A shortest job first algorithm for minimizing the average delay of vehicles at the un-signalized intersection

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***Abstract*—To develop smart transport intersection vehicular traffic control methods in the autonomous vehicle era, more emphasis is placed on non-signalized junction scenarios using interconnected vehicle technologies. We provide an efficient scheduling technique to reduce the average delay at non-signalized intersections and optimize intersection throughput while avoiding collisions. The collision-free traffic flow scheduling challenge is first formulated, and then the junction area is divided into eight collision segments. We distinguish the three types of vehicles based on their length car (5m), bus (10m), and truck (15m). In addition, an ideal method is provided to compute the optimal entrance time of each autonomous automobile and improve the intersection management efficiency. The Shortest Job First scheduling algorithm is used to the entire degree achievable. Finally, we performed a series of tests to see how well our suggested model and method performed. According to simulation data, the suggested (SJF) algorithm may effectively minimize traffic delays and is far more effective than first-come-first-serve scheduling procedure.**

Keywords— Un-signalized intersection, automated vehicle, SUMO, shortest job first algorithm, Collision-Free

I. Introduction

Traffic congestion has become a significant concern in large metropolitan areas because of the increasing population and traveling demand. Thus, considerable interest in the field of Intelligent Traffic Systems (ITS) has been noted in the last two decades. And many prominent studies have been carried out to optimize road networks, boost road capability, left go waiting zones, inconstant approach lanes, complex lane projects, and interconnected waiting zones [1]. Cooperative, Connected, and Automated Mobility (CCAM) is the most effective solution for enhancing road safety and optimizing traffic performance [2]. Crossing intersections is a vital stage where more complicated circumstances can occur as CAVs coming from multiple directions, and it is hard to maintain traffic safety and transportation efficiency. The preceding study presented the intersection scheduling to solve the collision problem; this method works based on first-come-first-go (FCFG). But this method is not more efficient for minimizing the average delay at the un-signalized intersection. The Intersection scheduling center (ISC) tended to maximize all vehicles' overall efficiency with higher valuations. This study introduced a new mechanism to prevent collision and minimize the average delay time at the signal-free intersection.

In this mechanism, the Intersection scheduling center gave priority to the shortest crossing time vehicles. In this scenario, we have some assumptions such as vehicles' acceleration or deceleration, speed limitations. Vehicles entering the junction in the same direction are unable to bypass each other. Left-turning vehicles should avoid collision with the approaching vehicles at the intersection. In the shortest job mechanisms, the detector will detect every vehicle's process time and report to the intersection scheduling center; after receiving the information, ISC prioritizes the fastest process time vehicles. In processor discipline, SJF positions for Shortest Job First. It labels a method of arrangement processes. The choice is complete according to the projected passage time of the vehicle. In this technique, the scheduler will let the lowest crossing time in the line go primary. Here are two types of this system: a preemptive type and a non-preemptive type. An automobile that has taken controller of the crossing path does not require dispensation until the track is ended. The preemptive kind, also called SRTF, Shortest Remaining Time First, is more stretchy. If a vehicle whose completing time is quicker than the rest of the crossing time of the vehicles entering the queue, it will take its place. Then there is a context switch, and the processing of the intervallic vehicles will start again later where it was left. SJF is one of the greatest gainful systems for dropping the time consumed in the crossing queue. Though, it is rarely used outside specialized situations because it needs an exact estimation of all processes' completing time to come for dispensation.

Current technical advances in identifying, calculating, and radio communication have placed the basis for the growth of a method based on Linked and Automatic Vehicles (CAVs) called Cooperative, Connected, and Automated Mobility (CCAM) [3]. Several research efforts in the literature have considered centralized control with the application of Vehicle-to-Everything (V2X) knowledge, sensing and calculating resources can be shared, and vehicle information, including speed, acceleration, origin, and destination, can be obtained before the vehicle enters the

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intersection [4]. The CAV system is designed to ensure driving safety, improve road traffic efficiency, save energy, decrease emissions [5], and minimize the overall length of overlapping CAV trajectories within the intersection[6]. Autonomous driving is an up-and-coming solution to facilitate the transformation of intelligent transport systems with improved efficiency and improved safety [7],[8].

This paper highlights the drawback of the first-com-first-go (FCFG) base scheduling algorithm and proposes the Shortest job first procedure (SJF). The major drawback of first-come-first-go (FCFG) is that ambulance. Fire brigade vehicles may be trapped in a complicated scenario and not appropriate for minimizing the average delay at the un-signalized intersection, so we have introduced the Shortest job first system (SJF).

The rest of the paper is set out as follows. The related study and complete description of the Shortest job first-based method are presented in section II. In section III, we describe the configuration of the intersection where the shortest process vehicles will pass the un-signalized intersection on a priority basis. In section IV, we describe the Shortest job first algorithm (SJF) mechanism. We run the Simulation and execute the performance evaluation in area V. Ultimately, in section VI, we drive the conclusion and guide upcoming work.

II. Related Work

This segment reviews the associated work focusing on the scheduling algorithms of the un-signalized intersection, Which is very significant in our context, approaches autonomous vehicle synchronization, and analyzes the shortest job first mechanism benefits at the signal-free intersection.

In the scheduling algorithms, ISC creates an optimum passing technique, allowing cars to cross the intersection safely and effectively. The efficacy of signal timing has been shown by Fethi Belkhouche in his literature[9]. By exchanging real-time positioning and speed information with signal controllers, connected vehicle technology allows for optimization. This data aids in estimating the arrival time, travel time, and duration of queues at intersections for connected and unconnected vehicles. Only connected and autonomous vehicles are included in this article. Au and Stone have created an AIM-compatible planning-based autonomous vehicle motion controller[10]. The first-come-first-serve (FCFS) algorithm used in AIM is improved in this research by better estimating vehicle arrival time and speed.

On the other hand, the improved algorithm cannot ensure that trajectories are optimal. The AIM has been extended to a multi-intersection network by Hausknecht et al. [11]. Before submitting their reservation demands, vehicles send a signal to intersection managers to update the traversal time of incoming vehicles. In response, the intersection planner uses a time-based navigation strategy to convey a minimum traversal distance to each vehicle. In this paper, the shortest job first scheduling approach is applied to determine the best vehicle options at intersections to reduce the average delay.

CAVs are assigned reservations by autonomous intersection management (AIM), obtaining information from all CAVs on each approaching path. This research formulated the conflict-point separation problem as a mixed-integer linear program[12]. Lee and Park.[13] propose a coordinated, collaborative intersection management system that reduces the cumulative length of intersected trajectories. Since their suggested formulation is complicated, they solved the problem using genetic algorithms. Despite this, since there are no explicit restrictions to prevent collisions, the solutions end in clashes. As a result, they must have a rescue mode to avoid crashes by avoiding cars moving in opposite directions. This technique cannot find suitable collision-free trajectories due to genetic algorithms and the use of the recovery mode. Hassan and Rakha.[14] formulated a heuristic method for communications between autonomous vehicles approaching an un-signalized intersection that prioritizes approaches with higher traffic volumes to minimize delays. While this method can be solved in real-time, it does not provide optimum trajectories. Autonomous intersection management approaches follow the first-come-first-serve (FCFS) concept to schedule a moving sequence for vehicles; we can see that they still have a low computing latency.

To sum up, the optimum solution is more effective than the autonomous intersection management reservations method in terms of moving strategy, but it has higher time complexity. We introduced a shortest job first algorithm for minimizing the average delay at the signal-free intersection.

III. The Intersection Model

This segment builds a hierarchical vehicle-level program to determine desired non-conflicting routes for a CAV. Fig. 1 reveals an integrated four-leg intersection with three special lanes on each approach for (i) left-turns, (ii) right-turn and (iii) go-straight. As vehicles in the turn-right lane do not disturb vehicles in other lanes, so we neglect this lane. The remaining eight lanes are marked with an I.D.

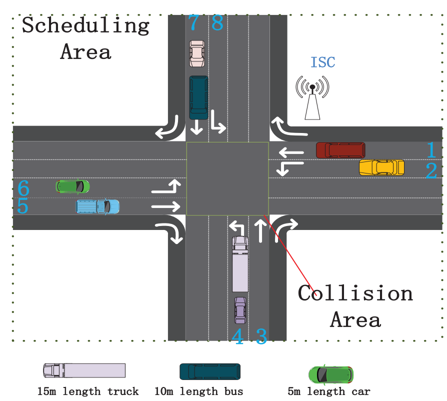


Fig. 1. The Scenario of an un-signalized intersection C.S.s and the conflicts

The i[th] lane is marked as L_i. The straight lane is marked by odd figures such as L_1 and the left-turn lane is characterized by even figures such as L_2. The intersection area has two parts: the collision area (C.A.) and the scheduling area (S.A.). The scheduling area is the excellent coordination area of the ISC, through which the ISC schedules a passing plan for vehicles' status information collected. At the intersection, the

Collision Area is the central area where vehicles can congest or crash

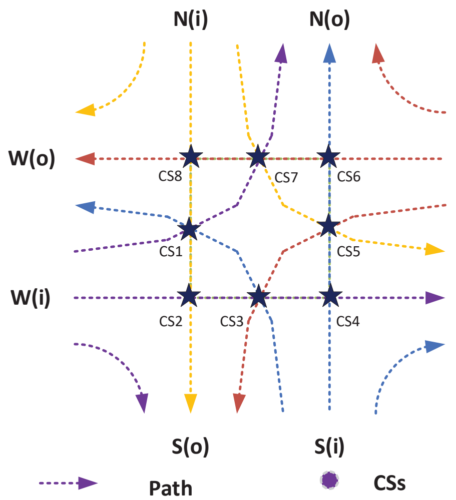


Fig. 2. C.S.s conflicts

We divide the collision area into eight collision parts, each of which is designated by the index C_iWhere I denote the number of collision parts, we will examine the joint segments that separate lanes can travel across based on the separation of dispute sections. In the case of lane L_8 and L_3, the covered dispute segment is C_5. In order to compute the time duration of CAVs for each conflict section, we initially determine the length of dissimilar routes. If an intersection's width is w and each lane's width is a, then the trajectories length for each collision section are different. Assume that the speed of the vehicles is constant at v. Using fowling equations, we can measure the travel time of each dispute segment.

We can find traveling time for going straight by fowling equations.

$$CS_a = W - (t_a + \bar{t_a})\left\{\frac{2a}{v} + \frac{7a}{2v}\right\} \quad (1)$$

$$CS_b = W - (t_b + \bar{t_b})\left\{\frac{a}{2v} + \frac{7a}{2v}\right\} \quad (2)$$

$$CS_c = W - (t_c + \bar{t_c})\left\{\frac{a}{2v} + \frac{2a}{v}\right\} \quad (3)$$

We can find traveling time for turning left by fowling equations.

$$CS_a = W - (t_a' + \bar{t_a'})\left\{\frac{\pi}{4} \times \frac{2a}{v}\right\} \quad (4)$$

$$CS_b = W - (t_b' + \bar{t_b'})\left\{\frac{\pi}{4} \times \frac{a}{2v}\right\} \quad (5)$$

Allocate the entering and exit time $T = (t_a, t_b, t_c)$, $\bar{T} = (\bar{t}_a, \bar{t}_b, \bar{t}_c)$ for going straight and $T' = (t_a, t_b)'$, $(\bar{T'} = \bar{t_a'}\bar{t_b'})$ for turning left to the collisions segments and assign $\lambda_{i,k}$ as the time tenancy of the vehicle in i_{th} lane and k_{th} conflict segment. We could calculate their vehicle's time occupancy by using their collision area entry and exit time, such as $\lambda_{1,8} = W - (t_c + \bar{t_c})\left\{\frac{a}{2v} + \frac{2a}{v}\right\}$. At the same time, two vehicles cannot pass the same collision segment. For example

$$\lambda_{1,6} \cap \lambda_{3,6} = \left(W - (t_a + \bar{t_a})\left[\frac{2\alpha}{v} + \frac{7a}{2v}\right]\right) \cap \left(W - (t_c + \bar{t_c})\left[\frac{\alpha}{2v} + \frac{2a}{v}\right]\right) = \emptyset \quad (6)$$

We have some assumptions to fulfill our simulations. The communication method is equipped with the Intersection Scheduling Center (ISC) deployed at the intersection. With accurate real-time output, the ISC will allocate an entry time for each arriving CAV. All the vehicles in the situation are CAVs. CAVs should automatically send their status information (such as location, speed, acceleration, and priority) to the ISC. Vehicles will retain their lane and velocity until the ISC returns the entry time, and in this analysis, overtaking is not permitted. Communication delay is not considered in this study.

IV. SHORTEST JOB FIRST-BASED SCHEDULING ALGORITHMS

There are many types of scheduling algorithms, but we will comparison our planned scheduling algorithm with a fundamental scheduling system called First-come-first-serve (FCFS) [33]. In this scheduling algorithm arriving time is considered at each scheduling step. This strategy will solve the passing-through question with less time difficulty in specific easy scenarios. But in more complicated situations, such as cars with multiple priorities, the approach will fail. Our main goal is to minimize the average delay at the intersection, proposing the shortest job first system (SJF). The Shortest job first algorithm (SJF) has the lowest execution time. Its process is having the shortest passing time at the intersection grows high importance and executes at first by the junction. The residual Vehicles wait for the execution throughout this time, and lastly, the Vehicles that have the maximum execution time will be performed at the end. The criteria of the Shortest Job First (SJF) scheduling system is that it processes the minor task first. We gave an example to verify the FCFS algorithm and SJF. There are four vehicles with different lengths and different passing times at the intersection to investigate.

TABLE I. FCFS SCHEDULING ALGORITHM

$V.I.D$	$V.D$	$A.T.$	$P.T$	$C.T.$	$T.A.T$	$W.T.$
v_1	5m	0s	1s	1s	1	0
v_2	15m	0.1s	3s	4s	3.9	0.9
v_3	5m	0.5s	1s	5s	4.5	3.5
v_4	5m	1s	1s	6s	5	4

Avg. Waiting Time = (0+0.9+3.5+4)/4

2.1s

TABLE II. SHORTEST-JOB-FIRST SCHEDULING ALGORITHM

$V.I.D$	$V.D$	$A.T.$	$P.T$	$C.T.$	$T.A.T$	$W.T.$
v_1	5m	0s	1s	1s	1	0
v_2	15m	0.1s	3s	6s	5.9	2.9

v_3	5m	0.5s	1s	2s	1.5	0.5
v_4	5m	1s	1s	3s	2	1

Avg. Waiting Time = (0+2.9+0.5+1)/4

1.1s

Before implementing our proposed algorithm, we first address the model's objective function focused on the passing delay time, and the required parameters for the model are illustrated. We will find the distance between detectors and conflict segments for each vehicle.

$$\boldsymbol{d_c} = \frac{\mathbf{3600} \times \boldsymbol{t_c} \times \boldsymbol{Q_c}(\mathbf{1}+\boldsymbol{\delta_C})}{\boldsymbol{CT}} \qquad (7)$$

$$\mathit{If}\, \boldsymbol{v_{Car}} \geq \mathit{10km/h,\ then}\ \boldsymbol{Q_c} = \mathbf{0}$$

$$\boldsymbol{d_b} = \frac{\mathbf{2700} \times \boldsymbol{t_b} \times \boldsymbol{Q_b}(\mathbf{1}+\boldsymbol{\delta_b})}{\boldsymbol{CT}} \qquad (8)$$

$$\mathit{If}\, \boldsymbol{v_{bus}} \geq \mathit{7.5km/h,\ then}\ \boldsymbol{Q_b} = \mathbf{0}$$

$$\boldsymbol{d_t} = \frac{\mathbf{1800} \times \boldsymbol{t_t} \times \boldsymbol{Q_t}(\mathbf{1}+\boldsymbol{\delta_t})}{\boldsymbol{CT}} \qquad (9)$$

$$\mathit{If}\, \boldsymbol{v_{truck}} \geq \mathit{5km/h,\ then}\ \boldsymbol{Q_t} = \mathbf{0}$$

Where $\boldsymbol{T}$ represents the proposed approaching time of $\mathbf{CAV}_i$ at the intersection, $\boldsymbol{t_c}, \boldsymbol{t_b}, \boldsymbol{t_t}$, represents the real approaching time of $\mathbf{CAV}_i$ at the intersection, and $\boldsymbol{C}$ represents the proposed capacity of $\mathbf{CAV}_i$. $\boldsymbol{d_c}, \boldsymbol{d_b}, \boldsymbol{d_t}$ represents the distance between the CAV and the Collision Area, $\boldsymbol{Q_c}, \boldsymbol{Q_c}$, $\boldsymbol{Q_c}$ represents the initial queue at the start of the Scheduling Area and $\boldsymbol{\delta_C}, \boldsymbol{\delta_b}, \boldsymbol{\delta_t}$ Represents the time delay of car, bus, and truck, respectively.

From the above equation, we can know the distance and time of all the vehicles and how long it will take to reach the intersection. We set the speed of all vehicles according to their length and type, such as car, bus, and truck. According to proposed scheduling algorithms, we prioritized the shortest passing time vehicles to reduce the delay of all vehicles.

$$\boldsymbol{\delta_c} = \mathbf{1} - \frac{\boldsymbol{d_c}(\boldsymbol{CT})}{\mathbf{3600} \times \boldsymbol{Q_c} \times \boldsymbol{t_c}} \qquad (10)$$

$$\boldsymbol{\delta_b} = \mathbf{1} - \frac{\boldsymbol{d_c}(\boldsymbol{CT})}{\mathbf{2700} \times \boldsymbol{Q_b} \times \boldsymbol{t_b}} \qquad (11)$$

$$\boldsymbol{\delta_c} = \mathbf{1} - \frac{\boldsymbol{d_c}(\boldsymbol{CT})}{\mathbf{1800} \times \boldsymbol{Q_t} \times \boldsymbol{t_t}} \qquad (12)$$

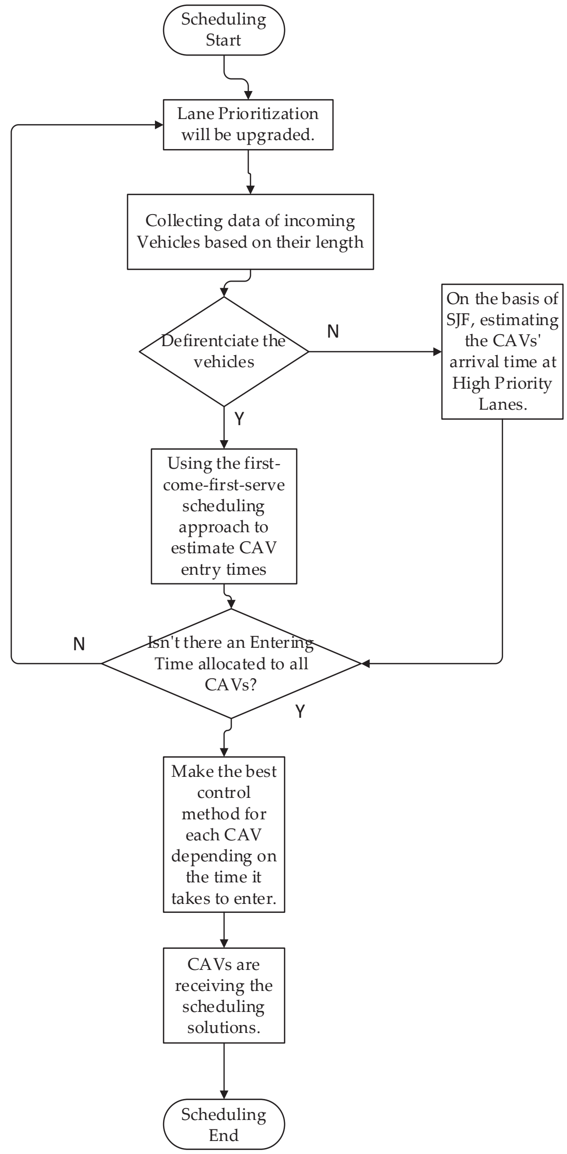


Fig. 3. The flow chart of Shortest job first algorithm

V. Experiment and Simulation

This segment included situations and parameterization, and simulations to evaluate the suggested models and Shortest Job First (SJF) scheduling algorithm.

A. Progress of Simulation

This article evaluates the proposed system's performance using the collaborative SUMO and Python simulation framework, and the created SUMO situation can be seen in Fig.3. The planned algorithm is compared to the FCFS algorithm management system, allowing vehicles to drive through intersections based on first-in-first-out. Our scheduling model divides the incoming traffic flow into three levels light traffic, modest traffic, and heavyweight traffic, determined by vehicle length and passing time. Figure 4 shows a snapshot of SUMO's four-bidirectional six-lane road scenario, with the Planning Zone length adjusted to 300m and the diameter of each lane set to 4m. From CS_1 through CS_8, the Collision Area is divided into eight collision sections (C.S.s). Each lane's CAV has a unique trajectory for passing through the Collision Area.

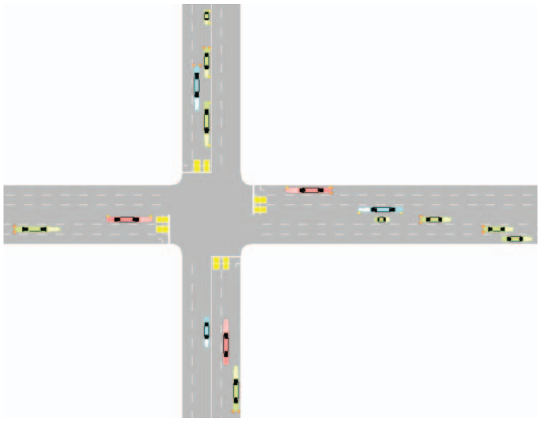


Fig. 4. The SUMO-generated simulation scenario

We produce traffic flow in two distinct ways to evaluate this algorithm's applicability in multiple traffic scenarios, i.e., all CAVs follow the first-come-first-serve scheduling algorithm, and CAVs follow the shortest-job-first-algorithm. To assure the unpredictability of traffic flow in each lane, we set cars to arrive from four directions (0 for the east, 1 for the south, 2 for the west, and 3 for the north), and the exit route of each vehicle was randomly assigned among go-straight, turn-left, and turn-right. In Fig.4. all the vehicles follow the shortest-job-first-algorithm, which is why there is a lot of space for passing the vehicles and minimum delay.

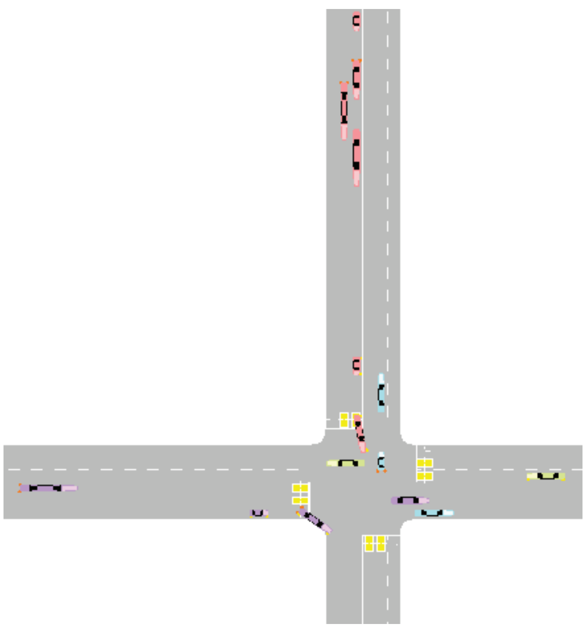
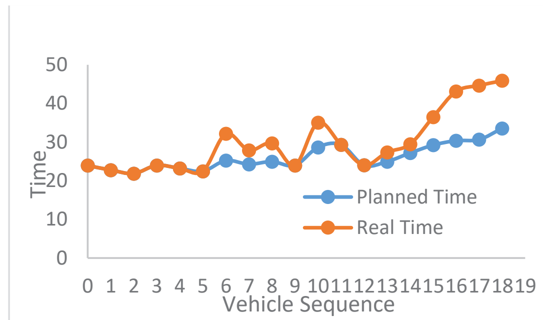


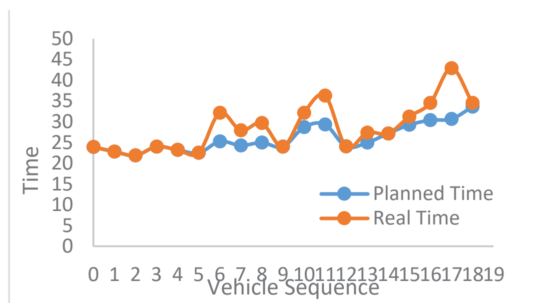
Fig. 5. The SUMO-generated simulation scenario

In Fig.5. all the vehicles are following the first-come-first-serve scheduling algorithm. Some of these vehicles are slowing down and waiting because they have many heavy vehicles ahead of them. Because of them a lot of cars have to wait and delay time is increasing. We have introduced an algorithm to reduce the time daily.

Fig.6(a) shows the time variations between planned time and real-time, here we apply the first-come-first-serve arrangement system, and we can see substantial time differences between intentional time and real-time. That is why we proposed our scheduling algorithm. The results of our proposed scheduling algorithm are much better than the first-come-first-serve arrangement algorithm. In Fig.6(b), we can see the better results of our proposed scheduling system. Here is a small-time difference between planned time and real-time. In the situation of uniform traffic spreading in all four directions, Fig.6(a) illustrates the vehicle postponements of the shortest job first scheduling algorithm and the First-come-first-serve scheduling algorithm with the non-signalized junction management approach. Delay refers to the gap between the time the system schedules the vehicle to cross the entire junction and the time it takes for the vehicle to depart the system at maximum rushing without collision risk. The two curves illustrate the time delay of two algorithms for three different vehicle types car(5m length), bus(10m length), and truck(15m length). In all instances, the Shortest Job First scheduling method has a substantially shorter delay than the first-come-first-served scheduling strategy.



(**a**)



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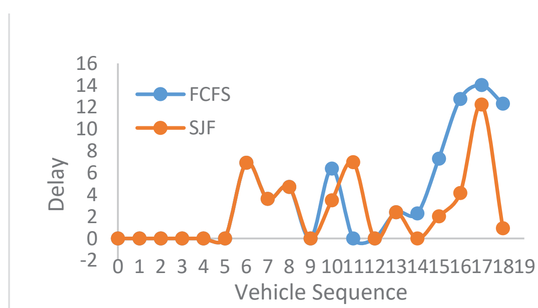

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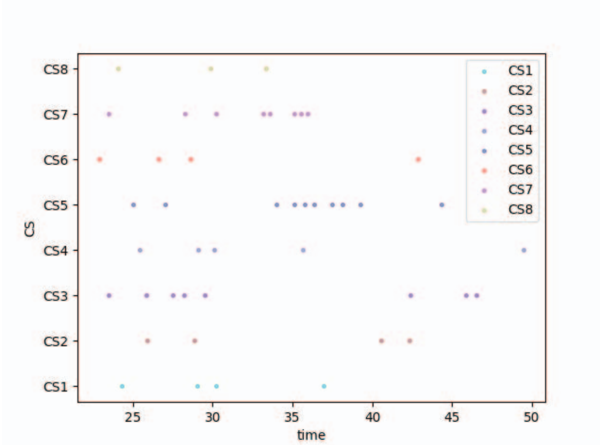

(**d**)

Fig. 6. Figs for FCFS. (a) SJF; (b) Vehicle delays; (c) CS (d)

VI. Conclusion

We explored collision avoidance for autonomous vehicles at non-signalized junctions in this work, as well as a collision-free traffic scheduling problem. We investigate and proposed the shortest job first-based scheduling algorithm to minimize the average delay at the un-signalized intersection rather than allocating a time for each CAV to enter the Conflict Area based on FCFS. Our solution can help with intelligent vehicle traffic management. In SUMO and Python, the suggested model and method are validated. In the future, we will use 5G technology to optimize vehicle traffic scheduling at non-signalized junctions, considering the importance of traffic management.

VII. Acknowledgement

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