Physica A 444 (2016) 622–640

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Effects of turning and through lane sharing on traffic performance at intersections

Xiang Li [a], Jian-Qiao Sun [b,*,1]

[a] Department of Mechanics, Tianjin University, Tianjin, 300072, China
[b] School of Engineering, University of California, Merced, CA 95343, USA

HIGHLIGHTS

- Developed a cellular automata model of traffic at interaction.
- Studied effects of sharing turning and through lane on the traffic, safety and fuel economy.
- Discovered pros and cons of lane sharing in different traffic situations.
- Studied pedestrian influence on the traffic at interaction.

ARTICLE INFO

Article history:
Received 23 July 2015
Available online 24 October 2015

Keywords:
Intersection simulation
Signal management
Shared turning lane
VEHICLE–PEDESTRIAN interaction
Cellular automata

ABSTRACT

Turning vehicles strongly influence traffic flows at intersections. Effective regulation of turning vehicles is important to achieve better traffic performance. This paper studies the impact of lane sharing and turning signals on traffic performance at intersections by using cellular automata. Both right-turn and left-turn lane sharing are studied. Interactions between vehicles and pedestrians are considered. The transportation efficiency, road safety and energy economy are the traffic performance metrics. Extensive simulations are carried out to study the traffic performance indices. It is observed that shared turning lanes and permissive left-turn signal improve the transportation efficiency and reduce the fuel consumption in most cases, but the safety is usually sacrificed. It is not always beneficial for the through vehicles when they are allowed to be in the turning lanes.

1. Introduction

Effective regulation of vehicle flow at intersections has always been an important issue in traffic control systems. With the ever-increasing traffic in urban areas, the need for more efficient utilization of existing lanes at intersections becomes urgent [1,2]. With low traffic, turning and through vehicles are usually allowed to share lanes. However, in congested situations, transportation efficiency and safety are sacrificed due to conflicts between turning and through vehicles, and lane sharing hinders the flow of vehicles and pedestrians [3]. This paper develops a microscopic cellular automata model that studies various conflicts and effects of lane sharing and turning signals on the traffic performance at intersections.

The interactions between pedestrians and vehicles have been widely investigated in the literature [4–6]. Crossing pedestrians have a significant impact on the movement of vehicles [7,8]. Li et al. [9] presented a study of variations of road safety, vehicle speed, fuel consumption and gas emissions due to random street crossings of pedestrians.

* Corresponding author.
E-mail address: jqsun@ucmerced.edu (J.-Q. Sun).
1 Honorary Professor of Tianjin University.

http://dx.doi.org/10.1016/j.physa.2015.10.052

Nomenclature

Δt Time step (s)
Veh_n Vehicle numbered n
$v_{\max}$ Vehicle desired speed (road speed limit) ($cell/\Delta t$)
x_n, v_n Longitudinal position ($cell$) and speed of Veh_n ($cell/\Delta t$)
v_r Required maximum speed of vehicle to avoid collision with pedestrian ($cell/\Delta t$)
d_n Longitudinal rear-to-end distance between Veh_n and its leader in the subject lane ($cell$)
d_{safe} Minimum safe distance for two consecutive vehicles ($cell$)
d_{cg} Critical distance between pedestrian and vehicle to cross road ($cell$)
p_{s2s}, p_{ran} Velocity-dependent randomization parameters
$p_{\max}$ Maximum randomization probability
λ Expected number of pedestrian arrivals at one location per unit time
N_p Average number of arriving pedestrians at one location per minute
N_{left}, $N_{straight}$, N_{right} Average number of arriving left-turn, straight-through and right-turn vehicles in one approach per minute
v_{pws} Pedestrian walk speed ($cell/\Delta t$)
t_{cg} Critical gap for crossing pedestrian (Δt)
$p_{i,j}$ Pedestrian transition probability
p_{follow} Probability for pedestrian to follow if the cell in front is occupied
l_n Longitudinal length of Veh_n ($cell$)
L_1 Length of driver's eyeshot ($cell$)
W_1 Vehicle width ($cell$)
L_{sw} Street width ($cell$)
t_{pth} Preferred time headway (Δt)
d_{check} Minimum length of driver eyeshot ($cell$)
$d_{n,p}$ Distance between Veh_n and the nearest pedestrian in front ($cell$)
p_0 A constant in randomization
α Sensitivity parameter of the vehicle in conflict with pedestrian
N_B Number of pedestrians in area B of the vehicle
$t_{\min}$ Minimum time required between two lane-changing behaviors for one vehicle (Δt)
$p_{forward}$, p_{rush}, p_{wait}, $p_{backward}$ Proportions of pedestrians who prefer to move normally, rush crossing, stand still and move backward in conflict with vehicles of all pedestrians
A_F Aggressiveness factor of driver
c_{aggre} Critical distance of opposing vehicles in conflict ($cell$)
G_1, G_3 Two green phase time for through traffic (s)
G_2, G_4 Two green phase time for left-turn traffic (s)
G_{1p}, G_{3p} Two green phase time for pedestrians (s)
t_{cycle}, A_t, A_0, F Signal cycle, amber, all-red and flashing time (s)
W_{cross} Width of pedestrian crosswalk ($cell$)
L_{wait} Length of left-turn vehicle waiting area ($cell$)
C_R Right-turn conflict point
$L_{conf,R,h}$, $L_{conf,R,v}$, $L_{conf,R}$ The horizontal, vertical and actual distance between right-turn vehicle and conflict point ($cell$)
$L_{conf,R,cri}$ Critical distance in right-turn conflict ($cell$)
$t_{gap,R}$ Time gap between through vehicle and conflict point in right-turn conflict (Δt)
$t_{gap,R,des}$ Desired time gap between right-turn vehicle and conflict point in right-turn conflict (Δt)
$L_{conf,cri}$ Critical distance between the turning vehicle and conflict point ($cell$)
$t_{gap,cri}$ Critical time gap between the through vehicle and conflict point (Δt)
C_{L1}, C_{L2}, C_{L3} Left-turn conflict points
$L_{conf,L1,h}$, $L_{conf,L1,v}$, $L_{conf,L1}$ The horizontal, vertical and actual distance between left-turn vehicle and conflict point C_{L1} ($cell$)
$L_{conf,L2,h}$, $L_{conf,L2,v}$, $L_{conf,L2}$ The horizontal, vertical and actual distance between left-turn vehicle and conflict point C_{L2} ($cell$)
$L_{conf,L3,h}$, $L_{conf,L3,v}$, $L_{conf,L3}$ The horizontal, vertical and actual distance between left-turn vehicle and conflict point C_{L3} ($cell$)
$t_{gap,L1}$, $t_{gap,L2}$, $t_{gap,L3}$ Time gap between the through vehicle and conflict point C_{L1}, C_{L2}, C_{L3} (Δt)
f_t, σ, β_1, β_2, b_1, b_2, ω, R_t Parameters in fuel consumption model
M Vehicle mass (kg)