



Application of the continuous green-t (CGT) intersection concept at signalized intersection to support sustainable mobility in peatland area

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ABSTRACT

The signalized intersection of Jl. HR. Soebrantas – Jl. SM. Amin is one of the congestion-prone intersections in Pekanbaru City, particularly due to its location in a peatland area. Peatland conditions, which are characterized by low bearing capacity and high compressibility, limit extensive physical expansion of road infrastructure. At the same time, this intersection serves as a key connector between major activity centers, including educational institutions, offices, commercial areas, and residential zones, resulting in significant traffic congestion and long queues, especially during peak hours. To address these challenges, this study proposes the implementation of a Continuous Green-T (CGT) intersection design as an operational and geometric solution that minimizes the need for large-scale infrastructure modification. The objective of this study is to evaluate the performance of the intersection after the implementation of the CGT design using microscopic traffic simulation with VISSIM. The analysis results indicate that the existing condition has an average delay of 62.5 seconds (Level of Service/LOS F), while the implementation of CGT reduces the average delay to 19.3 seconds (LOS C). This demonstrates that the CGT design is effective in reducing intersection delay by 43.2 seconds and improving the Level of Service from F to C, making it a suitable approach for traffic management in physically constrained environments such as peatland areas.

Keywords: continuous green-t (CGT); signalized intersection; vissim microsimulation

1 Introduction

Pekanbaru is one of the urban areas in Riau Province where transportation infrastructure development is closely associated with peatland conditions. Peatland areas are generally characterized by low bearing capacity, high compressibility, and susceptibility to deformation under loading, which can limit extensive physical modifications to road infrastructure [1], [2], [3]. In such conditions, improving traffic operations through management and geometric innovation becomes an important alternative to maintain the performance of urban road networks without relying solely on major infrastructure expansion.

In this context, the signalized intersection of Jalan HR. Soebrantas and Jalan SM. Amin becomes an important case to examine. Based on the Decree of the Governor of Riau No: KPTS.7464/x/2023, Jalan HR. Soebrantas and Jalan SM. Amin are included in the provincial road section, and according to Law No. 2 of (2022) are classified as secondary collector roads because these roads are on an urban scale. Based on [4], roads with secondary collector classification at an intersection must have at least a C service level, namely having a delay value of 15 to 25 seconds per vehicle.

Based on research [5], the results showed that the average delay at the signalized intersection of Jl. HR. Soebrantas and Jl. SM. Amin was 80.30 sec/smp

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with a service level of F (very poor), so it is necessary to carry out further analysis and efforts to improve the performance of the intersection to meet the required service level.

Improving the performance of 3-arm signalized intersections can be done with alternative intersection configurations that have been widely implemented abroad, one example is the Continuous Green-T Intersection (CGT) [6], [7]. Previous research found that the implementation of this CGT can reduce delays at intersections ranging from 16-37% and reduce maximum queue lengths by up to 37 and 40% [8].

Supporting this, previous studies indicate that, from an environmental perspective, alternative intersection designs such as CGT have benefits aligned with global sustainability agendas, particularly Sustainable Development Goal (SDG) 11 (Sustainable Cities and Communities), which emphasizes efficient and sustainable urban transport systems, and SDG 13 (Climate Action), which highlights the importance of reducing greenhouse gas emissions to mitigate climate change. [9], [10], [11].

CGT intersections can also be a safe intersection design for motorists. This can be proven based on research [12] which found that there is a potential reduction in the frequency of accidents that occur at CGT intersections compared to conventional T-intersections. The implementation of CGT lanes is cheaper than the alternative of widening the intersection [13], [14].

Based on this background, this study focuses on evaluating the application of the Continuous Green-T (CGT) intersection design at a three-arm signalized intersection of Jl. HR. Soebrantas – Jl. SM. Amin. Unlike previous studies that generally assess intersection performance under conventional configurations, this research specifically examines the effectiveness of CGT design under peatland-constrained conditions using microscopic simulation. This represents a novel contribution, as the application of CGT in such geotechnically limited urban environments has not been widely explored, particularly in the Indonesian context.

The analysis aims to assess the extent to which CGT can improve intersection performance in terms of delay and level of service. The findings of this study are expected to provide practical insights for transportation planners and policymakers in implementing cost-effective and sustainable traffic management strategies, especially in areas where physical infrastructure expansion is limited.

2 Data and Methods

This study employs a microscopic traffic simulation approach using PTV VISSIM to evaluate the operational performance of the intersection under existing and alternative CGT scenarios [15], [16], [17], [18]. The research process was conducted in several

sequential stages. First, field data collection was carried out, including traffic volume, vehicle composition, signal timing, and geometric characteristics of the intersection. Second, a base model representing existing conditions was developed in VISSIM and calibrated to ensure that the simulation outputs closely reflect real-world traffic conditions [19], [20]. Third, four CGT design scenarios were developed by modifying geometric configurations and traffic flow patterns. Fourth, simulation runs were performed for each scenario under various cycle time settings to obtain performance indicators such as delay and queue length. Finally, the simulation results were compared to identify the most optimal scenario in improving intersection performance.

CGT is a cost-effective intersection design alternative compared to conventional T-intersections (based on CMF point estimates) [21]. The application of CGT is carried out by focusing on the separation of lanes in the continuous flow of vehicles at an intersection, whether turning left or continuing straight. With the presence of CGT, the continuous flow at an intersection will be smoother and not hampered by vehicles stopped by red lights. The application of Continuous Green-T (CGT) at the signalized intersection of Jl. HR. Soebrantas – Jl. SM. Amin is carried out by adjusting to the existing intersection geometry. In this study, 4 CGT conditions were applied, where in CGT conditions 1 and 2 the existing geometric patterns were still used, while in CGT conditions 3 and 4 the geometric patterns had been widened by changing the road shoulder into a road body.

2.1 CGT 1

In CGT 1 conditions, the geometric width used is the existing width, while the barrier used to separate continuous lanes is applied at each intersection arm.

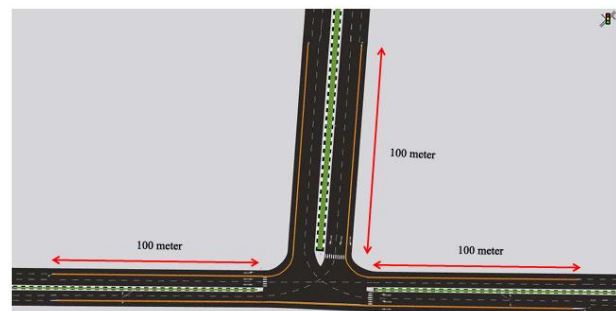


Figure 1. Design CGT 1

2.2 CGT 2

In CGT 2 condition, the geometric width used is the existing width, while the barrier used for continuous lane separation is applied on the intersection arm from West to North and from East to West, while the barrier in the North to East direction is removed. This is done with the consideration that

the traffic flow moving from North to East is small so that the barrier or continuous lane separation from North to East is removed. In addition, it is also done to see whether the results obtained in CGT 2 condition are better or worse when compared to CGT 1 condition.

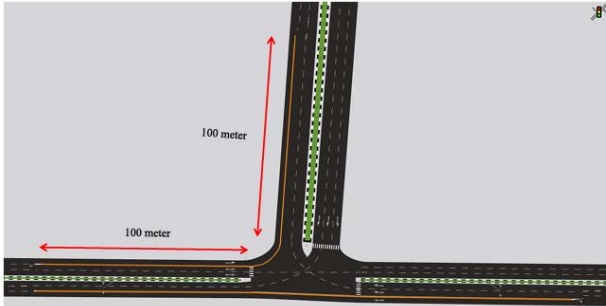


Figure 2. Design CGT 2

2.3 CGT 3

In the geometric CGT 3 condition, widening is carried out by converting the road shoulder into a road body. The road body widening is carried out only on the West arm in the direction of traffic flow entering and exiting the intersection and on the East arm in the direction of traffic flow leaving the intersection. The continuous lane separator applied in this CGT 3 condition follows the conditions of CGT 2, where the barrier used for continuous lane separator is only used on the intersection arms from West to North and from East to West.

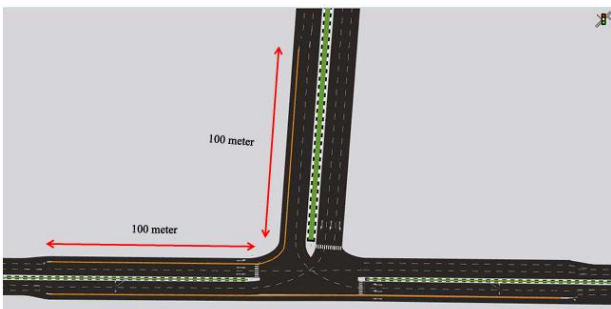


Figure 3. Design CGT 3

2.4 CGT 4

In the geometric CGT 4 condition, widening is carried out by changing the road shoulder into a road body as in the CGT 3 condition. Meanwhile, the continuous lane divider used in the CGT 4 condition follows the CGT 1 condition, where the barrier used for the continuous lane divider is used at each intersection arm.

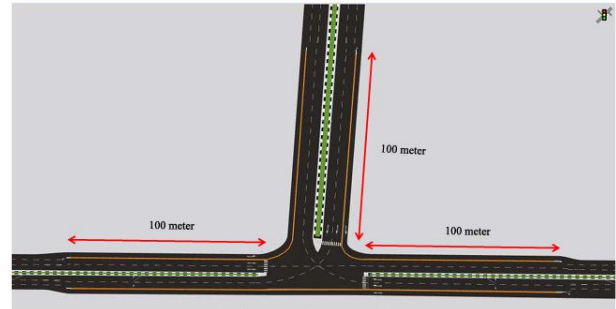


Figure 4. Design CGT 4

3 Results and Discussion

The implementation of CGT focuses on the separation of lanes in continuous vehicle flow at a 3-arm intersection, whether it is a left turn and continue straight on. With the presence of CGT, the continuous flow at an intersection will be smoother and not hampered by vehicles stopped at red lights as often occurs in existing conditions. In this study, the length of the continuous lane divider (barrier) used on each intersection arm is 100 meters. This distance is measured from the vehicle stop line on an intersection arm to 100 meters towards the vehicle queue. The determination of the length of this continuous lane divider is adjusted to the queue length measured in the field, where the average queue length obtained in the field survey ranges from 73 to 106 meters.

According to the 2023 PKJI, the appropriate cycle time for 3-phase regulation at signalized intersections is between 50 and 100 seconds. Therefore, in this study, the cycle time used was between 50 and 100 seconds with a 10-second interval. Furthermore, researchers also used cycle times greater than 100 seconds and smaller than the existing cycle time to determine whether the results were better or worse. Therefore, in this study, cycle time optimization used cycle times from 130 seconds to 50 seconds with a 10-second interval. Optimizing signal timing can have a positive impact on intersection performance [22].

In CGT 1 condition, a continuous lane divider (barrier) is used at each intersection arm and the geometry used is the existing geometry. Next, a run is carried out to see the intersection performance results in the form of queue length and maximum queue length. Then the maximum queue length value is used as a parameter to change the start of delay segment in vissim and then a run is carried out again to calculate the delay value. The results of running vissim in CGT 1 condition in the form of delay values can be seen below.

Table 1. Delay and LOS Values Under CGT Condition 1

CGT Condition 1										
Crossroads Arm	Existing Cycle Time 139 Seconds		Cycle Time 130		Cycle Time 120		Cycle Time 110		Cycle Time 100	
	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS
North (A)	141.5	F	119.4	F	106.0	F	104.4	F	102.5	F
East (A)	51.3	E	51.9	E	50.1	E	48.1	E	42.2	E
West (A)	63.2	F	50.2	E	52.2	E	52.0	E	51.0	E
North (M)	10.5	B	5.2	B	7.8	B	5.9	B	5.2	B
East (M)	13.3	B	10.5	B	9.9	B	9.2	B	9.2	B
West (M)	10.7	B	6.7	B	6.9	B	6.4	B	6.8	B
Average	42.4	E	35.8	D	34.1	D	34.1	D	32.3	D

Information :

(A) = Current stopped by Traffic Light

(M) = Continuous current

Table 2. Delay and LOS Values Under CGT Condition 1 (Continued)

CGT Condition 1										
Crossroads Arm	Cycle Time 90		Cycle Time 80		Cycle Time 70		Cycle Time 60		Cycle Time 50	
	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS	Vehicle Delay (S)	Vehicle Delay (S)	LOS	Vehicle Delay (S)	Vehicle Delay (S)	LOS
North (A)	108.7	F	116.7	F	104.9	F	115.7	F	110.0	F
East (A)	40.7	E	37.0	D	37.1	D	30.6	D	30.2	D
West (A)	50.0	E	52.3	E	55.6	E	48.3	E	55.2	E
North (M)	6.8	B	4.9	A	5.2	B	5.5	B	4.7	A
East (M)	10.1	B	10.1	B	10.1	B	10.1	B	9.7	B
West (M)	6.3	B	6.5	B	7.8	B	6.1	B	6.3	B
Average	33.6	D	35.1	D	34.7	D	32.4	D	32.4	D

Information :

(A) = Current stopped by Traffic Light

(M) = Continuous current

It can be seen that the lowest average delay value for the red signal stopped current is at cycle times of 60 and 100 seconds with a value of 65.4 seconds. Then the lowest continuous average delay value is at cycle time 110 seconds with a value of 7.8 seconds but the value is not significantly different from the 100-second cycle time which has a delay value of 7.9 seconds. If we look at the average delay of the intersection, it is found that at cycle time 100 seconds produces the lowest delay value of 32.3 seconds although the value is not significantly different compared to cycle times 50 and 60 seconds which produce a value of 32.4 seconds. Overall in this CGT 1

condition, the 100-second cycle time produces a better value when compared to other cycle times.

In CGT 2, the continuous lane divider (barrier) is only applied to the intersection arms from West to North and from East to West, while the intersection arm from North to East is removed. The intersection geometry used is the existing geometry. Then, a run is performed to see the intersection performance results in the form of queue length and maximum queue length. Then, the maximum queue length value is used as a parameter to change the start of delay segment in vissim and then a run is performed again to calculate the delay value.

Table 3. Delay and LOS Values Under CGT Condition 2

CGT Condition 2										
Crossroads Arm	Existing Cycle Time 139 Seconds		Cycle Time 130		Cycle Time 120		Cycle Time 110		Cycle Time 100	
	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS
North (A)	149.7	F	118.7	F	104.7	F	108.7	F	103.1	F

East (A)	50.9	E	51.3	E	48.0	E	45.7	E	40.1	E
West (A)	46.9	E	37.6	D	35.8	D	35.5	D	37.2	D
North (M)	82.2	F	77.6	F	57.4	E	38.4	D	39.9	D
East (M)	15.9	C	13.1	B	11.5	B	10.8	B	9.5	B
West (M)	8.7	B	6.6	B	6.2	B	5.9	B	5.8	B
Average	46.7	E	41.4	E	35.5	D	35.2	D	33.0	D

Information :

(A) = Current stopped by Traffic Light

(M) = Continuous current

Table 4. Delay and LOS Values Under CGT Condition 2 (Continued)

CGT Condition 2										
Crossroads Arm	Cycle Time 90		Cycle Time 80		Cycle Time 70		Cycle Time 60		Cycle Time 50	
	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS	Vehicle Delay (S)	Vehicle Delay (S)	LOS	Vehicle Delay (S)	Vehicle Delay (S)	LOS
North (A)	103.7	F	102.3	F	106.4	F	113.7	F	95.2	F
East (A)	39.5	D	35.2	D	34.0	D	30.4	D	27.6	D
West (A)	35.3	D	34.2	D	32.6	D	40.0	D	35.1	D
North (M)	38.9	D	42.9	E	39.0	D	27.7	D	31.6	D
East (M)	11.0	B	9.6	B	9.8	B	10.0	B	8.9	B
West (M)	5.9	B	5.5	B	5.7	B	5.7	B	5.1	B
Average	33.9	D	33.4	D	32.9	D	33.4	D	30.1	D

Information :

(A) = Current stopped by Traffic Light

(M) = Continuous current

The lowest average delay value for the flow stopped by the red signal was found at a cycle time of 50 seconds, at 53.4 seconds. Then the lowest average continuous delay value was found at cycle times of 60 and 50 seconds, at 11.8 seconds. If we look at the average delay of the intersection, it is found that the 50-second cycle time produces the lowest delay value at 30.1 seconds. Overall, in this CGT 2 condition, the 50-second cycle time produces a better value when compared to other cycle times.

In CGT 3, the continuous lane divider (barrier) is only applied to the intersection arms from West to

North and from East to West, while the intersection arm from North to East is removed. The intersection geometry has been widened by changing the road shoulder into a road body on the West and East arms along 100 meters. Next, a run is carried out to see the intersection performance results in the form of queue length and maximum queue length. Then the maximum queue length value is used as a parameter to change the start of delay segment in vissim and then a run is carried out again to calculate the delay value.

Table 5. Delay and LOS Values Under CGT Condition 3

CGT Condition 3										
Crossroads Arm	Existing Cycle Time 139 Seconds		Cycle Time 130		Cycle Time 120		Cycle Time 110		Cycle Time 100	
	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS
North (A)	115.4	F	84.2	F	74.9	F	74.1	F	73.4	F
East (A)	48.0	E	46.2	E	42.9	E	42.5	E	36.0	D
West (A)	33.7	D	30.8	D	29.7	D	29.4	D	28.6	D
North (M)	50.9	E	42.1	E	26.8	D	33.9	D	29.8	D
East (M)	11.6	B	9.9	B	9.7	B	9.5	B	9.9	B
West (M)	6.6	B	5.6	B	5.7	B	5.7	B	5.4	B
Average	37.7	D	32.0	D	27.7	D	29.0	D	27.3	D

Information :

(A) = Current stopped by Traffic Light

(M) = Continuous current

Table 6. Delay and LOS Values Under CGT Condition 3 (Continued)

CGT Condition 3										
Crossroads Arm	Cycle Time 90		Cycle Time 80		Cycle Time 70		Cycle Time 60		Cycle Time 50	
	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS	Vehicle Delay (S)	Vehicle Delay (S)	LOS	Vehicle Delay (S)	Vehicle Delay (S)	LOS
North (A)	75.0	F	72.8	F	70.5	F	75.7	F	85.3	F
East (A)	35.5	E	31.8	D	29.3	D	24.1	C	22.1	C
West (A)	24.2	D	24.1	C	21.7	C	21.7	C	20.3	C
North (M)	30.5	B	29.1	D	22.1	C	23.3	C	23.9	C
East (M)	8.9	B	9.3	B	9.3	B	8.9	B	10.5	B
West (M)	5.1	B	4.8	A	5.0	A	5.0	B	5.1	B
Average	26.9	D	26.2	D	24.8	C	24.1	C	25.8	D

Information :

(A) = Current stopped by Traffic Light

(M) = Continuous curre

The lowest average delay value for the flow that stopped the red signal was at 40.6 seconds. Then the lowest average continuous delay value was at 10.4 seconds, but the value was not significantly different from the 10.5 seconds at 70 seconds. If we look at the average delay of the intersection, it was found that the 60-second cycle time produced the lowest delay value of 24.1 seconds. Overall, in this CGT 3 condition, the 60-second cycle time produced a better value when compared to other cycle times.

In CGT 4 conditions, a continuous lane divider (barrier) is used at each intersection arm and the geometry used is a geometry that has been widened on the West and East arms along 100 meters. Then a run is carried out to see the results of the intersection performance in the form of queue length and maximum queue length. Then the maximum queue length value is used as a parameter to change the start of delay segment in vissim and then a run is carried out again to calculate the delay value.

Table 7. Delay and LOS Values Under CGT Condition 4

CGT Condition 4										
Crossroads Arm	Existing Cycle Time 139 Seconds		Cycle Time 130		Cycle Time 120		Cycle Time 110		Cycle Time 100	
	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS
North (A)	102.7	F	71.4	F	61.9	F	69.2	F	63.3	F
East (A)	45.3	E	46.2	E	43.7	E	44.1	E	35.6	D
West (A)	33.3	D	29.9	D	29.3	D	27.7	D	27.7	D
North (M)	5.8	B	4.5	A	4.4	A	4.7	A	4.4	A
East (M)	9.9	B	10.4	B	9.1	B	10.0	B	9.1	B
West (M)	5.1	B	4.5	A	3.8	A	4.2	A	3.9	A
Average	31.2	D	26.6	D	23.4	C	25.5	D	22.7	C

Information :

(A) = Current stopped by Traffic Light

(M) = Continuous current

Table 8. Delay and LOS Values Under CGT Condition 4 (Continued)

CGT Condition 4										
Crossroads Arm	Cycle Time 90		Cycle Time 80		Cycle Time 70		Cycle Time 60		Cycle Time 50	
	Vehicle Delay (S)	LOS	Vehicle Delay (S)	LOS	Vehicle Delay (S)	Vehicle Delay (S)	LOS	Vehicle Delay (S)	Vehicle Delay (S)	LOS
North (A)	75.0	F	72.8	F	70.5	F	75.7	F	85.3	F
East (A)	35.5	E	31.8	D	29.3	D	24.1	C	22.1	C
West (A)	24.2	D	24.1	C	21.7	C	21.7	C	20.3	C
North (M)	30.5	B	29.1	D	22.1	C	23.3	C	23.9	C

East (M)	8.9	8.9	9.3	B	9.3	B	8.9	B	10.5	B
West (M)	5.1	5.1	4.8	A	5.0	A	5.0	B	5.1	B
Average	23.4	C	20.6	C	20.7	C	19.3	C	21.0	C

Information :

(A) = Current stopped by Traffic Light

(M) = Continuous current

4 Conclusion

In CGT 1 condition, the best cycle time that produces the lowest delay value is a cycle time of 100 seconds. The average delay value for the flow stopped by the red signal in CGT 1 condition is 65.4 seconds (LOS F). Then the average continuous delay value is 7.9 seconds (LOS B), and the average delay value for the intersection is 32.3 seconds (LOS D). When compared to the existing condition, the decrease in the average delay value for the intersection in CGT 1 condition using a cycle time of 100 seconds is 30.2 seconds.

In CGT 2 condition, the best cycle time that produces the lowest delay value is a cycle time of 50 seconds. The average delay value for the flow stopped by the red signal in CGT 2 condition is 53.4 seconds (LOS E). Then the average continuous delay value is 11.8 seconds (LOS B), and the average delay value for the intersection is 30.1 seconds (LOS D). When compared with the existing condition, the decrease in the average delay value for the intersection in CGT 2 condition using a cycle time of 50 seconds is 32.4 seconds.

CGT 3 condition, the best cycle time that produces the lowest delay value is a cycle time of 60 seconds. The average delay value for the flow stopped by the red signal in CGT 3 condition is 40.6 seconds (LOS E). Then the average continuous delay value is 10.4 seconds (LOS B), and the average delay value for the intersection is 24.1 seconds (LOS C). When compared with the existing condition, the decrease in the average delay value of the intersection in CGT 3 condition using a cycle time of 60 seconds is 38.4 seconds.

In CGT 4 condition, the best cycle time that produces the lowest delay value is a cycle time of 60 seconds. The average delay value for the flow stopped by the red signal in CGT 4 condition is 34.6 seconds (LOS D). Then the average continuous delay value is 5.9 seconds (LOS B), and the average delay value at the intersection is 19.3 seconds (LOS C). When compared with the existing condition, the decrease in the average delay value at the intersection in CGT 4 condition using a cycle time of 60 seconds is 43.2 seconds.

Based on the four modeled CGT conditions, CGT condition 4 with a cycle time of 60 seconds provides the most optimal improvement in intersection performance. This configuration is able to reduce the average intersection delay by 43.2 seconds compared to existing conditions and improve the Level of Service

from F to C. These findings confirm the effectiveness of the CGT design as a practical solution for enhancing traffic performance at signalized intersections. Future research is recommended to incorporate traffic safety analysis, environmental impact assessment, and real-world implementation studies to further validate the applicability of CGT in different urban and geotechnical contexts.

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