# A Novel Two-Lane Roundabout Model with Central Cross Structure

Ke Xu
*Hangzhou Dianzi University*
Hangzhou, Zhejiang, China
xukehdu@outlook.com

Longfei Zhou*
*School of Medicine*
*Duke University*
Durham, USA
longfei.zhou@duke.edu

Fan He
*Shenzhen University*
*Shenzhen, Guangdong*, China
2100325014@email.szu.edu.cn

Siyu Wu
*Nanjing University of Information Science &Technology*
Nanjing, Jiangsu, China
yuiwsy@gmail.com

Haoliang Liu
*Nanjing University of Information Science & Technology*
Nanjing, Jiangsu, China
mortalneo@outlook.com

Fei Teng
*South China University of Technology*
Guangzhou, Guangdong, China
ttengf@163.com

Zehang Li
*Jiangnan University*
Wuxi, Jiangsu, China
1045200417@stu.jiangnan.edu.cn

Yuliang Gai
*Jilin University of Finance and Economics*
Changchun, Jilin, China
13180719799@163.com

Pengfei Liu
*Northern Arizona University*
Flagstaff, Arizona, USA
yunziyaoy@outlook.com

Yifan Mo
*Jiangsu University Jingjiang College*
Zhenjiang, Jiangsu, China
lazorop21@gmail.com

***Abstract*—With the increasing number of family cars, urban traffic congestion has become more and more common, which has a great impact on people's lives. In order to alleviate the traffic pressure caused by traffic congestion, the roundabout came into being. Compared with ordinary intersections, roundabouts are superior in traffic efficiency and traffic control. However, research has found that the number of halts per vehicle at roundabouts has increased relative to ordinary intersections, which means that there is an increased possibility of large-scale congestion and driving conflicts in today's huge traffic flow. This makes it possible to add traffic lights to the roundabout to control traffic flow to alleviate traffic congestion and driving conflicts. This paper aims to improve the traffic model of the ordinary two-lane roundabout and analyze whether different traffic light control methods are conducive to improving the traffic efficiency of the roundabout in the scenario of heavy traffic flow. Four improved models are established and compared with basic two-lane roundabout and signalized intersection. Based on two scenarios with different traffic volume, we analyze these models' performance through multiple evaluation metrics. Results illustrates that roundabout with central cross has the best performance in the two scenarios, and proves that these two traffic light control methods failed to improve the traffic efficiency of roundabout in heavy traffic scenarios.**

***Keywords*—roundabout, traffic light, modeling, simulation**

## I. Introduction

In modern transportation systems, more and more vehicles result in severe traffic congestion, affecting our daily life, modern logistics and human society, significantly and exhaustively. The quality of traffic infrastructure plays an important role in establishing safe and efficient transportation systems. Among different intersections, roundabout occupies the main position. Roundabout models have a significant impact on modern transportation systems in both big cities and small towns. Therefore, so many kinds of roundabouts have been designed, including roundabouts with traffic lights. The main research direction of the roundabout model generally includes three aspects: traffic control method, traffic efficiency and cost. From the perspective of traffic control method, ordinary roundabout is able to avoid the long-time exposure to rear-end conflicts because in the roundabout, the traffic pattern of vehicles has been basically determined, and there is no more complicated traffic situation than ordinary signalized intersections. However, when the roundabout contains multiple lanes, entering and exiting vehicles would probably cause conflicts at the entrance of exit of roundabout. Thus, roundabouts with traffic light set in those entrance and exit come into being. This new traffic control method has a good effect on alleviating the conflict between vehicles at the entrance and exit. The traffic efficiency is a complex aspect to be evaluated. It involves all aspects of the driving vehicle, including driving speed, travel time, number of halts and so on. Therefore, based on this aspect, researchers devote themself to develop roundabout models which have the highest traffic efficiency. From the perspective of cost, ordinary roundabouts have lower maintain and operating cost than signalized roundabout. The main reason is that it doesn't have to provide traffic lights power and maintenance.

When it comes to ways of coping with traffic congestion, Sidina developed three kinds of fluid mechanics model, which provided a method to control the traffic congestion pattern at a roundabout by build an algorithm controlling the traffic signals before the occurrence of congestion [2]. Paper [3] proposed a simulation study based on SUMO that investigates the effect of

*Corresponding author: Longfei Zhou (longfei.zhou@duke.edu)

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speed control at congested arms on overall performance of roundabouts. In [4], a micro-simulation software was utilized to compare the performance of traffic flow at the signalized roundabout in contrast to a four-way signalized intersection, in order to mitigate congestion. Some studies focused on the influence of traffic lights on traffic efficiency of roundabout model. Paper [5] presented the changing regularity of vehicle speed, vehicle headway and vehicle lane change rate in the different flow while crossing the roundabouts with traffic signals and its impact on driver behavior characteristics, used in the technology of video frequency collection and image processing technique. An artificial intelligence-based roundabout traffic control system in [6] was proposed to assist drivers near roundabouts, detect the car from the left side of the roundabout and notify the driver. We noticed that different degrees of conflict will happen in different kinds of lanes in the roundabout with different traffic flow [7]. One method to cope with this was to add traffic lights in roundabouts [8]. A precedence graph was built to optimize the lane marking and timing of signalized roundabouts [9]. Paper [10] developed two fuzzy layers for traffic control in signalized roundabouts. In order to cope with traffic flow unbalance, a stop-line setback method was proposed [11]. Some studies also explored the impact of inserted roundabouts on the main signalized corridor [12], [13]. What' s more, through lowering vehicle speeds and reducing delays, the mini roundabout structure was designed to mitigate traffic conflicts [14]. Simulation of roundabouts and signalized intersections in real cities such as Jeddah and Al-Madinah [15], Hlohovec [16], and Shanghai [17] also made huge breakthrough. Through simulation, the traffic performance at different times roundabouts in Japan were compared based on traffic flow data [18]. In [19], SUMO was proved to be a suitable software for traffic simulation and its development and applications were also presented in [20]. However, there is a lack of general conclusion whether traffic lights are conducive to alleviating traffic congestion in the roundabout under normal scenario.

From subjective experience, roundabouts with traffic lights are perhaps more traffic-efficient than ordinary roundabouts under some specific circumstances because it reduces the chance of conflicts. There is a lack of studies in evaluating the effect of traffic lights when they are added in a roundabout in general situation. In [1], multiple signalized intersection models and roundabout models were built to compare the traffic efficiency under two scenarios(heavy traffic flow and small traffic flow), which illustrated that roundabouts are more efficient than signalized intersections, especially in heavy traffic. This paper can be considered as its follow-up work. Our motivation is to propose a novel and effective roundabout model to better alleviate traffic congestion under heavy traffic flow, and to verify the effectiveness of traffic lights. This paper aims to improve the traffic model of the ordinary two-lane roundabout and analyze whether different traffic light control methods are conducive to improving the traffic efficiency of the roundabout in the scenario of heavy traffic flow. In order to get a conclusion, modeling and simulation method is applied to compare the performance among those roundabout models. There are two main contributions in this paper: (1) We established six models: roundabout with central cross, two roundabouts with central cross with different traffic light time, and roundabout with traffic light at junction, basic two-lane roundabout and signalized intersection under two scenarios and launched X-shaped central cross roundabout model that can effectively alleviate traffic congestion; (2) Based on simulation, we came up with the general conclusions about whether traffic lights are conducive to basic two-lane roundabout: Two traffic light control methods (junction traffic light, central cross traffic light) cannot improve the traffic efficiency of the two-lane roundabout.

The rest of this paper is organized as follows. In Section II, the detailed information about the mainly launched model is displayed in terms of the whole structure, the structure of exits and X central cross, control strategy. In Section III, we propose other models including roundabout with traffic light at junction, roundabout with central cross and traffic light, basic two-lane roundabout, signalized intersection model. In Section IV, two case studies are conducted to test the performance of different models according to multiple metrics. In Section V, conclusions and possible future work are discussed.

## II. The Proposed Roundabout with central cross

### *A. Background*

Given that in the case of heavy traffic flow, there are two main reasons for the decline of vehicle traffic efficiency in the roundabout.

- With the accumulation of travel time, the number of vehicles traveling in the roundabout continues to increase.
- Vehicles towards different directions must drive in the roundabout until they reach the target direction before they can leave the roundabout, which makes vehicles' driving distance in different directions inside the roundabout uneven.

The above two reasons also directly lead to the long-term congestion inside the roundabout.

### *B. Model Overview*

We define a model that combines two-lane roundabouts with central cross and connects the east-west and north-south exits to form an X-shaped central cross, as shown in Fig. 1. With this structure, we are able to divert left-turn traffic from the main traffic at roundabout and direct it into the middle X central cross. This not only reduces the total number of vehicles passing in the roundabout but also shortens the driving distance of left-turn vehicles. The shortened distance $d$ is shown in (1) as below:

$$d = 2S(\pi - 1) \tag{1}$$

In this way, the gap of driving distance of straight, right-turn and left-turn is minimized as much as possible.

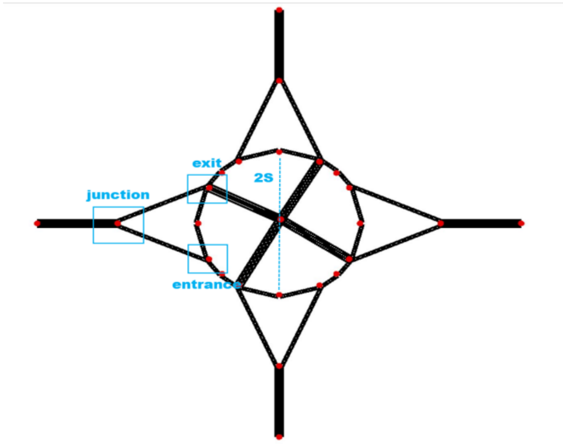



Fig. 1. The whole structure of roundabout model with central cross.

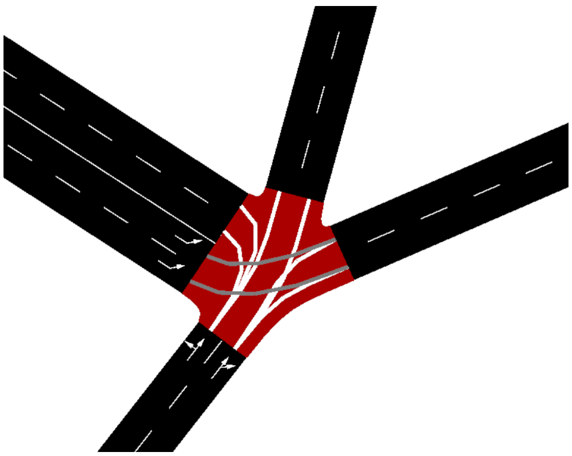


Fig. 2. The connection of lanes at the exit.

### C. Exit and Central Cross Structure

The connection of lanes at the exit is shown in Fig. 2. We stipulate that only left-turn vehicles in four directions are allowed to enter the central cross, and other vehicles are forbidden to enter. Vehicles exiting the central cross are forbidden to turn right and re-enter the roundabout. Vehicles must enter the central cross from the innermost lane, and leave the roundabout from the outermost lane.

The connection of lanes at the X central cross is shown in Fig. 3. Because the function of the central cross is to divert left-turn vehicles and reduce their travel distance in the roundabout, we stipulate those vehicles from four directions of the central cross are only allowed to pass straight through, so that they can quickly reach the exit of the target direction and drive out of the roundabout.

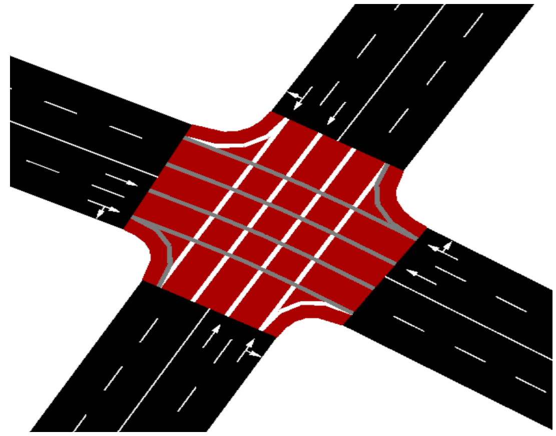


Fig. 3. The connection of lanes at the central cross.

### D. Control Strategy

For the control of vehicles, the model does not contain any traffic lights, the vehicle determines the right of way based on the priority attribute.

The right-of-way of vehicles at the exit is as follows: vehicles driving in the roundabout have the highest priority, vehicles leaving the roundabout from the outermost lane of the roundabout have the next priority, and vehicles leaving the roundabout from the central cross have the lowest priority. And the right-of-way of vehicles at the entrance is that vehicles driving in the roundabout have the highest priority, vehicles entering the roundabout have the next priority.

For vehicles' right-of-way at central cross, the default acquisition method is adopted, that is, the vehicles driving on the lane with the highest position get the right-of-way according to the priority, speed, and lane number of the driving lane.

At the junction, vehicles making U-turn have the lowest priority.

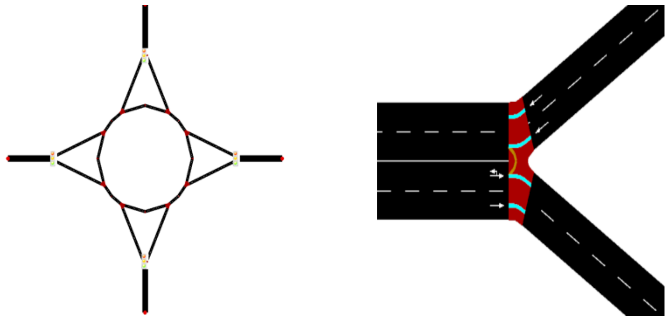
## III. Related Models

On the basis of the two-lane roundabout model, we also define two roundabout models with central cross with different traffic light time and a roundabout model with traffic light at junction. These models are used to analyze whether different traffic light control methods are conducive to improving the vehicle traffic efficiency in roundabout.

### A. Roundabout with Traffic Light at Junction

The model structure is shown in Fig. 4(a). Compared with the X-shaped central cross roundabout model, this model removes the central cross and adds traffic lights at junction in four directions to control traffic flow. The settings of other parts of the model are consistent with the X-shaped central cross roundabout model.

The connection of lanes at junction is shown in Fig. 4(b), and vehicles entering the direction of the roundabout are allowed to make U-turns in the innermost lane. The total duration of traffic lights is set to 46 seconds, the green light for entering and exiting the roundabout is 20 seconds, the yellow light is 3 seconds, and the duration of the traffic lights at four junctions is consistent.



(a) (b)

Fig. 4. Roundabout with traffic light at junction, including: (a) whole structure of the roundabout model; (b) junction in the roundabout model.

### *B. Roundabout with Central Cross and Traffic Light*

The model structure is shown in Fig. 5. On the basis of the X-shaped central cross roundabout model, traffic light control is adopted at central cross, and junctions in four directions are controlled by the same traffic light duration as the roundabout model with traffic light at junction.

We defined two models with traffic light duration of 46 seconds and 26 seconds at central cross, respectively. In the first model, the green light for straight is 20 seconds and the yellow light is 3 seconds. Correspondingly, the second model has a straight green light for 10 seconds and a yellow light for 3 seconds. The settings of other parts of the model are consistent with the X-shaped central cross roundabout model.

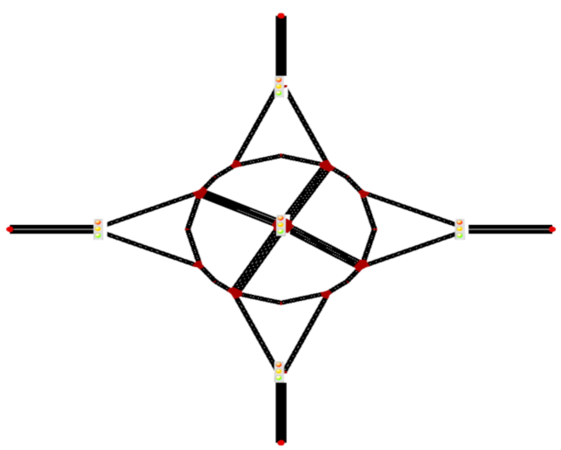


Fig. 5. The whole structure of roundabout with central cross and traffic light.

### *C. Basic Two-lane Roundabout*

The model structure is shown in Fig. 6. This model is obtained by removing the central cross on the basis of the X-shaped central cross roundabout model. The traffic flow is controlled by the vehicle's default right-of-way acquisition method rather than traffic lights. The setting of other parts of the model are consistent with the X-shaped central cross roundabout model. We use it as the basic roundabout model to compare it with improved models above.

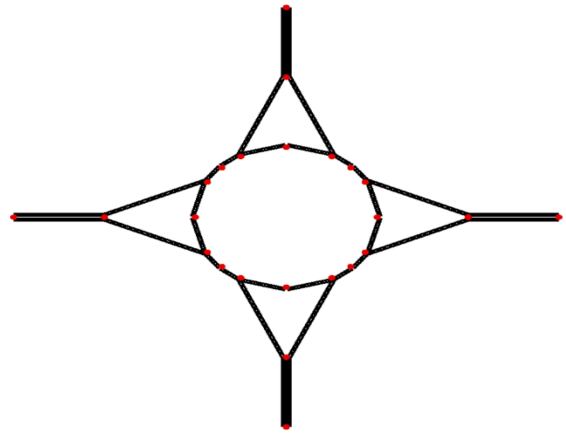


Fig. 6. The whole structure of basic two-lane roundabout.

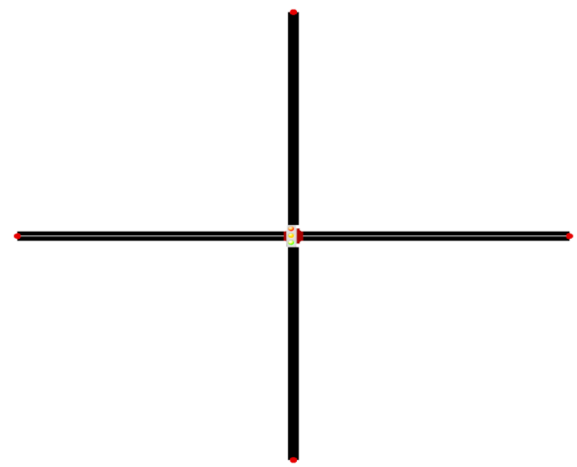


Fig. 7. The whole structure of signalized intersection.

### *D. Signalized Intersection*

The model structure is shown in Fig. 7. This model is a bidirectional four-lane intersection model defined on the basis of [1], using traffic lights to control the driving state of vehicles in the intersection.

There are four driving states of the vehicle: state 1 allows vehicles in the east-west direction to go straight and turn right, and the green light duration is 20 seconds; state 2 allows vehicles in the east-west direction to turn left and U-turn, and the green light duration is 10 seconds; state 3 allows vehicles in the north-south direction to go straight and right turn, the green light duration is 20 seconds; state 4 allows vehicles in the north-south direction to turn left and U-turn, and the green light duration is 10 seconds.

## IV. Simulation

### *A. Scenarios and Models*

We apply two different scenarios to evaluate and analyze the performance of the above six models. Based on [1], the average flow rate per time matrix of the vehicle arrival model is used to describe the traffic flow. We define the vehicle arrival rate as the sum of elements of the average flow rate per time matrix. The first is the heavy traffic flow scenario, which is applied to Model

1-6. The the average flow rate per time matrix is shown in (2) as below:

$$P(model_{1:6}) = \begin{bmatrix} 0.05 & 0.25 & 0.25 & 0.25 \\ 0.25 & 0.05 & 0.25 & 0.25 \\ 0.13 & 0.13 & 0.03 & 0.13 \\ 0.13 & 0.13 & 0.13 & 0.03 \end{bmatrix} \quad (2)$$

The vehicle arrival rate is 2.44 vehicles/second. The corresponding second scenario is the small traffic flow scenario, which is applied to Model 7-12. The average flow rate per time matrix is shown in (3) as below:

$$P(model_{7:12}) = \begin{bmatrix} 0.01 & 0.05 & 0.05 & 0.05 \\ 0.05 & 0.01 & 0.05 & 0.05 \\ 0.03 & 0.03 & 0.01 & 0.03 \\ 0.03 & 0.03 & 0.03 & 0.01 \end{bmatrix} \quad (3)$$

The vehicle arrival rate is 0.52 vehicles/second.

We define Model 1 and Model 7 as roundabout model with X central cross (RCC); Model 2 and Model 8, Model 3 and Model 9 as roundabout model with central cross and signal (RCCS); Model 4 and Model 10 as roundabout model with signal at junction (RS); Model 5 and Model 11 as basic two-lane roundabout model (BR); Model 6 and Model 12 as signalized intersection model (SI).

The parameters of simulation models are shown in Table I. We use SUMO to conduct simulations for each model under two scenarios of large and small traffic flow. Each model generates traffic flow according to the corresponding vehicle arrival model, and sensors in the model are used to record the traffic data.

### B. Sensor Development

In order to collect data from simulation results to evaluate model performance, we set up sensors on 16 lanes in four directions to collect traffic data about vehicles' entering and exiting the model. A pair of entry points and exit points are arranged adjacent to each other at the beginning of each lane in each direction. Sensors are placed close to the entry and exit points respectively. Therefore, each model has a total of 16 sensors to collect data. The sampling frequency of each sensor is uniformly set to 100Hz.

### C. Evaluation Metrics

We evaluate model performance by comparing the following 5 metrics based on [1]:

- Number of passing vehicles over time: The accumulation over time of the total number of vehicles that have passed the area.
- Mean speed of all passing vehicles: The average speed of all vehicles that have passed the area.
- Mean number of halts per vehicle: The average number of halts per vehicle that have passed the area. We define that when the vehicle's speed is lower than the minimum speed threshold ((5/3.6)m/s) for a travel time higher than the time threshold (1s), it is regarded as a halt.
- Mean time-loss per vehicle: The average time-loss for all vehicles that have passed the area. Time loss is defined as the difference in travel time when the vehicle's driving speed is lower than the ideal driving speed, that is, the difference between the ideal driving time and the actual driving time.
- Total time for all vehicles to pass: The sum of travel times for all vehicles that have passed the area.

TABLE I.

PARAMETERS OF SIMULATION MODELS

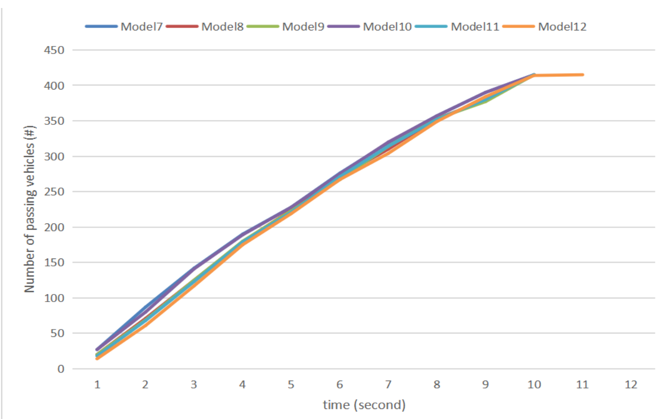
| **Model** | **Type** | **Central cross** | **Traffic light at junction** | **Traffic light at central cross** | **Traffic light duration (T1、T2、Ty/T1、T2、T3、T4、Ty)** | **Vehicle arrival rate** |
|---|---|---|---|---|---|---|
| Model1 | RCC | √ | × | × | N/A | 2.44 |
| Model2 | RCCS | √ | √ | √ | 20,20,3 | 2.44 |
| Model3 | RCCS | √ | √ | √ | 10,10,3 | 2.44 |
| Model4 | BR | × | √ | × | 20,20,3 | 2.44 |
| Model5 | RS | × | × | × | N/A | 2.44 |
| Model6 | SI | N/A | N/A | N/A | 20,10,20,10,3 | 2.44 |
| Model7 | RCC | √ | × | × | N/A | 0.52 |
| Model8 | RCCS | √ | √ | √ | 20,20,3 | 0.52 |
| Model9 | RCCS | √ | √ | √ | 10,10,3 | 0.52 |
| Model10 | BR | × | √ | × | 20,20,3 | 0.52 |
| Model11 | RS | × | × | × | N/A | 0.52 |
| Model12 | SI | N/A | N/A | N/A | 20,10,20,10,3 | 0.52 |

### D. Results and Analysis

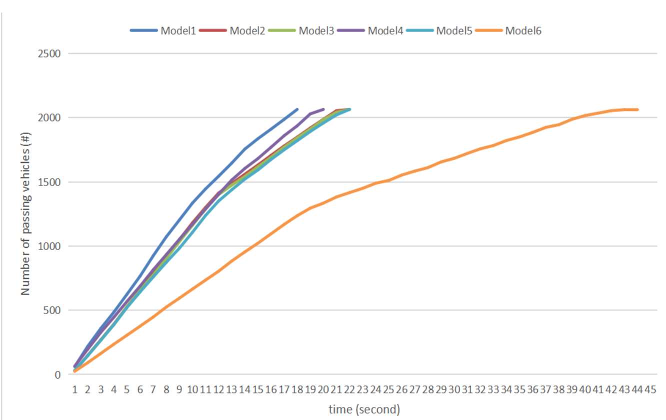
We calculate five evaluation metrics based on the data recorded by sensors. Then we obtain simulation results of different models to compare these models' performance in aspects of multiple evaluation metrics including the number of passing vehicles over time, mean speed of passing vehicles, mean number of halts per vehicle, mean time-loss per vehicle and total time for all vehicles to pass, as shown in Fig. 8, Fig. 9 and Fig. 10.

*1) Number of Passing Vehicles Over Time:* The cumulative curve of the total number of vehicles that have passed the model over time for Model 1-6 is shown in Fig. 8(a). The total number of vehicles that have passed each model is 2064. The results indicates that Model 1 has the best performance based on the number of passing vehicles over time, so Model 1 outperforms other five models in terms of vehicle traffic efficiency. The reason why Model 1 outperforms the second-best performing Model 4 is that all left-turn vehicles entering the roundabout will pass through the central cross but straight and right-turn vehicles will not enter it. Thus making left-turn vehicles in four directions divert from the main traffic flow in roundabout, greatly reducing the traffic flow in the roundabout and then alleviating congestion. Comparing Model 1 with Model 2 and Model 3, it shows that after adding traffic light control at central cross and junctions, the traffic efficiency of X-shaped central cross roundabout model does not increase but decreases. From the worst performance of Model 5, it can be seen that the addition of traffic lights at the junction further aggravates the congestion at the roundabout entrance and exit. We can see that the differences between Models 2, 3, and 5 are slight, indicating that in the case of traffic light control at the junction, adding central cross has almost no effect on the traffic efficiency. Model 6 performs significantly worse than other four roundabout models.

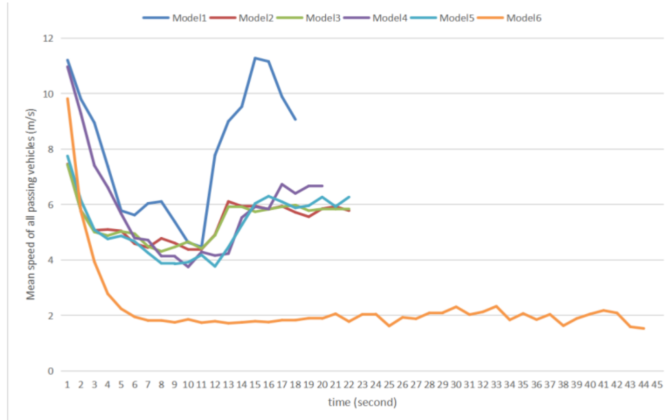
Fig. 8(b) shows the cumulative curve of the total number of passing vehicles over time for Model 7-12. In this scenario, the total number of vehicles that have passed each models is 415. Comparing these five models with Model 1-5, it can be seen that Model 7-11 have little difference in traffic efficiency. Nonetheless, we can see that Model 11 performs the worst among the roundabout models and Model 12 performs the worst relative to the overall models.



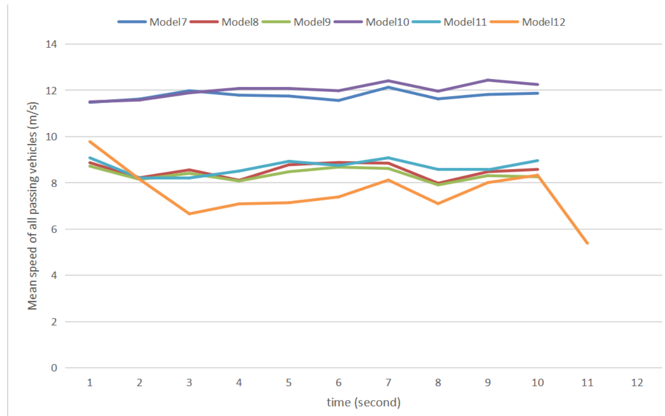

(a)




(b)




(c)




(d)

Fig. 8. Simulation results, including: (a) Number of passing vehicles over time (Model 1 – 6); (b) Number of passing vehicles over time (Model 7 – 12); (c) Mean speed of all passing vehicles (Model 1 – 6); (d) Mean speed of all passing vehicles (Model 7 – 12).

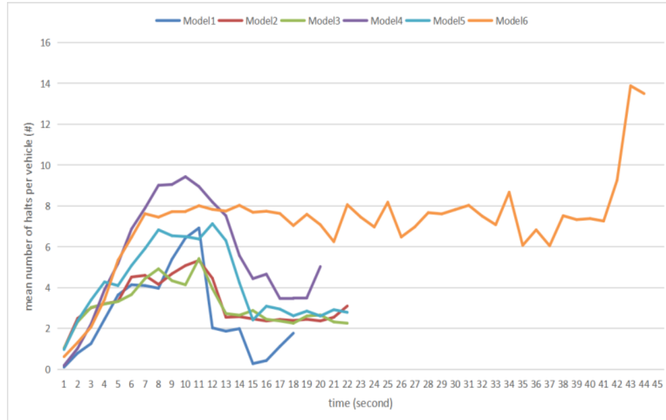
*2) Mean Speed of Passing Vehicles:* Fig. 8(c) shows the mean speed curve of all passing vehicles for Model 1-6. We can see that the initial mean speed of Model 1,4 is higher than that of Model 2,3,5, indicating that in the case of relatively small traffic flow, traffic light control will reduce the speed of vehicles in the roundabout. The mean speed of the 5 roundabout models continued to decrease before 1100 seconds, because the traffic flow in the roundabout continued to increase, reaching the peak traffic period, so as to cause congestion. The mean speed of Model 1 is higher than other models because it has the shortest simulation time. Its speed drops at 1100 second because of congestion in the central cross, but the speed increases significantly and much higher after the traffic peak compared with other four roundabout models. It is shown that the X-shaped central cross allows left-turn vehicles to exit the roundabout faster. In contrast, the results of Model 2, 3 have almost no difference. The speed does not increase significantly after the peak traffic period, and it tends to be saturated after 1300 seconds. The main reason is that traffic lights control at the junction makes the traffic flow from junction to roundabout maintain within a relatively large and stable range. On the contrary, there are relatively few vehicles in the roundabout, and the speed of left-turn vehicles has not been improved due to traffic lights control. The mean speed of Model 5 is always lower than that of Model 4, indicating that traffic lights control at the junction failed to increase the speed of the vehicle, and instead aggravates the congestion. The mean speed of Model 6 continues to drop until it reaches saturation at 600 seconds. The reason for the subsequent fluctuation of the curve is the small-scale congestion at the intersection.

Fig. 8(d) shows the mean speed curve of Model 7-12 of passing vehicles. Compared with Model 1-6, their speed changing are not drastic and they are faster. The speed of Model 7,10 has been maintained at around 12m/s, which is much higher than Model 8,9,11 with traffic light control. The mean speed of Model 7 is lower than that of Model 10, indicating that the diversion effect of central cross is not obvious in the small traffic flow scenario. The mean speed of model 12 is slower than that of roundabout models after 200 seconds.

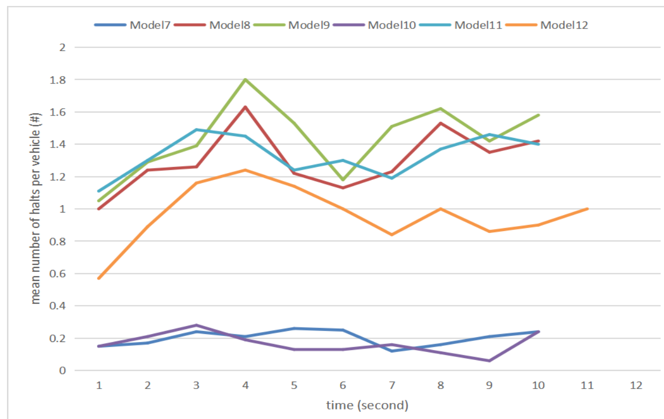
*3) Mean Number of Halts per Vehicle:* Fig. 9(a) shows the curve of the mean number of halts per vehicle of Model 1-6. We can see that the number of halts of Model 4 after 500 seconds is significantly higher than that of other models, indicating that with the increase in traffic flow, due to the lack of effective traffic control methods, constant congestion happens when the traffic peak period arrives. In contrast, Model 1 has fewer halts, showing that the central cross can effectively relieve the congestion in the roundabout. At 1200 seconds, the number of halts of Model 1 is drastically declined to a lower level than other models. We discover that because vehicles in the central cross have the lowest priority, they can only drive out of the central cross after all vehicles in the roundabout have passed. This will cause the traffic at the central cross to be congested at the exit. When congested vehicles exit the central cross, the model will return to its normal traffic state. Compared with Model 4, Model 2,3,5 have a smaller number of halts, indicating that traffic lights can effectively control the driving and stopping of vehicles in the roundabout. Model 2,3 has a smaller number of halts than Model 5, indicating that the vehicle driving state is more effectively improved after adding traffic lights controlled central cross. Model 6 has fewer number of halts than Model 4 before 1300 seconds, but it becomes greater after 1300 seconds than other roundabout models.

Fig. 9(b) shows the curve of the mean number of halts per vehicle of Model 7-12. We can see that in small traffic flow scenario, traffic lights control increases the number of halts per vehicle. The results of Model 7 and Model 10 are almost the same. Since the traffic flow is small, there is little congestion at the exit, indicating that vehicles in the central cross and roundabout are less affected by the traffic priority. Model 12 has a smaller mean number of halts compared to Model 8, 9, and 11.

*4) Mean Time-Loss per Vehicle:* Fig. 9(c) shows the curve of the mean time-loss per vehicle of Model 1-6. We find that Model 1 performs the best, benefit from to the diversion effect of the central cross. Due to the effect of traffic lights, the initial time loss of Model 2,3,5 appears from 20 seconds and is greater than that of Model 1,4. Compared with Model 2,3, the results of Model 1 do not remain relatively stable but fluctuates after 1200 seconds. The reason is that the control method of obtaining the right of way based on the traffic priority is not similar to that of traffic lights which follows certain pattern. The curve trends of Model 5 and Model 4 are almost the same after the peak traffic period, indicating that traffic lights control effect at the junction is almost the same as the priority control after that period. Model6 has the worst performance.




(a)

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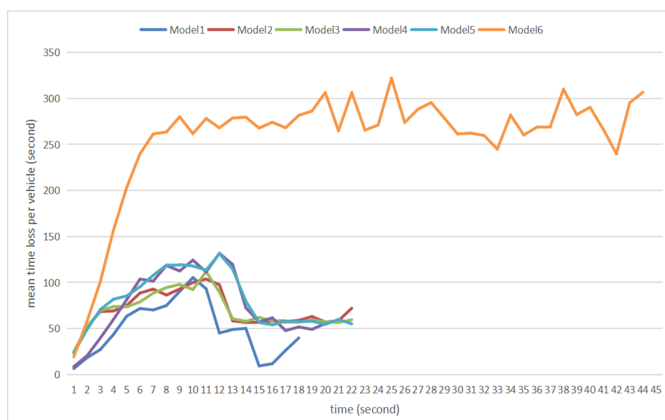


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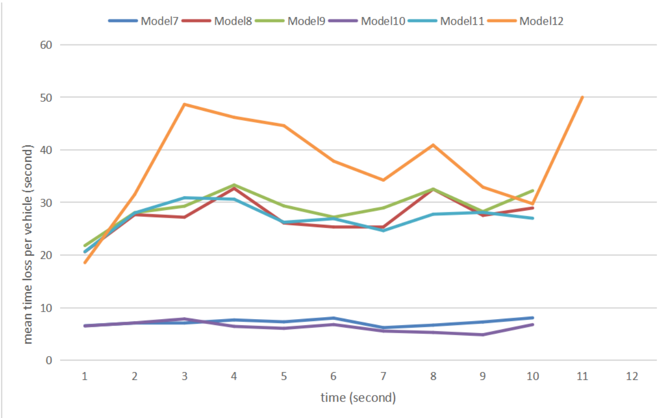


(d)

Fig. 9. Simulation results, including: (a) Mean number of halts per vehicle (Model 1 – 6); (b) Mean number of halts per vehicle (Model 7 – 12); (c) Mean time-loss per vehicle (Model 1 – 6); (d) Mean time-loss per vehicle (Model 7 – 12).

Fig. 9(d) shows the curve of the mean time-loss per vehicle of Model 7-12. It can be seen that Model 7,10 without traffic light control have lower time-loss in the small traffic flow scenario. Model 9 has higher time-loss than Model 8. Model 12 performed the worst overall.

*5) Total Time for All Vehicles to Pass:* Finally, we compare the total time for all vehicles to pass of the 12 models, as shown in Fig. 10. It is obvious that RCC (Model 1, 7) takes the shortest time for all vehicles to pass under two scenarios of large and small traffic flow, which takes 1669 seconds under heavy traffic flow and 489.55 seconds under small traffic flow. RCCS (Model 2,8 and Model 3,9) has no significant difference in results of large and small traffic flow scenarios. RS (Model 5,11) has the longest total travel time in the roundabout model under two scenarios, 2732.38 seconds and 709.15 seconds, respectively. SI (Model 6, 12) has the longest total vehicle travel time under two scenarios, 13038.32 seconds and 854.53 seconds, respectively.

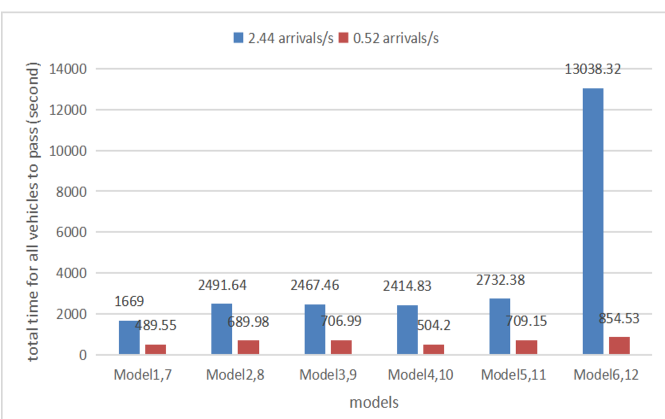


Fig. 10. Comparison of total time for all vehicles to pass different intersections.

## V. CONCLUSION

Based on the improvement of the ordinary two-lane roundabout, this paper proposes four improved two-lane roundabout models and compares their performance based on the SUMO simulation. According to the analysis of five evaluation metrics under the two scenarios of large (vehicle arrival rate is 2.44 vehicles per second) and small (vehicle arrival rate is 2.44 vehicles per second) traffic flow, we build five roundabout models and one intersection model to compare their performance through different evaluation metrics (i.e., number of passing vehicles over time, mean speed of passing vehicles, mean number of halts per vehicle, mean time-loss per vehicle, and total time for all vehicles to pass). The roundabout with X-shaped central cross has the best performance, and we regard it as the main improvement model. It is proved that two traffic lights control methods (junction traffic light, central cross traffic light) cannot improve the traffic efficiency of the two-lane roundabout. These improved models are intended to be used as guidance to design roundabout models in future traffic systems to improve traffic efficiency to cope with complex and volatile traffic environments. In the future, we will study the traffic efficiency of these roundabout models under different traffic flow scenarios in the real world based on simulation. Another possible future work is to model and simulate complicated real world roundabouts.

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