediately. In model dispersion we have mathematical and simulation [38].

The platoon dispersion happens mostly as a result of vehicle interaction with other vehicle entering and exiting the roadway which is commonly known as the road way side friction. Besides, the difference in driver's desired speed also plays an important role

in characterizing platoon dispersion especially when the side friction is low.

Formation of platoon means that improved traffic flow can be achieved if the green phase at the downstream traffic signal is applied to concede with the arrival of the platoon. To achieve this, traffic signal must be coordinated or linked. Signal coordination improves the level of service on road network where the spacing of traffic signals is such that isolated operation causes excessive delays.

Observation of the diffusion of traffic platoons has been reported by Lighthill and Witham (1955), Pacey (1956), Lewis (1958), Graham and Chenu (1962), Herman, Patts and Rothery (1964), Dokerty (1967), and Hillier and Rothery (1967), Robertson (1969). Robertson used a recurrence relationship to describe the platoon dispersion phenomena because of the simplicity of applying this model, Robertson's platoon dispersion model became a virtual universal standard [20]. This is a Robertson model:

$$q'_i = F \times q_{i-T} + (1-F) \times q'_{i-\Delta t} \quad (3.9)$$

$$F = \frac{1}{1 + \alpha\beta T_a} \quad (3.10)$$

Where:

q_{i-T} = discharging flow over a time step Δt observed at the upstream signal at time $t-T$

q'_i = flow rate over

Δ_i = time step duration, measured in the time intervals used for q'_i and q_i

T = minimum travel time on the roadway

α = dimensionless platoon dispersion, factor, express the degree of the dispersion of the platoon

β = dimensionless travel time factor = ratio of the average travel time of the first vehicle to the average travel time of all the vehicle in the platoon

$$= \frac{2T_a + 1 - \sqrt{1 + 4\sigma^2}}{2T_a}$$

β and α between 0 and 1, if $\beta=1$ and $\alpha=0$ situation of platoon compact and dispersion is minimal

F = smoothing factor

$$= \frac{\sqrt{1 + 4\sigma^2} - 1}{2\sigma^2}$$

T_a = mean roadway travel time (units of time steps)

σ = standard deviation of link travel time (s)

α = 0.2-0.5 (select the range that minimizes the sum of square error between field and estimate flow profile)

In Robertson formula, platoon dispersion coefficient α is an important parameter and significantly influences prediction accuracy, because traffic flow is the dependant and α is difficult to determine, prediction accuracy of Robertson is not satisfying.

Figure 3.7 simulates the dispersion of traffic as it travels along a roadway by attempting to estimate vehicle arrivals at downstream intersection location based on an upstream vehicle departure profile and a desired traffic stream speed. By doing observation with video cameras to calculate the vehicle travel time in each point (t_1 , t_2 , t_3) and average travel speed between observation location as well as the traffic flow at each location.

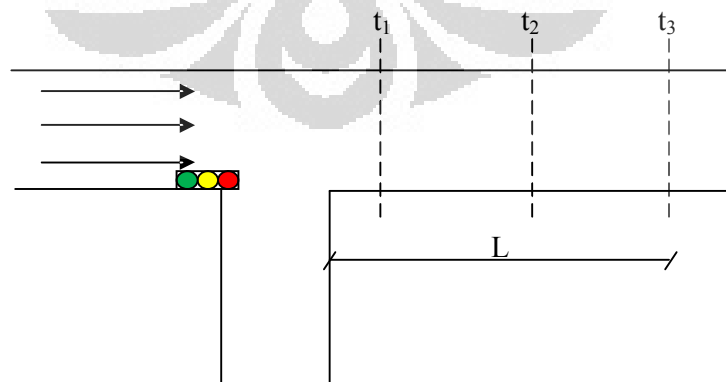


Figure 3.7. Illustration of Platoon Dispersion Model

3.4.4. KASHANI MODEL

This model is suitable to apply at intersection either with signalized or unsignalized and flow restrictions. In this model the state variables are the length of the queues that are waiting at an intersection or any other flow restriction, such as a reduction in the number of lanes, an obstacle, a pedestrian crossing, etc. The model assume that at an intersection the cars going to the same destination move into the correct lane, so that they do not block the traffic flows going to other destinations.

The various traffic situations which may be experienced are partitioned to five categories : sparse traffic/off-line control, light traffic, heavy traffic, oversaturated traffic, and immobile traffic/incident.

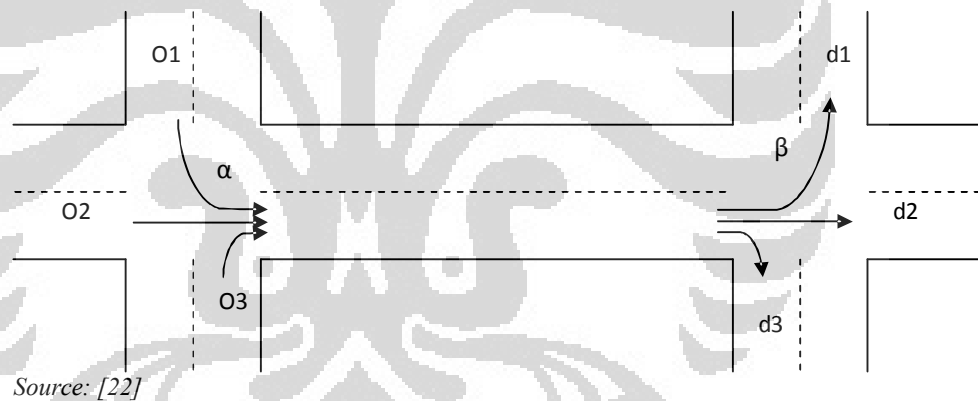


Figure 3.8. Illustration of a Link Connecting Two Intersections

Figure 3.8 represents observation area by using Kashani model. There are two intersections where traffic counting has done at each intersection from origin (o) to destination (d), while α is origin intersection and β is destination intersection.

After making classification and comparison of macroscopic model by its objectives, advantages and disadvantages of each model (it can be seen in Table 3.2), we conclude that the appropriate model for IAV in urban

area is stochastic model because traffic is always change everytime, it has many probabilities either in number of vehicle or in flow configuration.

3.5. MODEL SIMULATION

Traffic simulation models offer the possibility to experiment with an existing or a future traffic system in a safe and non disturbing way. The simulation of road traffic in the context of driving simulators presents different specificities, as the main objective is to immerse the driver in a realistic environment and to confront him with specific situations. The traffic has to be autonomous, but also controllable using scenario rules. In real world situations, drivers tend to reduce certain categories of interactions with others driver, this mechanism is used as a decision model for the autonomous vehicles. To limit the computation cost of the traffic simulation, the vehicle's level of details can also be reduced depending on their distance to the interactive vehicle.

In this work, we use SCANeR™studio to simulate the traffic. SCANeR™studio is a comprehensive driving simulation software package. It is used for vehicle ergonomics and advanced engineering studies as well as for road traffic research and development. It is also used for human factor studies and driver training [50].

3.6. CONCLUSION

The aim of this chapter is to present urban traffic modelling in macroscopic level. We have collected different models and compared them according to performances and objectives as shown in Table 3.2. In the next chapter we will choose appropriate model. To apply the model, we need the traffic data that obtained by the model simulator of SCANeR™studio.

Table 3.2. Macroscopic Model choice

No	Model	Type	Mathematical Model	Objective	Advantages/ disadvantages	Application	Reference
1	Greenberg	Logarithm/ Deterministic, static	$U = U_m \ln \left(\frac{K_j}{K} \right)$ where: U = speed (km/h) K = density (veh/km) U_m = speed at maximum flow (km/h) K_j = jam density (veh/m)	To describe the relationship between the traffic parameters (speed, density, flow)	Advantage : Good at congestion Disadvantage : - Poor at low density - infinite speed at free flow	On a merge influence section in an uninterrupted facility in KOREA	[34], [43]
2	Underwood	Exponential / Deterministic, static	$U = U_f \exp \left(\frac{-K}{K_m} \right)$ where: U = speed (km/h) K = density (veh/km) U_f = free flow speed (km/h) K_m = maximum density (veh/m)	To describe the relationship between the traffic parameters (speed, density, flow)	Advantage : Good at low density Disadvantage : - Poor at high density - Speed is zero only at infinity density	On a merge influence section in an uninterrupted facility in KOREA	[34]

No	Model	Type	Mathematical Model	Objective	Advantages/ disadvantages	Application	Reference
3	Kashani	Stochastic	$m_{\alpha\beta}^{t+\Delta t} (1 + \delta_{\alpha\beta}(Q)) = m_{\alpha\beta}^{t\Delta} (1 + \delta_{\alpha\beta}(Q)) + \sum_{\alpha/\beta \in \alpha} m_{\alpha\beta, \alpha/\beta}^{t\Delta}(Q)$ <p> m_{arr} = number of arrival vehicle m_{dep} = number of departure vehicle </p>	To describe traffic flow in urban traffic networks	Advantage : Suitable at intersection Disadvantage : Not applicable in road network	At signalized intersection	[22]
4	Continuous petri net with variable speed (VCPN)	Stochastic and dynamic	$K_i(t) = \frac{m_i(t)}{x_i}$ $U_i(t) = \frac{v_i(t)x_i}{m_i(t)}$ <p>where:</p> <p> $K_i(t)$ = average density for segment i $U_i(t)$ = average speed for segment i $m_i(t)$ = number of vehicles x_i = length of segment $v_i(t)$ = transition firing speed </p> <p>VCPN = (Q, Vmax)</p>	To model and perform evaluation in urban and interurban network	Advantage : It can model systems with dynamic and stochastic Disadvantage : Not comfortable to apply in confined area	Either to represent the traffic flow in motorway corridors or in complex road junctions	[7]

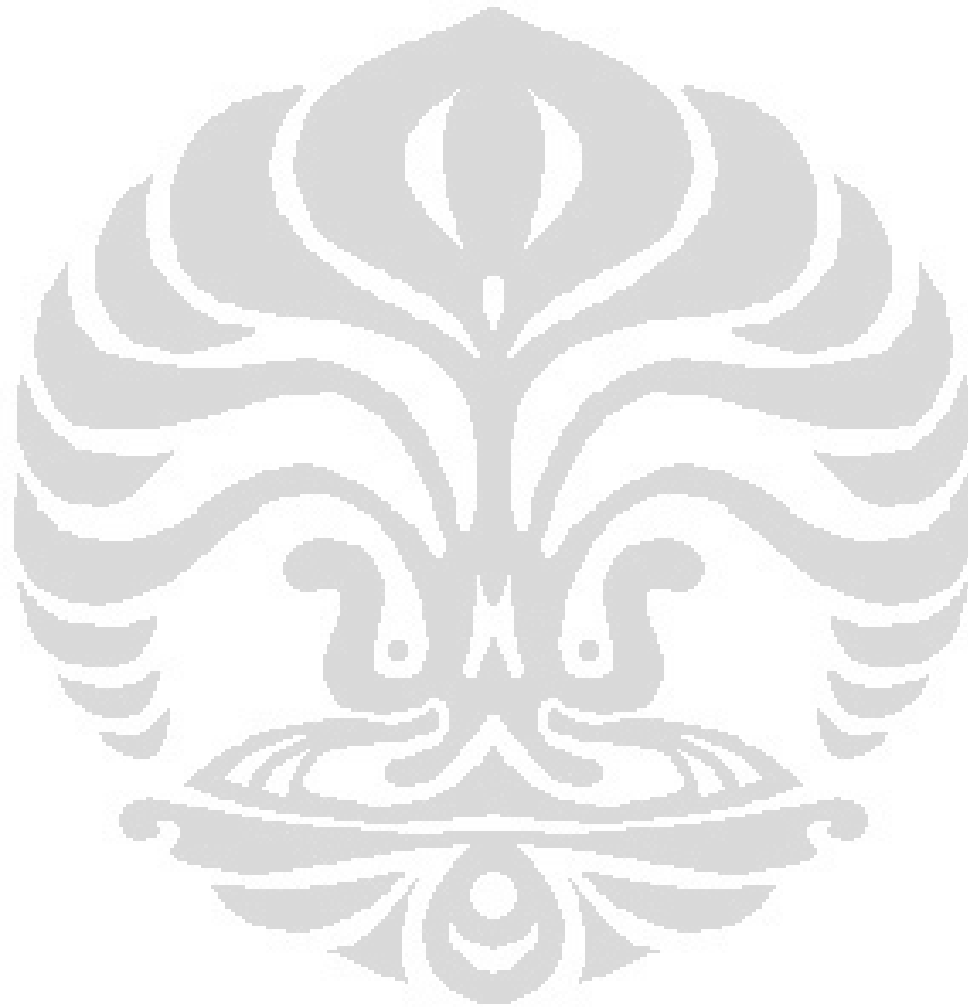
No	Model	Type	Mathematical Model	Objective	Advantages/ disadvantages	Application	Reference
			$Q = (P, T, \text{Pre}, \text{Post}, M_0)$ V_{\max} = real positive vector of transitions maximal firing speeds				
5	Bayesian Network	Statistical model/ Stochastic, static	Final prediction = $PS \times \alpha + RS (1 - \alpha)$ where: α = weight of the current traffic situation PS = prediction speed RS = vehicle speed of the real-time result	To forecast traffic in a short-term prediction	Advantage : Useful to predict traffic condition Disadvantage : The prediction is just for the future 60 minutes	For road link in Seoul city by used real-time traffic information	[41]
6	Variable Cell Transmission	Continuous, dynamic	(Inflow-outflow = change in quantity) $[q_i(t) - q_i + 1(t)]dT = [k_i(t+1) - k_i(t)]_i$ where: $q_i(t)$ = traffic flow rate $k_i(t)$ = traffic density rate l_i = length of cell i	To predict traffic flow	Advantage : Suitable for simple urban road Disadvantage : Poor adaptability in the complex urban road network	Applied in urban road consisting of the approach section and the general section	[40]

No	Model	Type	Mathematical Model	Objective	Advantages/ disadvantages	Application	Reference
7	Two-Fluid Model	Stochastic, static	$\ln T_r = 1/(n+1) \ln T_m + n/(n+1) \ln T$ where: T = total travel time T_r = running time T_m = average minimum trip time per unit distance n = indicator of the quality of traffic service in the network	To represent an urban non-freeway traffic network	Advantage : Knowing the quality and level of service in network in metropolitan areas, it is applicable in the domain of collective flow Disadvantage : it is still difficult to quantify the operating traffic quality of networks in whole or in portion because of uncertainty of traffic network	Urban area in Seoul, in many large city	[5], [9], [15], [17], [44]
8	Greenshield	Deterministic, linear, static	$U = U_f \left[1 - \frac{K}{K_f} \right]$ where: U = Speed (km/h) U_f = free flow speed (km/h) K = density (veh/km)	To predict and explain the trends that are observed in real traffic flow	Advantage : several researchers have found good correlation between model and field data Disadvantage :	In congested and uncongested traffic condition	[6], [8], [30]

No	Model	Type	Mathematical Model	Objective	Advantages/ disadvantages	Application	Reference
			$K_j = \text{jam density (veh/km)}$		it cannot express a realistic congestion density because that is mathematically simple so it could be a limitation in diverse traffic situations when using just this model		
9	Platoon-Dispersion	Dynamic, stochastic	$q_t' = F \times q_{t-T} + (1-F) \times q_{t-\Delta t}$ $F = \frac{1}{1 + \alpha \times \beta \times T_a}$ <p>where:</p> <p>Δt = time step duration, measured in the time intervals used for q_t'</p> <p>T = minimum travel time on the roadway in units of time steps, equal to $\beta \times T_a$</p> <p>β = dimensionless travel time factor</p> <p>α = dimensionless platoon dispersion factor</p> <p>F = smoothing factor</p>	To improve the efficiency of control system in various non-freeway traffic	<p>Advantage :</p> <p>vehicle platooning could enhance this transportation service because it directly influences the optimization of signal timing schemes</p> <p>Disadvantage :</p> <p>it is rather difficult and</p>	Inflow-outflow characteristics at urban intersection	[10], [13], [18], [20], [26], [31], [38]

No	Model	Type	Mathematical Model	Objective	Advantages/ disadvantages	Application	Reference
			T_a = mean roadway travel time, measured in units of time steps		expensive because the observation needs video cameras to calculate the vehicle travel in each node		
10	New mixed flow	Deterministic, static, static	$\bar{\xi}_{i,j} = \frac{1}{12} \sum_{k=1}^{12} \xi_{i,(j-1) \times 12 + k}$ $\sigma_{i,j}^2 = \frac{1}{12} \sum_{j=1}^{12} (\xi_{i,(j-1) \times 12 + k} - \bar{\xi}_{i,j})^2$ $\rho_i(\tau) = \frac{1}{12\sigma_{i,j}^2} \sum_{j=1}^{12-\tau} (\xi_{i,j} - \bar{\xi}_i)(\xi_{i(j+\tau)} - \bar{\xi}_i)$ <p>where: ξ = specific detector j = subset i = day</p>	To describe the characteristic of urban traffic flow	Advantage : Captures the main statistical features of traffic volume flows over transportation networks. This model can describe well the arriving behaviors of the “peaks” in the traffic volume flow.	Urban area (Beijing)	[4], [24], [29], [43]

No	Model	Type	Mathematical Model	Objective	Advantages/ disadvantages	Application	Reference
			$\sigma^2_{i,j}$ = variance $\rho_i(\tau)$ = covariance		Disadvantage : “Peaks” not considered as a valid information.		
11	Metanet	Discrete, non linier, dynamic	$q_{m,i}(k) = \rho_{m,i}(k) \cdot v_{m,i}(k) \cdot \lambda_m$ $\rho_{m,i}(k+1) = \rho_{m,i}(k) + \frac{\tau}{L_m \lambda_m} (q_{m,i-1}(k) - q_{m,i}(k))$ where: q = flow ρ = density v = space mean speed λ = number of lane in segmen T = sampling time L_m = length segmen	To provide predicting traffic flows	Advantage : Able to reproduce traffic congestion built in reality with considerably accuracy Disadvantage : a model only consider an uniform distribution of vehicle in a cell	In a freeway network	[1], [2], [11], [32], [33], [42]
12	α -relationship	Deterministic, static	$I = \alpha \left(\frac{v}{R}\right)^m$ where: I = traffic intensity (per unit area) R = road density v = space mean speed α and m = parameters	To quantify the quality of traffic service provided to the users in the network	Advantage : it can be use as an indicator for level of service at the network Disadvantage : it is not able to describe congested condition	In urban area	[14], [16], [25], [37]



Universitas Indonesia

CHAPTER 4

CONTRIBUTION TO TRAFFIC MANAGEMENT IN URBAN ENVIRONMENT USING IAV

4.1. INTRODUCTION

The aim of this chapter is to study the effect of using the IAV concept on the traffic quality in urban environment, making comparison with conventional vehicle. To study the quality of traffic, we used the traffic simulation tool that reproduces the real traffic condition and allows the validation of the model studied in Chapter 3.

4.2. METHODOLOGY OF WORK

We plot the methodology of work to reach our goal systematically. Flowchart of application of traffic modeling in CBD area in Jakarta can be seen in Figure 4.1.

Figure 4.1 represents the strategy to get the quality of traffic in macroscopic level. Firstly, we collected some existing macroscopic traffic modeling that applied in urban environment. We compared the modeling, and then selected appropriate one. We defined a CBD in Jakarta as the study area, it is called SCBD (Sudirman Central Business District). Then, we collected data of traffic and environment referred to Annex 2. After got the required data, we run the simulation of traffic. We run the simulation in two conditions: Firstly, we consider that all vehicles are IAVs, and secondly the vehicles are conventional. Finally, we analysed output data from the simulation by using Two-Fluid model approach.

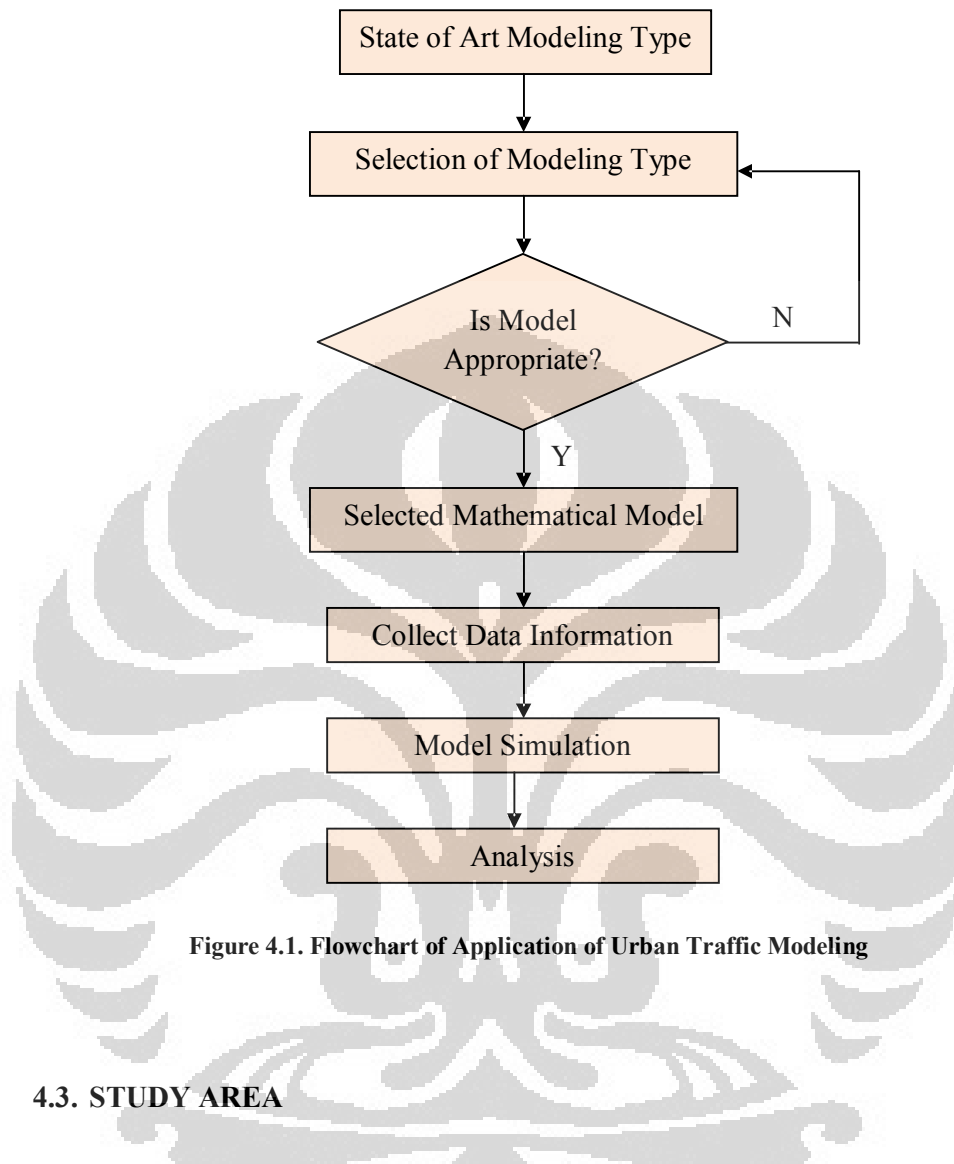
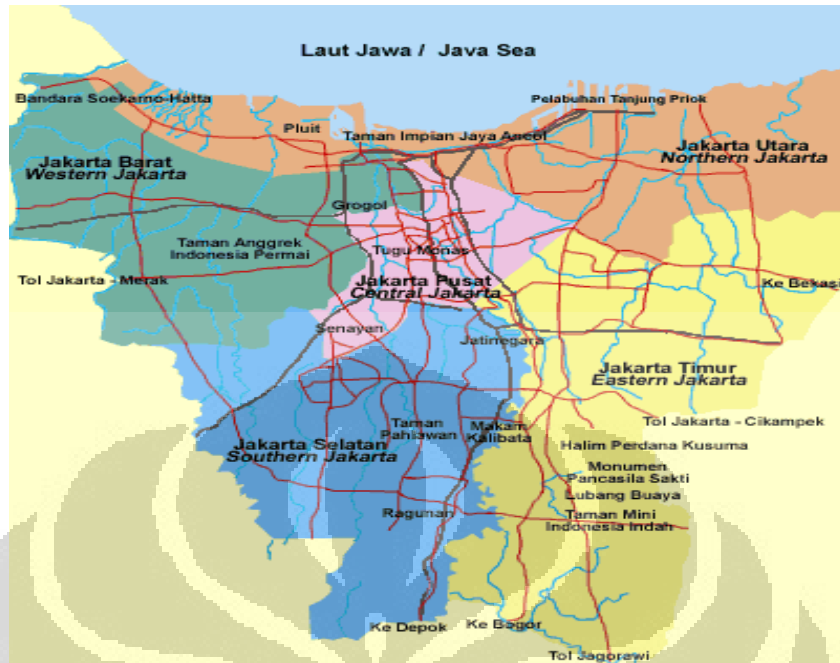


Figure 4.1. Flowchart of Application of Urban Traffic Modeling

4.3. STUDY AREA

The study area is confined area in Jakarta as capital of Indonesia. It called confined because that area is enclosed area that has business area and residential area developed by private company.

We choose the confined area because IAV have limitation in velocity and adaptation in mixed traffic. The map of Jakarta and study area can be seen in Figure 4.2.



Source: [48]

Figure 4.2. Map of Jakarta, Indonesia



Source: google earth

Figure 4.3. Study Area Image

Figure 4.3 represents confined area that called SCBD. SCBD is a business centre which is located in Jakarta's Golden Triangle (Sudirman-Gatot Subroto-Kuningan). SCBD will become the first of its kind in Indonesia, featuring an integrated area with offices, retail outlets, hotels and living amenities of world class standard. Variety of land use, which supports social and cultural needs of Jakarta, many activities, from business to leisure, all set in this prestigious area. Inside SCBD, approximately 13 hectares of the sites are devoted to an extensive road network and landscaping. To handle traffic problems in Jakarta, international experienced consultants have designed the internal road network to accommodate the traffic.

The concentration of high rise buildings, the accessibility of prestigious residential areas, and the volume of passing traffic make SCBD a prime location in Jakarta. Other than that, the strategic location makes SCBD easy to access from every part of Jakarta.

4.4. MACROSCOPIC MODEL CHOICE

After choosing study area, the next step is to find a macroscopic model for urban traffic. That process can be found in chapter 3, until we got the summary of all macroscopic model for traffic. The summary of macroscopic model choice can be found in Chapter 3. The entire model applied to homogeneous vehicles that means we apply the vehicle with same characteristics, such as all conventional vehicles or all IAVs.

From the comparison, we resumed that Two Fluid model most appropriate in our case according to the performance and the objective. To apply this model, we need the traffic data that fulfilled by the model simulation of SCANeR™studio [50]. By using this model, we can know the quality and level of service in network in metropolitan areas. This model has applied in many big cities such as London, New York, Seoul, etc.

4.5. TRAFFIC SIMULATION

SCANeR™studio proposes 5 main modes:

- Studio terrain

Import the image of the background from google earth and draw the road and intersection by following the background image. Next step is adding all the traffic sign, object (including building, trees, road properties and logical content of each road). The image of scanner for all this step can be found in annexe 2, and for the complete terrain shows in Figure 4.4.

- Studio vehicle

Here, we are using conventional vehicle (light vehicle, motorcycle and heavy vehicle) from the default database or IAV with the specification referred to chapter 2.

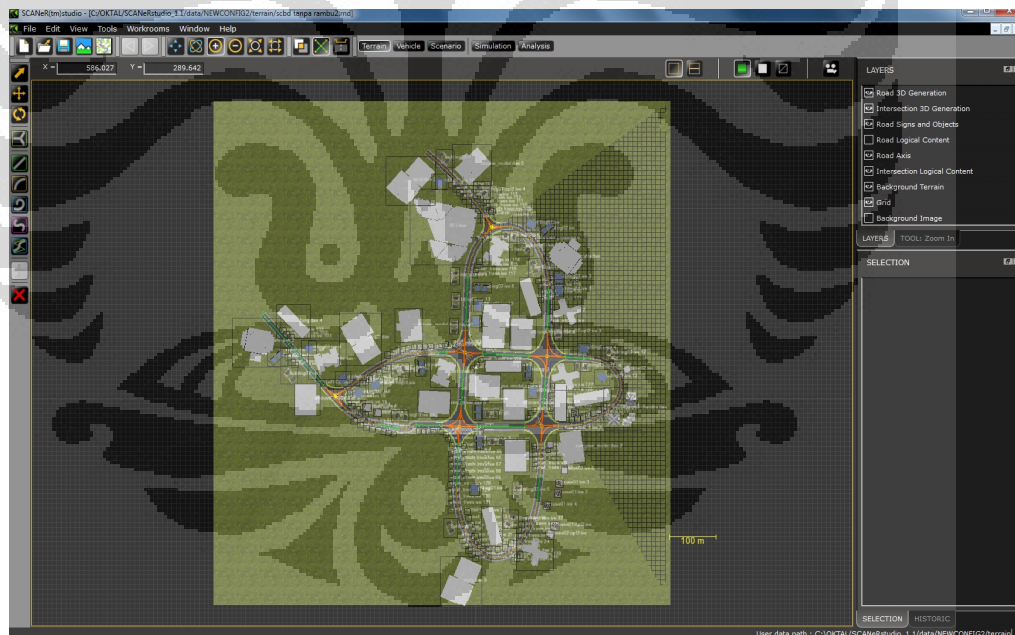


Figure 4.4. Image of The Complete Terrain

- Studio scenario

Choose and open the terrain file that have already generated. First scenario is using all conventional vehicles (cars, buses, motorcycles and trucks) and

pedestrians. Choose the vehicle from dock resources and put it on the road in right position. Input data based on the data in 2009 [9] and statistic index growth vehicle in 2011 [46]. Modify the properties of each vehicle by clicking it. Change the maximum speed for manual vehicle 50 km/h and 2 km/h for pedestrian, change the process in the vehicle parameters into traffic and the process in driver selection into traffic. The complete steps show in Annex 1 while the Figure 4.5 shows the image of first scenario.

Next scenario is putting all IAV in the road based on the same data as the first one. The image of the second scenario can be seen in Figure 4.6. Change the maximum speed of IAV into 25 km/h and 2 km/h for pedestrian. All vehicle parameters are same with the first scenario.

We put some script in dock scenario that can control the vehicle. We write down the script based on the algorithm shown in Figure 4.7 if one of car is in fault condition. We assumed fault of the car takes 3 minutes to restart (for conventional vehicle), with the same algorithm, we applied the fault condition to IAV for 3 seconds. The fault time is very short because IAV have performance to reconfigure by itself.

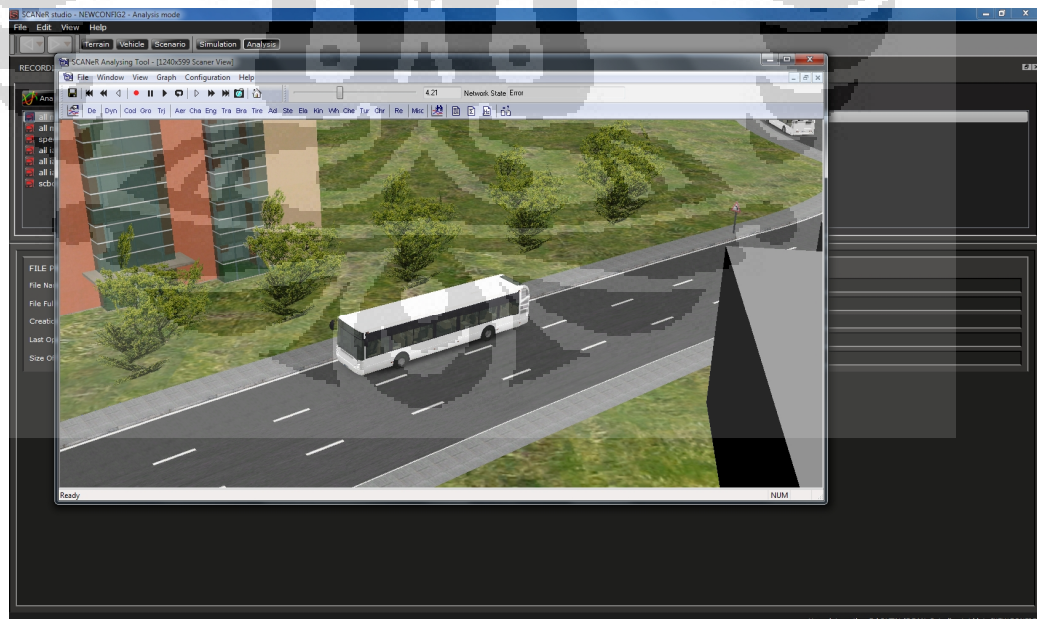


Figure 4.5. Image of Conventional Vehicle for the First Scenario

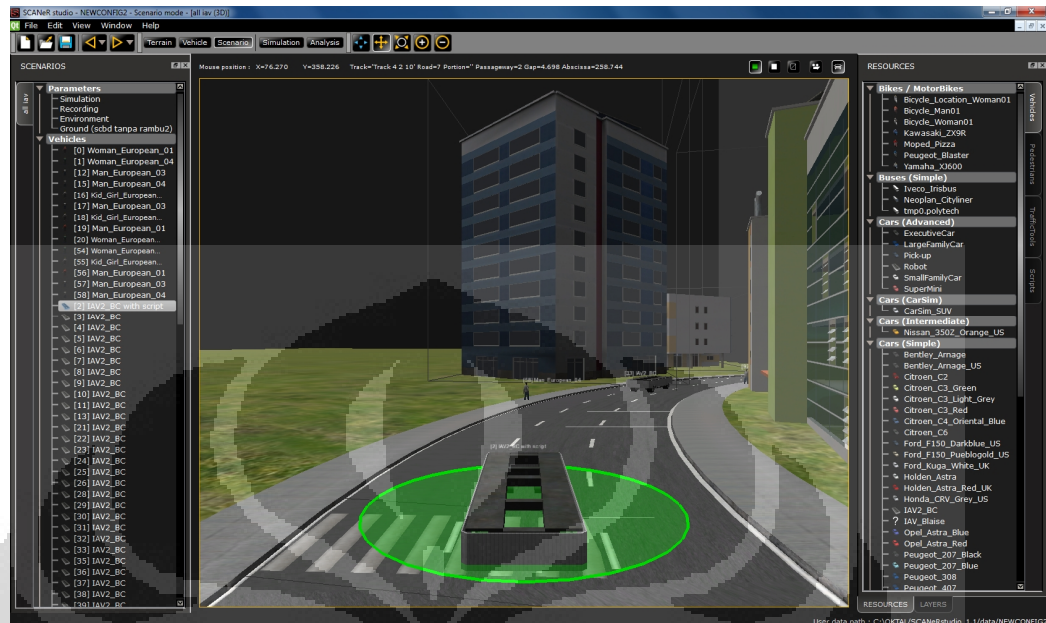


Figure 4.6. Image of IAV for the Second Scenario

Figure 4.8 shows the algorithm for shuttle bus that will stop at each bus stop. IAV used the same algorithm that we assumed 1 IAV as shuttle bus.

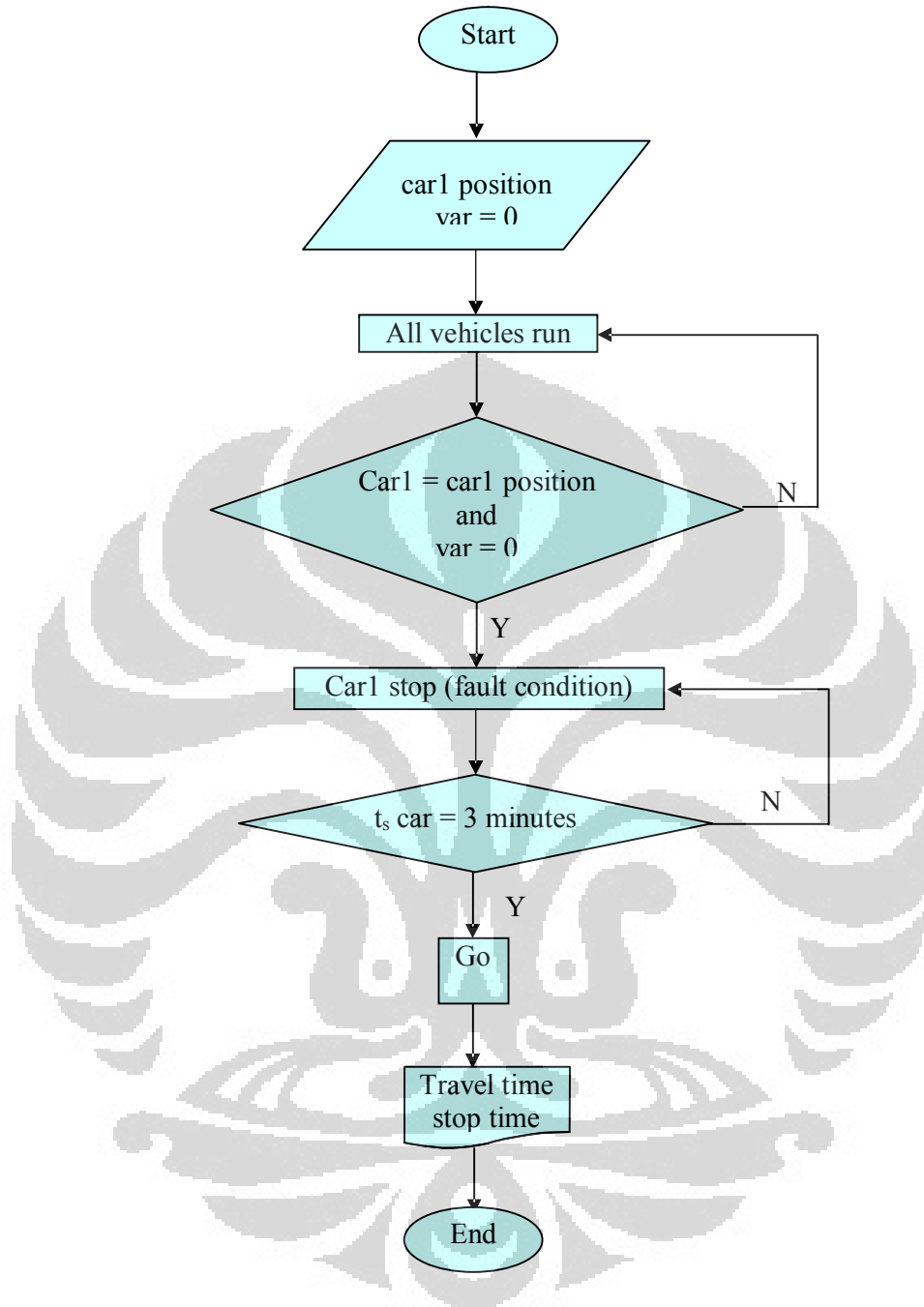


Figure 4.7. Flowchart in Fault Condition

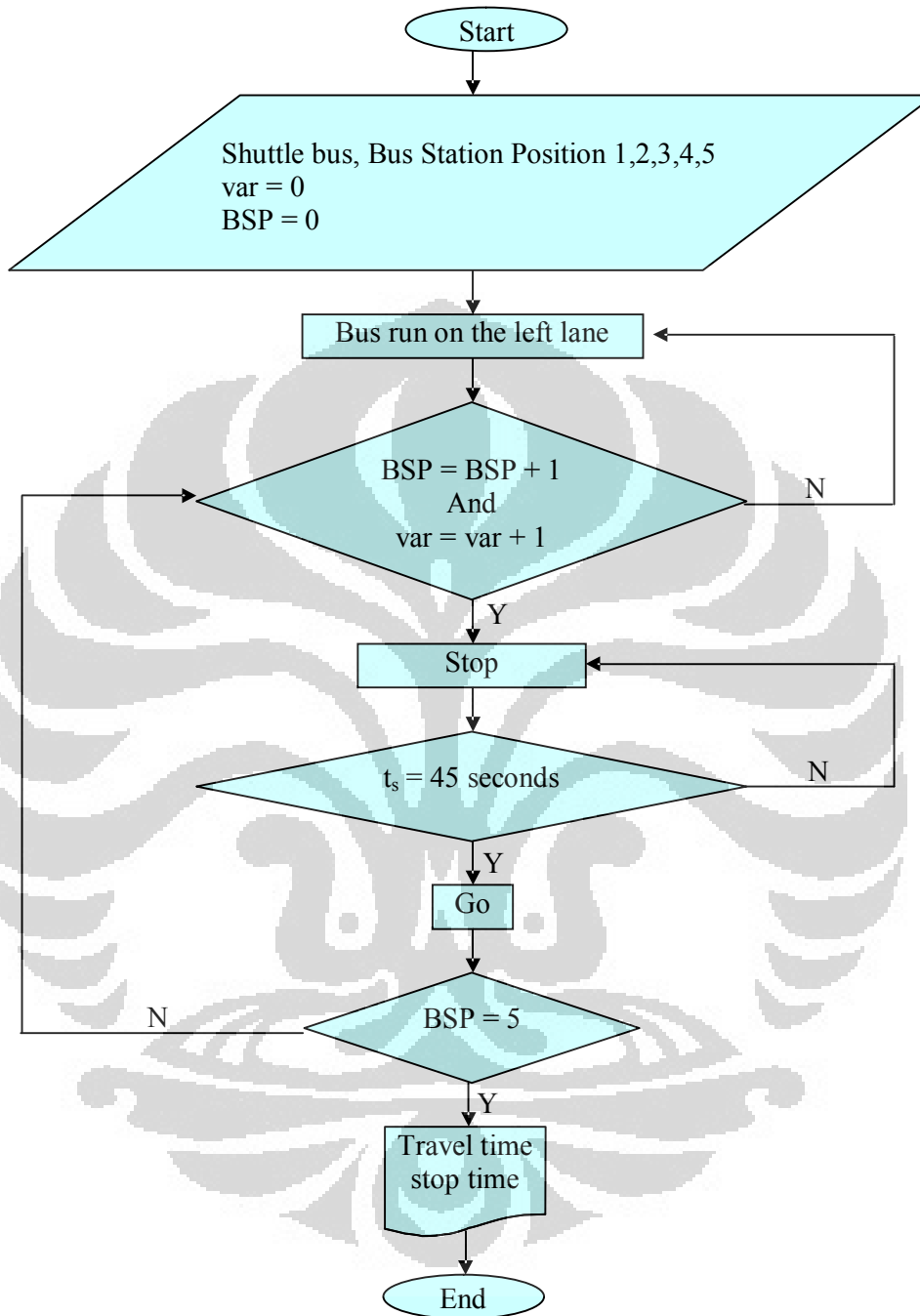


Figure 4.8. Flowchart for Shuttle Bus

- Studio simulation

When we finished with data terrain and scenario, click simulation tab to simulate traffic network. In dock simulator status, click traffic, scenario, visual and record. Traffic display means all the vehicles and pedestrians will be controlled by default program, scenario display means to simulate traffic network using script, visual display means we can see the simulation in 3D and we can change view position, weather condition and day lighting. After that click play scenario button. We run the simulation for 1 rotation of study area. Figure 4.9 shows the traffic network simulation.



Figure 4.9. Traffic Network Simulation

- Studio analysis

The last step is viewing the simulation result by clicking analysis tab. Click recorded last file and click analyse button until we got the simulation window as can be seen in Figure 4.10 then play it. While playing, save it into file.AVI. To get the tabular and graphical data, click tools button, export to ascii file until we got a data convertor window as shown in Figure 4.11. From here, we got time and speed every vehicle.

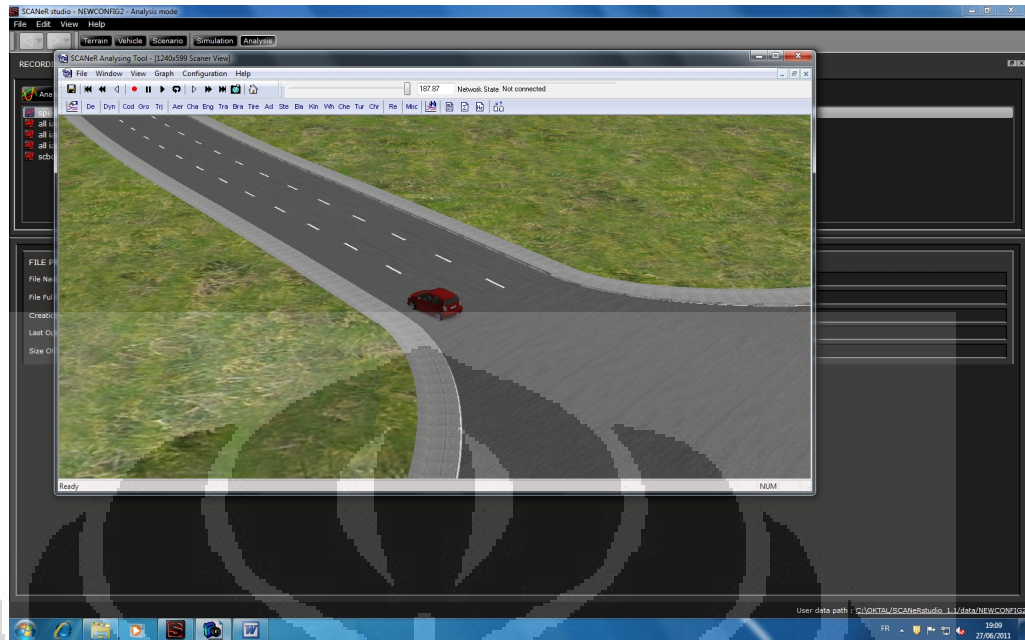


Figure 4.10. Traffic Network Simulation in 3D view

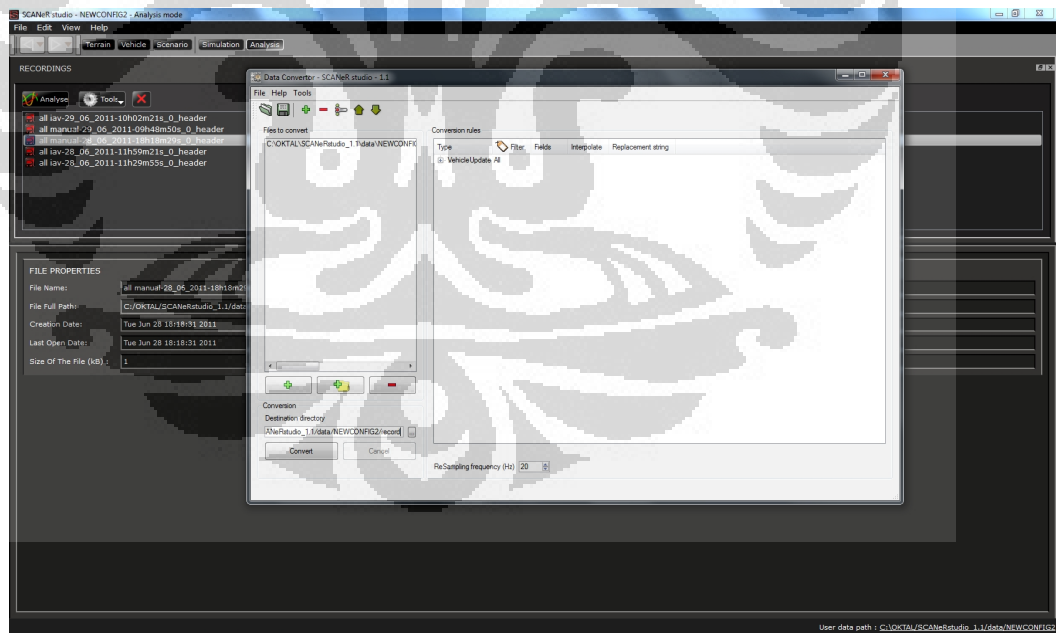


Figure 4.11. Display of Data Export to Ascii File

4.6. DATA COLLECTING

SCBD has 13 hectares of the sites area with 2.294 km long. Cross section of the road can be seen in Figure 4.12 and situation of SCBD area shown in Figure 4.13.

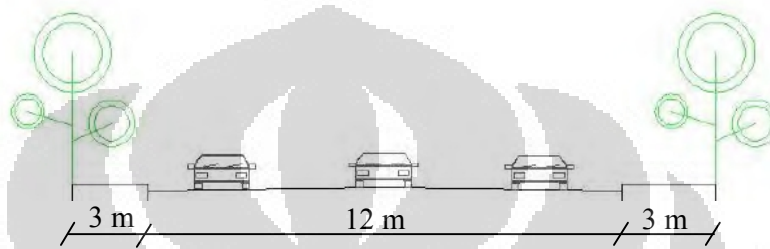


Figure 4.12. Cross Section



Figure 4.13. Situation of SCBD Area

All the traffic data can be seen in annex 2, based on data in 2004-2008, we have got traffic data:

- Average Speed (U) : 28.2 km/h
- Flow (q) of each different kind of vehicles:

The composition of traffic (0.85 light vehicle + 0.10 motorcycle + 0.05 heavy vehicle) and to predict the data in 2011, we use equation (4.1)

$$N = N(1+i)^n \quad (4.1)$$

Where:

N = number of vehicle
 i = growth index
 n = increasing year

Light vehicle : 659 veh/h
 Motorcycle : 84 veh/h
 Heavy vehicle : 38 veh/h

- To put the number of vehicle into simulation, calculate density each different type of vehicle by using equation (4.2)

$$K = \frac{q}{U} \quad (4.2)$$

Where:

K = density (veh/km)
 q = Flow (veh/h)
 U = speed (km/h)

Figure 4.14 describe taking data with different direction, direction 1 (Niaga-Sudirman), direction 2 (Sudirman-Niaga), direction 3 (south east way). To get the number of all vehicle to put into simulation, we take an average of all direction.

Light vehicle : 54 veh/2.294 km
 Motorcycle : 6 veh/2.294 km
 Heavy vehicle : 3 veh/2.294 km



Figure 4.14. Direction way

4.7. DATA ANALYZING

From the simulation, we have got macroscopic parameters such as, average speed, flow and density. All the results are shown in Annex 3.

a. Case of IAV

Average speed for each 57 considered IAV is shown in Figure 4.15.

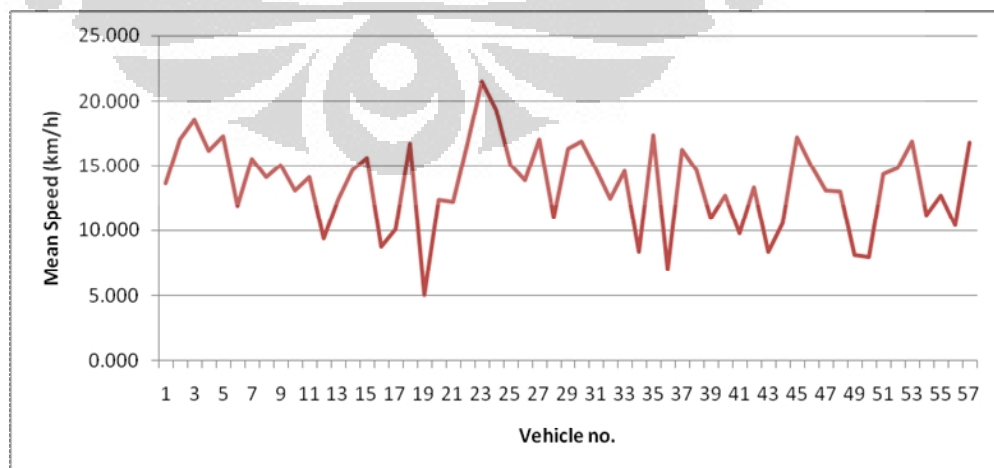


Figure 4.15. Speed for All IAV

From that figure, it can be seen that the maximum speed for IAV is 21.43 km/h, minimum speed is 4.997 km/h and space mean speed = 13.61 km/h. By using equation (4.2), we have got density = 28 veh/km and flow = 381.08 veh/h.

The simulation gave as a trip time, stop time and running time as can be seen in Annex 2, while Figure 4.16 shows the graph of $\ln T$ vs. $\ln T_r$ for this result.

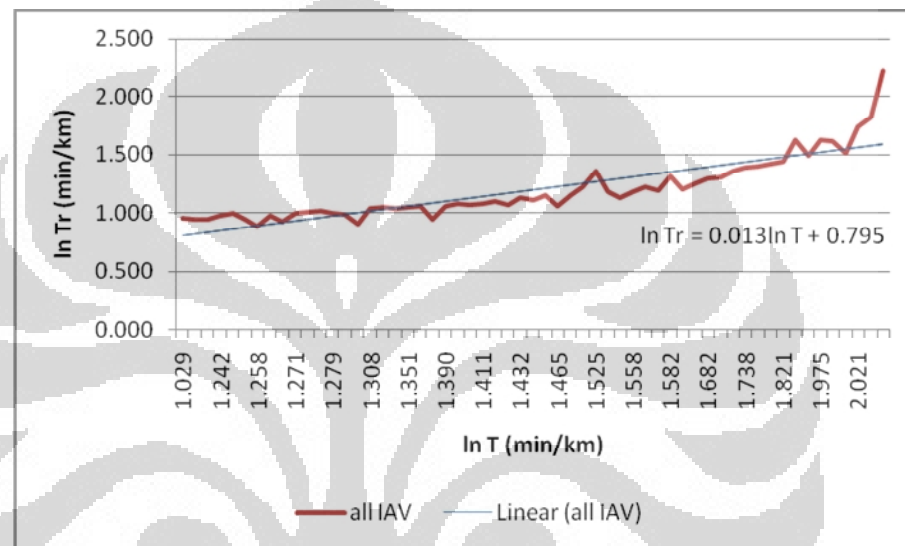


Figure 4.16. Graph $\ln T$ vs. $\ln T_r$ for All IAV

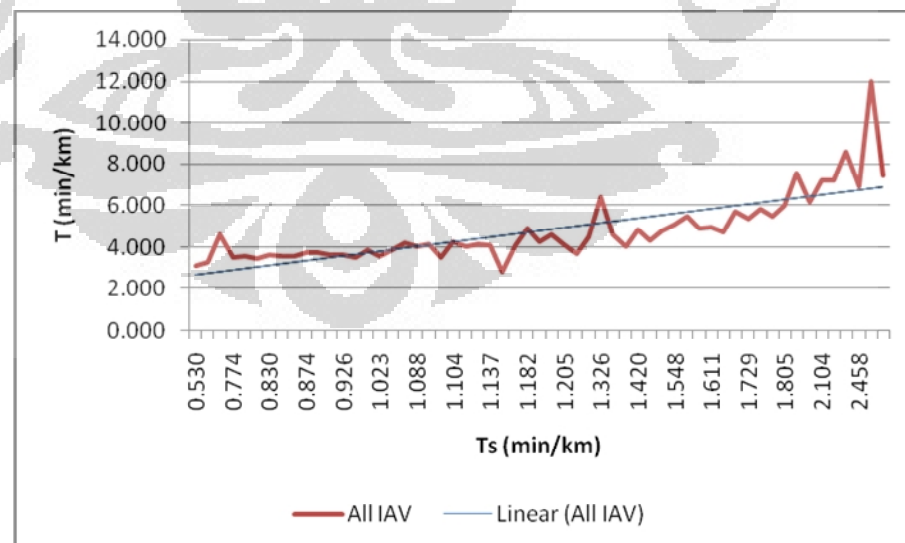


Figure 4.17. Relationship of T and T_s for All IAV

After applying the linear regression of the simulated result for Figure 4.16, we obtain the following linear equation:

$$\ln T_r = 0.795 + 0.013 \ln T \quad (4.3)$$

Figure 4.16 shows equation of regression linier for $\ln T - \ln T_r$ of IAV. By using equation (3.5) and (3.6) from equation (4.3), we have got $n = 0.01$ and $T_m = 2.24$. Figure 4.17 represents relationship of T and T_s , maximum travel time for all IAV = 12.007 min/km, while minimum travel time = 2.799 min/km with average travel time = 4.770 min/km.

b. Case of conventional vehicle

Average speed for the conventional vehicles shown in Figure 4.18.

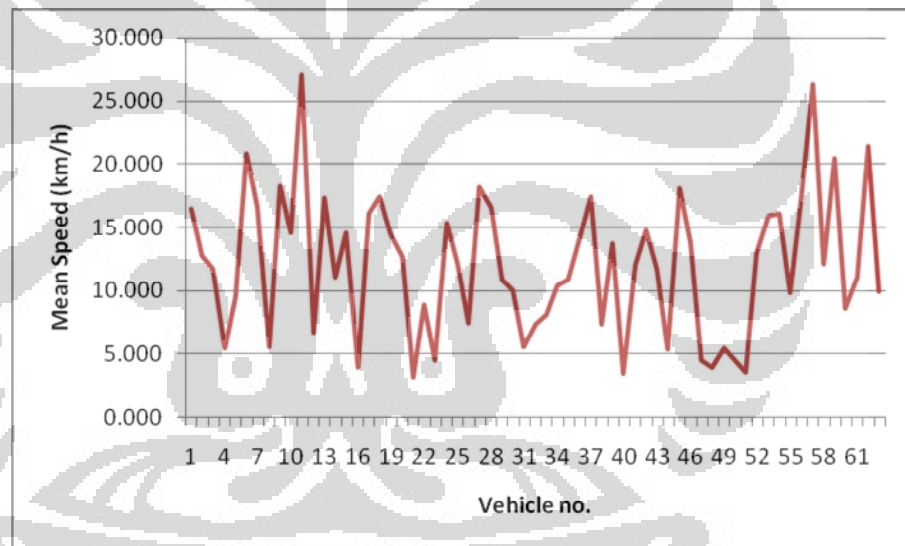


Figure 4.18. Speed for All Conventional Vehicle

From Figure 4.18, it can be seen that the maximum speed for all manual vehicle is 27.08 km/h, minimum speed is 3.190 km/h and space mean speed = 12.02 km/h. By using equation (4.2), we have got density = 32 veh/km and flow = 384.64 veh/h.

The result of trip time, stop time and running time for all manual vehicle can be seen in Annex 2, while figure 4.19 shows the graph of $\ln T$ vs. $\ln T_r$ for this result.

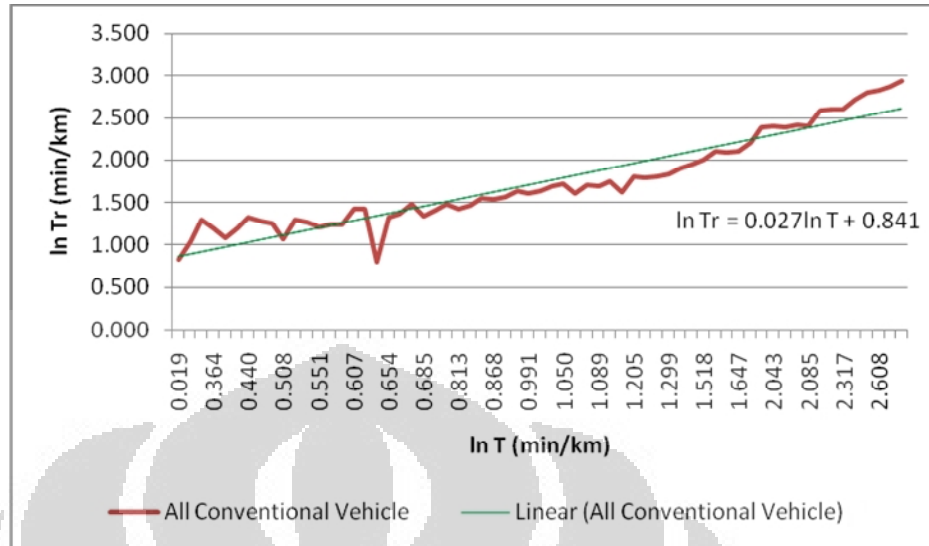


Figure 4.19. Graph $\ln T$ vs. $\ln T_r$ for All Conventional Vehicle

After applying the linear regression of the simulated result for Figure 4.16, we obtain the following linear equation:

$$\ln T_r = 0.841 + 0.027 \ln T \quad (4.4)$$

Figure 4.19 shows equation of regression linear for $\ln T - \ln T_r$ of all conventional vehicles. By using equation (3.5) and (3.6), from equation (4.4) we have got $n = 0.03$ and $T_m = 2.37$. Figure 4.20 represents relationship of T and T_s

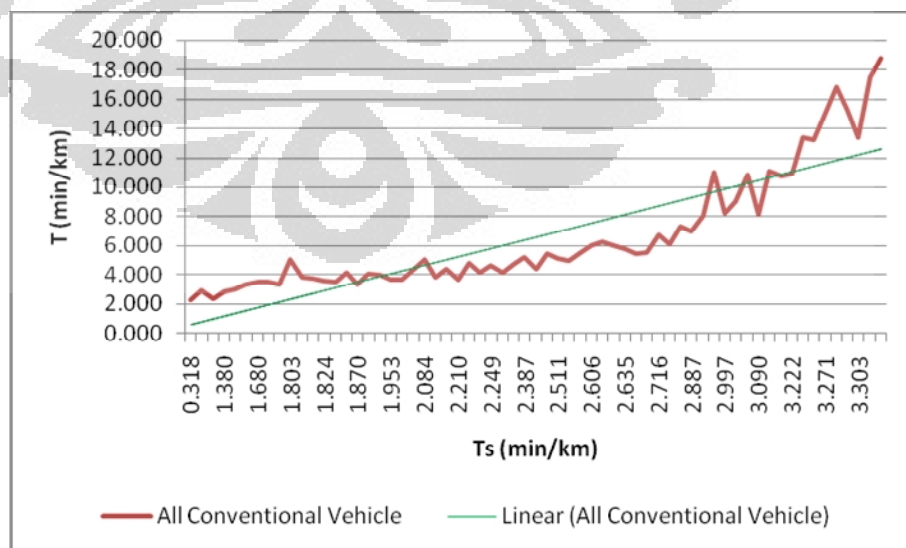


Figure 4.20. Relationship of T and T_s for All Conventional Vehicle

Figure 4.20 shows maximum travel time for all manual vehicle = 18.806 min/km, while minimum travel time = 2.216 min/km with average travel time = 6.609 min/km.

If we compare Figure 4.17 and 4.20 we can conclude that average travel time for all IAV is shortest than all conventional vehicle. And the comparison of two-fluid parameters (n and T_m) showing that the value from all IAV lower than all conventional vehicle. It means that the quality of traffic service in SCBD area will better if we use all IAV than all conventional vehicle. Figure 4.21 shows comparison of T - T_s between all IAV and all conventional vehicle.

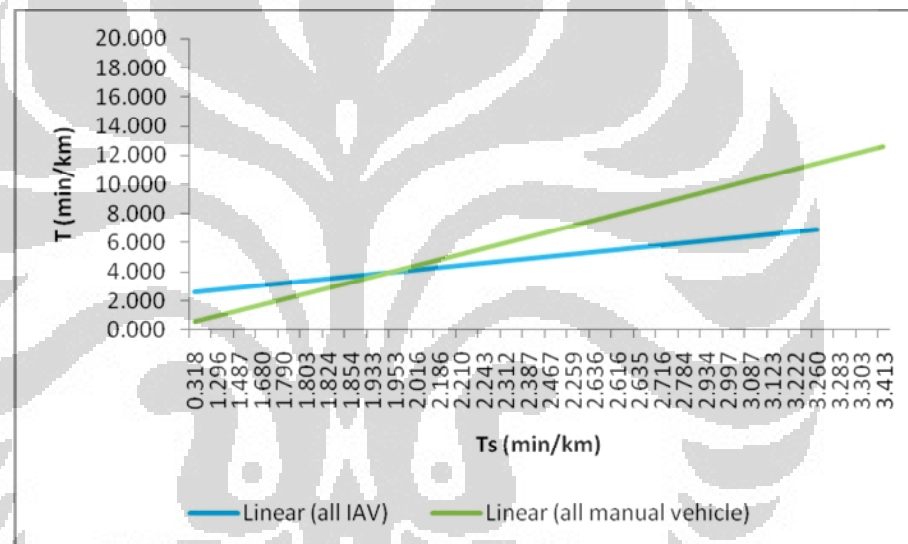
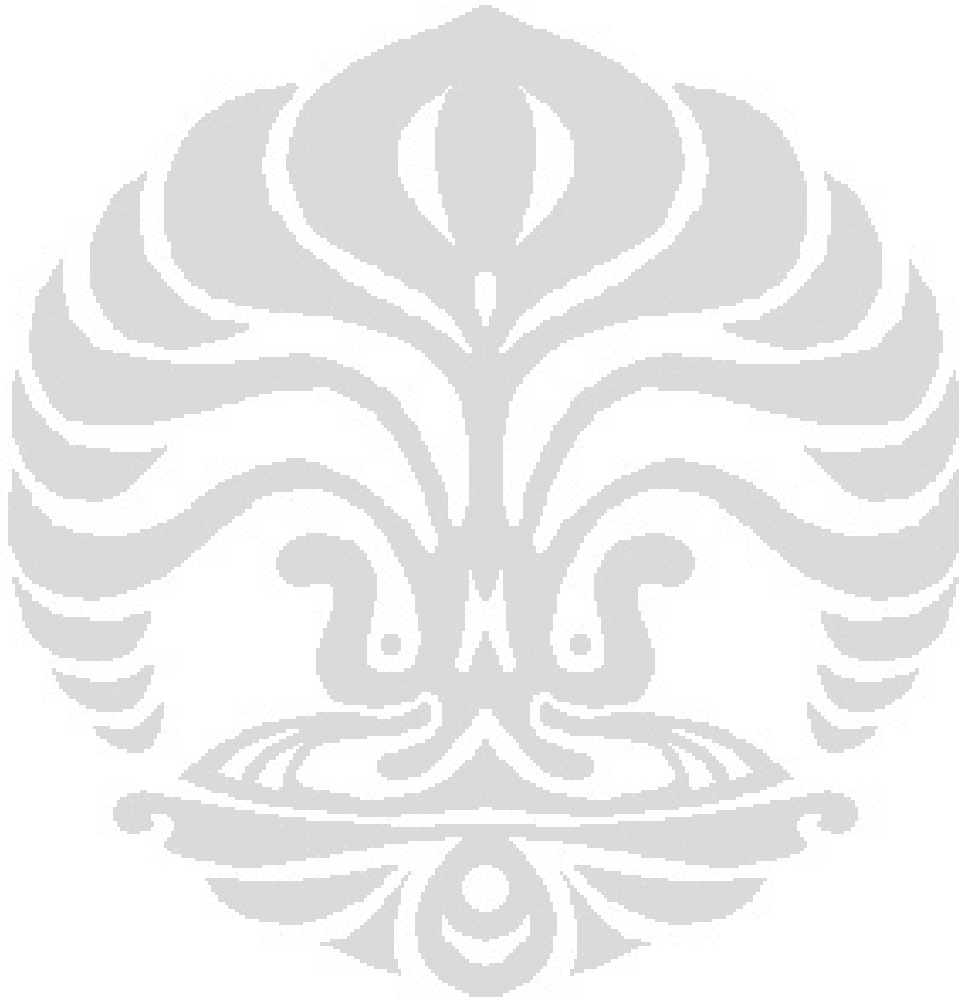


Figure 4.21. Comparison of T and T_s between IAV and Conventional Vehicle

From Figure 4.21 can be concluded that by using IAV, travel time will be shorter with same distance (if we compare the slope of two linear lines, we see that IAV has more stable travel time than conventional vehicle).

4.8. CONCLUSION

In this chapter, we got the result of the effect of using the IAV concept on the traffic quality in urban environment. Application of IAV in confined area contributes improvement of quality of traffic.



CHAPTER 5

CONCLUSION AND PERSPECTIVES

5.1. CONCLUSION

The use of macroscopic models such as the Two-Fluid model can describe the characteristics in urban area, namely density, flow and mean speed. When we compare two different kind of vehicle (using IAVs and conventional vehicles) and by using SCANeR™studio simulation, it can give us quality of traffic in one area.

According to the work presented in this report, the use of IAV in urban environment can improve traffic management since it has shortest time than the use of conventional vehicle. With its ability to reconfigure itself if there is a fault, it has no impact with any other vehicle behind and congestion can be avoided. It means that if we compare parameters quality of traffic by using all IAV ($n = 0.01$ and $T_m = 2.24$) better than using all conventional vehicles ($n = 0.03$ and $T_m = 2.37$).

Average mean speed for all IAV 13.61 km/h and for all conventional vehicle 12.02 km/h, it means that IAV can save more travel time than conventional vehicle. Other benefit of using IAV is environmental friendly since it use electrical power and it can reduce noise and gases pollution.

5.2. PERSPECTIVES

In the future, it is necessary to develop application of IAV in heterogeneous environment and to expand the scope of study area.

REFERENCES

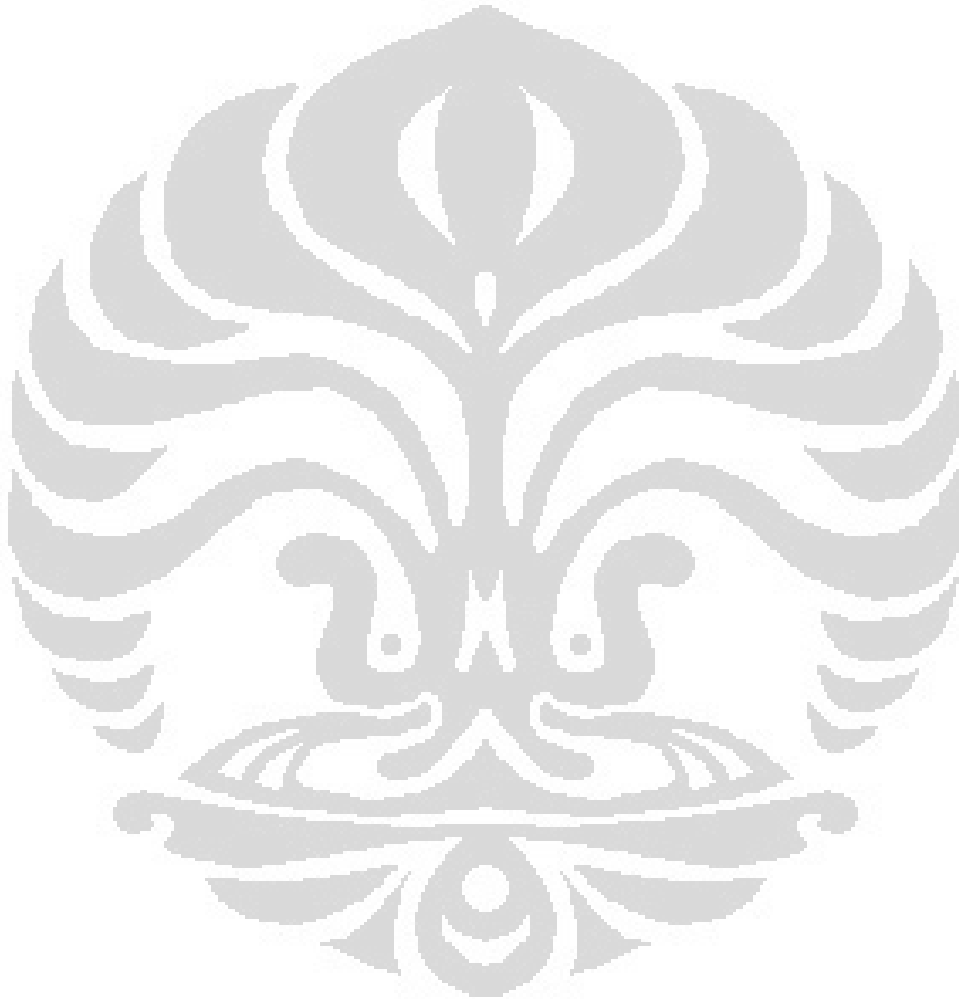
- [1] A. Gning, L. Mihaylova, "Interval Macroscopic Models for Traffic Networks", *IEEE Transactions on Intelligent Transportation Systems*, sept 2010.
- [2] A. Kotsialos, M. Papageorgiou, "Traffic Flow Modeling of Large-Scale Motorway Networks Using the Macroscopic Modeling Tool METANET", *IEEE* vol.3 no.4, 2002.
- [3] A.P. Tarko, "Handbook of transportation Engineering", *McGraw-Hill*, 2004.
- [4] B. Si, J. Long, Z. Gao, "Optimization Model and Algorithm for Mixed Traffic of Urban Road Network with Flow Interference", *Science in China series E: Technological Sciences*, vol.51, no.12, 2008.
- [5] C. Lee, J.W. Yu, H.R. Yoon, K. Sohn, "Characterizing Urban Network Performance Using Two-Fluid Model", *Journal of the Eastern Asia Society for Transportation Studies*, Vol. 6, pp. 1534 - 1544, 2005.
- [6] C. Quek, M. Pasquier, B. Lim, "A novel self-organizing fuzzy rule-based system for modeling traffic flow behavior", *Expert Systems with Applications* no.36, pp. 12167–12178, 2009.
- [7] C. Tolba, D. Lefebvre, P. Thomas, A. El Moudni, "Continuous and timed Petri Nets for the macroscopic and microscopic traffic flow modelling, Simulation Modelling practice and Theory", *Elsevier*, 2005.
- [8] D. Chen, L. Zhang, J. Wang, F.Y. Wa, "Freeway Traffic Stream Modeling Based on Principal Curves", *IEEE*, 2002.
- [9] D.C Gazis, "Traffic theory", *kluwer academic publishers*, 2002.
- [10] D. Wang, Y. Zhang, Z. Wang, "Study of Platoon Dispersion Models", in *TRB Annual meeting*, 2003.
- [11] D. Watling, "A Review of Models of Urban traffic Networks (with Particular Reference to the Requirements for Modelling Dynamic Route Guidance Systems)", in *Working Paper 356*, University of Leeds, 1991.
- [12] D.W. Stockburger, "Introductory Statistics: Concepts, Models, and Applications", *Atomic Dog Publishing 3rd Edition*, 2007.

- [13] H. Rakha, M. Farzaneh, "Macroscopic Modelling of Traffic Dispersion: Issues and Proposed Solutions", *Journal of Transportation Engineering*, vol.132, no.7, 2006.
- [14] J.C Williams, "Macroscopic Flow Models", *University of Texas*, 1998.
- [15] J.C. Williams, H.S. Mahmassani, R. Herman, "Sampling Strategies for Two-Fluid Model Parameter Estimation in Urban Networks", *Elsevier Science*. Vol.29A. No.3, pp. 229-244, 1995.
- [16] J.G. Eric, G. Nikolas, J.C. Michael, F.D. Carlos, "Allocating City Space to Multiple Transportation Modes: A new Modeling Approach Consistent with The Physics of transport", in *Working paper at International Workshop on Urban Transport: Today and Tomorrow*, 2008.
- [17] J.M. Crowe, "The Calibration, Validation, and Comparison of Vissim Simulations Using The Two-Fluid Model", *Florida Institute of Technology*, 2007.
- [18] K. Wen, S. Qu and Y. Zhang, "A Control-oriented Macroscopic Traffic Flow Model for Urban Diverse Intersections", in *International Asia Conference on Informatics in Control, Automation and Robotics, IEEE*, 2009.
- [19] L.A. Rakhmat, A.A. Bawono, "Analisis Dampak Lalu Lintas Akibat Pembangunan Gedung Graha Energi (Medco Tower)", in *Final Project Institut Teknologi Bandung*, 2009.
- [20] M. Farzaneh, "Modeling Traffic Dispersion", in *Dissertation Virginia Polytechnic Institute and State University*, 2005.
- [21] M.J. Lighthill, G.B. Witham, "Kinematic Waves, a Theory of Traffic Flow on Roads", *Proc. R. Soc. (229A)*, pp. 317-345, 1955.
- [22] M. Van den Berg, A. Hegyi, B. De Schutter, and J. Hellendoorn, "A Macroscopic Traffic Flow Model for Integrated Control of Freeway and Urban Traffic Networks", in *Proceedings of the 42nd IEEE Conference on Decision and Control Mad*, Hawaii USA, December 2003.
- [23] N. Christov, Laboratory of Automatics, Computer Engineering and Signal Processing (LAGIS) in ERRIC Kickoff Meeting, 2010.

- [24] N. Xu, L. Zhibeng, "A Practical Research on Dynamic Traffic Flow Data Profile", in *IEEE International Conference on ITS*, 2002.
- [25] O. Piotr, S.L.F. Henry, T. Yan-Weng, "Area-Wide traffic Speed-Flow Model for The Singapore CBD", *Transp. Res-A*, vol.29A, pp. 273-281, 1995.
- [26] P. Avanzini, B. Thuilot, E. Royer, P. Martinet, "A global decentralized control strategy for urban vehicle platooning relying solely on monocular vision", *University of BP Clermont*, 2010.
- [27] P.Y Park, M. Abdel-Aty, "A Stochastic Catastrophe Model Using Two-Fluid Model Parameters to Investigate Traffic Safety on Urban Arterials", in *Accident Analysis and Prevention*, Elsevier, 2011.
- [28] R. Herman, I. Prigogine, "A Two-Fluid Approach to Town Traffic", *Science* vol.204, issue 4389, pp. 148-151, April 1979.
- [29] R. Mahnke, J. Kaupuzs, I. Lubashevsky, "Probabilistic Description of Traffic Flow", *ScienceDirect*, vol.408, issues 1-2, 2005.
- [30] S. Erlingsson, A.M. Jonsdottir, T. Thorsteinsson, "Traffic Stream Modeling of Road Facilities", *Transport Research*, 2006.
- [31] S.F. Lu, X. Liu, S. Dai, "Platoon Dispersion Prediction under The Condition of Adjacent Cycle Traffic Flow Overlapping Based on Support Vector Regression", *Journal of Communication and Computer*, vol.5, no.5, 2008.
- [32] S.K. Zegeye, B. De Schutter, J. Hellendorn, E.A. Breunese, "Integrated Macroscopic Traffic flow and Emission Model based on METANET and VT-Micro", in *Technical Report 09-017*, Delft University of Technology, 2010.
- [33] S.P. Hoogendoorn, P.H.L. Bovy, "State of the Art Vehicular Traffic Flow Modeling", *Journal of Systems and Control Engineering*, 2001.
- [34] T. Doh, H. Kim, K. Kang, W. Kook, "Analysis of Speed-Density Traffic Flow Models on A Merge Influence Section in Uninterrupted Facility", in *Proceedings of the Eastern Asia Society for Transportation Studies*, Vol.7, 2009.

- [35] T. Litman, "Well Measured: Developing Sustainable Transport Indicators". in *Victoria Transport Policy Institute*, 2005.
- [36] T. Murata, "Petri Nets: Properties, Analysis and Application", in *Proceeding IEEE*, vol.77, no.4, 1999.
- [37] V.D. Vinayak, A.R. Essam, "Strategies to Improve Dissipation into Destination Networks Using Macroscopic Network Flow Models", in *Symposium on the Fundamental Diagram: 75 years ("Greenshields 75" Symposium)*, 2007.
- [38] V.T. Arasan, S.H. Kashani, "Modeling Platoon Dispersal Pattern of Heterogeneous Road Traffic", in *TRB Annual Meeting*, 2003.
- [39] W. Hendrata, "Perbandingan Model Greenshield dan Greensberg pada Studi Karakteristik Arus Lalu Lintas di Ruas Jalan Ngagel Jaya Selatan Surabaya", *Jurnal Teknologi dan Rekayasa Sipil*, Juli 2008.
- [40] X. Hu, W. Wang, H. Sheng, "Urban Traffic Flow Prediction with Variable cell Transmission Model", *Journal of transportation systems eng and IT*, 10(4), 2010.
- [41] Y.J. Yu, M.G. Cho, "A Short-Term Prediction Model for Forecasting Traffic Information Using Bayesian network", in *International conference on convergence and hybrid IT*, 2008.
- [42] Z. Hidayat, Zs. Lendek, R. Babuska, B. De Schutter, "Fuzzy observer for state estimation of the METANET traffic model", in *13th International IEEE Annual Conference on Intelligent Transportation Systems Madeira Island, Portugal*, September 19-22, 2010.
- [43] Z. Li, S. Yin, Y. Tian, L. Li, Z. Zhao, Y. Ji, "Urban Traffic Flow Volume Modeling for Beijing Using a Mixed-Flow Model", *Journal of Transportations Systems Engineering and Information Technology*, Vol.8, Issue 3, June 2008.
- [44] Z. Xiang, R. Jian, W. Jiancheng and S. Changqiao, "Network-wide Performance Assessment of Urban Traffic Based on Probe Vehicle Data", in *Proceedings of IEEE Intelligent Transportation Systems Conference Seattle, WA, USA*, Sept. 30 - Oct. 3, 2007.
- [45] www.intrade-nwe.eu

- [46] www.jakarta.bps.go.id
- [47] www.oktal.fr
- [48] www.petajakarta.info
- [49] www.robosoft.com
- [50] www.scanersimulation.fr
- [51] www.scbd.com



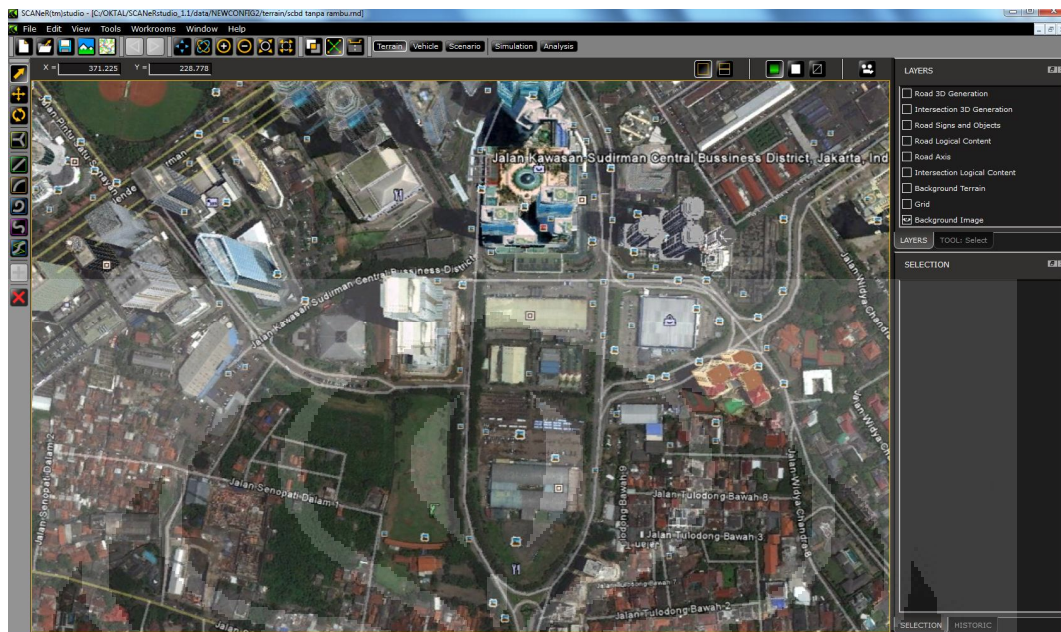


ANNEX 1

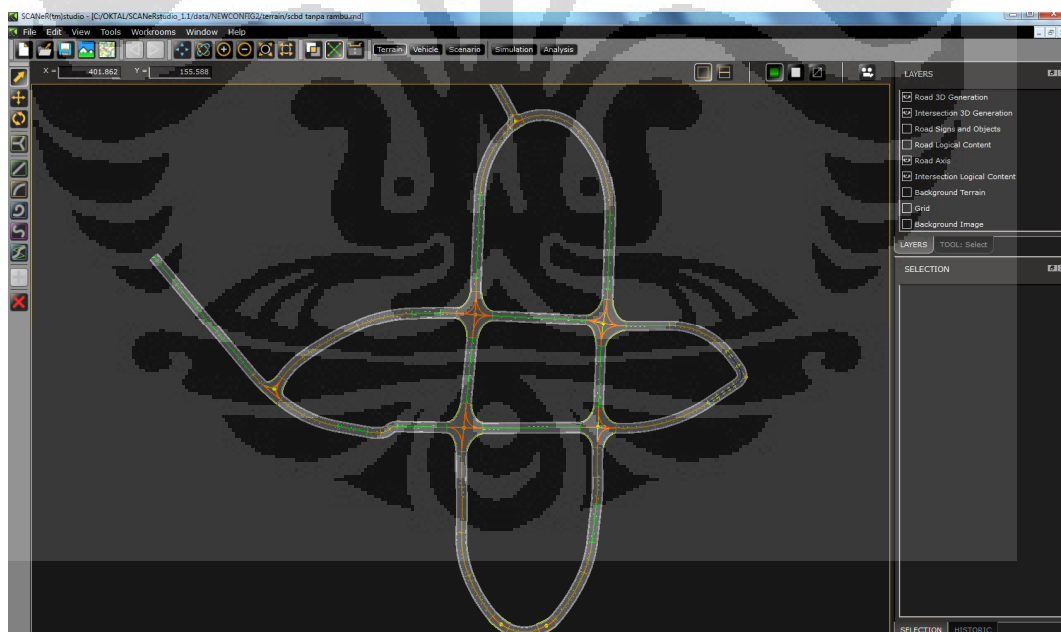
Description of SCANeRÎ studio through an Example

Step for making the terrain:

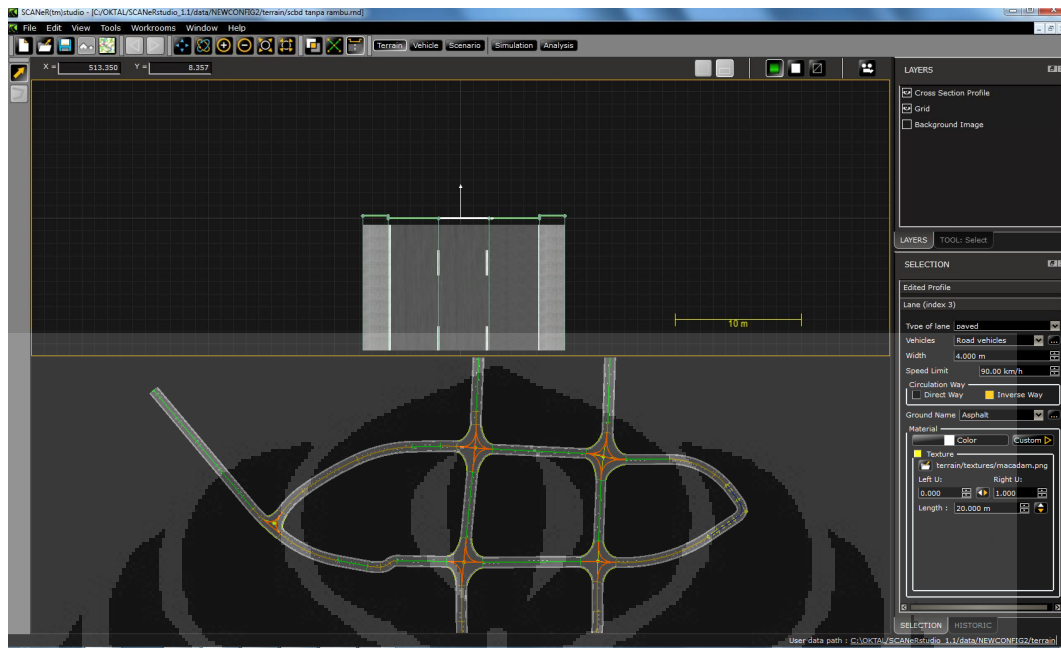
1. Import background from google earth



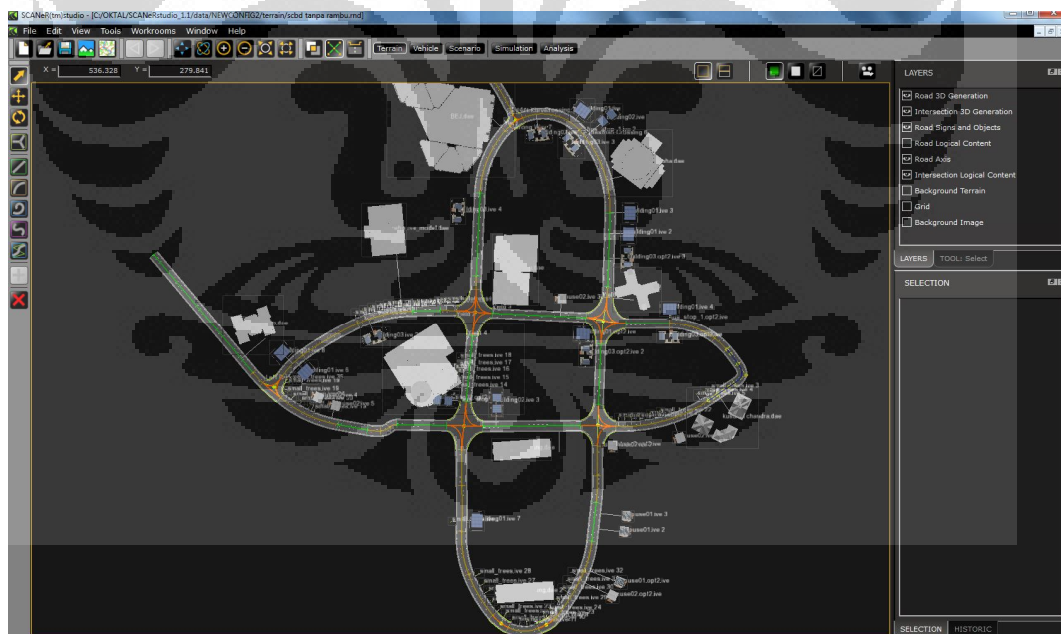
2. Draw the road based on the background



3. Change the properties of the road (size, road marking)



4. Adding all the object such as: building, pedestrian, trees and traffic signals

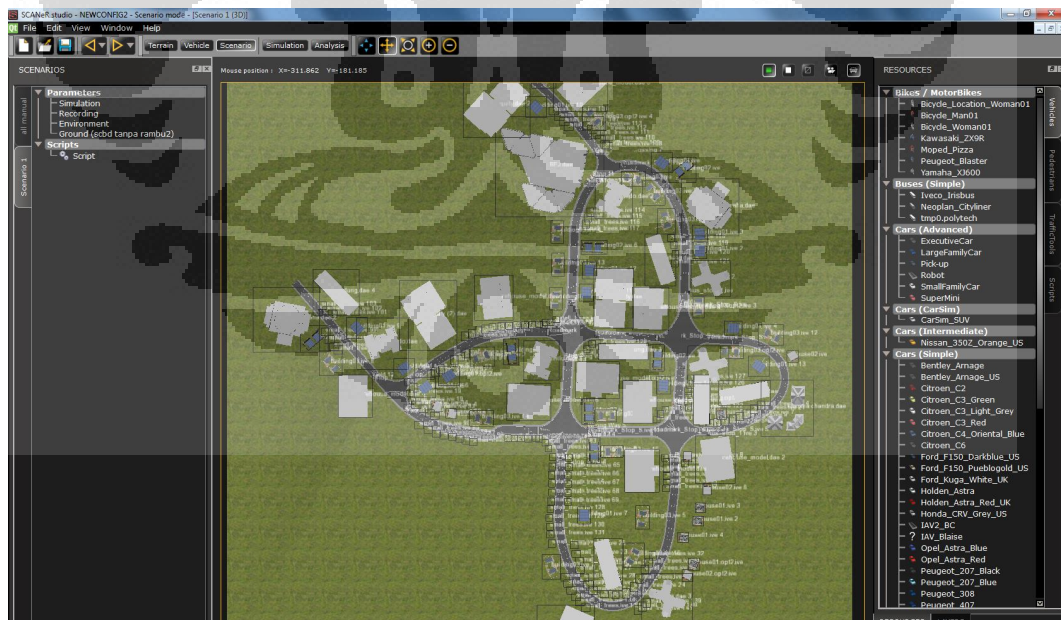


5. Generate terrain and export it to make the scenario

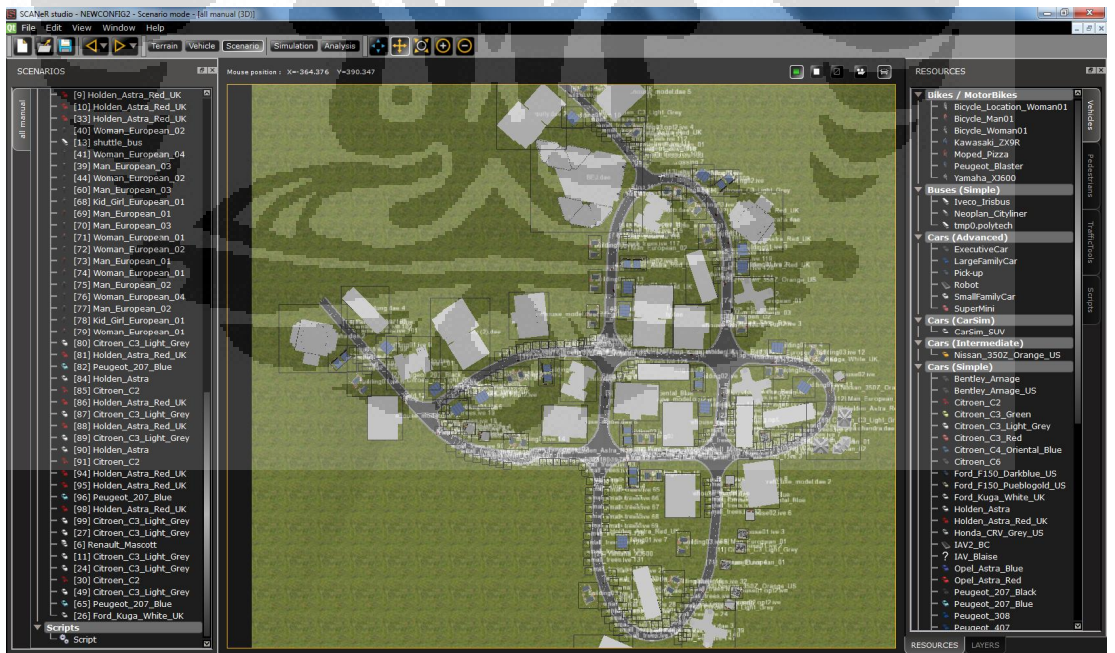
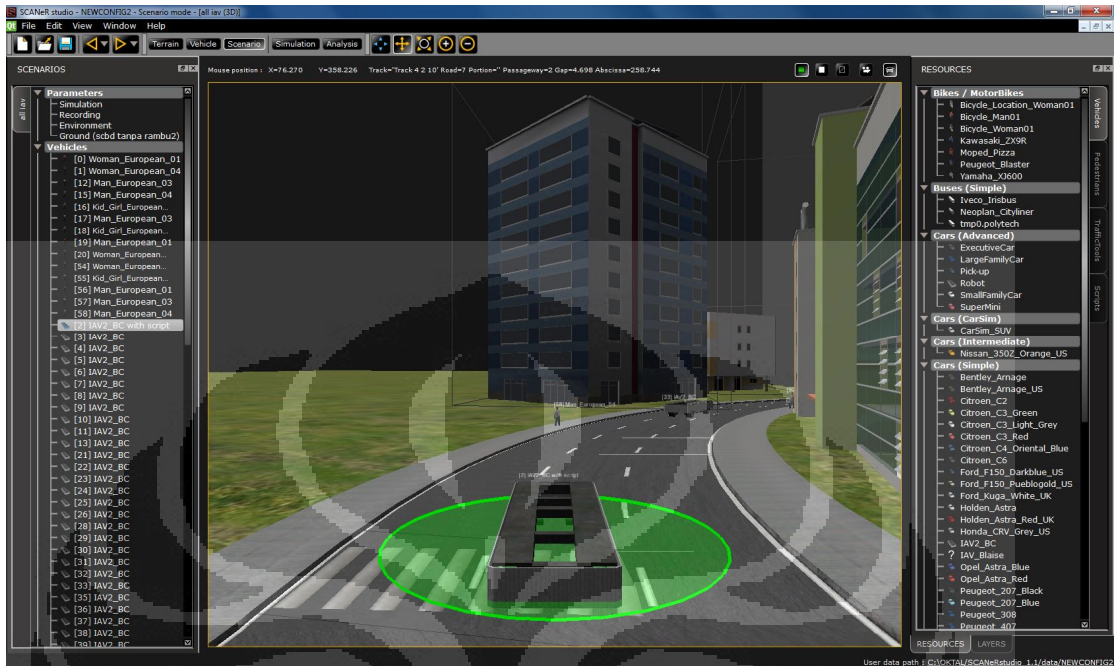


Step for scenario:

1. Choose and open terrain file that already have generated

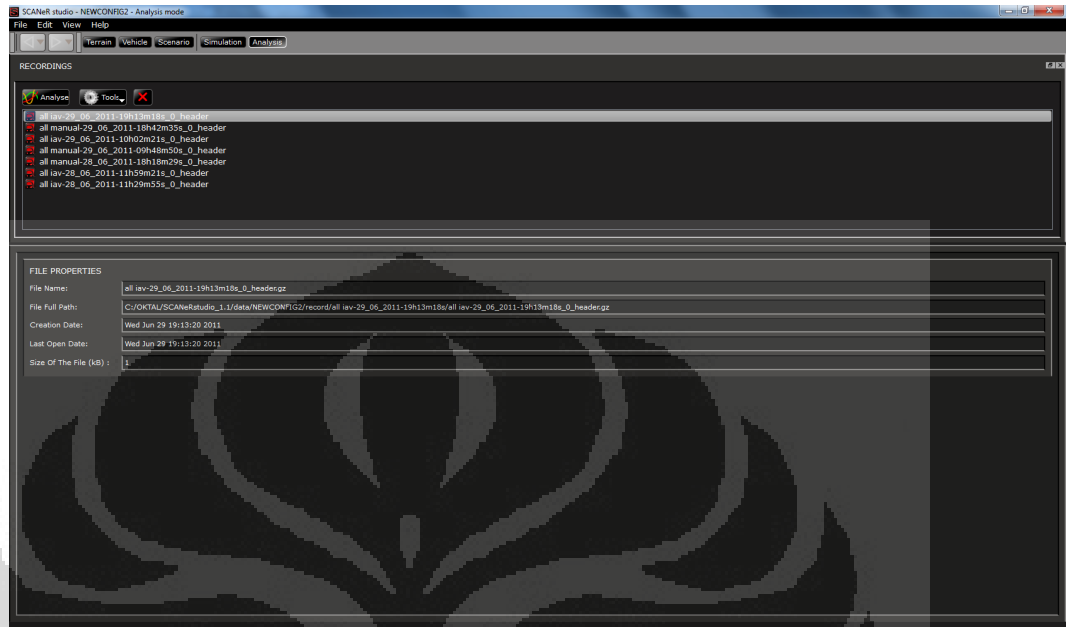


- Choose all conventional vehicles and pedestrian (first scenario) and all IAV (second scenario)

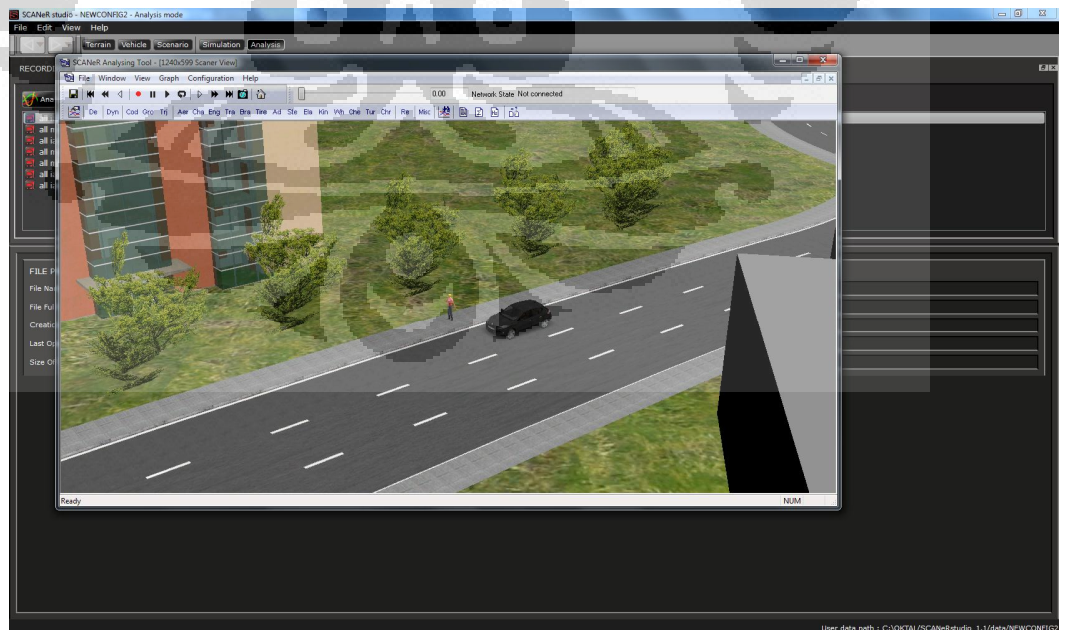


Step for analysis:

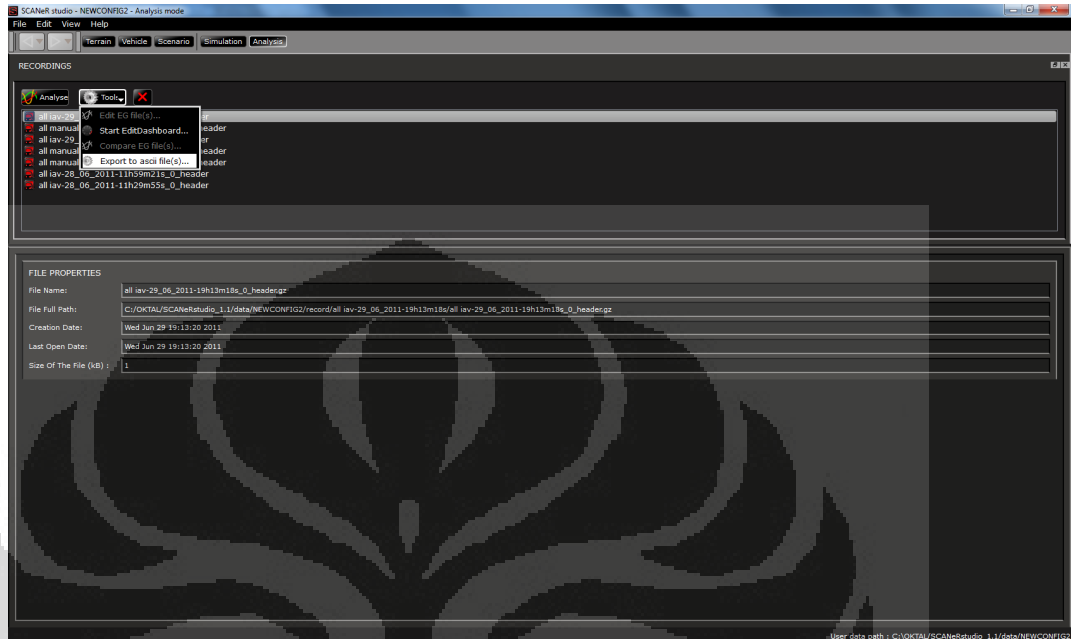
1. Choose the recorded file.



2. Click Analyse button to review the simulation and save it into video format.



3. Click Tools and choose Export to ascii file to get the output data such as time and speed. The data format is in *.txt (notepad).





ANNEX 2

Data of Traffic in SCBD Area

Table of Number of Registered Motor Vehicles by Month and Kind of Type Motor Vehicles, 2009 in Jakarta

Year	Motor Cycle (veh)	Passenger Cars (veh)	Buses (veh)	Total (veh)
2004	3,940,700	1,645,306	488,517	6,074,523
2005	4,647,435	1,766,801	499,581	6,913,817
2006	5,310,068	1,835,653	504,727	7,650,448
2007	5,974,200	1,916,500	518,991	8,409,691
2008	6,765,723	2,034,943	538,731	9,339,397

Source: BPS DKI Jakarta, 2011

Table of Growth Index for Motor Cycle from 2004-2008 in Jakarta

Year	Number of Motorcycle (MC)	Increasing of Motorcycle (MC)	Growth Index (%)
2004	3,940,700		
2005	4,647,435	706,735	17.93%
2006	5,310,068	662,633	14.26%
2007	5,974,200	664,132	12.51%
2008	6,765,723	791,523	13.25%
Average Growth Index			14.49%

Source:[19]

Table of Growth Index for Light Vehicle from 2004-2008 in Jakarta

Year	Number of Light Vehicle (veh)	Increasing of Vehicle (veh)	Growth Index (%)
2004	1,645,306		
2005	1,766,801	121,495	7.38%
2006	1,835,653	68,852	3.90%
2007	1,916,500	80,847	4.40%
2008	2,034,943	118,443	6.18%
Average Growth Index			5.47%

Source:[19]

Table of Growth Index for Heavy Vehicle from 2004-2008 in Jakarta

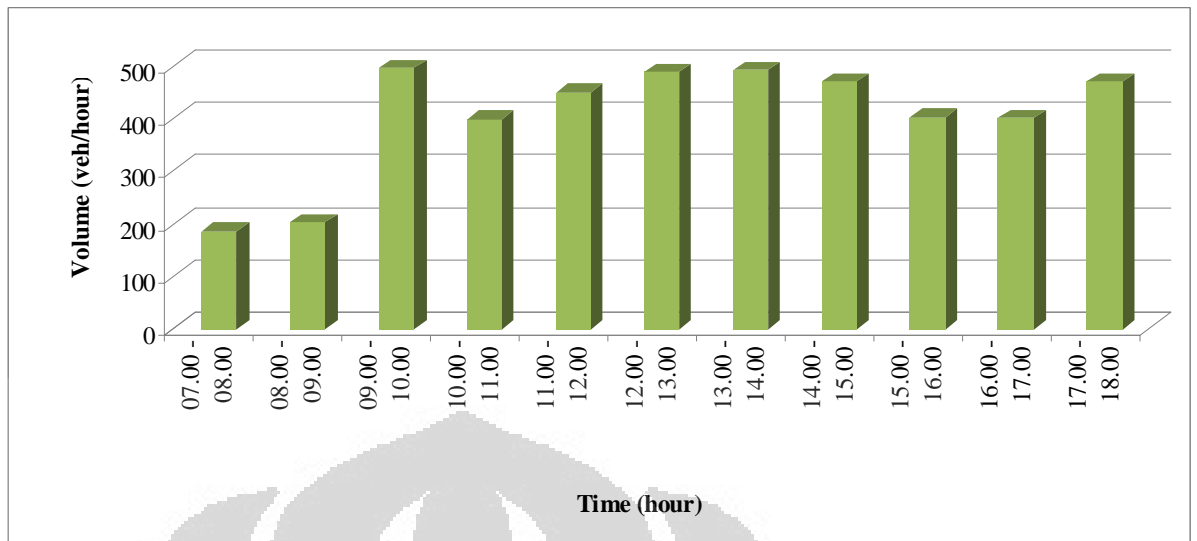
Year	Number of Heavy Vehicle (veh)	Increasing of Vehicle (veh)	Growth Index (%)
2004	488,517		
2005	499,581	11,064	2.26%
2006	504,727	5,146	1.03%
2007	518,991	14,264	2.83%
2008	538,731	19,740	3.80%
Average Growth Index			2.48%

Source:[19]

Table of Traffic Volume from 07.00-18.00 (Niaga-Sudirman)

Time	volume (veh/h)
07.00 - 08.00	187
08.00 - 09.00	202
09.00 - 10.00	496
10.00 - 11.00	399
11.00 - 12.00	450
12.00 - 13.00	488
13.00 - 14.00	492
14.00 - 15.00	470
15.00 - 16.00	403
16.00 - 17.00	400
17.00 - 18.00	470

Source:[19]



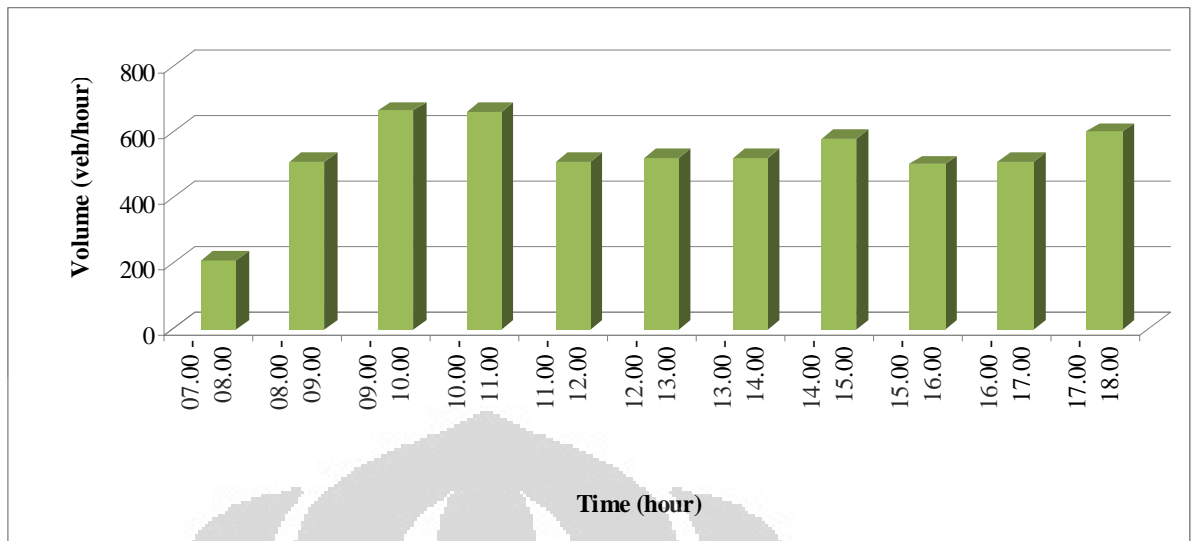
Source:[19]

Figure of Total Traffic Volume per Hour (Niaga-Sudirman)

Table of Traffic Volume from 07.00-18.00 (Sudirman-Niaga)

Time	volume (veh/h)
07.00 - 08.00	210
08.00 - 09.00	510
09.00 - 10.00	664
10.00 - 11.00	660
11.00 - 12.00	510
12.00 - 13.00	520
13.00 - 14.00	520
14.00 - 15.00	580
15.00 - 16.00	500
16.00 - 17.00	510
17.00 - 18.00	600

Source:[19]



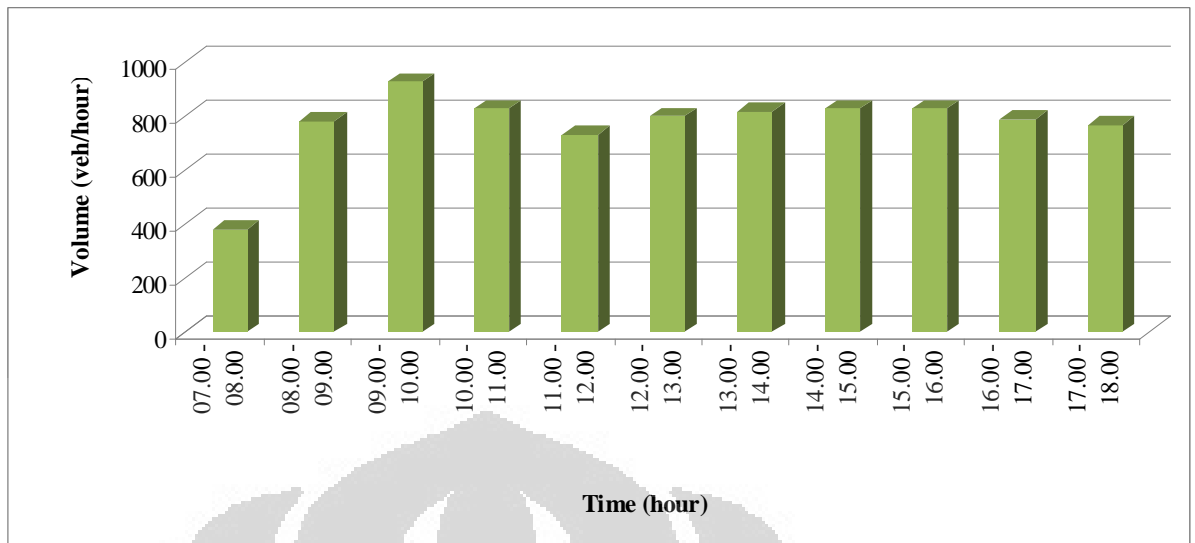
Source:[19]

Figure of Total Traffic Volume per Hour (Sudirman-Niaga)

Table of Traffic Volume from 07.00-18.00 (South East Way)

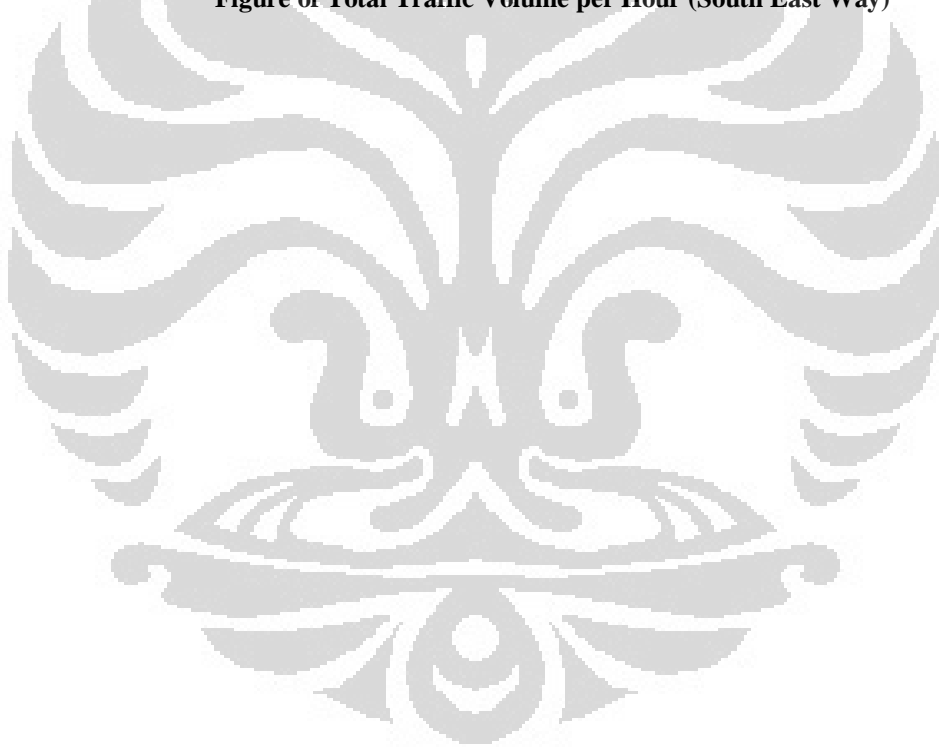
Time	volume (veh/h)
07.00 - 08.00	380
08.00 - 09.00	780
09.00 - 10.00	929
10.00 - 11.00	830
11.00 - 12.00	730
12.00 - 13.00	800
13.00 - 14.00	820
14.00 - 15.00	830
15.00 - 16.00	830
16.00 - 17.00	790
17.00 - 18.00	770

Source:[19]



Source:[19]

Figure of Total Traffic Volume per Hour (South East Way)





ANNEX 3

result

Table of Mean Speed, Travel Time, Running Time and Stop Time for All IAV

Vehicle No.	Mean speed (km/h)	T (min/km)	Ts (min/km)	Tr (min/km)	In T (min/km)	In Tr (min/km)
1	13.608	3.610	0.926	2.684	1.284	0.987
2	17.046	3.520	1.097	2.423	1.258	0.885
3	18.553	3.234	0.655	2.579	1.174	0.947
4	16.122	3.722	0.874	2.848	1.314	1.046
5	17.251	3.478	0.774	2.704	1.246	0.995
6	11.895	5.044	1.548	3.496	1.618	1.252
7	15.543	3.860	0.996	2.865	1.351	1.052
8	14.084	4.260	1.104	3.156	1.449	1.149
9	15.007	3.998	1.413	2.585	1.386	0.950
10	13.061	4.594	1.200	3.393	1.525	1.222
11	14.094	4.257	1.200	3.057	1.449	1.117
12	9.380	6.397	1.326	5.071	1.856	1.624
13	12.337	4.863	1.137	3.726	1.582	1.315
14	14.641	4.098	1.137	2.961	1.411	1.086
15	15.600	3.846	1.028	2.818	1.347	1.036
16	8.689	6.905	2.458	4.447	1.932	1.492
17	10.070	5.959	1.805	4.153	1.785	1.424
18	16.691	3.595	0.890	2.705	1.279	0.995
19	4.997	12.007	2.733	9.273	2.485	2.227
20	12.340	4.862	1.572	3.291	1.582	1.191
21	12.168	4.931	1.611	3.320	1.596	1.200
22	16.718	3.589	0.830	2.759	1.278	1.015
23	21.439	2.799	0.182	2.616	1.029	0.962
24	19.335	3.103	0.530	2.573	1.132	0.945
25	15.045	3.988	1.088	2.900	1.383	1.065
26	13.869	4.326	1.434	2.892	1.465	1.062
27	17.030	3.523	0.861	2.662	1.259	0.979
28	10.997	5.456	1.768	3.688	1.697	1.305
29	16.267	3.688	1.226	2.462	1.305	0.901
30	16.826	3.566	0.855	2.710	1.271	0.997
31	14.758	4.065	1.151	2.915	1.403	1.070
32	12.429	4.827	1.420	3.407	1.574	1.226
33	14.522	4.132	1.205	2.926	1.419	1.074
34	8.330	7.203	2.104	5.099	1.975	1.629
35	17.323	3.464	0.797	2.666	1.242	0.981
36	7.001	8.570	2.378	6.193	2.148	1.823
37	16.224	3.698	0.883	2.816	1.308	1.035
38	14.620	4.104	1.090	3.014	1.412	1.103
39	10.953	5.478	1.571	3.907	1.701	1.363
40	12.683	4.731	1.618	3.112	1.554	1.135

Table of Mean Speed, Travel Time, Running Time and Stop Time for All IAV (continue)

Vehicle No.	Mean speed (km/h)	T (min/km)	Ts (min/km)	Tr (min/km)	In T (min/km)	In Tr (min/km)
41	9.711	6.178	1.959	4.220	1.821	1.440
42	13.329	4.501	1.317	3.185	1.504	1.158
43	8.310	7.220	2.169	5.051	1.977	1.620
44	10.554	5.685	1.687	3.998	1.738	1.386
45	17.161	3.496	0.932	2.564	1.252	0.942
46	14.952	4.013	1.114	2.899	1.390	1.065
47	13.062	4.593	0.718	3.875	1.525	1.355
48	12.996	4.617	1.351	3.266	1.530	1.183
49	8.093	7.414	2.880	4.533	2.003	1.511
50	7.955	7.542	1.812	5.731	2.021	1.746
51	14.333	4.186	1.071	3.115	1.432	1.136
52	14.824	4.047	1.115	2.932	1.398	1.076
53	16.878	3.555	1.023	2.531	1.268	0.929
54	11.160	5.376	1.729	3.647	1.682	1.294
55	12.634	4.749	1.486	3.263	1.558	1.183
56	10.347	5.799	1.744	4.055	1.758	1.400
57	16.784	3.575	0.821	2.754	1.274	1.013

Table of Mean Speed, Travel Time, Running Time and Stop Time for All Conventional Vehicle

Vehicle No.	Mean speed (km/h)	T (min/km)	Ts (min/km)	Tr (min/km)	In T (min/km)	In Tr (min/km)
1	16.460	3.645	2.210	1.435	1.293	0.361
2	12.759	4.703	2.374	2.329	1.548	0.845
3	11.684	5.135	2.387	2.749	1.636	1.011
4	5.444	11.021	2.972	8.049	2.400	2.085
5	9.568	6.271	2.606	3.665	1.836	1.299
6	20.814	2.883	1.221	1.662	1.059	0.508
7	16.692	3.594	1.996	1.598	1.279	0.469
8	5.544	10.822	3.087	7.735	2.382	2.046
9	18.246	3.288	1.790	1.498	1.190	0.404
10	14.600	4.110	1.854	2.255	1.413	0.813
11	27.080	2.216	0.318	1.898	0.796	0.641
12	6.652	9.019	3.027	5.992	2.199	1.790
13	17.289	3.470	1.828	1.642	1.244	0.496
14	11.033	5.438	2.467	2.971	1.693	1.089
15	14.533	4.129	2.243	1.885	1.418	0.634
16	3.978	15.083	3.271	11.812	2.714	2.469
17	16.091	3.729	1.805	1.924	1.316	0.654
18	17.399	3.448	1.680	1.768	1.238	0.570
19	14.470	4.146	2.312	1.834	1.422	0.607
20	12.679	4.732	2.217	2.515	1.554	0.922
21	3.190	18.806	3.413	15.393	2.934	2.734
22	8.914	6.731	2.716	4.015	1.907	1.390
23	4.473	13.413	3.303	10.111	2.596	2.314

Table of Mean Speed, Travel Time, Running Time and Stop Time for All Conventional Vehicle (continue)

Vehicle No.	Mean speed (km/h)	T (min/km)	Ts (min/km)	Tr (min/km)	In T (min/km)	In Tr (min/km)
24	15.370	3.904	1.950	1.954	1.362	0.670
25	12.076	4.969	2.084	2.885	1.603	1.059
26	7.492	8.008	2.934	5.075	2.080	1.624
27	18.130	3.310	1.870	1.439	1.197	0.364
28	16.578	3.619	1.953	1.667	1.286	0.511
29	10.847	5.532	2.675	2.856	1.711	1.050
30	9.975	6.015	2.636	3.379	1.794	1.218
31	5.567	10.778	3.154	7.624	2.378	2.031
32	7.326	8.190	2.997	5.193	2.103	1.647
33	8.166	7.348	2.784	4.564	1.994	1.518
34	10.432	5.752	2.628	3.123	1.749	1.139
35	10.858	5.526	2.570	2.955	1.709	1.084
36	13.920	4.310	2.016	2.294	1.461	0.830
37	17.429	3.443	1.697	1.745	1.236	0.557
38	7.382	8.128	3.090	5.038	2.095	1.617
39	13.736	4.368	2.395	1.973	1.474	0.680
40	3.428	17.502	3.368	14.134	2.862	2.649
41	11.960	5.017	1.803	3.214	1.613	1.167
42	14.773	4.061	1.933	2.129	1.402	0.755
43	11.716	5.121	2.511	2.610	1.633	0.959
44	5.393	11.126	3.123	8.002	2.409	2.080
45	18.052	3.324	1.589	1.735	1.201	0.551
46	13.792	4.350	2.200	2.150	1.470	0.766
47	4.486	13.374	3.226	10.147	2.593	2.317
48	3.919	15.310	3.294	12.016	2.729	2.486
49	5.487	10.934	3.222	7.712	2.392	2.043
50	4.544	13.205	3.260	9.945	2.581	2.297
51	3.561	16.851	3.283	13.568	2.824	2.608
52	12.954	4.632	2.249	2.383	1.533	0.868
53	15.851	3.785	1.803	1.983	1.331	0.685
54	16.049	3.739	2.186	1.552	1.319	0.440
55	9.869	6.080	2.743	3.337	1.805	1.205
56	17.036	3.522	1.824	1.698	1.259	0.530
57	26.349	2.277	1.296	0.981	0.823	-0.019
58	12.116	4.952	2.259	2.693	1.600	0.991
59	20.422	2.938	1.487	1.451	1.078	0.372
60	8.592	6.983	2.887	4.096	1.944	1.410
61	11.018	5.446	2.635	2.811	1.695	1.034
62	21.356	2.809	1.380	1.429	1.033	0.357
63	9.963	6.022	2.616	3.406	1.795	1.226