

SIMULATING MOTORBIKE DOMINATED TRAFFIC

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ABSTRACT

Mixed traffic, where motorbikes dominate the traffic composition (more than 70%) like in Vietnam, Malaysia, or Thailand, is difficult to simulate microscopically with well established simulation tools, since they are mostly designed for a lane based network, and motorbikes in these countries do not follow any lanes. From a macroscopic perspective it is difficult to establish the correct passenger car equivalent for motorbikes, and those found in literature are varying significantly. Recently, it has been proposed that passenger car equivalents in developed countries (mainly car and truck traffic) are depending on the speed in the road section and we think that in non-lane based traffic situations the composition of vehicles inside a road section is another major factor.

Since observations are rare and costly, we have decided to first develop a microscopic simulation model for mixed traffic, which we can calibrate with road segment and intersection video footage from Hanoi, Vietnam and based on this to investigate possible factors that influence the passenger car equivalent.

To calibrate the model we have used several hours of video footage from Hanoi, Vietnam. Among the available video were intersection observations, videos for saturation flow-rate detection and videos that show queuing and dispersion of the mixed traffic at signal control installations. Calibrated with parts of this footage, we compare our model to the other video material available.

Keywords: motorbike, microscopic, traffic, simulation

INTRODUCTION

Mixed traffic, where motorbikes dominate the traffic composition (more than 70%) like in Vietnam, Malaysia, or Thailand, is difficult to simulate microscopically with well established simulation tools, since they are mostly designed for a lane based network, and motorbikes in these countries do not follow any lanes. From a macroscopic perspective it is difficult to establish the correct passenger car equivalent for motorbikes, and those found in literature a varying significantly. Recently, it has been proposed that passenger car equivalents in developed countries (mainly car and truck traffic) are depending on the speed in the road section and we think that in non-lane based traffic situations the composition of vehicles inside a road section is another major factor.

Since observations are rare and costly, we have decided to first develop a microscopic simulation model for mixed traffic, which we can calibrate with road segment and intersection video footage from Hanoi, Vietnam and based on this to investigate possible factor that influence the passenger car equivalent.

For the microscopic simulation we have chosen a cellular automata model with adjusted properties. To be able to represent the different vehicle types, we are representing the network in a cell grid of 0.25 by 0.25 m, where vehicles occupy not only one, but several cells and can move more freely in both longitudinal and lateral direction. The rules for the automata were also adjusted. The movement now depends not only on the distance and relative speed of the vehicle and its leader, but also takes into account the general tendency of some vehicle types preferring to remain on the left or right side of the road stretch, preferences in following other vehicle types, and the comfort or safety considerations of each vehicle class. Intersections are fully modelled and not represented as a black box. The inside of the intersection is modelled as a full grid where vehicles react on each other, independent from which basic stream they belong to.

To calibrate the model we have used several hours of video footage from Hanoi, Vietnam. Among the available video were intersection observations, videos for saturation flow-rate detection and videos that show queuing and dispersion of the mixed traffic at signal control installations. Calibrated with parts of this footage, we compare our model to the other video material available.

MIXED TRAFFIC SIMULATION

Due to the development of goods and people transportation, the traffic stream in many countries composes of different vehicle types, sizes, speed and driving behaviour. This mixed traffic can be lane – based (LB) mixed traffic (see Figure 1) or non lane – based (NLB) mixed traffic (see Figure 2, Figure 5). In LB mixed traffic, because the vehicle runs in a lane, all the considerations to model this traffic can be extended from the homogeneous passenger car flow models. But in NLB mixed traffic, a vehicle effected by more than one leading vehicles and its movement does not restricted in a lane. Further, the flow characteristics of mixed traffic depend on road way geometry, prevailing traffic condition and static an dynamic properties of vehicles in traffic stream (Khan et al. 1999). Therefore,

models of these NLB traffic are developed for specific conditions and most of them are microscopic models (Khan et al. 1999).



Figure 1 – California, US, Lane based traffic



Figure 2 – Dhaka, Bangladesh. Non lane-based mixed traffic

Current models for Mixed traffic

Dealing with mixed traffic, macroscopically, is done by introducing a Passenger Car Equivalent (PCE - Highway Capacity Manual) value to replace all the other modes by passenger cars and then to employ theories for homogeneous flow to heterogeneous flow. Several studies on lane based mixed traffic of passenger cars and heavy vehicles (trucks...) using PCE value such found in Van Lint et al. (2007) and S. Chanut et al. (2007). Ta-Yin Hu et al. (2006) developed an integrated dynamic simulation-assignment model, DynaTAIWAN, for Advanced Traffic Management Systems as well as Advanced Traveller Information Systems in Taiwan. The model is composed of two layers, namely simulation-layer and real-time control layer. DynaTAIWAN is able to model multiple vehicle classes, including four

different vehicle types: car, bus, motorbike, and truck by using PCE value. Motorbikes are moving along the link through macroscopic flow relationships, and the speed of motorbikes is adjusted through empirical factors. At intersections, motorbikes are moved according to the sequence of left-turn-waiting section, waiting section, and normal traffic lane (see Figure 3). But in other mixed traffic, it is impossible to separately store each vehicle type as this special situation.

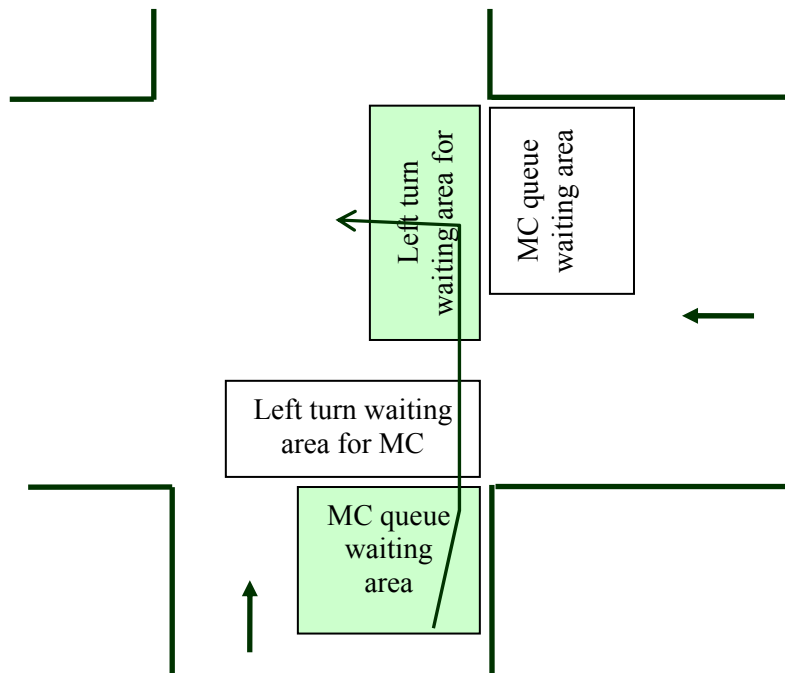


Figure 3 – Movement at intersection in DynaTAIWAN - Ta-Yin Hu et al. (2006)

However, studies on passenger car equivalent (PCE values in Hsu 2003) or motorbike unit MCU (motorcycle unit, Hien 2007) and DMCU (dynamic motorcycle unit, Nguyen 2007) have shown that these values vary in different traffic conditions. The empirical relationships (fundamental diagram) for mixed traffic are normally unavailable due to the lack of equipment and especially the unique patterns in developing countries. It was also concluded that for mixed vehicles, linear density measurements are inadequate, thus requiring a non dimensional measure such as total vehicle area projected per unit area of roadway, or areal density. Most studies have also shown that a uniform definition of passenger car equivalent is not applicable; the values of equivalency depend on traffic composition, degree of saturation, and location (intersection or mid block) (Khan et al. 1999).

From the microscopic point of view, LB mixed traffic is still the conventional car – following traffic based on the car – following and lane changing models discussed in previous chapters. However as can be seen in Figure 6 and Figure 9, the NLB mixed traffic is different. The rest of this section introduces about how these difference have been dealing with in simulation up to now.

The first microscopic model developed by Palaniswamy (1985) was for two lane and multilane highways mixed traffic in India called INSWERTS. Nine different types of vehicles

were modelled: passenger cars, pickups and jeeps; trucks and buses; but bicycles, cycle rickshaws and other slow vehicles were account as noise on the system. INSWERTS was modified from its origin (SWERTS), which modelled lane-based movement, just by changing intervehicular interactions. Overtaking situations were developed based on observation and probability of the gap acceptance function. Ramanayya (1988) developed a microscopic simulation model MORTAB (Model for depicting road traffic behaviour) to replicate a stream of mixed traffic in a lane with a certain width in order to obtain speed – flow – density relationships. Sutomo (1988) developed a TRASMIC (Traffic simulation of mixed condition) model for micro-simulation of mixed traffic at signalised intersections by applying a strip-based approach in stead of a lane-based approach, where the available road width was divided into strips (1m) and a lane analogy was applied to strips. However, it is difficult to find a strip width which evenly fits road width, vehicle width and side clearances, necessary in this model, as a vehicle with side clearances is required to be fitted within a whole number of strip(s). In addition, lateral movement is simulated by allowing one strip width of lateral movement within a time interval. To overcome the rigid lateral movement by TRASMIC, Hoque (1994) developed a micro-simulation model, MIXSIM (Mixed traffic simulation), still adopted a strip-based approach similar to that in the TRASMIC but with consideration narrower strip widths (0.5m). This modification described the interactions between vehicles during turning movements in much greater detail. MIXIM was developed for studying isolated signalised intersections with the characteristics of mixed traffic conditions as below:

- Non lane – based movement
- High proportion of non-motorized vehicles
- More than one leading vehicles
- Lane – changing is not very sensitive to gap acceptance criteria
- Queue formation based on making maximum use of available roadway space

MIXNETSIM is the extension to network scale by Hossain (1996) from MIXSIM which was validated using field data in Dhaka, Bangladesh. Due to the problem of strip-based coordination, a new vehicle referencing technique based on a co-ordinate system has been devised to provide more accurate method of locating vehicles in MIXNETSIM. With coordinate based referencing all the vehicles in a single road link can be represented in a single list. Also, it is possible to track each vehicle using the co-ordinates of one of the corners of the vehicle. The working principle of the simulation model is based on a logical description of the driver behaviour. During each simulation interval of real time, all vehicles within the system are processed using a car-following model which governs the longitudinal movements, and a lateral movement model which controls lateral movement. When a vehicle approaches a junction its movements are controlled by appropriate junction procedures.

Timothy (2007) developed a model which covers different vehicle types, including nonmotorized ones (bicycles), and allows for some special behaviours, such as seepage to fronts of queues by two wheeled vehicles and simultaneous use of two lanes. In addition to normal car- following rules, the model incorporates lateral movement with a gradual lane change manoeuvre, the decisions of which are governed by fuzzy logic rules.

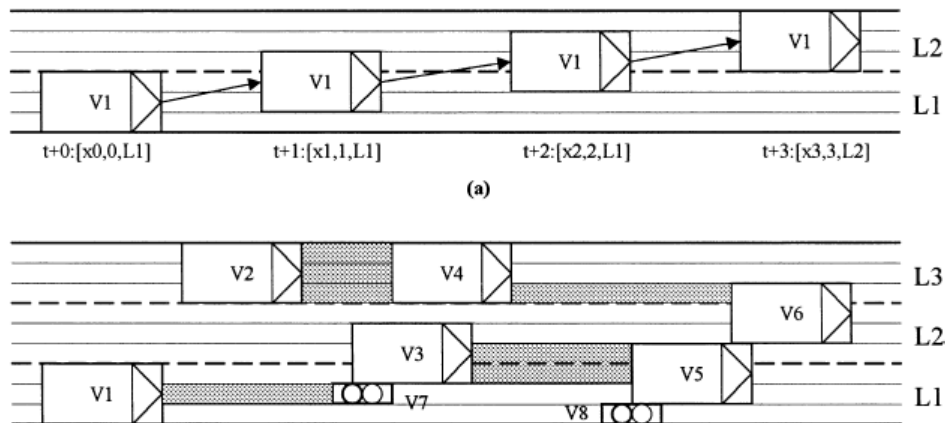


Figure 4 – Strip-based model Timothy (2007)

However, strip – based approach constraints the movement of vehicle along the strip. In the case in Figure 4, the diagonal position of the vehicles is out of strip – based model. To overcome the shortcoming of strip-based model and avoid the complication of continuous space model, CA model have been used in some mixed traffic studies.

Lawrence W. LAN, Chiung-Wen CHANG (2003) introduced a particle-hopping model with pre- assigned CA rules to describe the motorbikes' moving behaviours in a mixed traffic flow with cars and motorbikes on 2.5-meter (case I) and 3.75-meter (case II) lanes. Two types of vehicles modelled in this model are motorbike and car. Based on the field observation in Taiwan, possible relative positions for a motorbike (or car) and its surrounding vehicles are identified therefore considered variables are distance to surrounding vehicles. Mathew et al. (2006) also proposed their attempt to simulate heterogeneous traffic in a conventional cellular automata model. The principle adopted in this study is to retain the PCE concept of HCM and the basic structure of the CA model. The modifications are done at three levels: First, the cell size is reduced to take the concept of passenger car equivalents. Second, the randomizing rule is modified to suit heterogeneous traffic conditions. And the lane changing rules are modified to handle overtaking manoeuvres and consider different types of vehicles characterized by their dynamic characteristics.

These models are developed based on certain rule sets for many scenarios. In case of more complicated interaction between vehicles, the number of rules would increase. This makes the decision making become a complex process much more than how human really thinks.

All mentioned models are developed for different mixed traffic conditions: lane – based mixed traffic (INSWERTS), non lane – based mixed traffic but dominant mode is passenger car, mixed traffic with tricycle, push car...(MIXNETSIM). Characteristics of mixed pattern or dominant traffic mode as well as other prevailing traffic conditions can result unpredictable traffic performance. Therefore, it is necessary to develop a new framework of simulation the motorbike dominated traffic.

Current models for Mixed traffic

Hsu et al.(2003) have reported the results from field observation which was made on the existing mixed-traffic situation the characteristics of motorcycle traffic in Vietnam and some other motorbike dominated traffic countries (Malaysia and Taiwan) as below:

- Motorcycles area relatively small in size, giving manoeuvring flexibility and capability to weave through queues in congested areas.
- Motorcycle will not follow the “First In First Out” rule at intersections with queues. Due to its high manoeuvrability, motorcycles will almost always attempt get in between queuing vehicles to get to the front of the queue.

Figure 5 shows the unique pattern of road space usage which is easily observed in the big cities in Vietnam.



Figure 5 – Traffic in Hanoi, Vietnam

Dealing with this pattern, we propose a CA based microscopic model which will in the following be described in more detail.

METHODOLOGY

This part describes the methodology of traffic network modelling which consists of two main parts: the representation of the road network and the modelling of driving behaviour. Cellular automata method is chosen in this study because it has advantages of efficient and fast performance (Maerivoet (2005)). Further, it also allows develop different traffic scenarios.

The chapter will start from the physical representation of the modelled network. Next sections will deal with modelling driving logic. For the behaviour aspect, our developed model will not

use the rule – based approach as traditional CA models, but a psychology – based decision making logic for the lane – changing behaviour.

Cellular automaton

The cellular automata is a well known mathematical concept and used in several fields of research. In this section we give a short overview of the history, the concept and the usage of CA models in traffic engineering. Figure 6 illustrates an example of the tempo-spatial dynamics of CA model. Based on that review we introduce the adapted CA model used in our proposed model.

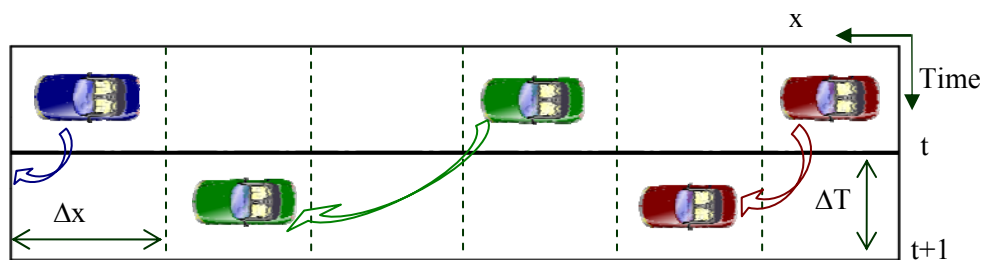


Figure 6 – Schematic diagram of the operation of a single lane traffic CA

The mathematical concepts of cellular automata (CA) models can be traced back as far as 1948, when Johann Louis von Neumann introduced them to study (living) biological systems (Neumann, 1948). Central to von Neumann's work, was the notion of self-reproduction and theoretical machines (called kinematons) that could accomplish this. As his work progressed, von Neumann started to cooperate with Stanislaw Marcin Ulam, who introduced him to the concept of cellular spaces. These described the physical structure of a cellular automaton, i.e., a grid of cells which can be either 'on' or 'off' (Wolfram, 1983 & Delorme, 1998). The components of a cellular automaton are:

- Physical environment, to define the universe on which the CA is computed. This underlying structure consists of a discrete lattice of cells with a rectangular, hexagonal, or other topology. Typically, these cells are all equal in size; the lattice itself can be finite or infinite in size, and its dimensionality can be 1 (a linear string of cells called an elementary cellular automaton or ECA), 2 (a grid), or even higher dimensional. In most cases, a common—but often neglected—assumption, is that the CAs lattice is embedded in a Euclidean space (Maerivoet, 2005), in order to describe natural systems accurately on an ordinary scale.
- Cells' states, where typically an integer represents the number of distinct states a cell can be in, e.g., a binary state. Note that a cell's state is not restricted to such an integer domain (e.g., \mathbb{Z}^2), as a continuous range of values is also possible (e.g., \mathbb{R}^+), in which case we are dealing with coupled map lattices (CML) (Crutchfield et. al. 1987 & Kaneko, 1990). We call the states of all cells collectively a CAs global configuration. This convention asserts that states are local and refer to cells, while a configuration is global and refers to the whole lattice. In our model we use an object to define a cell state. Therefore, we can use more than one parameter to describe the cell's state.

- Cells' neighborhoods, which locally determines the evolution of the cell. The size of neighborhood is the same for each cell in the lattice. In the simplest case, i.e., a one-dimensional lattice, the neighborhood consists of the cell itself plus its adjacent cells. In a two-dimensional rectangular lattice, there are several possibilities, e.g., with a radius of 1 there are, besides the cell itself, the four north, east, south, and west adjacent cells (von Neumann neighborhood), or the previous five cells as well as the four north–east, south– east, south–west, and north–west diagonal cells (Moore neighborhood). Note that as the dimensionality of the lattice increases, the number of direct neighbors of a cell increases exponentially (Maerivoet, 2005).
- Local transition rule (also called function) acting upon a cell and its direct neighborhood, such that the cell's state changes from one discrete time step to another (i.e., the system's iterations). The CA evolves in time and space as the rule is subsequently applied to all the cells in parallel. Typically, the same rule is used for all the cells (if the converse is true, then the term hybrid CA is used). When there are no stochastic components present in this rule, we call the model a deterministic CA, as opposed to a stochastic (also called probabilistic) CA. As the local transition rule is applied to all the cells in the CAs lattice, the global configuration of the CA changes. This is also called the CAs global map. Sometimes, the CAs evolution can be reversed by computing past states out of future states from deterministic CAs. By evolving the CA backwards in time in this manner, the CAs inverse global map is computed. If this is possible, the CA is called reversible, but if there are states for which no pre-cursive state exists, these states are called Garden of Eden states (Gutowitz et al., 1996) and the CA is said to be irreversible. Finally, when the local transition rule is applied to all cells, its global map is computed. In the context of the theory of dynamical systems, this phenomenon of local simple interactions that lead to a global complex behaviour (i.e., the spontaneous development of order in a system due to internal interactions), is termed self-organization or emergence in some cases. (Maerivoet, 2005)

In MIXSIM, a representative road stretch (link) of 3.75m width, unidirectional traffic is a 2D square grid of 0.25mx0.25m (see Figure 7). The time step is 1/20 second. Therefore the increment of speed is 5m/s. Each line paralleling to road direction is defined as a “virtual lane”.

At intersections vehicles are assumed to traverse though the intersection in a virtual link. The two boundaries (green curves in Figure 8a) are determined by the most left and most right trajectories of traversing vehicles on one turning direction. The virtual link will be straightened and discretized into a 2D grid as a normal road stretch, in this case, called the left turning grid. It will be connected with the grids of in-going and out going links (see Figure 8b).

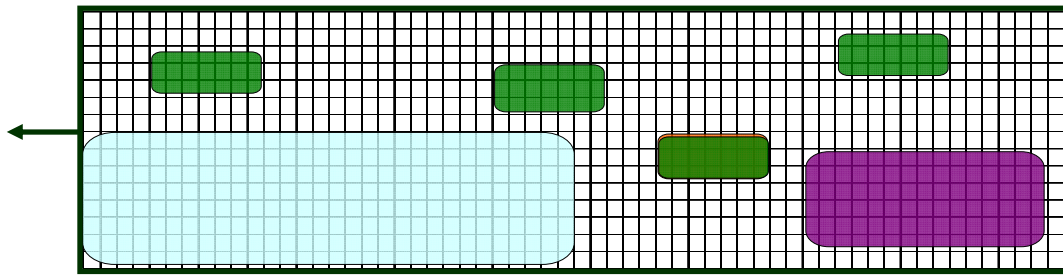


Figure 7: Illustration of Road stretch with 2D grid

The movement of traffic on this grid is similar to which on road stretch grid. The difference is that the driver has to scan whole intersection area for the vehicles from other direction to find acceptable time and space gap to make his decision. A based grid for intersection area is created. Traffic flow in each turning grid will be projected on this grid and an illustration in Figure 8c is an example of intersection occupancy.

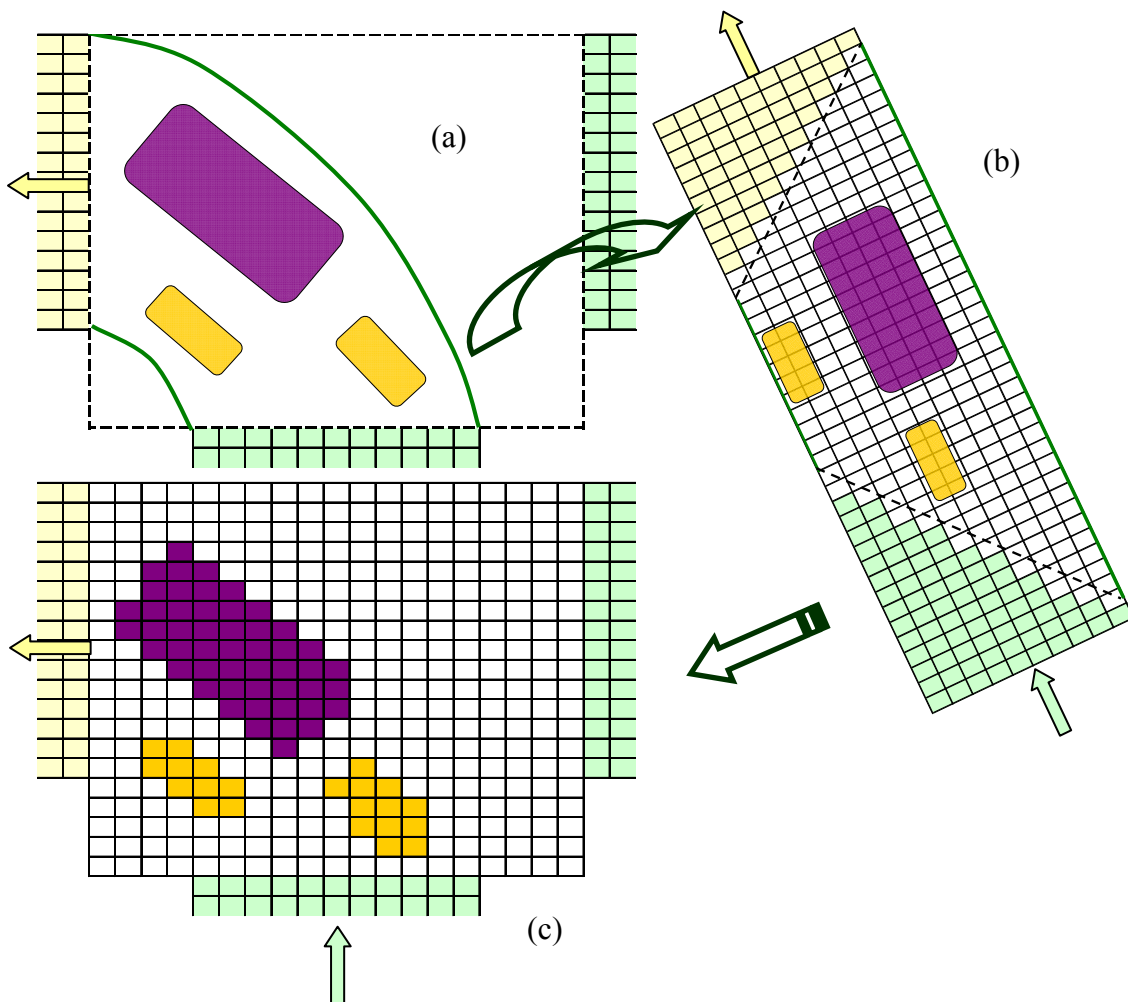


Figure 8: Illustration of Intersection and traversing grid

Our modified CA model is developed for the mixed traffic with three representative vehicle-classes which are significantly different in their specifications, such as length, width and speed. Table 1 shows the vehicle class specification in CA model units:

Table 1: Default parameters of model

Vehicle Type	Maximum speed		Dimension			
	cells/time step	m/s	Width		Length	
			cells	m	cells	m
Motorbike	3	15	3	0.75	8	2
Car	6	30	6	1.5	15	3.75
Bus	4	20	10	2.5	40	10

Driving behaviour

Understanding the role and impact of motorbikes on whole traffic system, many studies have been carried out in the motorbike dependent countries such as Vietnam, Thailand, Malaysia, Taiwan...(Hsu 2003, Hien 2007, Minh CC. 2003). Those studies also draw most of the major patterns of motorbikes in the road stretch, intersection approach as well as intersection in Vietnam – the case to be considered in this study.

In the road stretch, motorbike will normally drive on the side-lane of a street; the car will try to drive on the middle lane of a street (Hsu etc., 1995). However, in Vietnam, probably due to the shear volume of motorbikes, they practically drive everywhere across the street. The situation is made worst, as there is no regulation to control lane-discipline for motorbikes in Vietnam. The speed of a motorbike in mid stream is usually lower than that of a car (Hsu etc., 1995). The acceleration rate of motorbike is higher than car from stationery position, but less than that of cars when driving above 40 kph (Wu, 1983). Microscopically, the behaviour of motorbikes in traffic stream is according to the car following and lane changing, as well as the side-by-side following and with overtaking behaviour (Hsu, 1994).

While at intersection approaches, motorbikes will have negative starting delay (Hsu, 1982) since many of them stop ahead of the stop line and will wait for the green phase on the pedestrian crosswalk. The saturation flow of motorbike is dependent on their queuing behaviour near the stop line (Hsu, 1996) and the discharge rate variation depends on traffic patterns at the intersection (Hien 2007).

Based on those facts, we made the assumptions on behaviours of three representative vehicle classes as followings for the road stretch and intersection respectively:

In road stretch

- Car and bus behave as in normal passenger car traffic
- Cars and bus at desired speed travel on the left road-side
- Motorbikes at low speed prefer the right road-side and at high speed they prefer middle to left road-side.
- In congestion, buses, cars and motorbikes can be at any position in lateral direction
- Motorbikes do not have preference either following buses or cars or followed by buses or cars

Intersection approaching and intersection traversing

- At intersection approach, the vehicles have MLC therefore they will make their effort to be on the desired position to perform the turn.

- Each vehicle is assumed to travel in an own virtual link
- First vehicles will traverse though intersection with higher speed than the followers.

In the study of Hierarchical driver modelling framework, Boer and Hoedemaeker (1998) have pointed out that drivers are generally engaged in multiple tasks which require task scheduling and attention management. Reflecting on the decision making process, we proposed in our model following driving logic:

- Scan driving environment
- Determine safe speed
- Determine possible directions

Scan driving environment:

The driver scans his visible area to get information of surrounding vehicles, which are the perceptual variables that effect his decision, such as: gap distance, speed and vehicle type (Figure 9).

Determine speeds:

Based on driving environment, he or she will determine his or her speed which can be the maximum speed or the safe speed in order to avoid collision with other vehicles. The safe speeds are basically the representations of the gap acceptances to the left, straight or right side of the vehicle (Figure 10).

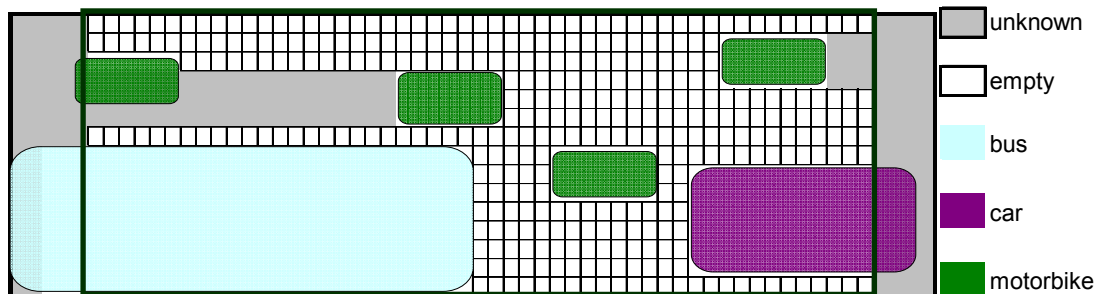


Figure 9: Scan area

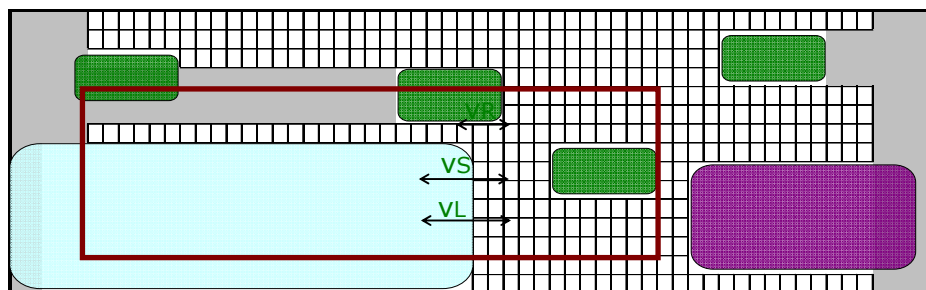


Figure 10: Scan area

Determine possible directions

Also based on driving environment, the driver can have at maximum three options: keep going straight, move to left or right side. Changing direction depends on the preferred “virtual lane” changing. This lane is determined by a utility function taking into account a set of possible reasons for lane changing.

At every time step, longitudinal position is increased by its speed calculated in current step; and lateral position is adjusted to the left or right by number of 1 cell to the width of vehicle from current position as long as it does not jump out of the two road marking lines. The updated rule can be written as below:

$$(1) : x(t) = x(t-1) + v(t)$$

$$(2) : y(t) = \begin{cases} \min(y(t-1) + \text{vehicle's width}; \text{road width}) & \text{if move to left} \\ \max(y(t-1) - \text{vehicle's width}; 0) & \text{if move to right} \\ y(t-1) & \text{if go straight} \end{cases}$$

The formula describes the longitudinal position where:

$$(*) : v(t) = \max(v_{\text{left}}^{\text{safe}} \vee v_{\text{right}}^{\text{safe}} \vee v_{\text{straight}}^{\text{safe}}, 0)$$

$v_{\text{left}}^{\text{safe}}, v_{\text{right}}^{\text{safe}}, v_{\text{straight}}^{\text{safe}}$: Speed if vehicle moves to the left, right side or straight, respectively.

Changing direction to the left, right or straight depends on the preferred “virtual lane” which is determined from previous step.

Utility function

The utility function shows the level of satisfaction a driver perceives at every “virtual lane” at a certain time; taking all the possible reasons of lane changing as its parameters to describe how the driver is attracted by each position over the cross section. Virtual lane changing behaviour is performed based on two parts, which are the reasons to change and the safety criteria (Nagel 2002). Both are differentiated between car/bus and motorbike.

We assume that the decision of choosing a lateral position of motorbikes depends on all the vehicles in his front and back within his observable area, and also depends on the distance to the next desired turning point (Gipps 1986). Within a road stretch (without any effect of bus stop, intersection...), in free flow traffic, motorbike drivers can freely use all road space. However, from observation, motorbike drivers do not like following big, slow vehicles (buses, cars). In congestion, vehicles attempt to use every road space or in other words, they are stimulated by free space in front. Vehicles want to adjust their lateral position when they do not like following the leading vehicles or find appropriate free space. But those changes are not necessary to be performed – discretionary lane changing. While at an intersection approach, both with and without clear turning split, the turning direction forces the driver to change lane from a certain distance to the intersection – mandatory lane changing.

Therefore, the utility function contains variables such as gap distance, type and speed of those observed vehicles. Further, depending on the subject vehicle type and speed, the effect of the desired lateral position in the link and intersection approach is also taken into

account by the lane factor and turning factor respectively. Variables of this function and their explained factors are shown in Table 2.

The ranges or boundaries in which each factor varies due to personal preferences is still to be determined (see future work) and is for now set according to personal perception. The utility function can be written as:

$$U(i) = \{ (front_gap + front_speed) \times Front_factor + (back_gap - back_speed) \times Back_factor \} \times Lane_factor \times Turning_factor$$

Where $U(i)$: Utility of virtual lane i

$$P \text{ is a preferred lane } \Leftrightarrow \forall U(P \pm k) \geq U(i)$$

Where:

k : integer; $k=0$ =vehicle' width (“+”: range at the left side; and “-“: rang at the right side)

i : current virtual lane

Table 2: Variables and factors of Utility function

Variable	Factor
Speed, vehicle type	Lane_factor
Front vehicle speed+gap; type	Front_factor
Back vehicle speed+gap; type	Back_factor
Turning direction	Turning_factor

To make the contents of the utility function easier accessible let us consider the situation at the bottom of Figure 11. A motorbike with the speed of 2 cells /time-step evaluates first the attractiveness of each virtual lane by the gap size, incorporating the speed of leading vehicles (Figure 11a). Since following a bus or car is less desirable for the motorbike than driving among other motorbikes or without a leader, the utility function get adjusted on these lanes (see Figure 11b). Additional, in this situation, the motorbikes get followed by a bus. Feeling unease about the situation as the weakest member of the traffic stream, the utility gets lowered in the width of the bus (Figure 11c), resulting in the final shape of the cross section utility (see Figure 11d).

The vehicle will choose the position where not only the utilities are higher than in current position but also the number of consecutive higher utility cells must not be smaller than the vehicle's width. The preference lane is the most left or most right boundary of those cells. In this example, the driver will set the new preferred lane to 15 and hence try to move to the right inside the road stretch.

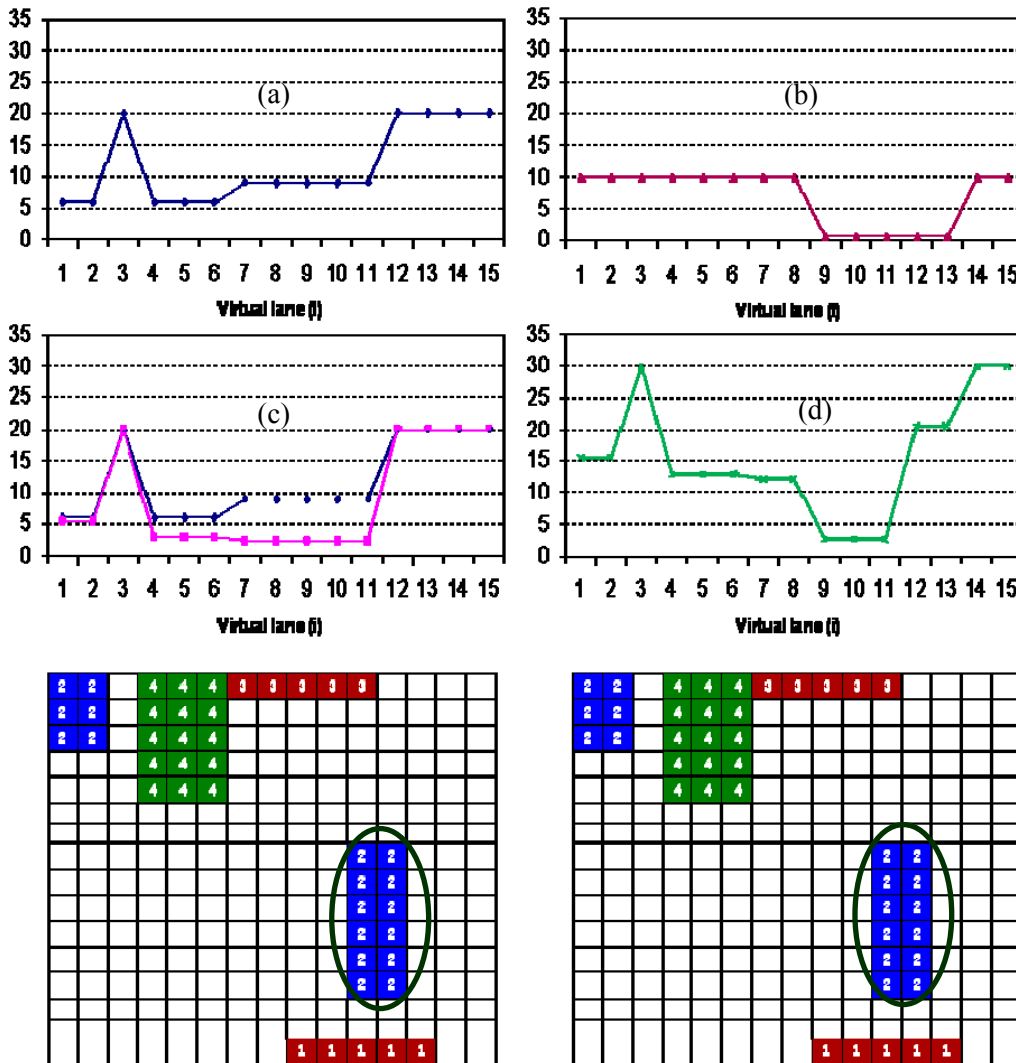


Figure 11: Illustration of Utility Function

CALIBRATION FOR AN INTERSECTION APPROACH

The calibration was performed for a representative road stretch (Figure 12) with:

- Length of 600m (equivalent to 1200 cell length);
- Width of 3.75m (equivalent to 15 cell width);
- A traffic light at 300m downstream of the entrance with cycle of 60 seconds, 45 second green time and 15 second red time.

Traffic composition is synthesized from Hien 2007 (see Figure 13). In this study, the authors also found that the performance and behaviour of motorbikes and pedal cycles in the queue and discharge from the queue are similar. Therefore, we generated in the simulation 90% motorbikes (including pedal bicycle volume), 8% passenger cars and 2% buses. Each

vehicle class is described by several characteristics such as: length, width, maximum speed, reaction time, acceleration rate, and set of default factors which are introduced in Table 2.

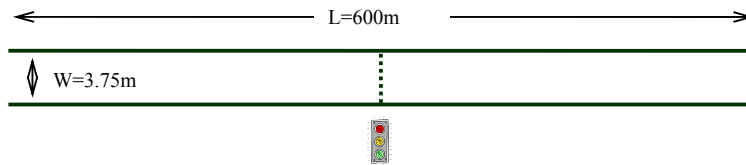


Figure 12: Sketch of the road stretch

The first four parameters were found in the studies by Minh C.C 2007 and Nguyen 2007. These values can be found in Table 1. The acceleration rate of motorbike, car and bus were extracted from Hsu 2003 (see Figure 14) with the assumption that bus and car have the same performance.

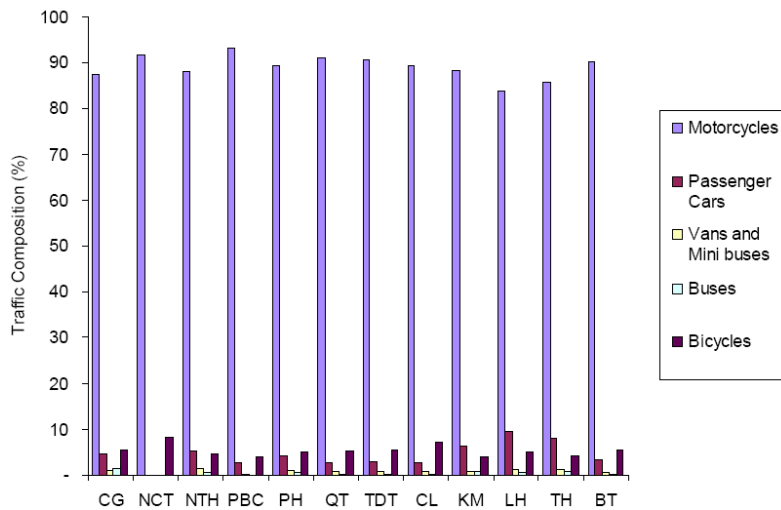


Figure 13: Traffic composition in 12 intersections in Hanoi, Vietnam (Source Hien 2007)

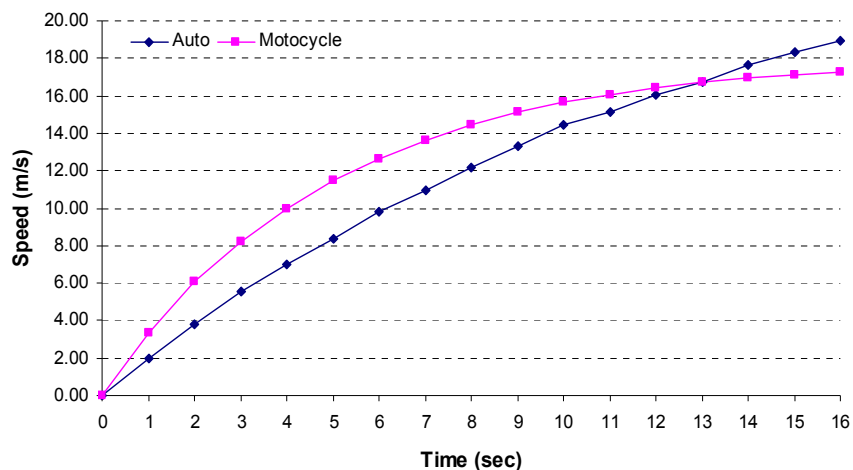


Figure 14: Cruise speed after starting of motorcycle and automobile (Source: Hsu 2003)

The drivers' observable area boundary, which reflects the maximum area that the driver can see to get the driving information in a time step, is assumed as in Figure 15.

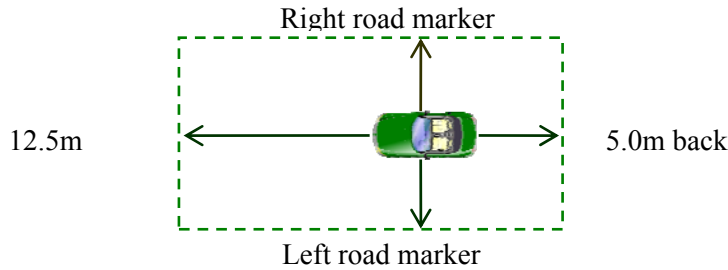


Figure 15: Observable area

We calibrated the model by running different random parameter sets. The reasonable set is chosen based on the discharge flow rate result. This set will be used later to investigate discharge headway distribution and queue formation patterns. Since there is no standard to calculate discharge flow rate for the motorbike dominated traffic, we used the method described in Hien 2007 and compare simulation result to the observed discharge flow rate found in this study.

Hien 2007 investigated the discharge flow rate in 10 intersection approaches in Hanoi, Vietnam (see Figure 16). In this study, for each approach, the discharge rate values were computed with average width of 3.65m in an hour. The flow rates were recorded in each portion of 4 second period in green time and calculated by asynchronous counting model as follows:

$$S.T = P + aM.M + aL.L + aB.B + aC.C$$

Where:

S: saturation flow in time interval T (PCU/h);

P, M, L, B and C: the numbers of passenger car or small van; motorcycle; LGV and medium van; buses or coaches; pedal cycle, respectively, passing stop line in time interval T.

aM, aL, aB, aC: the passenger car unit (PCU) values for the corresponding vehicle types.

According to URDS 2007, aM=0.25, aL=2.0, aB=2.5, aC=0.25.

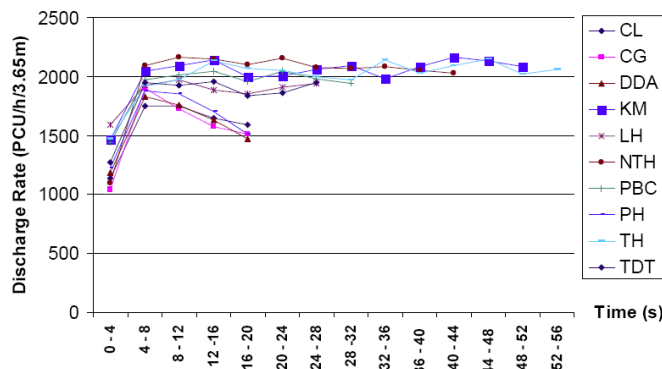


Figure 16: Variation of saturation flow in 10 approaches in Hanoi (Source: Hien 2007)

Firstly, the starting up pattern was checked and compared with available video footage in Hanoi (Figure 17). From the simulation, the pattern that motorbikes are the firsts leaving from the stop line is well represented. The following parts will describe more detail about the discharge patterns of the queue.



Figure 17: Discharge pattern comparison

Twelve factor sets were randomly generated in each time running the simulation (Table 3). Based on the observation, the motorbike squeezing in the queue does not care much about vehicles in the back or concerning about the lateral position, as he might do within the road segment when driving with desired speed. Therefore, we used the default value for the back factors and lane factors in the simulation to focus on calibrating the effect of leading vehicle type as well as speed, distance on the direction change behaviour of motorbikes.

Table 3: Front factor sets of Motorbike

Set No.	To Motorbike (fM)	To Car (fC)	To Bus (fB)	Relative value of front factor		Average discharge flow rate (PCU/h/3.65m)
				fC/fM	fB/fM	
1	0.43	0.96	0.54	2.23	1.26	1770
2	0.49	0.77	0.15	1.57	0.30	1615
3	0.74	0.42	0.39	0.57	0.53	1711
4	0.05	0.84	0.47	16.15	9.08	1746
5	0.97	0.60	0.85	0.62	0.87	1994
6	0.31	0.37	0.35	1.19	1.14	1921
7	0.69	0.67	0.10	0.96	0.14	1889
8	0.87	0.46	0.08	0.53	0.09	1972
9	0.41	0.90	0.06	2.21	0.15	1812
10	0.47	0.61	0.43	1.30	0.91	1812
11	0.13	0.22	0.62	1.73	4.87	1804
12	0.39	0.84	0.73	2.15	1.88	1897

By changing value of the factors, different discharge patterns were produced (Figure 18). Most results show the steep slope of the discharge rate after the first 4 seconds of green time. However, the similar patterns were found in factor set (1), (2), (4), (9), (10), (11) and

(12). The discharge rate change as a zigzag shape during green time. This can be explained by the relative values of the front factors f_B/f_M and f_C/f_M in Table 4. The larger this value is, the more possibility motorbike driver prefers following bus or car than other motorbike under same gap distance and speed of front vehicles. In this case, the 8-10 second period is the starting time of bus or car for slowly passing the measure point. After that, group of motorbikes following them will be quickly discharged causing the flow rate again increase. Depending on the traffic composition of the queue, the discharge rate may go up and down during green time. The patterns found in other factor set are: at two first periods, the discharge rate increase and remain almost same rate. However the set (5) shows a lower increasing in 4-8 second period.

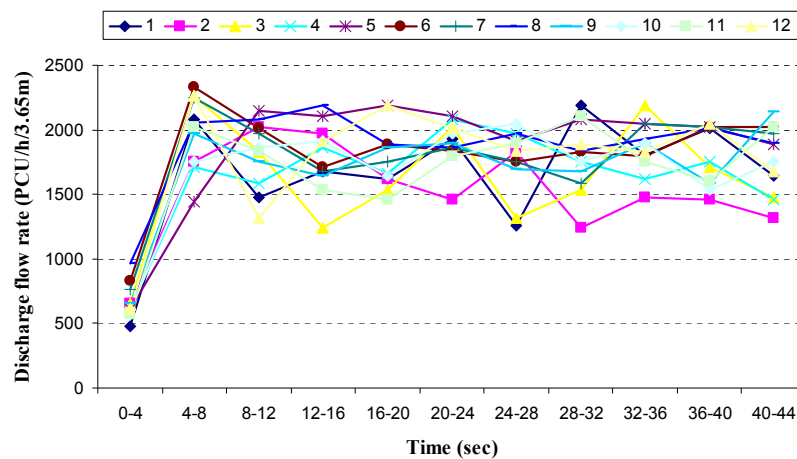


Figure 18: Variation of discharge flow rate with front factor set

Next we test the discharge headway distribution which is the distribution of the time difference between successive vehicles passing the based line. The distribution is also plotted for motorbike in order to compare with findings in Minh C.C 2005 (see Figure 19). The average headway value is 0.7 s in the simulation while this value is 1.16 s in Minh C.C 2005. The reason for this difference might count for the chosen grid size and time step. In CA model, the vehicle does not change its speed gradually and hustle to follow the leading vehicles. Although the acceleration rate is used, representing this continuous state variable still remains as one of CA model's shortcomings.

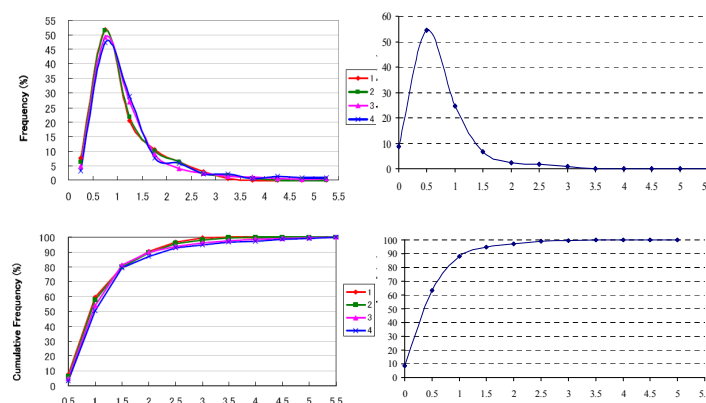
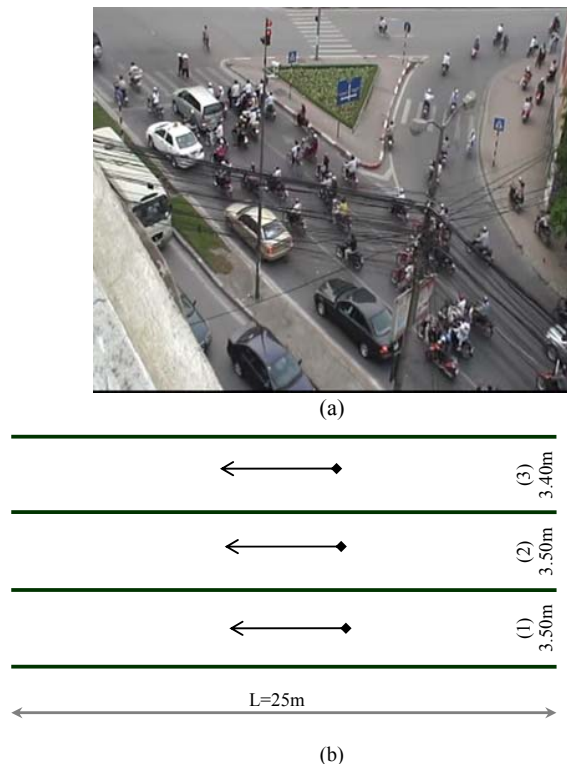


Figure 19: Motorcycle headway. Left: Observation in Minh C.C 2005; Right: Simulation

As mentioned before, discharge patterns depend on not only the composition of the queue but also the position of vehicles in the queue. Further, queue formation is resulted from drivers' behaviour, reflects traffic flow characteristics. In lane based traffic, vehicles mainly perform one dimensional movement, thus its queue develops in one dimension. While in non lane based, especially motorbike dominated, traffic the effect of two dimensional movement results in the formation of the queue in longitudinal and lateral direction. In this section, we compared the traffic composition and position allocation in the queue resulted from the simulation with the queue in front the stop line in real traffic.

The 25m of Kim Ma – Nguyen Chi Thanh intersection approach segment was selected (Figure 20a) for the reason that a full range of traffic composition is observed in this intersection and, the width of three approaches is approximate the simulated road stretch. Since those approaches are separated by the bold continuous lines, we considered each approach as a single unit of road segment. Based on traffic movement direction, we defined the number for each unit from 1 to 3 in the order from left to right (Figure 20b).

At each red light period, when all the vehicles come to stop, the number of each vehicle type and their position were recorded (Table 4 – left column). In most case, the cars and buses are on the left side of the approach unit. They are surrounded by a lot of motorbikes. This is the result from the behaviour that motorbike drivers try to percolate into small available space in order to move further.








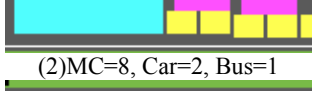
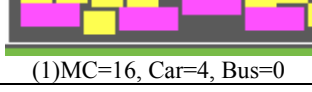

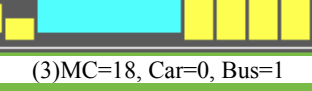
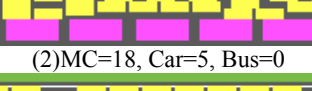
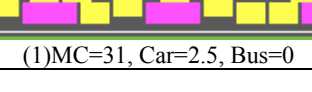

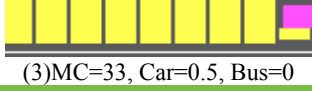




(b)
 Figure 20: Observation site (a) and layout (b)

We generated the queue in the simulation and applied above procedure for each 25m segment of the simulated queue. Most observed cases of traffic composition and allocation were well represented in our simulation. However, some inaccuracies still arise in low traffic

volume. The summarized comparison can be found in Table 4. The number in bracket stands for the approach unit name. In the right column, yellow, purple and cyan rectangles are the motorbike, car and bus respectively.

Table 4: Queue formation comparison

Observation	Simulation
 (1)MC=24, Car=3, Bus=0  (1)MC=20, Car=4, Bus=0	 (1)MC=19, Car=3, Bus=0
 (2)MC=16, Car=1, Bus=1 (1)MC=24, Car=3, Bus=0	 (2)MC=19, Car=1, Bus=1  (1)MC=24, Car=3, Bus=0
 (2)MC=9, Car=2, Bus=1 (1)MC=16, Car=4, Bus=0	 (2)MC=8, Car=2, Bus=1  (1)MC=16, Car=4, Bus=0
 (3)MC=20, Car=0, Bus=1 (2)MC=15, Car=4.5, Bus=0 (1)MC=23, Car=2, Bus=0	 (3)MC=18, Car=0, Bus=1  (2)MC=18, Car=5, Bus=0  (1)MC=31, Car=2.5, Bus=0
 (3)MC=36, Car=0.5, Bus=0 (2)MC=13, Car=2.5, Bus=0 (1)MC=11, Car=4, Bus=0	 (3)MC=33, Car=0.5, Bus=0  (2)MC=18, Car=2.5, Bus=0  (1)MC=15, Car=4, Bus=0

CONCLUSIONS AND FURTHER RESEARCH

In this study, we have proposed a microscopic model for motorbike dominated traffic based on Cellular Automata modelling approach. With a fine grid cell size and time step, our model allows the vehicles, especially, the motorbikes to perform their gradually changing in lateral position. Incorporating with that, a Utility Function has been introduced to model the logic of lane changing behaviour. This function takes into account the effects from surrounding vehicles such as: speed, gap distance and type. A road stretch with signal light has been modelled to represent the behaviour of queuing formation and dispersion. The model was calibrated by using the intersection video footage in Hanoi. The queue formation and discharge patterns matched quite well with observation result. In extending to network scale model, a representation of signal control intersection, which is a promising approach, has also been introduced. In our proposed framework, the parameters and the driving rules are very flexible, enable later adjustments in case of changing traffic share (e.g. mode choice change) or changing of driving behaviour (e.g. due to traffic education). The driving logic of motorbike drivers is also applicable to model bicyclist behaviour.

This model is our first trial to represent mixed traffic environment which is dominated by motorbikes. Therefore it is still needed further improvements to make it more macroscopically realistic. The factors of the utility function can be extracted by statistical method from video data. They also depend on vehicle speed and driver's characteristics. Further, several intersection types are needed to be modelled to accomplish a network scale model. From the simulation, the relationships between traffic flow, density and velocity for each vehicle type and for whole traffic stream can be extracted. These relationships will be used later to develop a controllable multi-class macroscopic model.

ACKNOWLEDGEMENT

All observation data for this study was provided by the International Traffic Database (ITDb). The International Traffic Database is part of the Energy ITS project, funded by the Ministry of Economy, Trade and Industry of the Japanese Government. Data available to the public can be accessed through www.trafficdata.info.

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