Comment on "Cellular automata model simulating traffic interactions between on-ramp and main road"

Ding-wei Huang and Wei-neng Huang
Department of Physics, Chung Yuan Christian University, Chung-li, Taiwan

(Received 30 September 2002; published 20 June 2003)

In a recent study of traffic flow around on-ramp [R. Jiang, Q. S. Wu, and B. H. Wang, Phys. Rev. E **66**, 036104 (2002)], two different types of phase diagrams are reported: four distinct regions are observed in the cases of $v_{max}>1$, while only two regions are present in the case of $v_{max}=1$. We point out that the characteristics of the phase diagram are totally dictated by the prescribed asymmetric rule of the on-ramp. In the congested phase (region IV), the configurations evolve as stable limit cycles, and are independent of v_{max}. The saturated currents can be obtained analytically.

DOI: 10.1103/PhysRevE.67.068101 PACS number(s): 45.70.Vn, 89.40.−a, 02.60.Cb

In a recent paper [1], the cellular automaton model is adapted to simulate the traffic interactions between the main road and the on-ramp. The main road and the on-ramp are both single lane and connect only at one lattice site C_0. The main road upstream of C_0, the on-ramp, and the main road downstream of C_0 are denoted as roads *A*, *B*, and *C*, respectively. The phase diagram is specified by the injection rates a_1 and a_2 on roads *A* and *B*, respectively, and the removal rate on road *C* is 1. In total, there are four distinct regions observed in numerical simulations. In region I, the traffic on both roads *A* and *B* are free flows; in region II, the traffic is free on road *A* and congested on road *B*; in region III, the traffic is congested on road *A* and free on road *B*; in region IV, the traffic flows are congested on both roads *A* and *B*. Depending on the setting of maximum velocity v_{max}, two different types of phase diagrams are distinguished. In the cases of $v_{max}>1$, all the four regions are observed. Also region IV is recognized to have a saturated current at $J_C=0.6$. While in the case of $v_{max}=1$, only regions I and II are realized; the absence of the other two regions is attributed to the fact that the maximum current achieved is not large enough ($J_{max}<J_C$ or $0.5<0.6$).

The congestion on road has been recognized as a boundary-induced phase transition, and the on-ramp is the crucial boundary, even when its length is insignificant (in this case a single lattice site C_0). As the random noise is neglected ($p=0$), the system is deterministic. We point out that the dynamics is completely dictated by the update rule at the on-ramp. In the case of $v_{max}=1$, every car hops forward to the next site if it is empty. Let A_0 and B_0 denote the sites right before C_0 in road *A* and road *B*, respectively. When both A_0 and B_0 are occupied, the car on road *A* always gets the chance to hop forward to C_0 and then blocks the car on road *B*. Such asymmetry is prescribed to assume the priority of the main road. In the next time step, the car on C_0 hops forward, while the car on road *B* is still waiting on B_0. The car on B_0 gets a chance to move into C_0 only when there is no following car to occupy A_0, i.e., until there are two consecutive sites left unoccupied on road *A*, the car waiting on B_0 will not be able to move forward. Thus, the asymmetric rule dictates that the cars on road *A* always block cars on road *B* and not the reverse. As the site C_0 acts like a free boundary to road *A*, the congestion will never emerge on road *A*. Thus, regions III and IV cannot be realized in the case of $v_{max}=1$. This should not be interpreted as the below-capacity consequence of road *C*, otherwise region II should also disappear.

In the cases of $v_{max}>1$, the car on A_0 may hop further to the next site of C_0 in a single time step. Since both A_0 and C_0 are now left unoccupied, the car on B_0 gets a chance to move into C_0 in the next time step. Only in such cases, the cars on road *B* block the car on road *A*, which results in regions III and IV. When the high-density configurations are further analyzed, the asymmetric rule dictates the stable limit cycles shown in Fig. 1. In the time step denoted by $t=1$, C_0 is empty and both A_0 and B_0 are occupied. In the next time step ($t=2$), the car on A_0 hops to C_0 and blocks the car on B_0. At $t=3$, the following car on road *A* moves to A_0 and the car on B_0 keeps on waiting. At $t=4$, the car on A_0 hops to the site next to C_0 and the car on B_0 gets a chance to occupy C_0. At $t=5$, the car on C_0 cannot hop forward, and both A_0 and B_0 are occupied by the following cars. Thus, completes a cycle. In the next time step, the configuration at $t=1$ is resumed. Such stable limit cycles are dictated by the update rule of on-ramp when both roads *A* and *B* are congested. The configurations on roads *A* and *B* are independent of the maximum velocity v_{max}, as long as $v_{max}>1$. The saturated currents and densities can be easily obtained as $J_A=0.4$, $J_B=0.2$, and $\rho_A=0.6$, $\rho_B=0.8$. The configurations

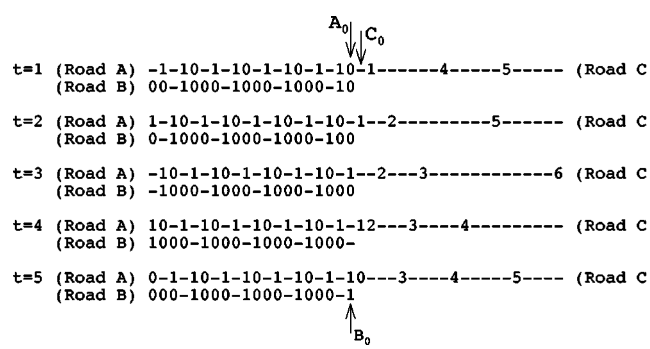

FIG. 1. The stable limit cycle of configurations dictated by the update rule of on-ramp. The location of each car is marked with a one-digit integer showing its velocity.

on road C depend on v_{max}. With a larger v_{max}, the cars on road C will accelerate to a higher speed and the headways will increase accordingly. The saturated current and density are $J_C = 0.6$ and $\rho_C = 0.6/v_{max}$, respectively.

In summary, we show that the dynamics of the model is totally dictated by the prescribed asymmetric rule of on-ramp. For $v_{max} > 1$, the configurations of the congested phase (region IV) evolve as stable limit cycles. The saturated currents can be obtained analytically, and are completely independent of v_{max}.

[1] R. Jiang, Q.S. Wu, and B.H. Wang, Phys. Rev. E **66**, 036104 (2002).