# URBAN TRAFFIC MANAGEMENT USING INTELLIGENT TRANSPORTATION SYSTEM (ITS)

**THESIS**

**HASRIWAN PUTRA**

**0906580312**

**FACULTY OF ENGINEERING**

**DEPARTMENT OF CIVIL ENGINEERING**

**TRANSPORTATION**

**DEPOK**

**JULY 2011**

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**Proposed as one of the requirements for obtaining a Master of Engineering**

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# Statement of Originality

This thesis was the work of myself, and all sources whether quoted of referenced, I have stated correctly.

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Date : 9 July 2011

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Program Studi : Teknik Sipil – Transportasi

Judul Tesis : Manajemen Lalu Lintas Perkotaan dengan Menerapkan Sistem Transportasi Cerdas (*Intelligent Transportation System*)

**Telah berhasil dipertahankan didepan Dewan Penguji dan diterima sebagai bagian persyaratan yang diperlukan untuk memperoleh gelar Master 2 Université de Lille1 (Perancis) dan Magister Teknik pada Program Studi Teknik Sipil, Fakultas Teknik, Universitas Indonesia.**

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Hopefully this thesis brings benefits to development of science.

**HALAMAN PERNYATAAN PERSETUJUAN PUBLIKASI TUGAS AKHIR UNTUK KEPENTINGAN AKADEMIS**

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Yang menyatakan

(Hasriwan Putra)

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**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

$\alpha$ = origin intersection

$\beta$ = destination intersection

$\delta$ = 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

*ceil (r)* with r a real number denotes the smallest integer larger than or equal to r

*VCPN* = (Q, Vmax)

*Q* = (P,T,Pre, Post, M0)

*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 ti (km/h)

$x$ = length of segment (continuous petri net model)

$\rho$ = density

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

$\alpha$ : 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)

$\Delta t$ = 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 $\beta.T_a$ (platoon dispersion model) (s)

$\beta$ = dimensionless travel time factor (platoon dispersion model)

$\alpha$ = dimensionless platoon dispersion factor (platoon dispersion model)

$F$ = smoothing factor

$T_a$ = mean roadway travel time, measured in units of time steps (s)

$\xi$ = specific detector

$j$ = subset

$i$ = day

$\hat{\sigma}_{i,j}^2$ = variance

$\hat{\rho}_i(\tau)$ = covariance

$\rho$ = density

$v$ = space mean speed

$\lambda$ = 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

$\alpha$ and $m$ = parameters ($\alpha$-relationship model)

# Abstract

*This thesis has focus study in traffic management using intelligent transportation system in urban area. The goal of this thesis is to improve the traffic management and space optimization using Intelligent Autonomous Vehicle (IAV) by describing traffic flow in macroscopic level. The two fluid model is appropriate model which provides characteristics of the performance of traffic flow on an urban road network. The model can generate a relationship between trip time, stop time and running time per km. To apply the model, the traffic data that obtained by using the traffic simulator of SCANeR™studio.*

Keyword : Macroscopic, Urban Traffic Modeling, Mean Speed, Density, Flow, Intelligent Autonomous Vehicle (IAV)

# 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, hydrologie impacts.

Jakarta has an area of approximately 662.33 km², with a total population of 9,588,198 inhabitants [46]. The city become fast developped 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-Docs [22].

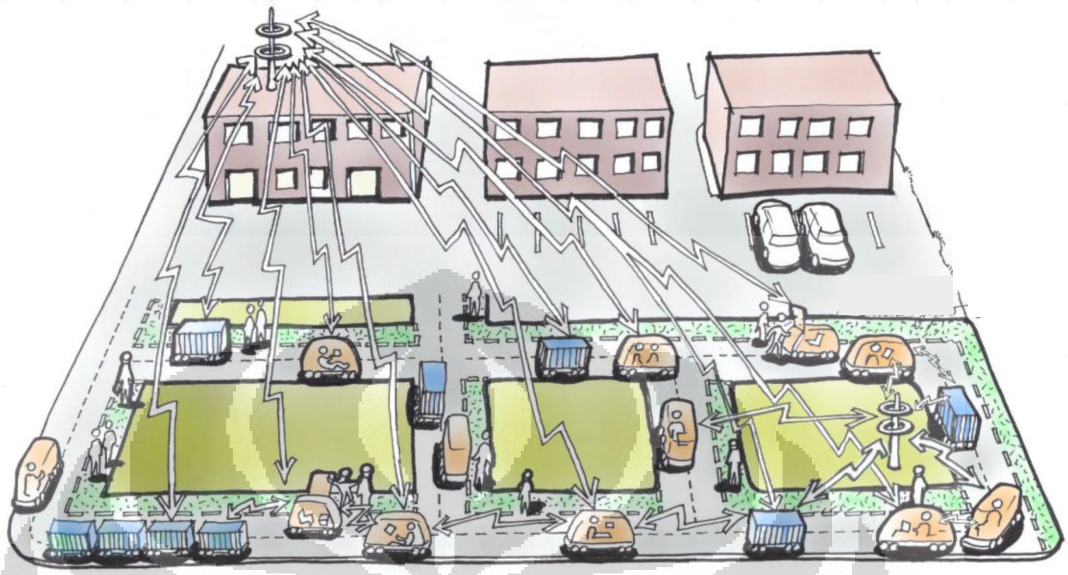
The LAGIS research objectives concern the development of fundamental, methodological, and technological research in the fields of automatic control, computer engineering and signal processing. The LAGIS research teams are active in [22]:

- 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 in 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

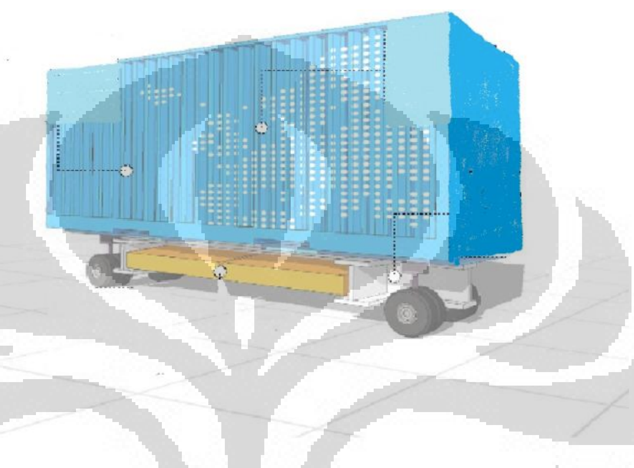


**Figure 2.2 Heavy Intelligent Autonomous Vehicle (IAV) of InTraDE**

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*

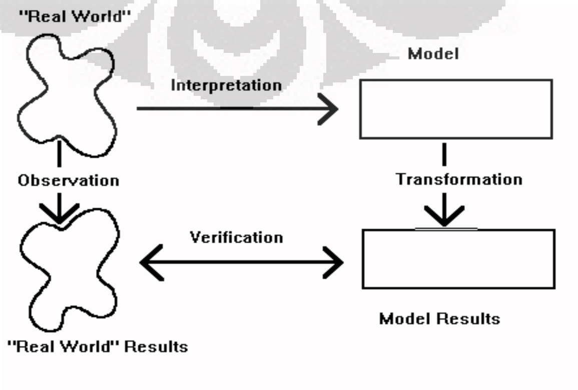
The aim of this chapter is to do literature study of modeling of urban traffic at macroscopic levels and make comparison between different models according to performances and objectives.

## *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.

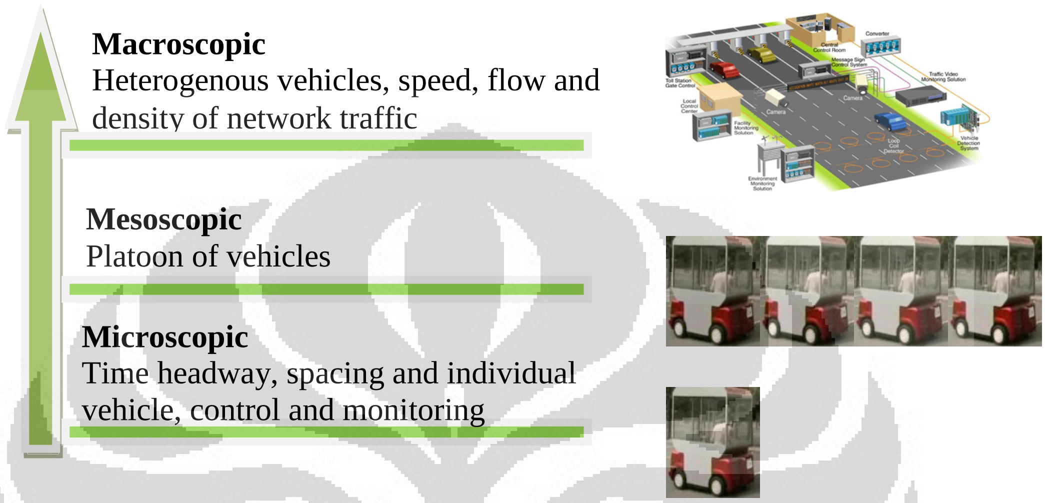



**Figure 3.2. Classification of Urban Traffic Model**

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.

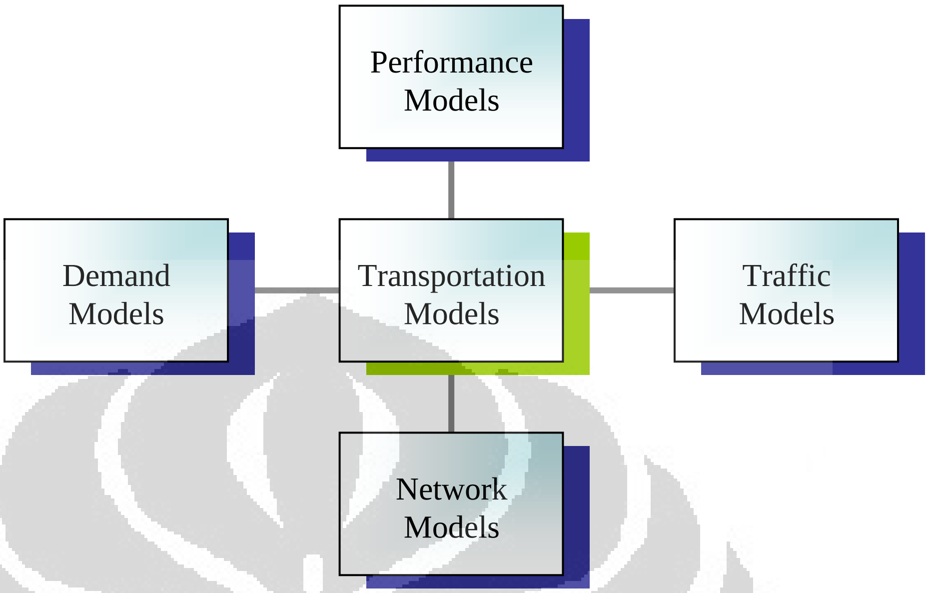



**Figure 3.3. Transportation Model**

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 probability distribution, while in deterministic model has precisely determined distribution.

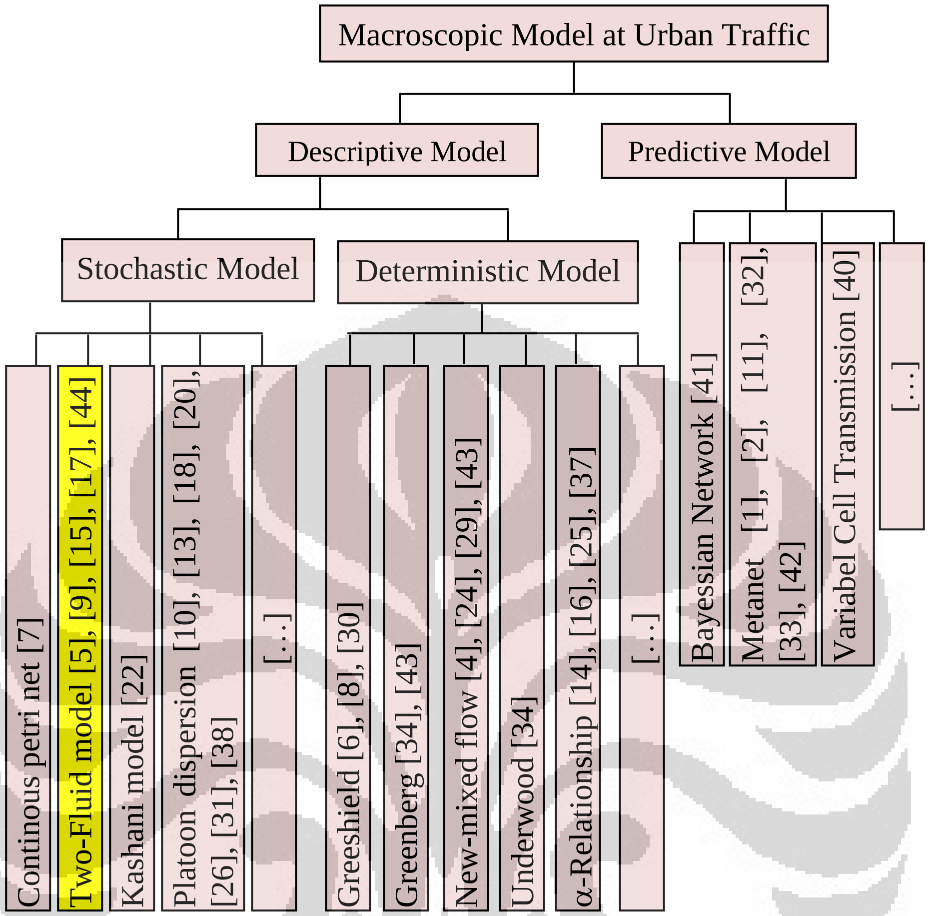



**Figure 3.4. Urban Traffic Model Classification**

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 usely deterministic in term 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 were 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)

$T_m$ translate 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

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

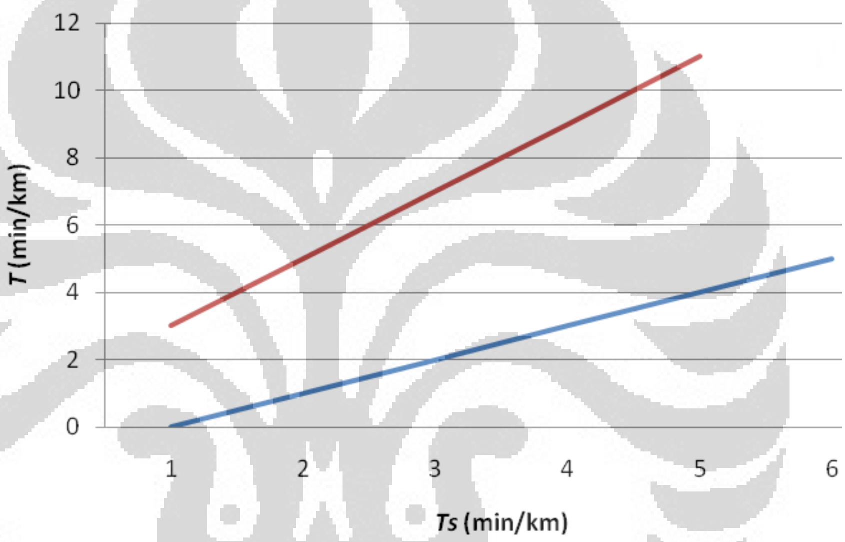
Where:

$$n = \frac{B}{1-B} \tag{3.5}$$

$$T_m = e^{\frac{A}{1-B}} \tag{3.6}$$

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, $M_o$),

where :

P = {P1, P2, …, PL} is a finite, nonempty set of places

T = {T1, T2, …, Tn} is a finite, nonempty set of transitions

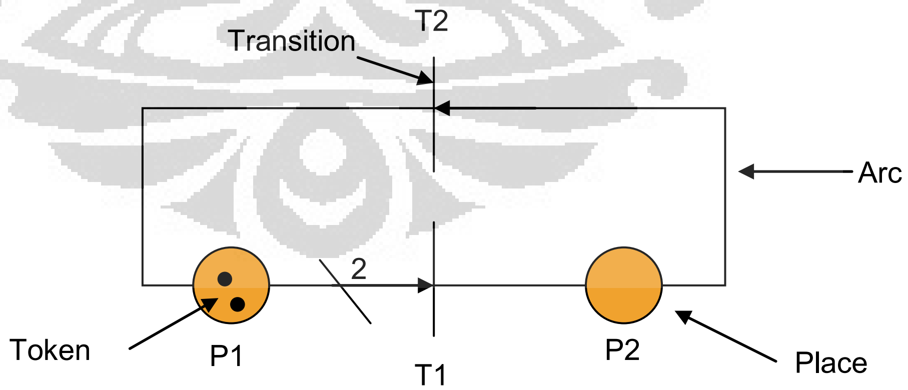
$P \cap T$ = φ(i.e., the sets P and T are disjoint)

Pre = $PxT \longrightarrow \{0,1\}$ 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 $T_j$

Post = $PxT \longrightarrow$ {0,1} is the output incidence function such that 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,…,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.

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

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

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:

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

$$F = \frac{1}{1+\alpha\beta T_a} \tag{3.10}$$

Where:

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

$q'_t$ = flow rate over

$\Delta_t$ = time step duration, measured in the time intervals used for $q'_t$ and $q_t$

$T$ = minimum travel time on the roadway

$\alpha$ = dimensionless platoon dispersion, factor, express the degree of the dispersion of the platoon

$\beta$ = 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

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

$\beta$ and $\alpha$ 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)

$\sigma$ = standard deviation of link travel time (s)

$\alpha$ = 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 $\alpha$ is an important parameter and significantly influences prediction accuracy, because traffic flow is the dependant and $\alpha$ 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.

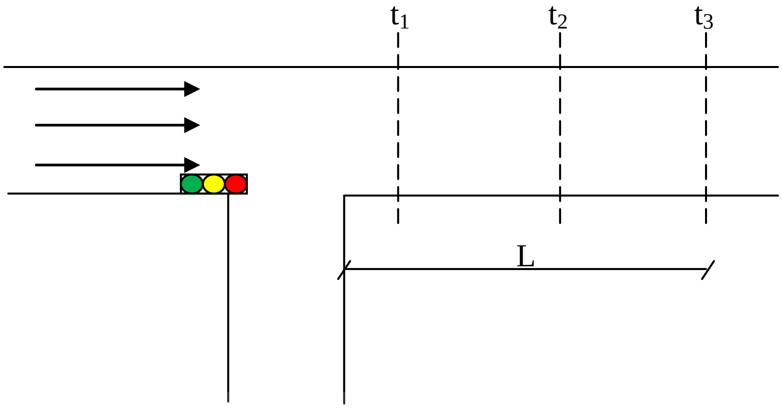
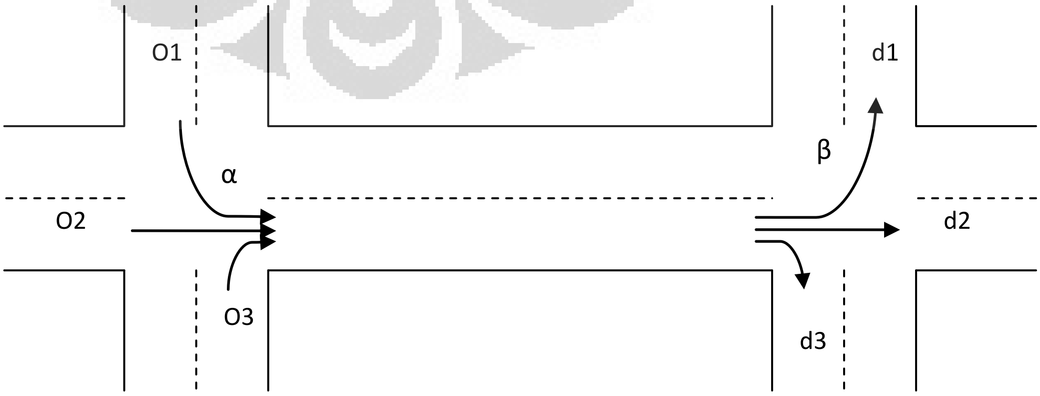



**Figure 3.7. Illustration of Platoon Dispersion Model**

### *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.




*Source: [22]*

**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 $\alpha$ is origin intersection and $\beta$ 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 | $U = U_m \ln\left(\frac{K_j}{K}\right)$<br>where:<br>$U$ = speed (km/h)<br>$K$ = density (veh/km)<br>$U_m$ = speed at maximum flow (km/h)<br>$K_j$ = jam density (veh/m) | To describe the relationship between the traffic parameters (speed, density, flow) | Advantage :<br>Good at congestion<br><br>Disadvantage :<br>- Poor at low density<br>- infinite speed at free flow | On a merge influence section in an uninterrupted facility in KOREA | [34], [43] |
| 2 | Underwood | Exponential / Deterministic, static | $U = U_f \exp\left(\frac{-K}{K_m}\right)$<br>where:<br>$U$ = speed (km/h)<br>$K$ = density (veh/km)<br>$U_f$ = free flow speed (km/h)<br>$K_m$ = maximum density (veh/m) | To describe the relationship between the traffic parameters (speed, density, flow) | Advantage :<br>Good at low density<br><br>Disadvantage :<br>- Poor at high density<br>- 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 | $m^{new}_{arr,\alpha,\beta}\left(l+\delta_{\alpha\beta}(l)\right) = m^{old}_{arr,\alpha,\beta}\left(l+\delta_{\alpha\beta}(l)\right) + \sum_{oi \in o\alpha} m_{dep,oi,\alpha,\beta}(l)$<br>$m_{arr}$ = number of arrival vehicle<br>$m_{dep}$ = number of departure vehicle | To describe traffic flow in urban traffic networks | Advantage :<br>Suitable at intersection<br><br>Disadvantage :<br>Not applicable in road network | At signalized intersection | [22] |
| 4 | Continuous petri net with variable speed (VCPN) | Stochastic and dynamic | $K_i(t) = \frac{m_i(t)}{x_i}$<br>$U_i(t) = \frac{v_i(t)x_i}{m_i(t)}$<br><br>where:<br>$K_i(t)$ = average density for segment i<br>$U_i(t)$ = average speed for segment i<br>$m_i(t)$ = number of vehicles<br>$x_i$ = length of segment<br>$v_i(t)$ = transition firing speed<br><br>VCPN = (Q, Vmax) | To model and perform evaluation in urban and interurban network | Advantage :<br>It can model systems with dynamic and stochastic<br><br>Disadvantage :<br>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,Pre, Post, $M_0$)<br>Vmax= real positive vector of transitions maximal firing speeds | | | | |
| 5 | Bayesian Network | Statistical model/ Stochastic, static | Final prediction = $PS \times \alpha + RS(1-\alpha)$<br>where:<br>$\alpha$ = weight of the current traffic situation<br>$PS$ = prediction speed<br>$RS$ = vehicle speed of the real-time result | To forecast traffic in a short-term prediction | Advantage :<br>Useful to predict traffic condition<br><br>Disadvantage :<br>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)<br>$[q_i(t) - q_i + 1(t)]dT = [k_i(t+1) - k_i(t)]l_i$<br>where:<br>$q_i(t)$= traffic flow rate<br>$k_i(t)$= traffic density rate<br>$l_i$ = length of cell i | To predict traffic flow | Advantage :<br>Suitable for simple urban road<br><br>Disadvantage :<br>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 | $\ln T_r = 1/(n+1)\ln T_m + n/(n+1)\ln T$<br>where:<br>$T$ = total travel time<br>$T_r$ = running time<br>$T_m$ = average minimum trip time per unit distance<br>$n$ = indicator of the quality of traffic service in the network | To represent an urban non-freeway traffic network | Advantage :<br>Knowing the quality and level of service in network in metropolitan areas, t is applicable in the domain of collective flow<br><br>Disadvantage :<br>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, linier, static | $U = U_f \left[1 - \frac{K}{K_j}\right]$<br>where:<br>$U$ = Speed (km/h) | To predict and explain the trends that are observed in real traffic flow | Advantage :<br>several researchers have found good correlation between model and | In congested and uncongested traffic condition | [6], [8], [30] |

| No | Model | Type | Mathematical Model | Objective | Advantages/ disadvantages | Application | Reference |
|---|---|---|---|---|---|---|---|
| | | | $U_f$ = free flow speed (km/h)<br>$K$ = density (veh/km)<br>$K_j$ = jam density (veh/km) | | field data<br><br>Disadvantage :<br>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 | $q_t' = F \times q_{t-T} + (1-F) \times q'_{t-\Delta t}$<br>$F = \frac{1}{1+\alpha \times \beta \times T_a}$<br><br>where:<br>$\Delta t$ = time step duration, measured in the time intervals used for $q_t$'<br>$T$ = minimum travel time on the roadway in units of time steps, equal to $\beta \times T_a$ | To improve the efficiency of control system in various non-freeway traffic | Advantage :<br>vehicle platooning could enhance this transportation service because it directly influences the optimization of signal timing schemes | Inflow-outflow characteristics at urban intersection | [10], [13], [18], [20], [26], [31], [38] |

| No | Model | Type | Mathematical Model | Objective | Advantages/ disadvantages | Application | Reference |
|---|---|---|---|---|---|---|---|
| | | | $\beta$ = dimensionless travel time factor<br>$\alpha$ = dimensionless platoon dispersion factor<br>$F$ = smoothing factor<br>$T_a$ = mean roadway travel time, measured in units of time steps | | Disadvantage :<br>it is rather difficult and expensive because the observation needs video cameras to calculate the vehicle travel in each node | | |
| 10 | New mixed flow | Deterministic, statistic, static | $\bar{\xi}_{i,j} = \frac{1}{12}\sum_{k=1}^{12} \xi_{i,(j-1)\times 12+k}$<br>$\sigma^2_{i,j} = \frac{1}{12}\sum_{j=1}^{12}\left(\xi_{i,(j-1)\times 12+k} - \bar{\xi}_{i,j}\right)^2$<br>$\rho_i(\tau) = \frac{1}{12\sigma^2_{i,j}}\sum_{j=1}^{12-\tau}\left(\xi_j - \bar{\xi}_i\right)\left(\xi_{i(j+\tau)} - \bar{\xi}_i\right)$<br>where:<br>$\xi$ = specific detector<br>$j$ = subset<br>$i$ = day<br>$\sigma^2_{i,j}$ = variance | To describe the characteristic of urban traffic flow | Advantage :<br>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 |
|---|---|---|---|---|---|---|---|
| | | | $\rho_i(\tau)$= covariance | | Disadvantage :<br>"Peaks" not considered as a valid information. | | |
| 11 | Metanet | Discrete, non linier, dynamic | $q_{m,i}(k) = \rho_{m,i}(k).v_{m,i}(k).\lambda_{r}$<br>$\rho_{m,i}(k+1) = \rho_{m,i}(k) + \frac{T}{L_m \lambda_m}(q_{m,i-1}(k) - q_{m,i}(k)$<br>where:<br>$q$ = flow<br>$\rho$ = density<br>$v$ = space mean speed<br>$\lambda$ = number of lane in segmen<br>$T$ = sampling time<br>$L_m$ = length segmen | To provide predicting traffic flows | Advantage :<br>Able to reproduce traffic congestion built in reality with considerably accuracy<br><br>Disadvantage :<br>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 | $I = \alpha(\frac{v}{R})^m$<br>where:<br>$I$ = traffic intensity (per unit area)<br>$R$ = road density<br>$v$ = space mean speed<br>$\alpha$ and $m$ = parameters | To quantify the quality of traffic service provided to the users in the network | Advantage :<br>it can be use as an indicator for level of service at the network<br><br>Disadvantage :<br>it is not able to describe | In urban area | [14], [16], [25], [37] |

| No | Model | Type | Mathematical Model | Objective | Advantages/ disadvantages | Application | Reference |
|---|---|---|---|---|---|---|---|
| | | | | | congested condition | | |

## 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*

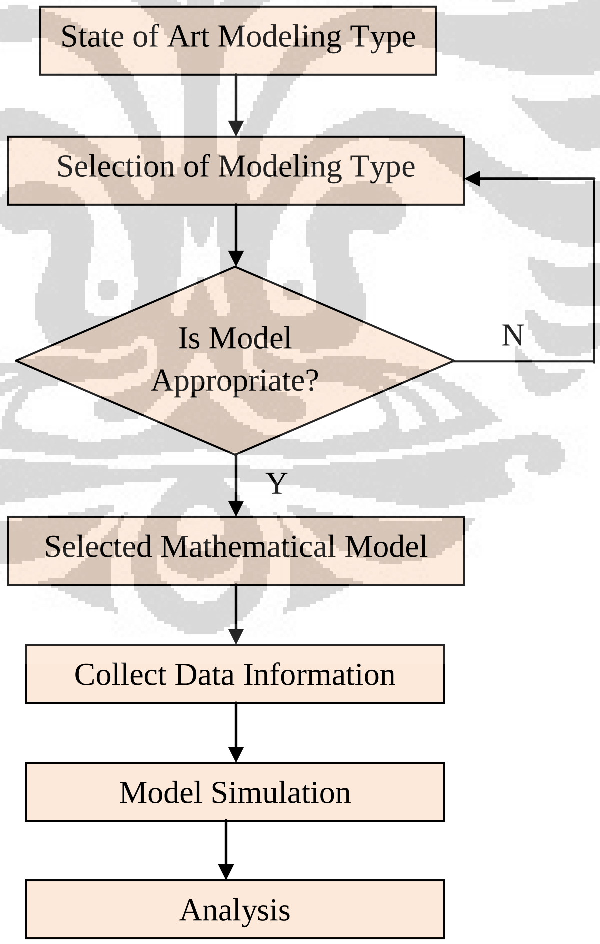


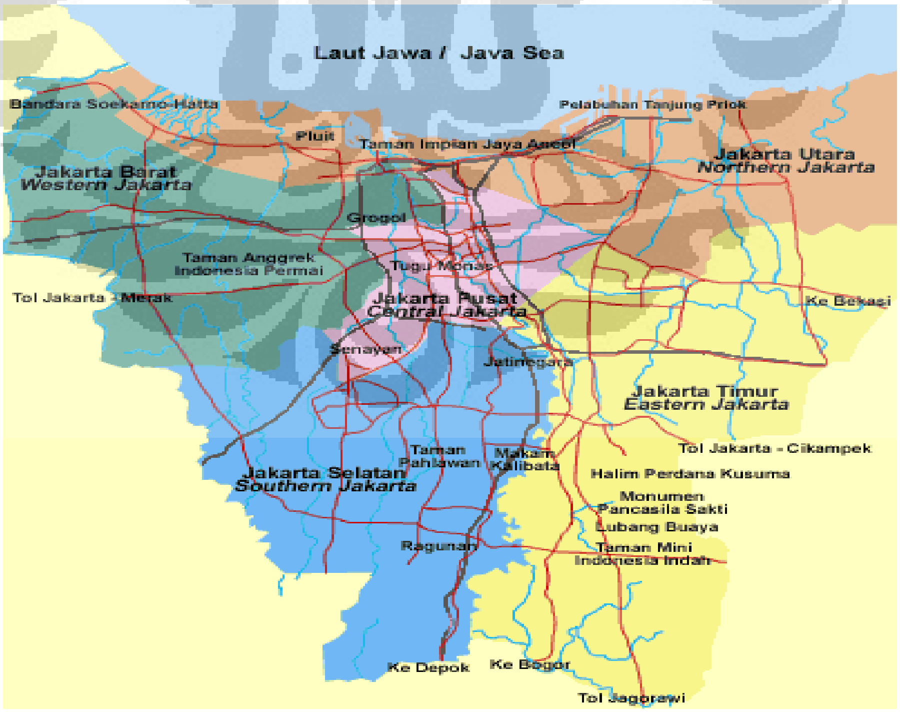

**Figure 4.1. Flowchart of Application of Urban Traffic Modeling**

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.

## *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.




*Source: [48]*

**Figure 4.2. Map of Jakarta, Indonesia**

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: 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.

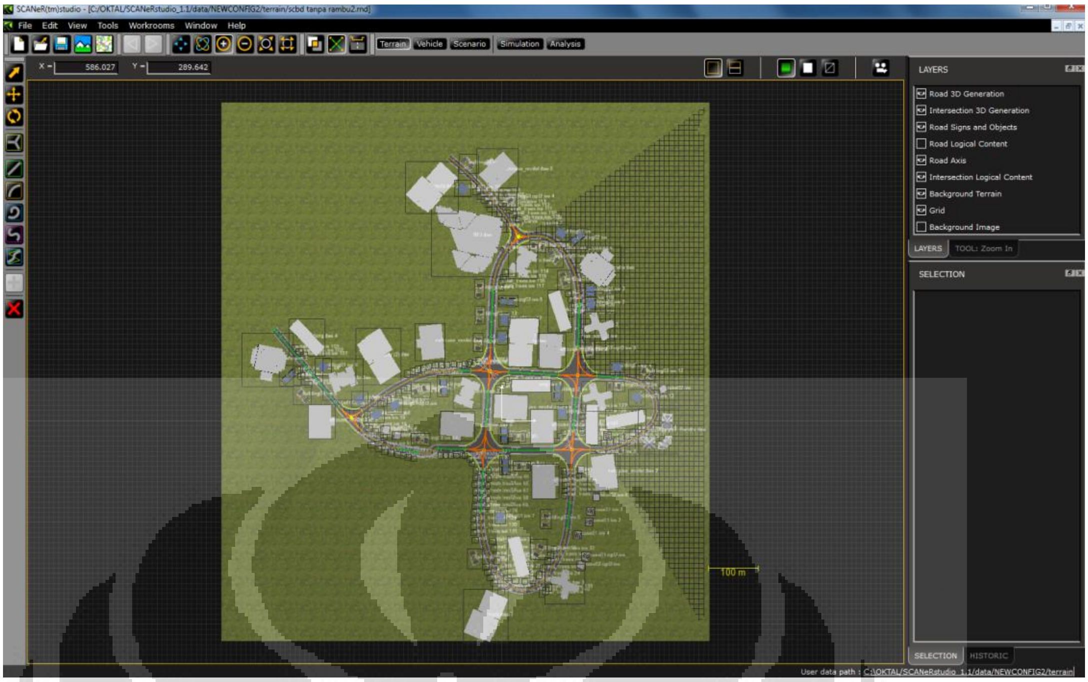



**Figure 4.4. Image of The Complete Terrain**

- 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.

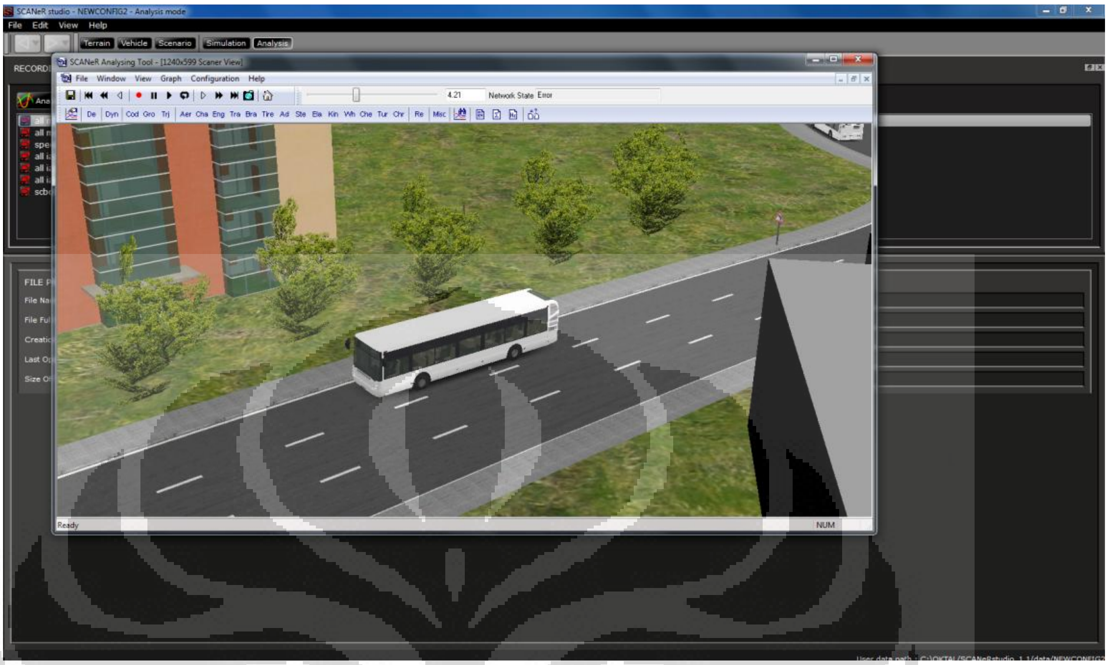


**Figure 4.5. Image of Conventional Vehicle for the First Scenario**

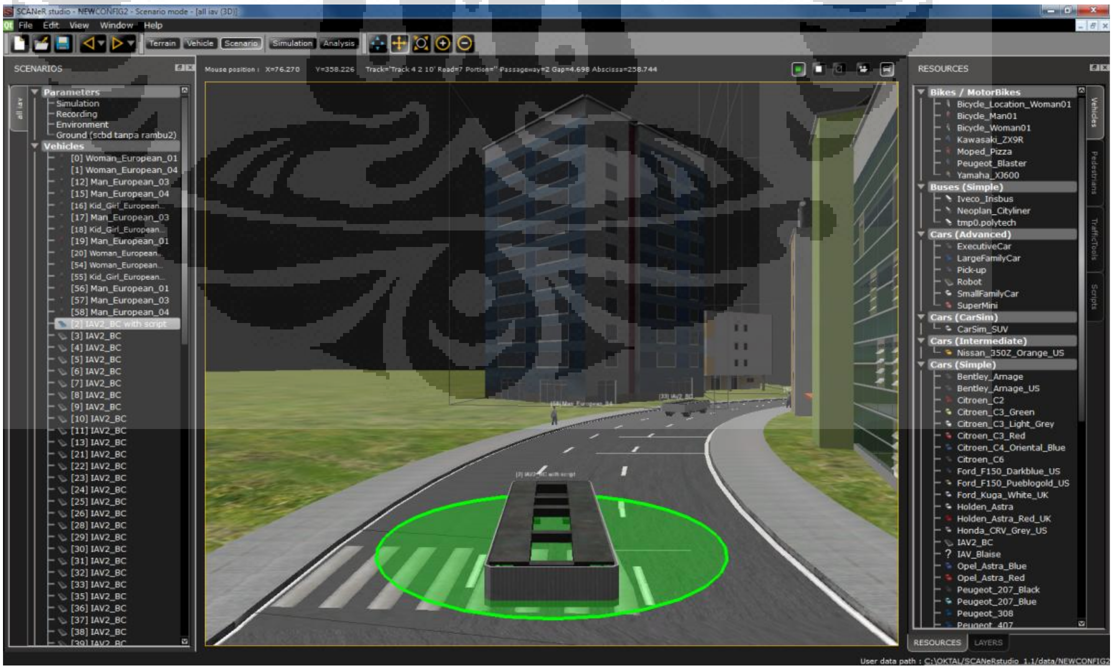


**Figure 4.6. Image of IAV for the Second Scenario**

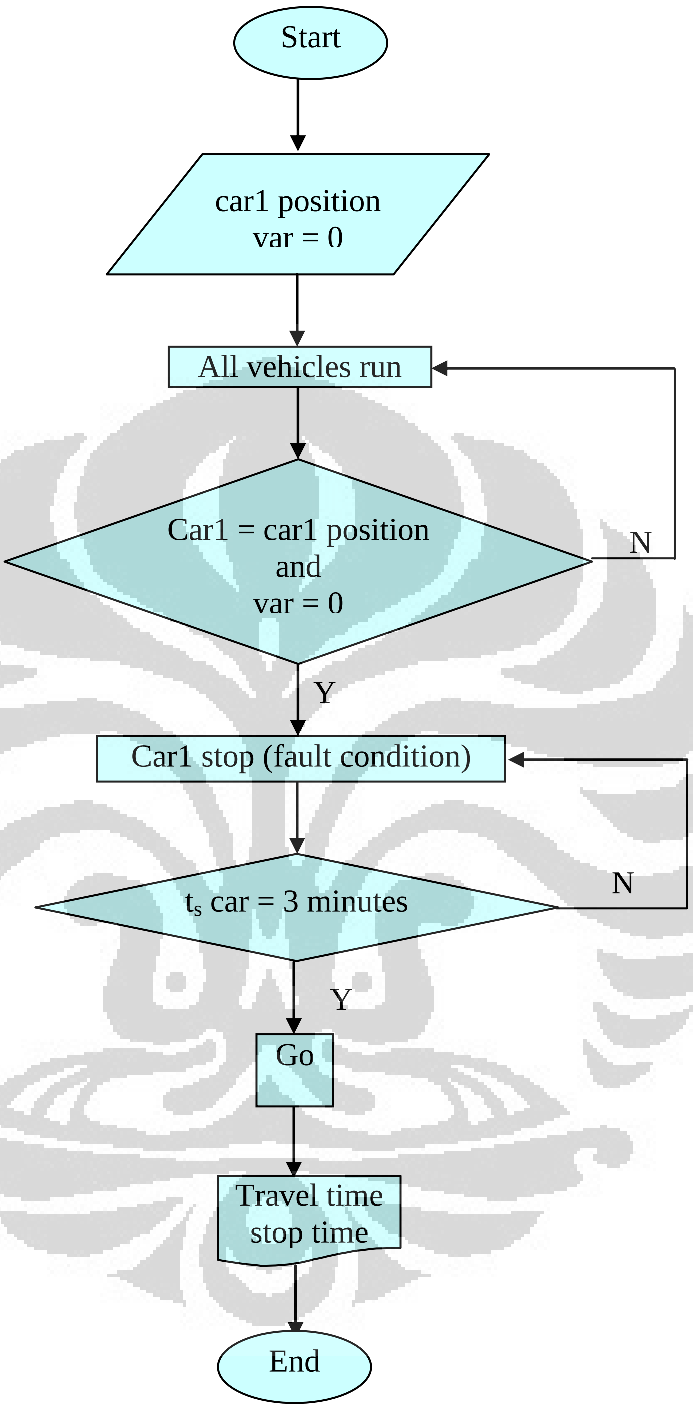



**Figure 4.7. Flowchart in Fault Condition**

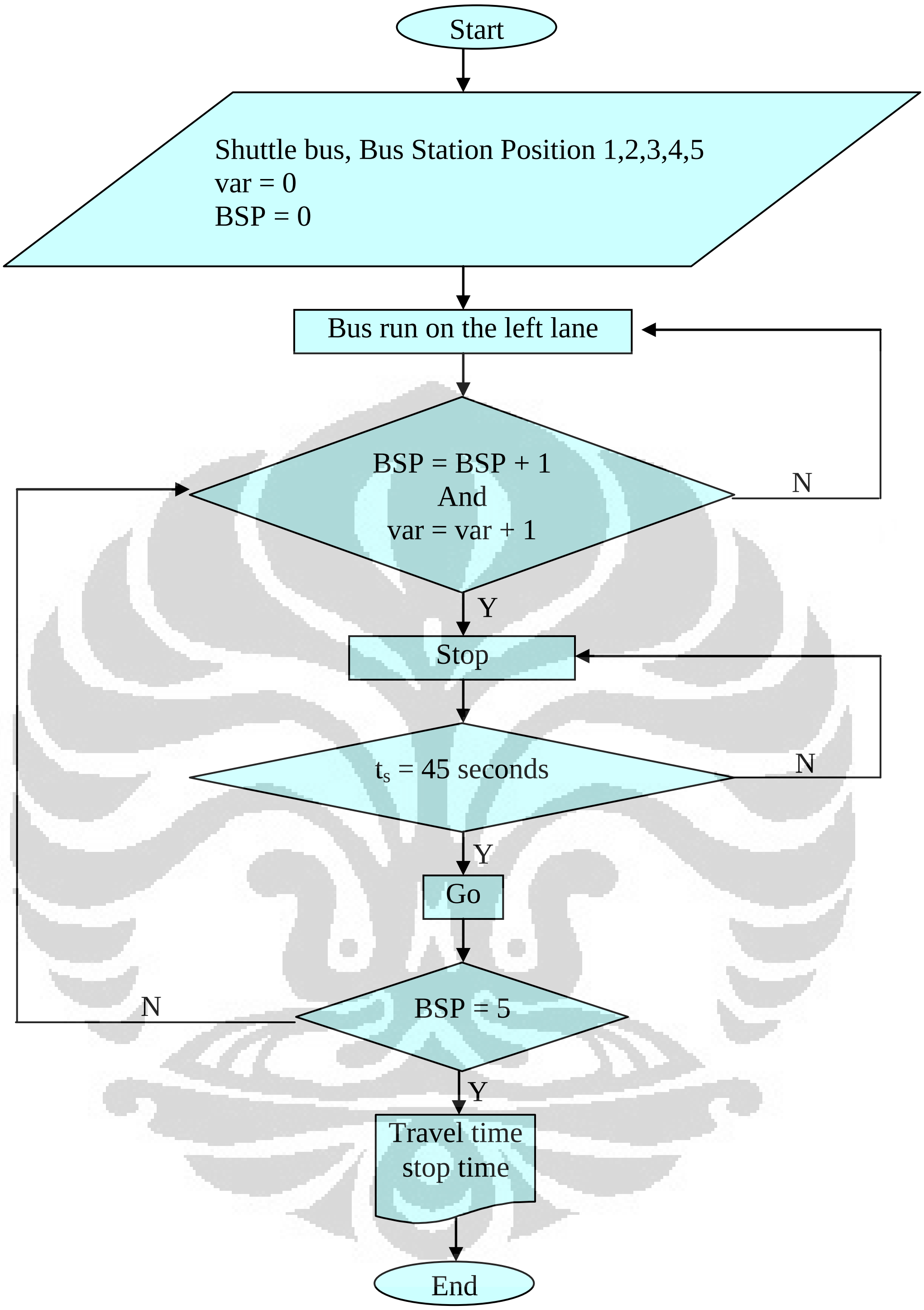



**Figure 4.8. Flowchart for Shuttle Bus**

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.

- 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 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.

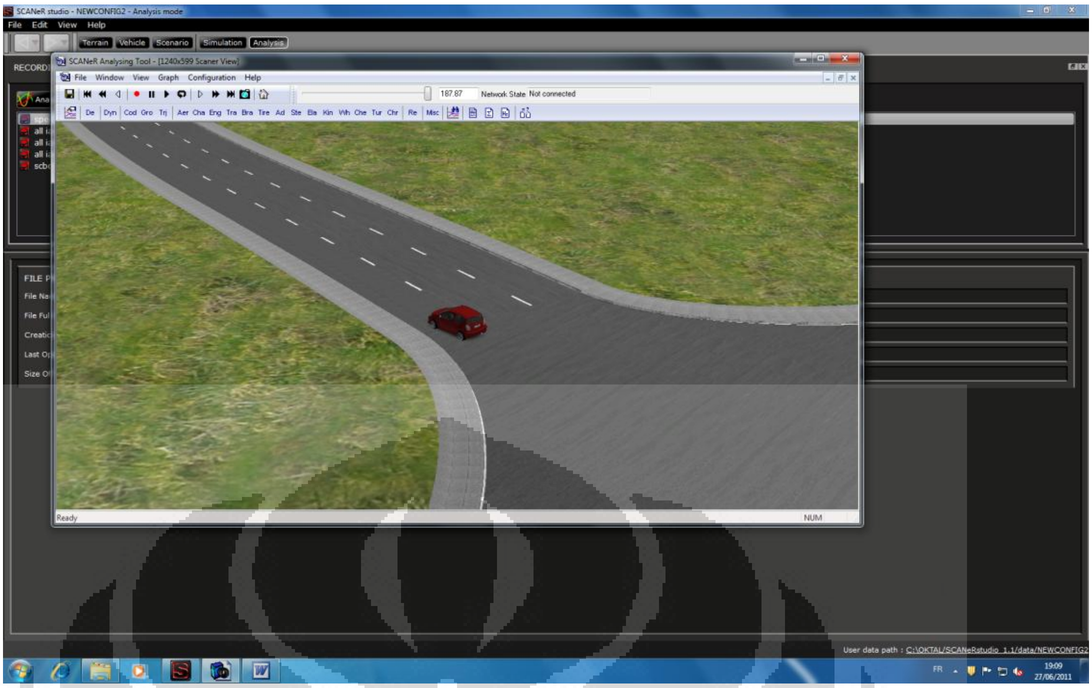


**Figure 4.10. Traffic Network Simulation in 3D view**

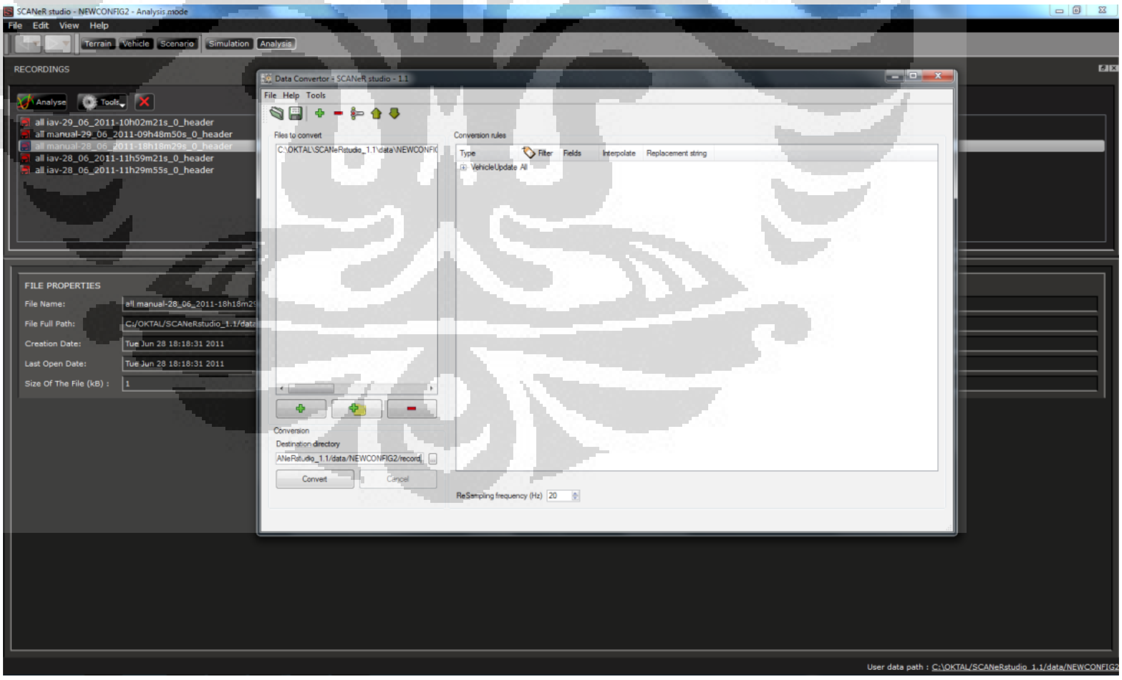


**Figure 4.11. Display of Data Export to Ascii File**

## 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.

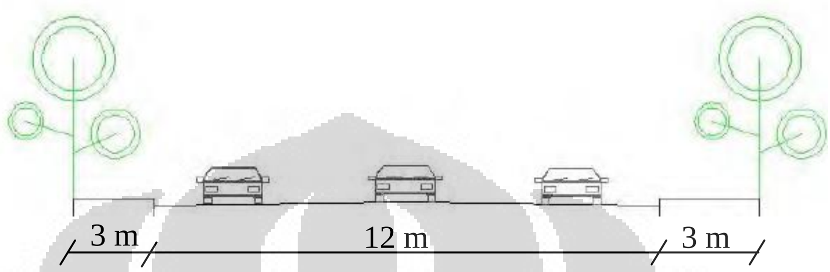



**Figure 4.12. Cross Section**


**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)

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

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)

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

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.

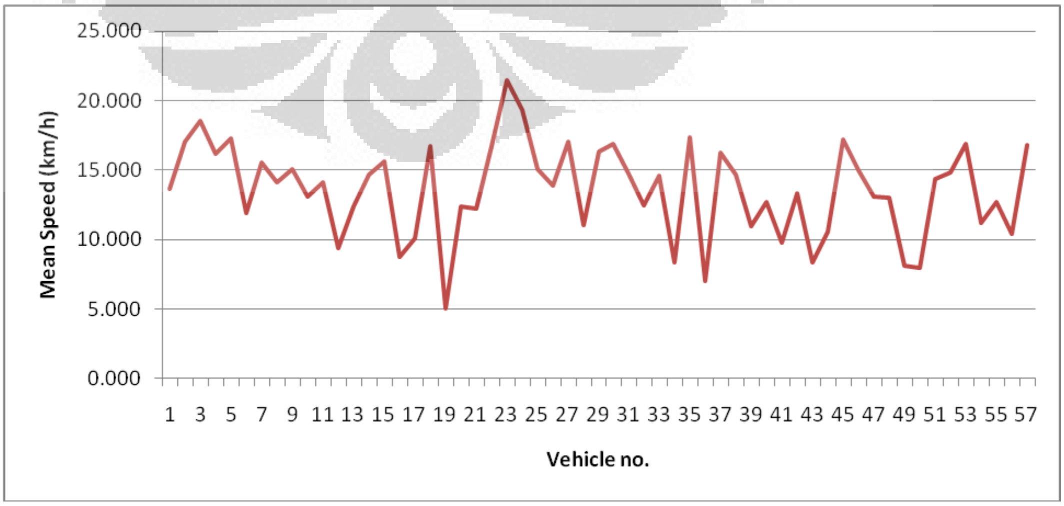



**Figure 4.15. Speed for All IAV**

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 (4.1), 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.

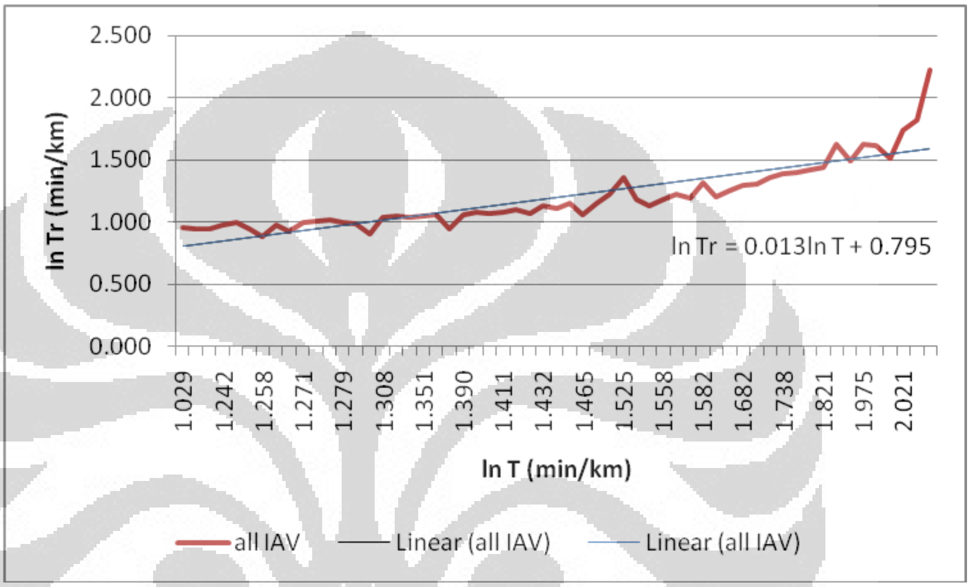



**Figure 4.16. Graph ln*T* vs. ln$T_r$ for All IAV**

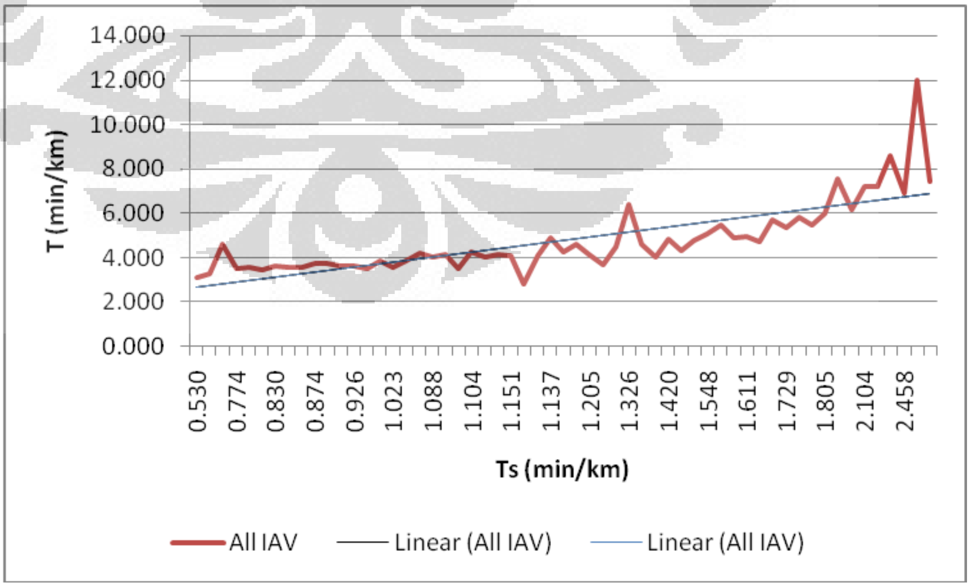



**Figure 4.17. Relationship of *T* and $T_s$ for All IAV**

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

$$\ln T_r = 0.795 + 0.013 \ln T \qquad (4.1)$$

Figure 4.16 shows equation of regression linier for ln$T$-ln$T_r$ of IAV. By using equation (3.4) and (3.5) from equation (4.1), 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.

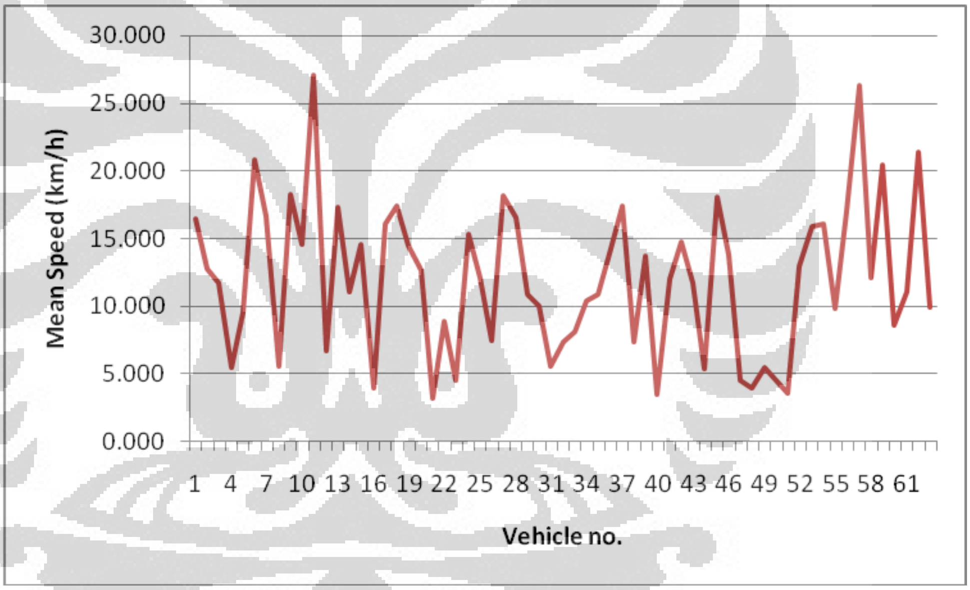



**Figure 4.18. Speed for All Conventional Vehicle**

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 (4.1), 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.

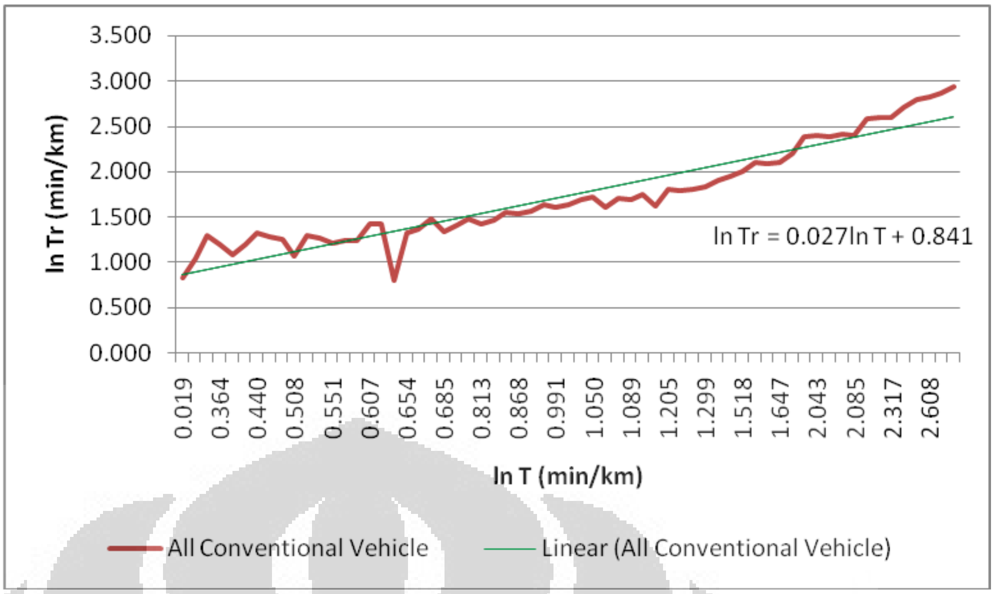



**Figure 4.19. Graph ln*T* vs. ln*T*$_r$ for All Conventional Vehicle**

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

$$\ln T_r = 0.841 + 0.027 \ln T \tag{4.1}$$

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 (4.1) we have got $n$ = 0.03 and $T_m$ = 2.37. Figure 4.20 represents relationship of $T$ and $T_s$

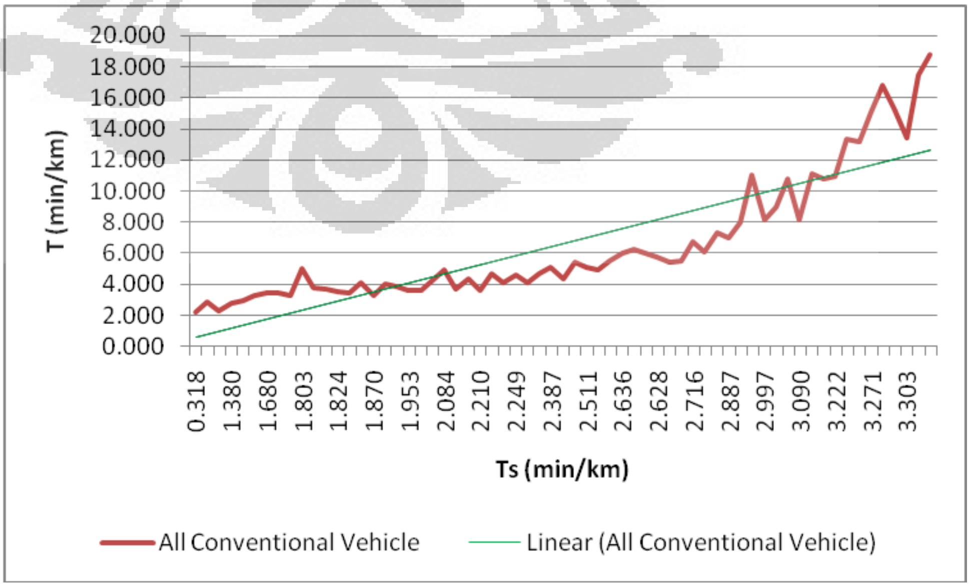



**Figure 4.20. Relationship of *T* and *T*$_s$ for All Conventional Vehicle**

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 manual vehicle. And the comparison of two-fluid parameters ($n$ and $T_m$) showing that the value from all IAV lower than all manual vehicle. It means that the quality of traffic service in SCBD area will better if we use all IAV than all manual vehicle. Figure 4.21 shows comparison of $T$-$T_s$ between all IAV and all Manual vehicle.

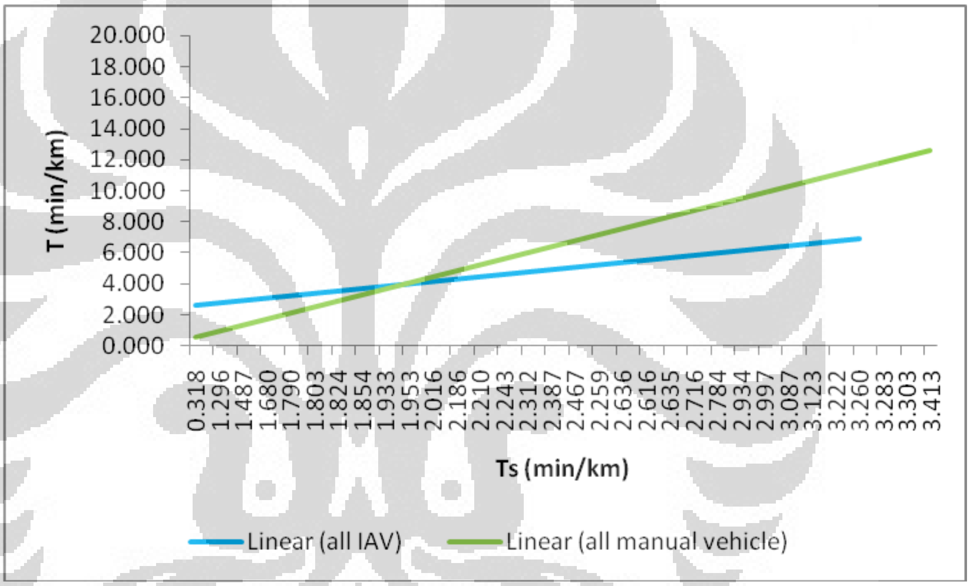



**Figure 4.21. Comparison of $T$ and $T_s$ between IAV and Conventional Vehicle**

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 Tm = 2.24) better than using all conventional vehicles (n = 0.03 and Tm = 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.

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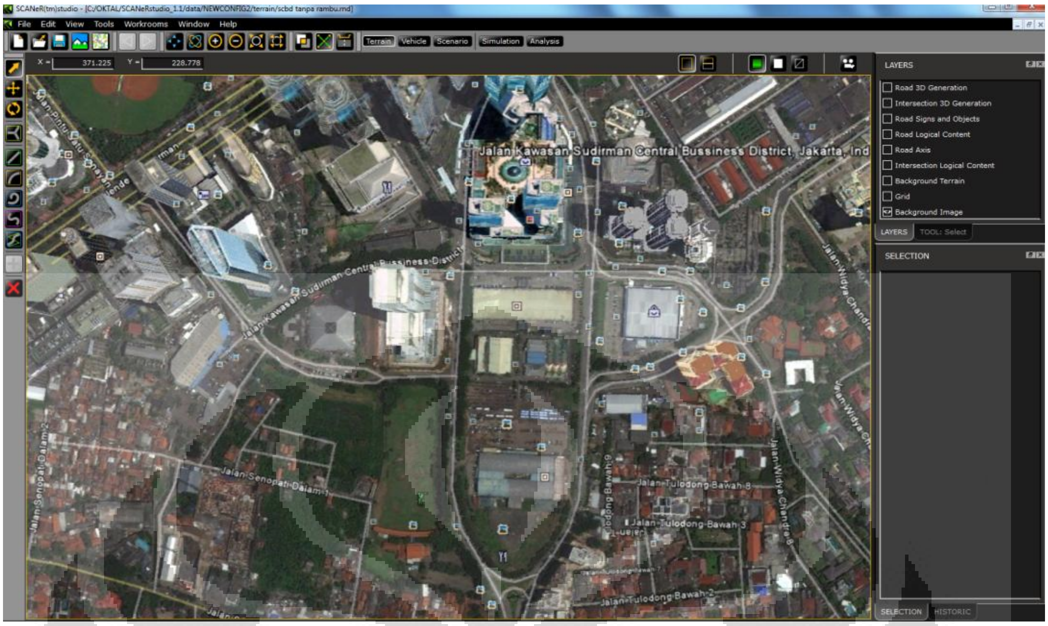
# ANNEX 1

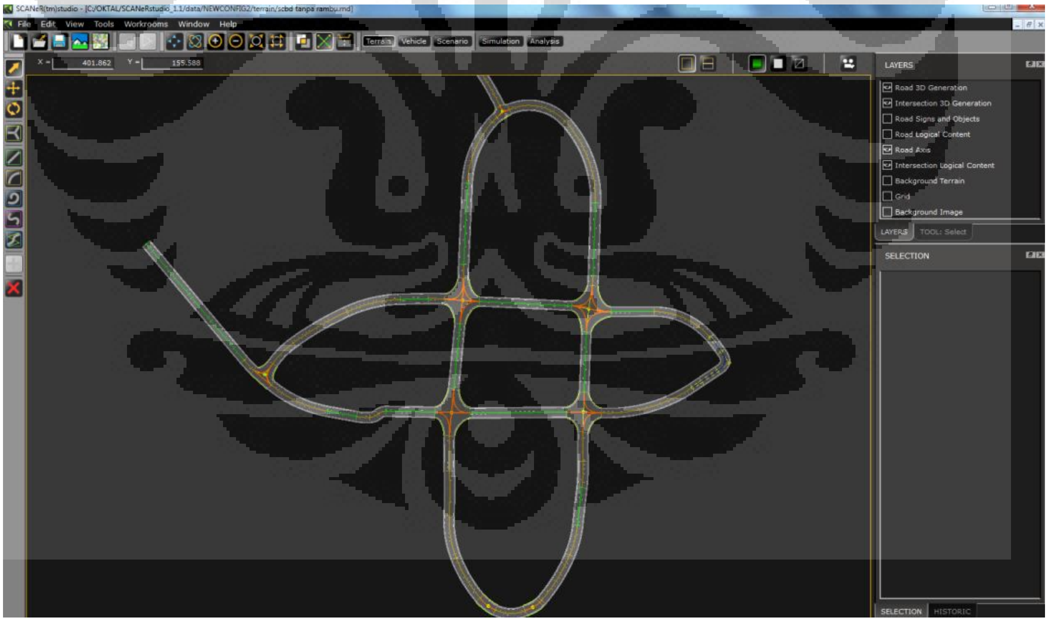
Description of SCANeR™studio through an Example

**Step for making the terrain:**

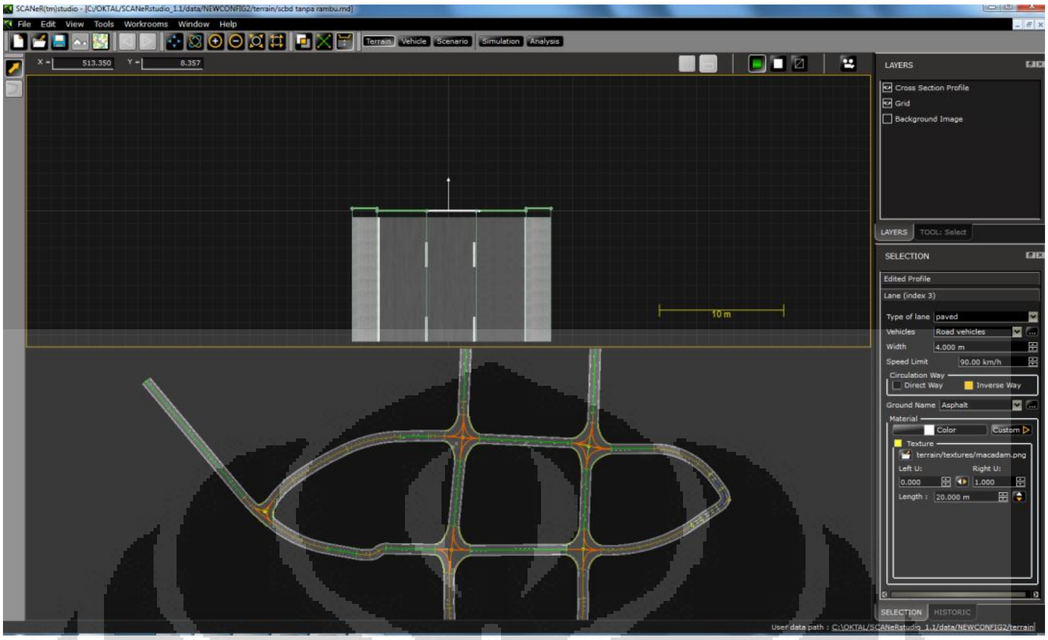
1. Import background from google earth



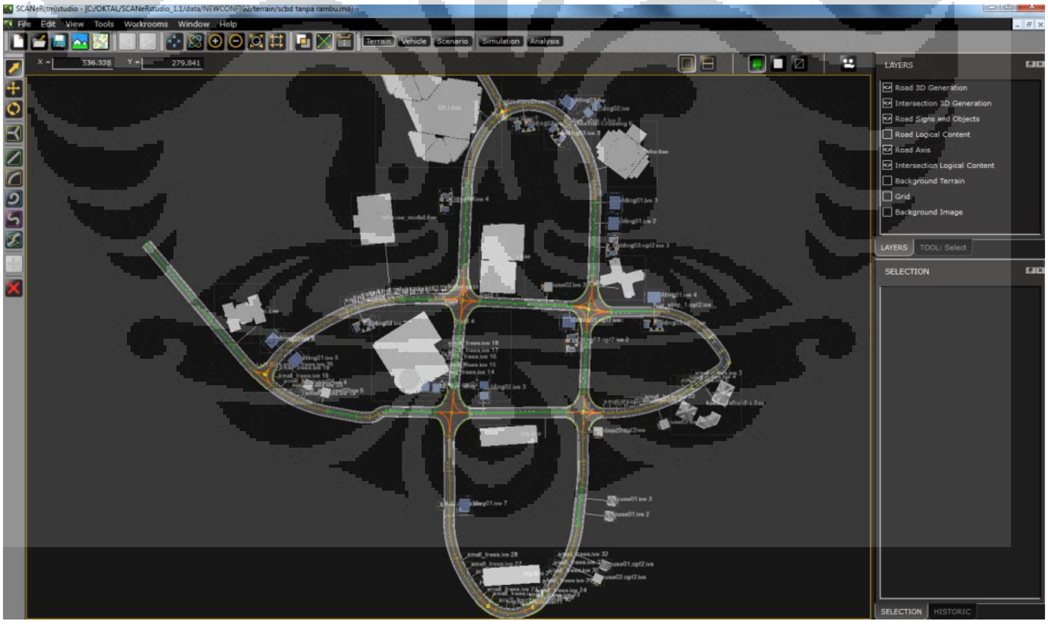
2. Draw the road based on the background



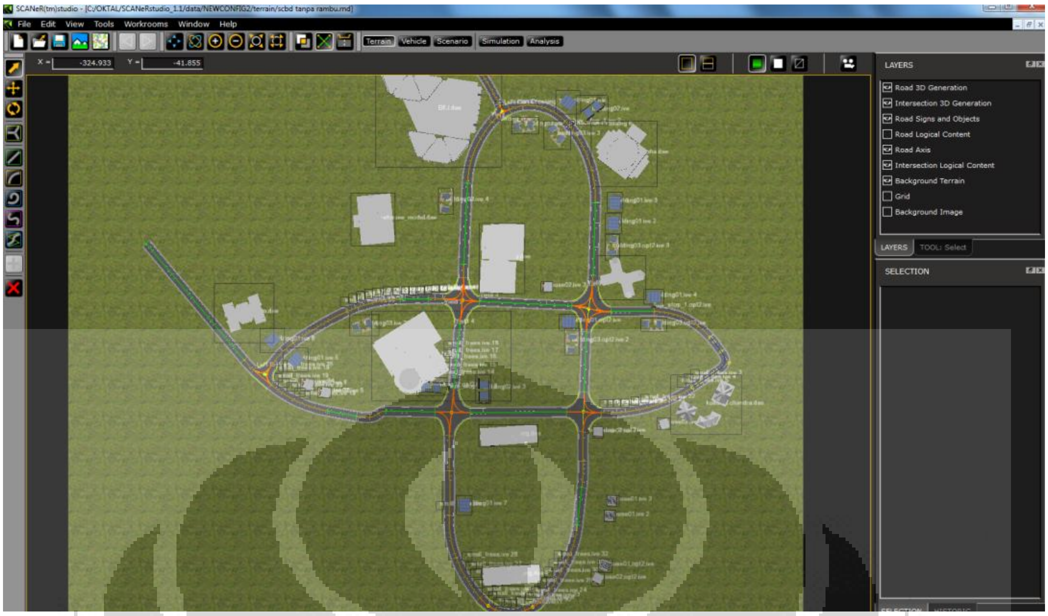
3. Change the properties of the road (size, road marking)



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



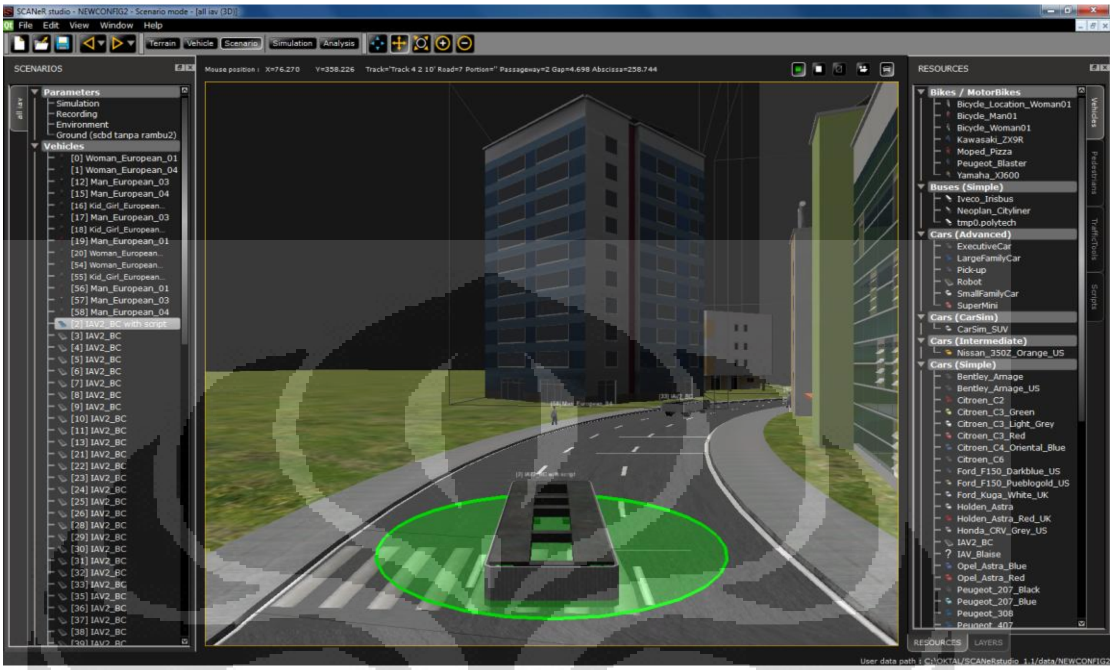
5. Generate terrain and export it to make the scenario

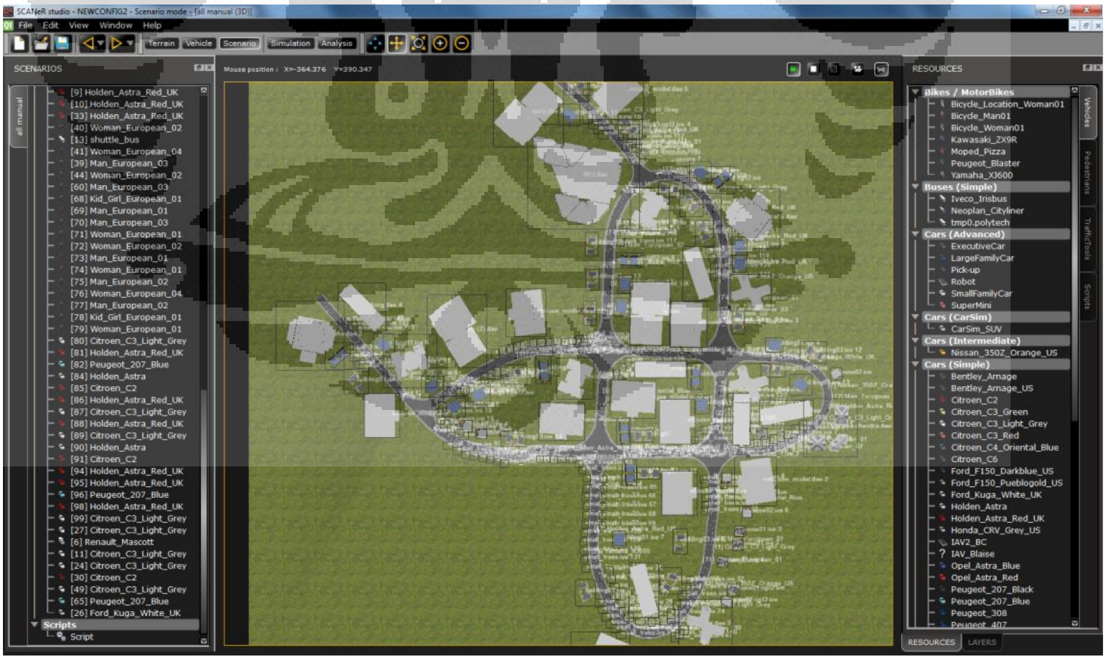


**Step for scenario:**

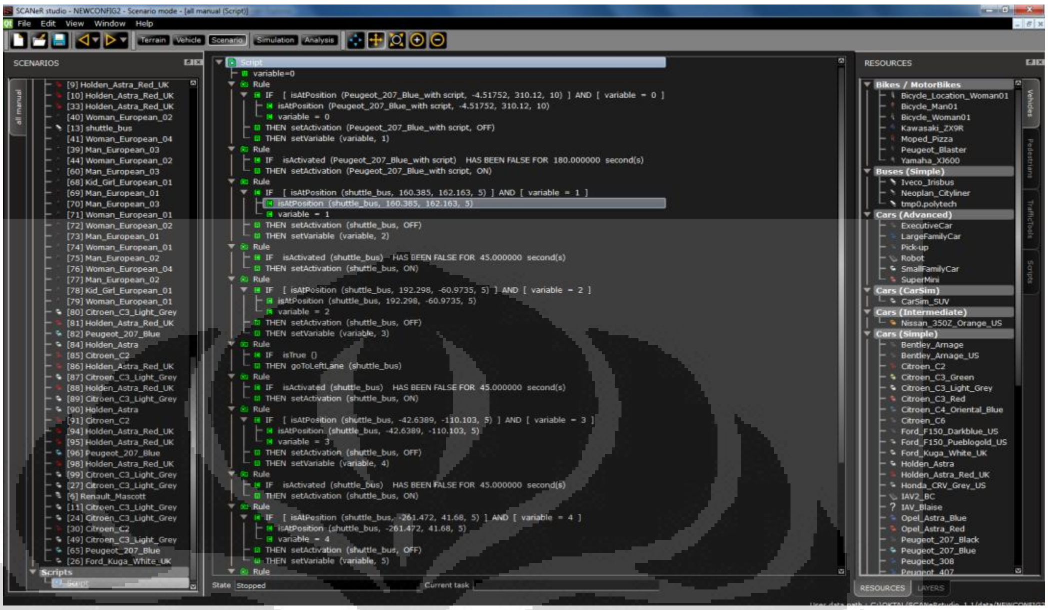
1. Choose and open terrain file that already have generated

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





3. Making of the script for the shuttle bus and 1 car (first scenario) and 1 IAV (second scenario)

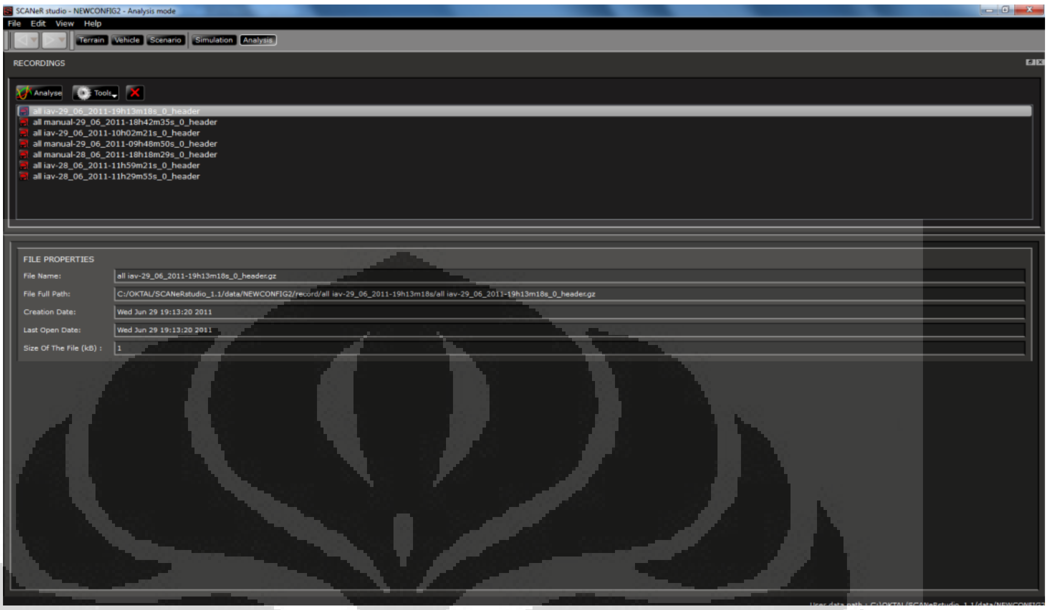


**Step for simulation:**

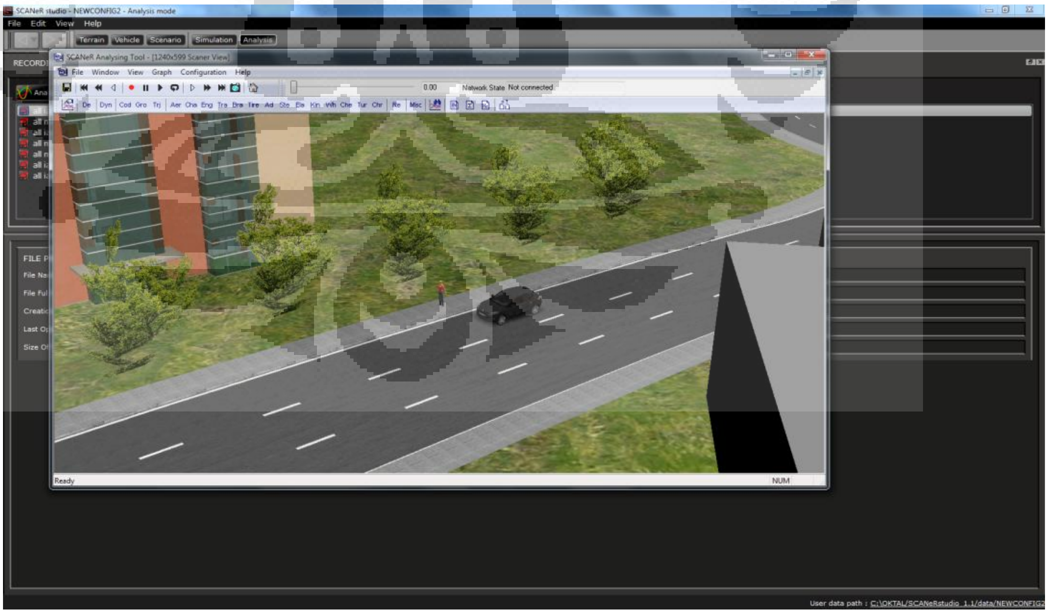
Choose and open terrain file that already have generated, then click traffic, scenario, visual and record in dock simulator status. Finally, click play to run the simulation.

**Step for analysis:**

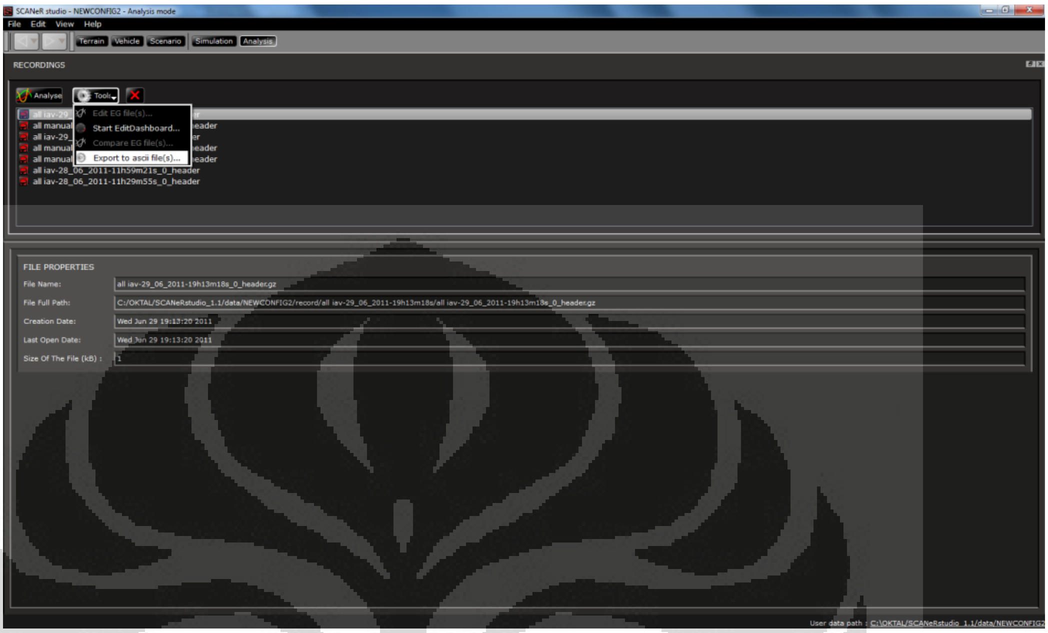
1. Choose the recorded file.



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**

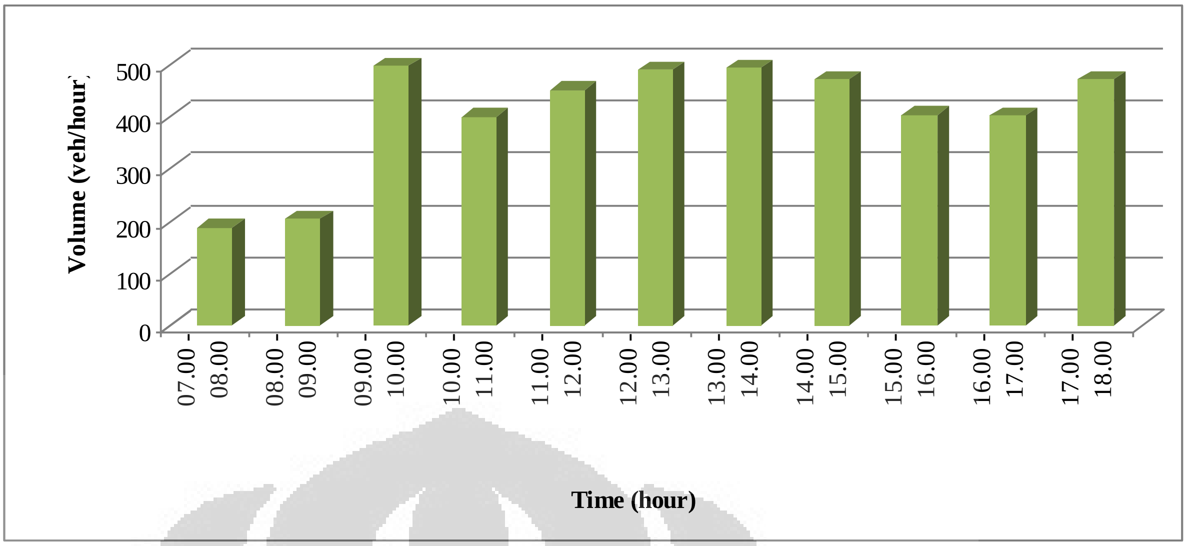
| Year | Number of Heavy Vehicle (veh) | Increasing of Vehicle (veh) | Growth Index (%) |
|---|---|---|---|
| 2004 | 488,517 | | |
| 2005 | 499,581 | 11,064 | 2.26% |
| 2006 | 504,727 | 5,146 | 1.03% |
| 2007 | 518,991 | 14,264 | 2.83% |
| 2008 | 538,731 | 19,740 | 3.80% |
| **Average Growth Index**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



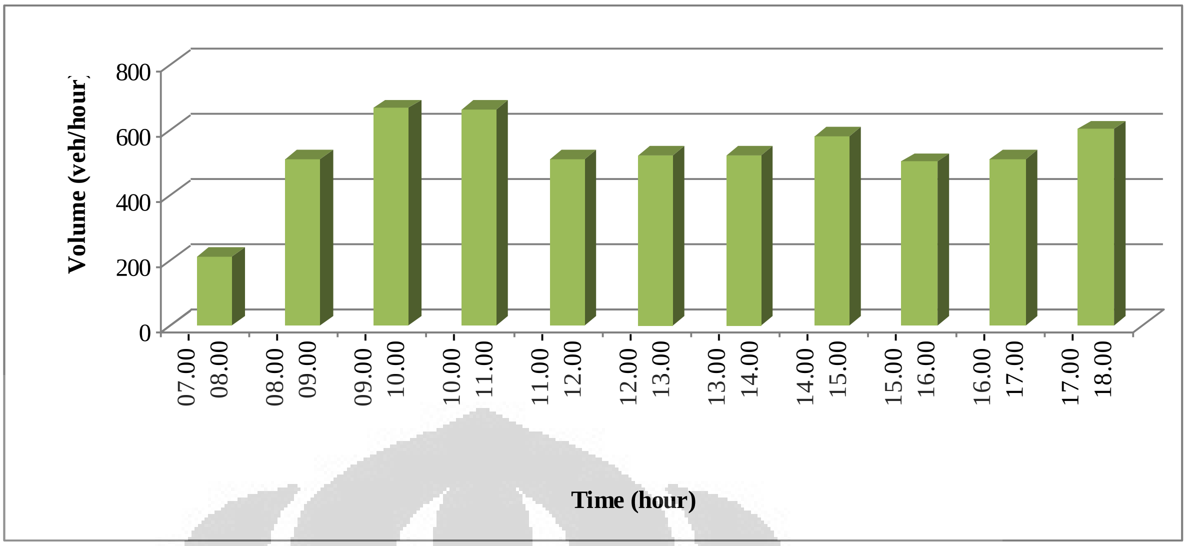

*Source:[19]*

**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]*



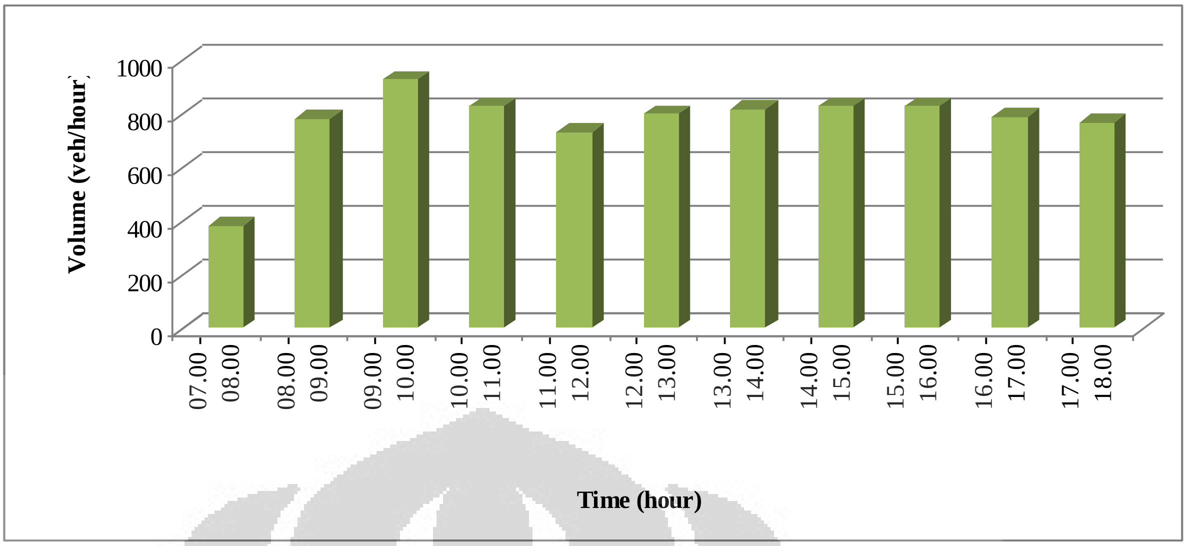

*Source:[19]*

**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) | ln T (min/km) | ln 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) | ln T (min/km) | ln 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) | ln T (min/km) | ln 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) | ln T (min/km) | ln 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 |