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Traffic flow behavior at a single lane roundabout as compared to traffic circle

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ABSTRACT

In this paper, we propose a stochastic Cellular Automata (CA) model to study traffic flow at a single-lane urban roundabout (resp. traffic circle) of N entry points (resp. exit points), the entry points are controlled by rates α_1 and α_2 while the removal rates from the exit points are denoted by β. The traffic is controlled by a self-organized scheme. Based on computer simulation, density profiles, global density and current are calculated in terms of rates. Furthermore, the phase diagrams for roundabout as well as traffic circle are constructed. It has turned out that the phase diagrams consist essentially of two phases namely free flow and jamming. It is noted that the typology of the phase diagrams of the roundabout is not similar to it in the traffic circle. Furthermore, we have compared the performance of the two systems in terms of the geometrical properties and the number of entry points.

1. Introduction

In the past few decades, transportation problems have become the subject of intensive research by different scientific groups, and many studies have been conducted with different traffic models [1–10]. Since more traffic congestions occur in urban districts, in particular at the intersections; much attention has been paid to controlling traffic flow at intersections [11–20].

Traditionally, at the intersection traffic can be regulated either by a roundabout or a traffic circle or by traffic lights. A roundabout is a type of circular intersection which give priority to circulating traffic and which is physically designed to slow traffic entering the junction to improve safety. It is often reported that roundabouts offer additional advantages over other intersection types especially in low-volume situations (they increase the flow of vehicles in the road because they tend to avoid the complete stop of vehicles). Therefore, notable attention has been paid to study roundabouts [21–25]. Fouladvand et al. [21] investigated the waiting time of traffic caused by an isolated roundabout at intersection in the framework of CA and car-following models. Wang and Ruskin [22] propose Multi-stream Minimum Acceptable Space (MMAS) CA models to study unsignalized multi-lane urban roundabout. Chen Rui-Xiong et al. [23] investigated the traffic-flow at the grade roundabout crossing with inner-roundabout-lane and outer-roundabout-lane using a CA model. Ding-Wei Huang [24] has investigated numerically and analytically a simple CA model of a roundabout, where there is only two entry point (resp. exit point). Bai Ke-Zhao et al. [25] proposed CA model of the roundabout crossing with an open boundary condition.

Typically, roundabouts are distinguished from traffic circles by their uniform characteristics in design and operation. Compared with great research interests in roundabouts, traffic circles, however, have not attracted enough attention [26].

This paper investigates the characteristics of the traffic flow at single-lane traffic circle, as well as at single-lane roundabout. Phase diagrams are also obtained using numerical simulations based on the CA model. We plan to address the following questions. Under what circumstances traffic circle perform better than the roundabout in term of throughputs? What are the factors influencing the performance of the roundabout as well as the traffic circle?

The paper is organized as follows. In Section 2, we describe the model. Section 3 will be devoted to results and discussions. The conclusion is given in Section 4.

2. Model

The circulating single-lane of the roundabout (resp. traffic circle) is considered as a discretized closed chain. The chain is divided into L cells. Each cell can be either empty or occupied by one vehicle. Accumulation is forbidden. In the rotary vehicles move counterclockwise and orderly, passing is not allowed. Moreover, each vehicle can take discrete-valued velocities $1, .., V_{max}$.

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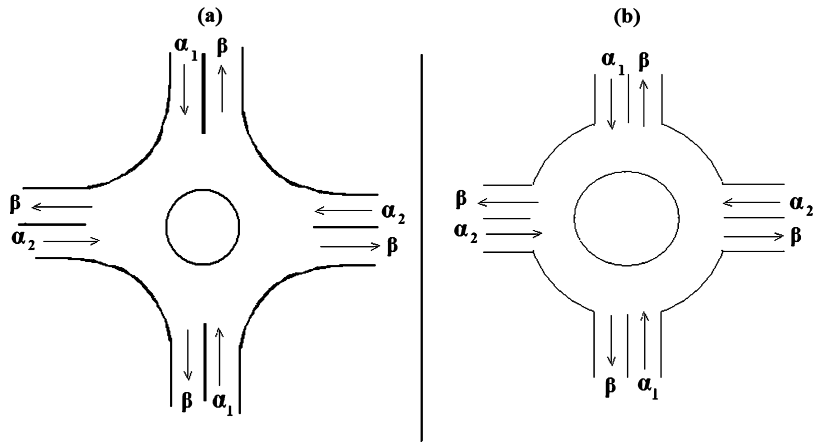

Fig. 1. Sketch of the model, (a) roundabout, (b) traffic circle.

The dynamics is prescribed by the cellular automaton model developed by Nagel and Schreckenberg [1], where all vehicles are handled in parallel during one time step according to the four rules:

(1) Acceleration: $V_i \rightarrow \mathrm{Min}(V_i + 1, V_{\max})$.
(2) Deceleration: $V_i \rightarrow \mathrm{Min}(V_i, d_i)$.
(3) Randomization: $V_i \rightarrow \mathrm{Max}(V_i - 1, 0)$ with probability P.
(4) Motion: $X_i \rightarrow X_i + V_i$.

Here V_i denotes the velocity of the vehicle i and its takes only positive integer values and X_i is the position of the vehicle i, d_i is the number of empty cells in front of the vehicle i; P is the randomization probability.

Let N denote the number of entry point (resp. exit point). The injection probabilities from the on-ramp (i.e. entry point) are denoted by α_1 and α_2 (see Fig. 1). The removal probabilities from the off-ramp (i.e. exit point) are denoted by β. The destined exit for each vehicle is selected with equal probability once and at the step the vehicle is enters the ring (i.e. vehicles make decisions on which exit is appropriate). In the circulation lane vehicles can inform the others of their exit direction by the usage of indicators.

As mentioned above, there are many differences between roundabout and traffic circle; as we know roundabout accommodates traffic flow in one direction around a central island and gives priority to the circulating flow, on the other side the traffic circle give priority to the incoming vehicles.

The entry rules for the roundabout are given by:

– If the oncoming vehicle already in the circle displays its indicator and the cell of the entrance point is empty, a vehicle enters the roundabout with the injection probabilities α_1 (resp. α_2) (Fig. 1(a)). In this case the incoming vehicle has not to judge the gaps within the circulating stream.
– Otherwise, the incoming vehicles check the number of empty cells (g_1) of the ring, in the left of an entrance. If $g_1 > V_c + 1$, the waiting vehicle at the entrance enter the roundabout with a probability α_1 or α_2. Here V_c denotes the velocity of the oncoming vehicle. This criterion ensures that the incoming vehicles do not disturb the oncoming vehicles already in the circle.

After the entry rules for the roundabout are fulfilled a vehicle is generated in the entrance points with the velocity $V_i = \mathrm{Max}(V_{\max} - 1, 1)$ this regulation appears as the result of traffic rules at the roundabout. Yield-at-entry make the vehicle slow down their speed when entering (i.e. roundabout is designed to reduce the speed of approaching vehicles without requiring them to stop, thus prepare the incoming vehicles to yield as one approach the roundabout). Once a vehicle is permitted to enter the roundabout, it continues moving until it reaches its aimed exit direction.

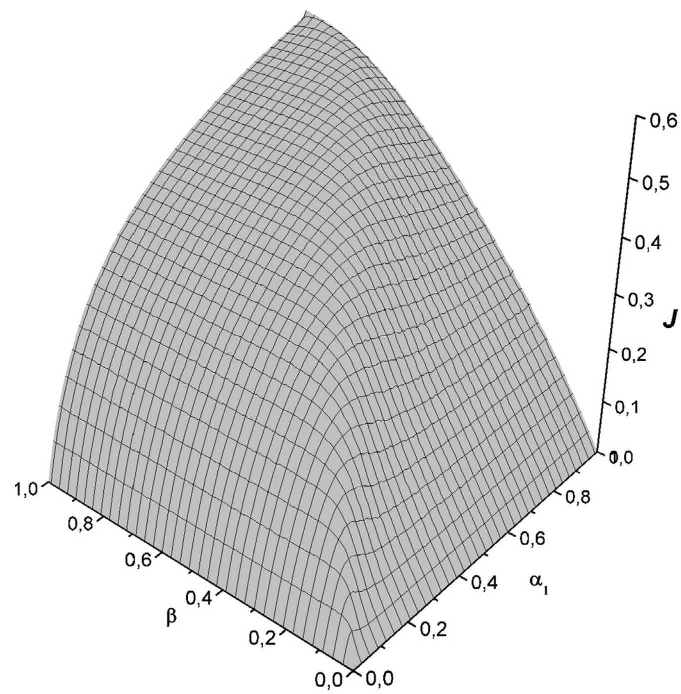

Fig. 2. Current as function of probabilities α_1 and β, for $N = 4$ and $L = 40$.

The entry rule for the traffic circle is given by:

– At each time step and with probability α_1 (resp. α_2) a vehicle is injected to the entrance site when this site is empty (Fig. 1(b)).

After this rule is fulfilled a vehicle is generated at the entrance points with the velocity $V_{\max}$ because they have priority, this describes the geometry at the entry of the traffic circle (i.e. in the traffic circle entry angle likely to be reduced to allow higher speed at entry). Therefore entering vehicles drive with their desired speed.

At the off-ramp the rules of extraction are the same between the roundabout and the traffic circle, the exit rules are given by:

– Vehicles already in the circle check the number of empty cells (g_2) of the ring, between it and its desired off-ramp.