Traffic flow simulation using agent-based model: A case of single lane with multiple traffic lights and input-output node

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Abstract. Vehicle is modeled as a point, which is moving along a closed trajectory. A small amount of time is defined as the time step, the smallest time difference, so that any time measurement is simply multiple of this value. Lowest positive velocity (but greater than zero) is where in the time step a vehicle advances its position for only a spatial step. Higher velocities and also the negative ones can be constructed from this value. Only a single lane is investigated in this work, where a vehicle must wait until there is an empty space in front of it before it can move forward. As perturbation several traffic lights are also installed in the trajectory. Number of vehicles stop at a stoplight or $N_s$ is observed.

1. Introduction
It is still interesting nowadays to study traffic flow using simulation. In an agent-based multilane traffic model a related concept of entropy can be used to describe the self-organization phenomenon in traffic dynamics [1], even when a Java-based simulator for different type of junctions is already available for microscopic traffic models with open source code [2].

2. Model
In this work only single lane is considered. A lane $L_i$ is started with an input cell $I_i$ and ended with an output cell $O_i$, where as simulation object, vehicles or agents $A_j$ are created in $I_i$ dan destroyed in $O_i$. Two lanes $I_i$ and $I_k$ can intersect and vehicle $A_j$ can change its lane in the intersection. Along a lane there are possible several stop light $S$. Illustration of the model is given figure 1. Creation of agents in $O_i$ can have a certain distribution [3].

Time $t$ can be only advanced by a time step $\Delta t$ to be $t + \Delta t$ and each agent moves forward $v_i$ cells in the direction from $I_i$ to $O_i$ in lane $L_j$, with $v_i$ is vehicle velocity with discrete value, e.g. 1, 2, .., $V$, where

$$V << l_j,$$  \hspace{1cm} (1)

with $l$ is length of lane $L$ or number of cells between $I_i$ and $O_i$. Equation (1) assures that the vehicle $A$ does not go to nowhere since it is too fast compared to available lane length $l_j$ at each time step $\Delta t$. Cell $k$ in lane $L$ has two possible states 0 or 1
There are possible some vehicles located at several cells in the same lane. In a lane $L_i$ before vehicle $A_j$ can move from cell $k$ to cell $l$ it must check whether the destination cell is empty or the state of a stop lamp $S_m$ before the destination cell.

\[
L_{j,k} = \begin{cases} 
0, & \text{cell } k \text{ is empty}, \\
1, & \text{cell } k \text{ is occupied}. 
\end{cases}
\]

There are several configuration tested in this work.

### 3. Results and discussion

Simulation is built using JavaScript programming language running on an ordinary internet browser, e.g. Google Chrome, and does not need a special computational resources. A typical processor of 2 GHz and 4 GB RAMs are already sufficient. The JavaScript code of this simulation can be accessed at GitHub [https://github.com/dudung/butiran/blob/master/app/ab_ssltfs.js](https://github.com/dudung/butiran/blob/master/app/ab_ssltfs.js), which should be first included in a HTML file and then the HTML file is opened using an internet browser.

#### 3.1. Variation of stoplight duration

BC = periodic, $N_{\text{max}} = 5$, $c_{\text{max}} = [0, 1, 2, 3, 4]$, $v_{\text{max}} \in [1, 5]$, $l_{\text{max}} = 20$, $S_m = 10$.

![Image 1](image1.png)

**Figure 1.** Lanes ($L_1 \ldots L_3$) are represented by series of connected cells, where agents ($A_1 \ldots A_9$) are created in $I_i$ and destroyed in $O_i$, while they must obey state of stop light $S_i$ as they move along their lane, whereas two lanes can intersect and also be connected through relation $I_i$–$O_j$.

**Figure 2.** Results in case 0 for $S_{\text{pattern}} = [0000011111]$ at iteration 4, 148, 308.

**Figure 3.** Results in case 1 for $S_{\text{pattern}} = [0000111111]$ at iteration 4, 148, 341.
Figure 4. Results in case 2 for $S_{\text{pattern}} = [000111]$ at iteration 4, 148, 322.

Figure 5. Results in case 3 for $S_{\text{pattern}} = [0011]$ at iteration 4, 148, 330.

Figure 6. Results in case 4 for $S_{\text{pattern}} = [01]$ at iteration 4, 148, 344.

From figures 2 – 6 average number of stopped vehicle $N_{\text{stop}}$ in the stoplight against stoplight duration $T_{\text{stoplight}}$ is given in figure 7.

![Figure 7](image_url)

**Figure 7.** Average number of stopped vehicles in the stoplight influenced by stoplight duration.

3.2. Variation of number of vehicles

$BC = \text{periodic, } c_{\text{veh}} = [0, 1, 2, 3, 4], v_{\text{veh}} \in [1, 5], l_\text{veh} = 20, S_\text{veh} = 10, S_{\text{pattern}} = [0000111111]$. 

![Graph](image_url)
Figure 8. Results in case 5 for $N_{\text{max}} = 1$ at iteration 8, 145, 308.

Figure 9. Results in case 6 for $N_{\text{max}} = 2$ at iteration 8, 145, 308.

Figure 10. Results in case 7 for $N_{\text{max}} = 3$ at iteration 8, 145, 308.

Figure 11. Results in case 8 for $N_{\text{max}} = 4$ at iteration 8, 145, 308.

Figure 12. Results in case 9 for $N_{\text{max}} = 5$ at iteration 8, 145, 317.

From figures 8 – 12 average number of stopped vehicle $N_{\text{stop}}$ in the stoplight against number of vehicle $N_{\text{vehicle}}$ is given in figure 13.
3.3. Variation of number of maximum velocity

BC = periodic, $N_{max} = 5$, $c_{max} = [0, 1, 2, 3, 4]$, $l_{ve} = 20$, $S_{p} = 10$, $S_{pattern} = [0000011111]$. 

**Figure 13.** Average number of stopped vehicles in the stoplight influenced by number of vehicles.

**Figure 14.** Results in case 10 for $v_{ve} \in [1, 1]$ at iteration 8, 145, 308.

**Figure 15.** Results in case 11 for $v_{ve} \in [1, 2]$ at iteration 8, 145, 308.

**Figure 16.** Results in case 12 for $v_{ve} \in [1, 3]$ at iteration 8, 145, 308.

**Figure 17.** Results in case 13 for $v_{ve} \in [1, 4]$ at iteration 8, 145, 308.

**Figure 18.** Results in case 14 for $v_{ve} \in [1, 5]$ at iteration 8, 145, 308.
From figures 14 – 18 average number of stopped vehicle $N_{\text{stop}}$ in the stoplight against maximum velocity $v_{\text{max}}$ is given in figure 19.

![Graph showing $N_{\text{stop}}$ vs $v_{\text{max}}$.](image)

**Figure 19.** Average number of stopped vehicles in the stoplight influenced by maximum velocity.

### 3.4. Variation of length of lane

$BC = \text{periodic}, N_{\text{max}} = 5, c_{\text{max}} = [0, 1, 2, 3, 4], v_{\text{max}} \in [1, 5], S_{\text{pos}} = 10, S_{\text{pattern}} = [000011111]$.  

![Image of lane configurations.](image)

**Figure 20.** Results in case 14 for $L_{\text{lane}} = 16$ at iteration 8, 145, 308.

![Image of lane configurations.](image)

**Figure 21.** Results in case 14 for $L_{\text{lane}} = 17$ at iteration 8, 145, 308.

![Image of lane configurations.](image)

**Figure 22.** Results in case 14 for $L_{\text{lane}} = 18$ at iteration 8, 145, 308.
Figure 23. Results in case 14 for $l_{\text{lane}} = 19$ at iteration 8, 145, 308.

Figure 24. Results in case 14 for $l_{\text{lane}} = 20$ at iteration 8, 145, 308.

From figures 20 – 24 average number of stopped vehicle $N_{\text{stop}}$ in the stoplight agains length of lane $l_{\text{lane}}$ is given in figure 25.

Figure 25. Average number of stopped vehicles in the stoplight influenced by length of lane.

3.5. System with more than one lane
System with two lanes and one intersection is used for testing the simulation, where the system is shown in figure 26.

Figure 26. System of two lanes with one intersection and two stoplights as illustration.

Since periodic BC is also applied in figure 26, the results are simply composite of previous results.

3.6. Circular lane and four stoplights
BC = periodic, $N_{\text{veh}} = 5$, $c_{\text{veh}} = [0, 1, 2, 3, 4]$, $v_{\text{veh}} \in [1, 5]$, for $l_{\text{c}} = 76$, $S_{\text{pos}} = [10, 28, 48, 66]$, $S_{\text{pattern}} = [00001111, 00111100, 11110000, 11000011]$ with the results are shown in Figure 27.
Figure 27. A circular lane with four stoplights tends to segregate 10 vehicles to group of two at each stoplight as observed at iteration 0, 6, 15, 29, 37, 42, 63, 86, and 130.

All the results still must be compared to guidance in traffic management system in Indonesia [4], which is used to regulate the traffic. And for future plan it will be advanced into a multilane system.

4. Summary
From the results we can summarized that stoplight duration $T_{\text{stoplight}}$ has no tendency in influencing number of stopped vehicle $N_{\text{stop}}$, as also with length of lane $L_{\text{lane}}$. Initial $N_{\text{stop}}$ is larger than final $N_{\text{stop}}$ as influenced by maximum velocity $v_{\text{max}}$. Number of vehicle $N_{\text{vehicle}}$ seperates initial and final stopped vehicle $N_{\text{stop}}$ for larger value of $N_{\text{vehicle}}$.

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